R0: March 2010

Maintenance Management
and
New Inspection Program

Incorporated administration agency
Japan Nuclear Energy Safety Organization (JNES)

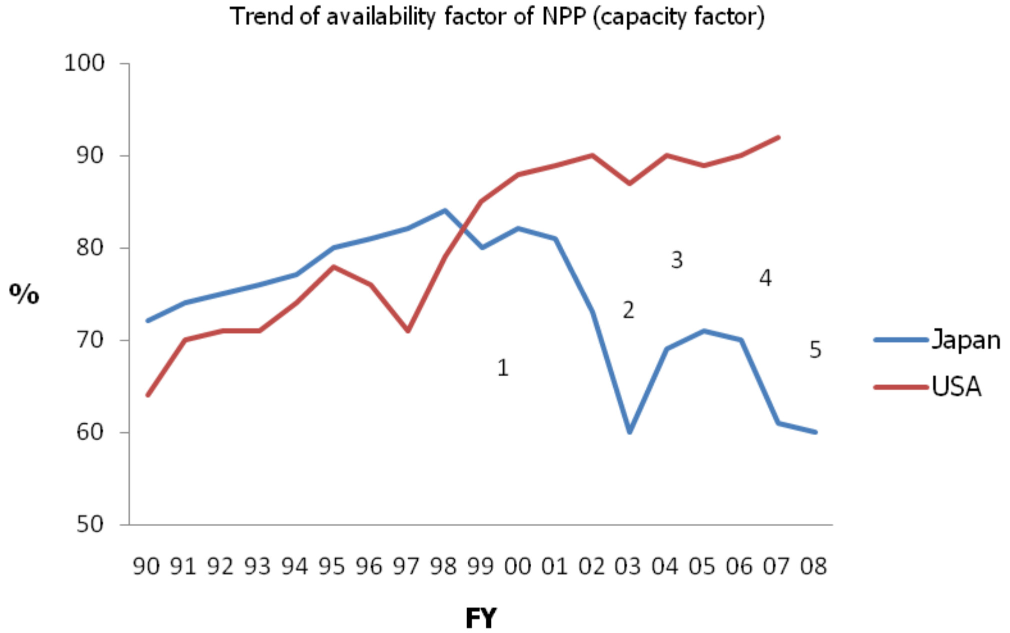
Contents

Introduction

There are 54 nuclear power plants in Japan (as of February 2010), and they account for about 30% of the total electrical energy generated. Since nuclear power generation hardly produces carbon dioxide (CO_2) while generating electricity, nuclear power plays a central role in curbing global warming. The average capacity factor of nuclear power plants had been above 80% in the second half of the 1990s as shown in the figure titled "Trend of availability factor of NPP (capacity factor) and electric energy generated", and it reached 84.2 % at its peak in fiscal year 1998. It started declining after 2002, however, and the capacity factor of fiscal year 2008, announced in April 2009, was 60.0%, indicating a substantial decline. The reasons for such a substantial decline in the capacity factor were a series of electric utilities' scandals revealed in 2002. The Niigata Chuetu-oki Earthquake in 2009 has aggravated the decline.

The scandals resulted in shutdowns of all the 17 units of the Tokyo Electric Power Co., Inc. (TEPCO). It affected as far as 2005. All the 7 units at the Kashiwazaki-Kariwa Nuclear Power Station of the same licensee were shut down again due to the Niigata Chuetu-oki Earthquake, and Unit 7 and Unit 6 of the Kashiwazaki-Kariwa Nuclear Power Station resumed power generation in May 2009 and January 2010, respectively. Units 1 to 5 of the power station are under inspection as of February 2010.

It is said that CO_2 emission will increase by about 3 million tons when 1% of the capacity factor of nuclear power plants is made up for by thermal power plants. The amount of CO_2 emission in Japan in fiscal year 2007 was 1,374 million tons, which was 9.0% more than that of the base year (mainly fiscal year 1990) provided in the Kyoto Protocol. The Ministry of Environment estimates that if the capacity factor of the nuclear power generation were about 80% as was the case in fiscal year 1998, the amount of CO_2 emission could have been lower by 5%.



Asahi Newspaper, May 2009

1 : Coverup of incidents by Tokyo Electric Power Co., Inc. 2 : Fatal accident at Mihama Unit 3

3: Outage of Onagawa NPP due to earthquake 4 : Coverup of criticality accident at Shiga NPP revealed

5 : Outage of Kashiwazaki-Kariwa NPP due to earthquake

Japan is promoting the "Action Plan for Achieving a Low-carbon Society" with a target to increase the fraction of "Zero-emission Electric Sources" including solar, wind and hydro powers to 50% or more by about 2020 and increase the fraction of nuclear power generation to "considerable level" (matter determined by the Cabinet in 2008). The preliminary estimation made by the Agency for Natural Resources and Energy (ANRE) of the Ministry of Economy, Trade and Industry (METI) indicates that the target rate of 50% of "Zero-emission Electric Sources" can be narrowly achieved if 9 planned units start operation within 10 years from now on with a capacity factor of 80%. If the capacity factor is 70%, however, it is said that 18 new units are required.

It takes a long period of time to construct a new nuclear power plant, and the plant will not be available in a short period of time. It takes about 20 years from construction planning to start of its operation. Since the improvement in the capacity factor of existing nuclear power plants is a quick-fix for energy increase, ANRE of METI is considering to promote steadily the following measures to make full use of existing nuclear power plants.

- Extension of periodic inspection interval, and adoption of long-life fuel
- To shorten a periodic inspection period by increasing on-line maintenance
- To shorten a period from the occurrence of an incident to resumption of operation
- Power up-rate with an increase in thermal power and/or turbine revamping
- Longer use of existing nuclear power plants

These new measures can be taken on the premise that licensees' maintenance activities of nuclear power plants are reliably performed on the basis of adequate scientific data and technical verifications which commit safety. They can be realized only when they are supported by regulatory programs. In addition, realization of these measures is, as any rate, needed to acquire understanding of local residents and local governments in the areas which host the nuclear power plants.

With the aging of nuclear power plants, improvement in the inspection program for nuclear power generating facilities was studied. In the study, courses of action for the improvement in inspection program have been indicated. Courses for action are: "the employment of an inspection program for maintenance activity based on the Maintenance Program," "the employment of an inspection program focusing on the actions important to safety, "and "the development of guidelines for root cause analysis."

The basic principles underlying these courses of action are:

<u>Extension of periodic inspection interval, and adoption of long-life fuel</u>

The capacity factor of nuclear power plants can be further increased by extending the periodic inspection interval. Nuclear power plants in Japan, without exception, used to be shut down for periodic inspection every 13 months, but the New Inspection Program permitted the periodic inspection interval to extend according to performances of nuclear power plants since April 2009. If it is possible to change the interval to 18 months, a simple calculation shows that the capacity factor of about 90 percent can be achieved. And, if the periodic inspection duration which usually takes 2 to 3 months can be shortened by increasing on-line inspections, the capacity factor will be further increased. Such efforts have been made in the U.S. since the 1990s, and the capacity factor has gone up to around 90%. The use of long-life fuel is also helpful to extend the periodic inspection interval.

<u>Long-term use of existing nuclear power plants</u>

At nuclear power plants, equipment performance and functions are examined by implementing periodic inspections or maintenance. Planned replacement of component parts and renewal of components and equipment are made as necessary to incorporate the latest technology. Such efforts are called the "Aging Management." These efforts are similar to those for cars to which periodic checks and part replacements are made to drive cars safely and comfortably for a long period of time. The Aging Management are carried out to operate nuclear power plants safely for a long period of time. The Aging Management should be incorporated into the maintenance activities from the beginning of nuclear power plant operation, and is one of the basic matters constituting the Maintenance Program. After identifying and understanding the progression characteristics of aging degradation of structures, systems, and components which constitute a nuclear power plant, the implementation of maintenance correlated with the characteristics is required.

1. Previous licensee's maintenance activities and inspections by NISA

Nuclear power facilities consist of piping, pumps, pressure vessels, etc. As these components deteriorate with the use and time, licensees examine the progression of deterioration by monitoring component conditions during power operation and by overhauling and replace parts as part of maintenance activities. Such activities are implemented during periodic inspections in which a nuclear power plant is shut down. In Japan, nuclear power plants are shut down for periodic inspection every not more than 13 months. The work items which licensees perform during periodic inspections are given in Table1-1. All the components do not necessarily undergo overhauling during each periodic inspection, but active components (pumps, valves etc.) are periodically (for example, once per five periodic inspections) overhauled for examination of deterioration progression. Currently, when an active component reaches its specified cycle, it undergoes overhauling and its consumables are replaced regardless of its conditions. How to scientifically collect and analyze the data on component conditions during inspection and how to make use of them for improvement of the subsequent maintenance activities are up to the individual licensee, and these are not institutionally mandatory.

For major deterioration events generated in passive components (piping, vessels etc.), standards etc. of academic societies and industrial associations specify inspections to be performed within a certain period of time. (Example: as the "Rules on Fitness-for-Service for Nuclear Power Plants," the Japan Society of Mechanical Engineers, specify ultrasonic inspections to be performed on weld lines of a pressure vessel within ten years, it is required to inspect all the weld lines of the pressure vessel within ten years.) Therefore, licensees currently plan and perform all the inspections to complete within a period of time specified by the standards. NISA performs mainly functional examinations of important components out of those inspected by licensees before plant startup during periodic inspections conducted at intervals not exceeding 13 month. NISA also examines that the overhauled components operate without abnormality.

Table1-1 Examples of work items performed by licensees during periodic inspections

Work item	Content
Detection of progression of deterioration	• To perform planned ultrasonic test etc. on the pressure vessel etc. for specified years (for example, ten years) according to the technical standards. • To perform periodic overhauling on active components (for example, once per five periodic inspections).
Replacement of component parts	• To replace deteriorated component parts and fuel.
Functional check before plant startup	• To examine that the overhauled components operate without abnormality.

2. Enhancement of NISA involvement by adopting inspections based on the Maintenance Program

Under the "New Inspection Program Based on the Maintenance Program," NISA requires licensees to additionally perform various maintenance activities described below to enhance licensees' maintenance activities. NISA strictly examines the implementation status.

The "New Inspection Program Based on the Maintenance Program" was promulgated in August 2008 by the Ministry Order to partially amend the Rules for the Installation, Operation, Etc. of Commercial Nuclear Power Reactors ("Rules for Commercial Power Reactors") and the Ministry Order to partially amend the Rules for the Establishment, Operation Etc. of Nuclear Power Reactors at the Stage of Research and Development ("Rules for Reactors at the Research and Development Stage"). Each reactor establisher (licensee) applied for an approval of the amended Fitness-for-Safety Program to NISA in October 2008. NISA, as a result of strict review, approved the amended Fitness-for-Safety Program since there were no concerns that would impair the prevention of disasters caused by reactor incidents. The New Inspection Program has been put in place after undergoing the process described above.

2.1 Addition of requirements to be described in the Fitness-for-Safety Program to improve maintenance

Licensee's maintenance activities have been performed according to the Fitness-for-Safety Program established for each nuclear power plant by the licensee pursuant to Article 37 of the Act for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors (Reactor Regulation Act). The Fitness-for-Safety Program (FFS Program) is approved by NISA. Under the New Inspection Program, requirements to be described in the FFS Program have been reinforced. Comparisons of the items to be described in the previous and new FFS Programs are shown in Table 2-1. The new FFS Program requires a continuous implementation of maintenance in which operational experiences, such as component conditions during operation and during outage, component failure histories, aging degradation, are evaluated according to the importance of components to enhance safety. Upon approving the new Fitness-for-Safety Program, NISA mainly examines that the newly added requirements are appropriately incorporated in the Program.

Furthermore, when a licensee intends to amend the Fitness-for-Safety Program already approved by NISA, NISA strictly reviews technical rationale to endorse those amendments.

Table2-1 Comparison of the standard description items in the previous and new Fitness-for-Safety Programs

Previous Fitness-for-Safety Program	New Fitness-for-Safety Program (Underlined parts indicate newly established or enhanced items.)
(1) Implementation policy and goal of maintenance management (2) Development of maintenance scope (3) Development of the Maintenance Program (4) Implementation of maintenance (5) Maintenance plan (6) Check and assessment of results of inspections, repairs, etc. (7) Corrective action (8) Periodic assessment of maintenance management (9) Information sharing	(1) Implementation policy and goal of maintenance management (2) Development of maintenance scope (3) <u>Setting of maintenance importance</u> (4) <u>Setting of Management Indicators for Maintenance Activities (MIMAs) and development of monitoring plan and monitoring</u> (5) Development of maintenance plan (6) Implementation of maintenance (7) Confirmation and evaluation of inspections, repairs etc. (8) Nonconformance management, corrective and preventative actions for inspections, repairs etc. (9) <u>Evaluation of the maintenance effectiveness</u> (10) <u>Evaluation of the effectiveness of maintenance management</u> (11) Information sharing (12) <u>Reactor shutdown interval</u>

* Under the "New Inspection Program Based on the Maintenance Program," the procedures from (2) Development of maintenance scope to (9) Evaluation of the maintenance effectiveness is called the "Maintenance Program."

* "(12) Reactor shutdown interval" is discussed in Paragraph (4) of Chapter 2.

2.1.1 Setting of importance level for maintenance activities

The importance to ensure safety of a nuclear power plant is identified after analyzing each maintenance activity. The quality of safety is enhanced by paying more careful attention to matters with higher importance.

The importance of maintenance is established by licensees based on the "Review Guide for Classification of Importance of Safety Functions for Light Water Nuclear Power Reactor

Facilities" established by the Nuclear Safety Commission of Japan, and also based on a detailed study concerning risk information obtained from probabilistic safety assessment (PSA) and such operational experiences as incidents and failures at home and overseas. Maintenance and maintenance management are appropriately performed by licensees under licensee's responsibility.

2.1.2 Setting of Management Indicators for Maintenance Activities (MIMAs)

To make efforts to improve maintenance while continuously performing maintenance activities, licensees are required to establish the "Management Indicators for Maintenance Activities (MIMAs)" and to evaluate their maintenance activities. The MIMAs are to measure objectively the performance of maintenance activities and to identify effectiveness and weaknesses of them.

2.1.3 Evaluation of maintenance effectiveness and evaluation of the effectiveness of maintenance management

The assessment on the maintenance effectiveness has been made as part of the periodic assessment of maintenance management. Document control, education and training etc. associated with overall maintenance management will be performed as before. In addition to these traditional assessments, it has become mandatory to evaluate maintenance activities in each operating cycle based on scientific data, as a mechanism to ensure that maintenance activities are continuously improved. And, it is required to analyze and assess maintenance management for its effectiveness.

In the assessment on the maintenance effectiveness, it is required to assess appropriate inspection and maintenance intervals of components using collected information, such as degradation mechanisms (degradation events and factors) on a part-to-part basis for components, information obtained from components of own plants and similar components in other plants, and the latest knowledge collected, including research results of endurance tests. In order to insure such assessments, licensees are going to prepare summary table of aging degradation mechanism covering degradation events assumed for each typical component.

2.2 Mandatory requirements for prior notification of the Maintenance Plan

Previously, NISA used to examine the results of maintenance activities by Periodic Inspection and Periodic Safety Management Review during each operating cycle. Under the New Inspection Program, to assure secure implementation of assessments and continuous improvements of maintenance activities, a Maintenance Plan regarding inspections and repair, etc. including maintenance activities during operation as shown in Table2-2 is to be notified to NISA as the Safety Controls pursuant to Article 42 of the Electric Utility Act. NISA examines the implementation plan of the Aging Management, inspection items regarding the components concerned during the subject inspection cycle, and appropriateness of assessments on the maintenance effectiveness. NISA, if necessary, orders to amend the Maintenance Plan pursuant to Paragraph 3 of the said Article. And, the implementation status of the Maintenance Plan is examined during the Periodic Safety Management Review and the Periodical Inspection. Findings from the Periodic Safety Management Review etc. are to be reflected in the subsequent Maintenance Plan.

Table 2-2 Comparison of items to be notified in the Maintenance Plan

Previous Items to be notified in the Maintenance Plan	New Items to be notified in the Maintenance Plan
Plans only on steam turbine and auxiliary boiler need to be notified. No need for notification on systemized plan regarding the overall nuclear facility.	The following items need to be described and reported covering the overall nuclear facility. Assessments on the maintenance effectiveness in the preceding cycle need to be attached. • Target values of MIMAs in the next cycle • Check plan, and repair, replacement and modification plan • Safety management during plant outages • Judgment criteria on periodic licensee's inspections • Special maintenance plan

Detailed description on the new items that should be described in the Maintenance Plan is as follows.

2.2.1 Evaluations on the maintenance effectiveness

The licensee is required to submit evaluations on the maintenance effectiveness in the preceding cycle which is the basis for the next cycle. NISA examines that the continuous improvement of maintenance activities is performed according to the Fitness-for-Safety Program.

2.2.2 Target values of MIMAs activities in the next cycle

In order that licensees objectively aware the weakness of its own maintenance activities based on the assessments on the maintenance effectiveness and past operating performance, it is required that the self-established target values of indicators be described in the Maintenance Plan. Meeting the target values means that the maintenance activities were effective, whereas not meeting them means that the maintenance activities had weak points. Those weak points must be corrected in the maintenance activities of the next cycle.

2.2.3 Check plan and plans on repair, replacement and modification

Plans are notified to NISA after establishing development criteria for all plans such as a check plan, repair, replacement and modification plans, and other items conducted other than periodic licensee's inspection. NISA examines the appropriateness of the plans in advance. According to the Maintenance Plan, licensees perform inspections, repairs, replacements, and modifications with considering the plant characteristics such as the past incident history.

2.2.4 Safety management during plant outage

Benefitting from lessons learned from actually occurred incidents, i.e. the occurrence of criticality of a nuclear reactor due to control rod partial withdrawal during periodic inspection, it has become necessary for licensees to incorporate "safety management during plant outages" into the Maintenance Plan. Description regarding the "planned implementation of maintenance and walkdown activities important to safety other than periodic license's inspection" is also required. NISA examines the licensee's safety management activities during plant outages through the Safety Fitness Inspection.

2.2.5 Judgment criteria on periodic licensee's inspections

Article 39 of the Electric Utility Act mandates that the equipment be maintained so as to conform to the technical standards. Under the New Inspection Program, it has become necessary for licensees to maintain their plant equipment so as to conform to the technical standards after certain periodic licensee's inspection until the next inspection. For this reason, it is required for licensees to describe principles on how to set up judgment criteria during periodic licensee's inspection in the Maintenance Plan.

2.2.6 Special Maintenance Plan

When licensees put their plants out of service under special circumstances for a long period of time, it is required for the licensee to draw up the following plan as a special maintenance plan and to notify it to NISA.

a) Plan for integrity assessment on equipment to be placed out of service for a long period of time

For equipment to be placed out of service for a long period of time, if necessary, a plan for inspection and analysis to examine possible impairments that could affect the conformity to the technical standards, is to be notified to NISA in advance. NISA examines its appropriateness.

b) Plan for storage, etc. of the equipment to be placed out of service for a long period of time

A plan to storage the equipment to be placed out-of-service for a long period of time is to be notified to NISA in advance. NISA examines its appropriateness.

c) Plan for validation of equipment integrity after plant restart

A plan for additional checking which will be conducted after plant restart to validate the equipment integrity is to be notified to NISA in advance. NISA examines its appropriateness.

2.3 Mandating inspections during power operation using applicable new technologies

It has become possible to detect indications of anomalies at an early stage to reduce the occurrence of incidents by positively employing condition monitoring during power operation which uses new equipment diagnostic technologies such as vibration diagnostics of active components. As such, NISA considers "condition monitoring using vibration measurements during power operation" as "periodic licensee's inspection," and examines its implementation status in the Periodic Safety Management Review.

Specifically, the vibration measurement being widely performed as condition monitoring of active components such as rotating components is being studied as a tool for quantitative control. Licensees are encouraged to positively promote condition monitoring for licensees' maintenance activities. NISA examines that licensees are positively employing equipment diagnostic technologies by examining the Maintenance Plan (Walk Down Plan).

2.4 Inspection interval under enhanced maintenance activities based on the "Maintenance Program"

The New Inspection Program aims to enhance scientifically and reasonably maintenance activities by licensees and inspections by NISA and make them more effective to ensure safety. Through the implementation of the Program, licensees accumulate experiences and technical information, and make it possible to establish optimum inspection methods and appropriate inspection intervals or frequencies. By establishing appropriate inspection intervals or frequencies, it becomes possible to prevent incidents due to age-related degradation and to reduce the occurrence of malfunctions due to potential unnecessary change in conditions of components.

If the technical information on many components is accumulated and more appropriate inspection intervals or frequencies are established, the existing periodic inspection intervals that were established without scientific and rational basis can be replaced by scientific and rational inspection intervals.

The procedures to substantiate this process are as follows;

2.4.1 Determination of intervals for checks and inspections which accompany reactor shutdown

Nuclear power plants are shut down periodically and conformance with the technical standards of components are inspected. Since many of the components at the nuclear power plants are in service or on standby during power operation, and they have to be checked and inspected by shutting down the reactor to confirm the conformity with the technical standards. The intervals for walk downs and inspections are governed by the shortest interval among those of the subject components. Therefore, it is important to determine the inspection intervals for components based on degradation status observed during inspection and scientific and rational bases such as operating performance and technical knowledge. Furthermore, it is necessary to determine the periodic inspections intervals taking into account the aging effect of the plant itself.

2.4.2 Determination of the duration of reactor operation

Factors to determine the duration of reactor operation include, other than operation interval for walk downs and inspections, operational aspects such as electricity supply planning, planned refueling schedule, fuel procurement. The refueling interval is required to be planned so as to satisfy the limits specified by the reactor establishment permit. The duration of reactor operation is determined by the licensee for each plant considering these factors. The duration of reactor operation is described in the Fitness-for-Safety Program and the justification for it is reviewed and approved by NISA. When the approved duration of reactor operation is altered, the extent of durational alteration needs to be conservatively determined based on the past operating records.

2.4.3 Categories of periodic inspection intervals

The duration of reactor operation is specified in the Fitness-for-Safety Program considering refueling interval in addition to intervals for walk downs and inspections as mentioned above. According to the legal requirements, the timing of Periodic Inspection is required to be categorized according to the Ministry Order which implements the Electric Utility Act. Benefitting from the past studies in academic societies and industrial associations, and equipment inspection frequency program and the past operating performances in foreign countries, the following three categories have been established for the Periodic Inspection Interval.

- Within 13 months (conventional interval for periodic inspections: the duration of reactor operation)
- Within 18 months
- Within 24 months

Under the New Inspection Program, NISA applies either one of these categories.

2.4.4 Implementation of setting Periodic Inspection intervals

When setting the interval for the Periodic Inspection of a power plant, NISA strictly reviews the results of evaluation on inspection intervals for all equipment performed by the licensee during a shutdown interval determination process. Licensee's assessments regarding the inspection intervals for all equipment are attached to the licensee's Maintenance Plan as a part of the assessment on the maintenance effectiveness and submitted to NISA.

In addition, there are equipment that, in the periodic licensee's inspections, the duration of reactor operation shall be considered in the judgment criteria in light of maintaining the conformance with the technical standards until the next periodic licensee's inspection. NISA examines the appropriateness of the judgment criteria and inspection results through Periodic Inspection. After examining these matters for each power plant, NISA specifies the category of the Periodic Inspection interval, and approves reactor shutdown intervals.

In addition, it is possible for the licensee to set an interval of the periodic inspection less than 13 months in the Maintenance Plan in order to implement ahead-of-schedule repair work in terms of preventive maintenance.

2.5 Smooth transfer to the New Inspection Program

Smooth transfer to the New Inspection Program requires a step-by-step approach in an orderly fashion. Hasty transfer to the New Inspection Program is more likely to cause confusion. Therefore, the following steps are adopted to introduce the New Program:

(a) Licensees prepare Fitness-for-Safety Programs incorporating new requirements. The new requirements to be incorporated in them are provided in Table 2-1. By so doing, licensees establish clear maintenance management programs on their own, and thereby, are committed to implementation of more advanced maintenance activities. At the beginning of the new program application, all the outage intervals are supposed to be within 13 months based on the current interval of the periodic inspections.

(b) When changing the reactor outage interval from the current within-13 months, licensees are required to collect and organize the data which justify the interval of walk downs and inspections to be conducted nuclear reactor outage, and submit them to NISA.

Even if licensees accumulated the inspection data, performed aging management, adopted condition monitoring, and demonstrated the adequacy of a periodic inspection interval of 24 months or more by technical assessments, from the standpoint of taking a cautious attitude, a 24-month outage interval would not be applicable until many plants undergo about three cycles.

(c) When changing a reactor outage interval from the current within-13 months, it should be noted that an actual reactor shuddown interval will be within the limit on the Periodic Inspection Interval specified by NISA and determined by a nuclear reactor operating period controlled from necessities such as refueling. As illustrated in Figure 2-1 "Transfer process to the New Inspection Program," even when accumulated technical information such as track records of specific maintenance activities and outcomes for changing an inspection interval justify a reactor operating period within 18 months, the operating period will be within 16 months if refueling schedule etc. limits the operating period to within 16 months.

(d) For a reactor operating period provided in the Fitness-for-Safety Program, its each increment is required to be conservatively set so that operating experiences can be gained.

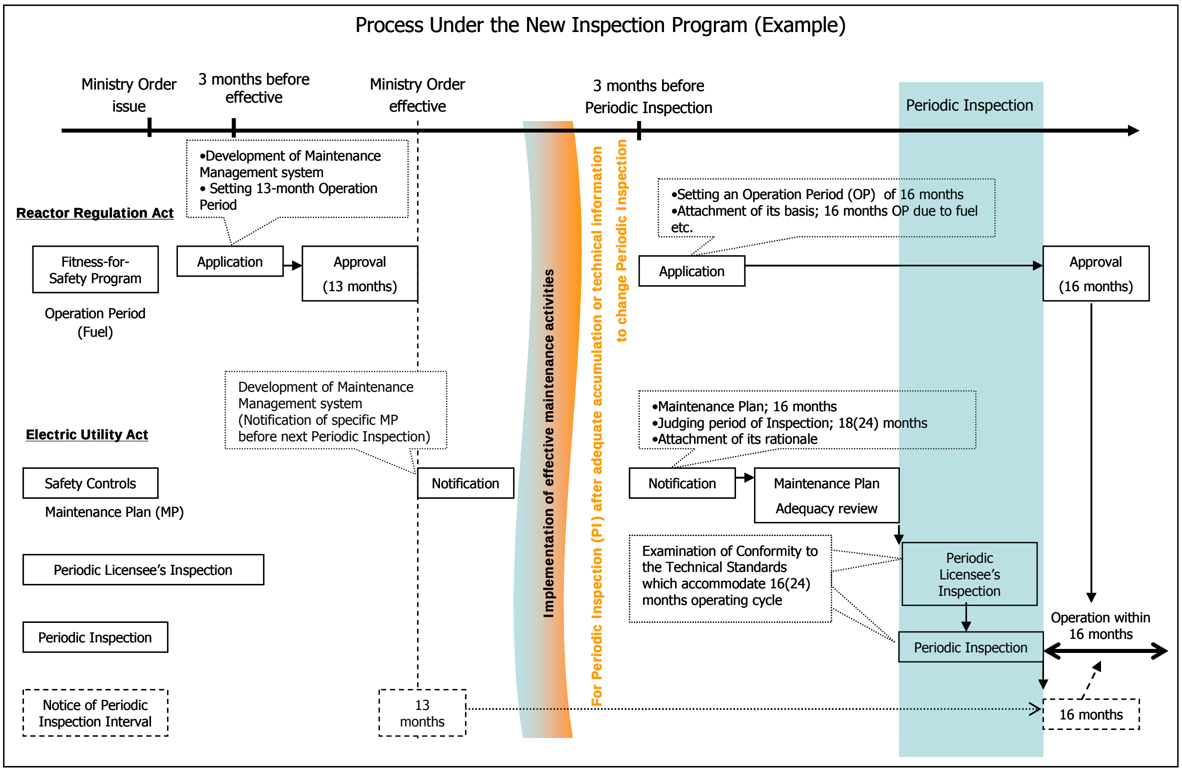


Figure 2-1 Transfer process to the New Inspection Program

2.6 Change in work items of NISA and licensees during Periodic Inspection (Table 2-3)

The Periodic Inspection of NISA is performed focusing on functional examinations as before. In addition to this, NISA examines in advance the appropriateness of programs for maintenance activities such as nondestructive inspections to be conducted by licensees before functional tests, and examines the implementation status and results through the Periodic Safety Management Review. Important nondestructive inspections among those to be conducted by licensees are subject to review by NISA during its Periodic Inspection. The subjects to be reviewed are selected from the prescribed items in the Maintenance Plan.

Table 2-3 Change in work items of NISA and licensees during Periodic Inspection

NISA examines in advance these matters by reviewing the Maintenance Plan.

Licensee's maintenance activities	Previous Inspection Program	New Inspection Program
Identification of degradation progress	Identification of state of degradation on active components (pumps etc.) by periodic overhaul (once every 5 periodic inspections)	Continuous improvement in the method and frequency. Additional adoption of condition monitoring during plant operation.
	To perform planned inspections of pressure vessel etc. over specified years (ten years etc.) according to the standards of academia, etc.	No change (Change in the periodic inspections interval will result in an increase in workload of a periodic inspection.)
Replacement etc. of component parts	Replacement, etc. of component parts is performed when a nuclear reactor is shut down.	Continuous improvement in the method and frequency.
Functional test before plant startup	To confirm by tests that components operate normally after overhaul.	No change

NISA focuses on these tests as the subjects of the NISA's Periodic Inspection.

3. Licensee's specific maintenance activities under the New Inspection Program

In order to steadily perform maintenance activities of a nuclear power plant, it is essential to continuously repeat a process of "Plan, Do, Check, and Act". It is important to establish a carefully thought-out plan, steadily carry out the plan, analyze and evaluate objectively and quantitatively the results, correct unsatisfactory portions, and reflect improvements in the next plan. A series of these persistent activities and efforts are necessary. Under the New Program, the following items are incorporated in addition to the traditional activities.

(1) Accumulation of pre-maintenance data of components and determination of proper inspection methods or frequencies

(2) Preparation of summary table of aging degradation mechanism and thorough aging management

(3) Continuous improvements in maintenance by periodic effectiveness evaluation of maintenance activities

(4) Reduction of incidental failures by enhanced checks and monitoring during operation

(5) Establishment of MIMAs and identification of improvement target

(6) Establishment of the Maintenance Plan

Figure 3-1 shows flow of the maintenance activities which licensees perform under the New Program.

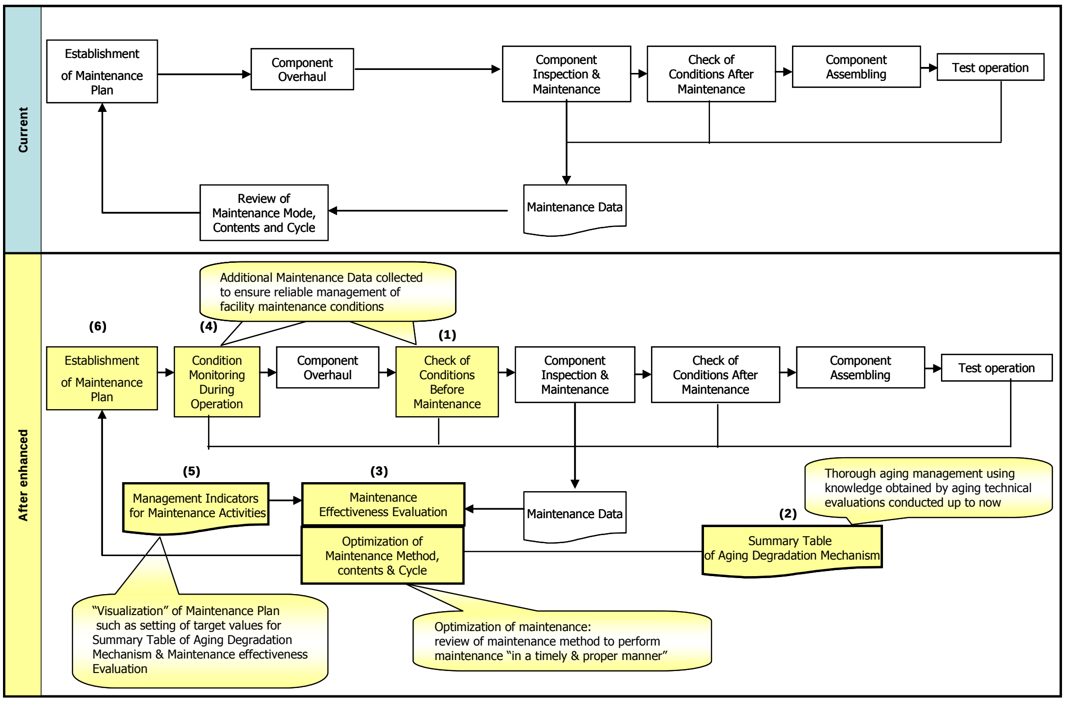


Figure 3-1 Flow of licensee's maintenance activities under the New Inspection Program

Contents of the newly added items are discussed in the following.

3.1 Accumulation of pre-maintenance data of components and determination of proper inspection methods or frequencies

Most of the components (valves, pumps, fans, vessels, etc.) provided in a nuclear power plant undergo overhauling and maintenance at a specified frequency during a periodic inspection. Although overhauling and maintenance could change the conditions of components, emphasis was placed on condition confirmation of components after overhauling and maintenance. The component data during operation and/or before overhauling and maintenance of components were rarely utilized. Under the New Inspection Program, the degradation level of major parts of the subject component is evaluated by paying attention to the conditions of a component before maintenance. In this process, whether the contents, frequency etc. of the current maintenance on the component are appropriate is determined. Accumulating data before maintenance and incorporating the results into the evaluation of maintenance activities, the maintenance method, the contents of the inspections and inspection frequency are re-examined as necessary to make them appropriate. With this, an inadvertent change of state given to components by maintenance activities can be avoided and incidents due to human errors during maintenance can be reduced. Figure 3-2 shows an example to make use of the valve data before overhauling and maintenance.

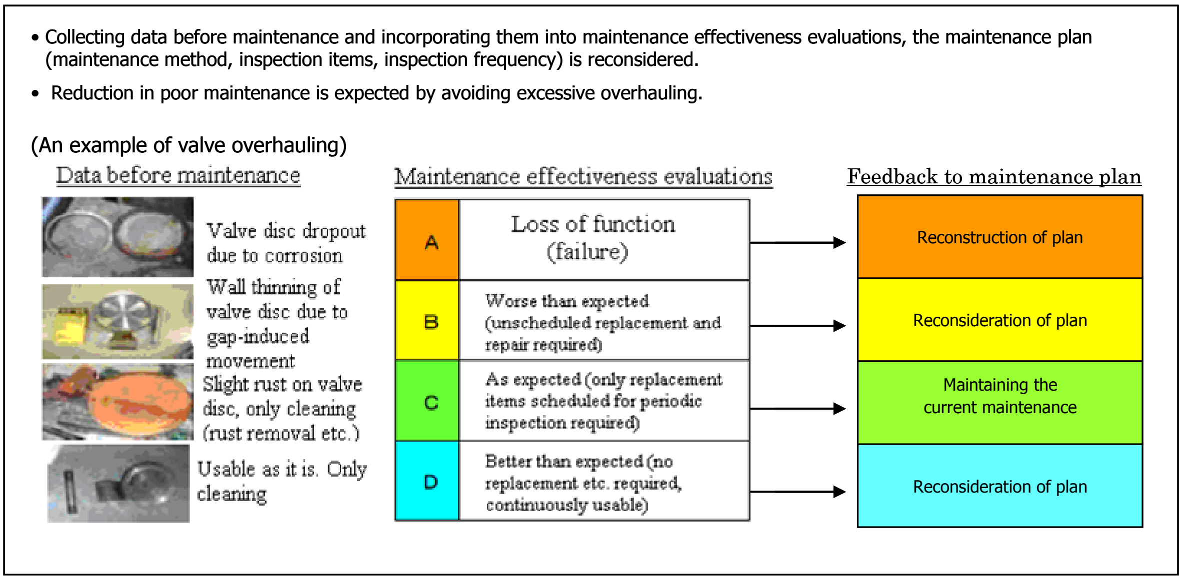


Figure 3-2 Examples to make use of the valve data before overhauling and maintenance

3.2 Preparation of summary table of aging degradation mechanism and thorough aging management

Maintenance activities of a nuclear power plant exercise continuous improvement efforts, such as identification of incident causes, implementation of measures to prevent recurrence of similar incidents, and their feedback to other power plants. For power plants, which have operated more than 30 years after commissioning, reduction of incidents due to aging degradation and preventive maintenance measures have been discussed, and technical evaluations of aging were performed for 14 PWR and BWR power plants, resulting in accumulation of technical knowledge of aging. The number of the power plants with their operating lives exceeding 30 years increases and measures to aging degradation will become more important.

Making use of the technical knowledge obtained by the technical assessments of aging, licensees wrap up anticipated degradation events for each component as summary tables of aging degradation mechanism and establish Maintenance Plans (maintenance methods and items, and their frequencies) based on the tables.

It is possible to perform repairs and replacements with appropriate cycles and in a timely manner by continuously accumulating data and systematically wrapping up them from the beginning of the commissioning, since the aging degradation starts at the beginning of the plant operation. Figure 3-3 shows an improved inspection plan using the summary table of aging degradation mechanism.

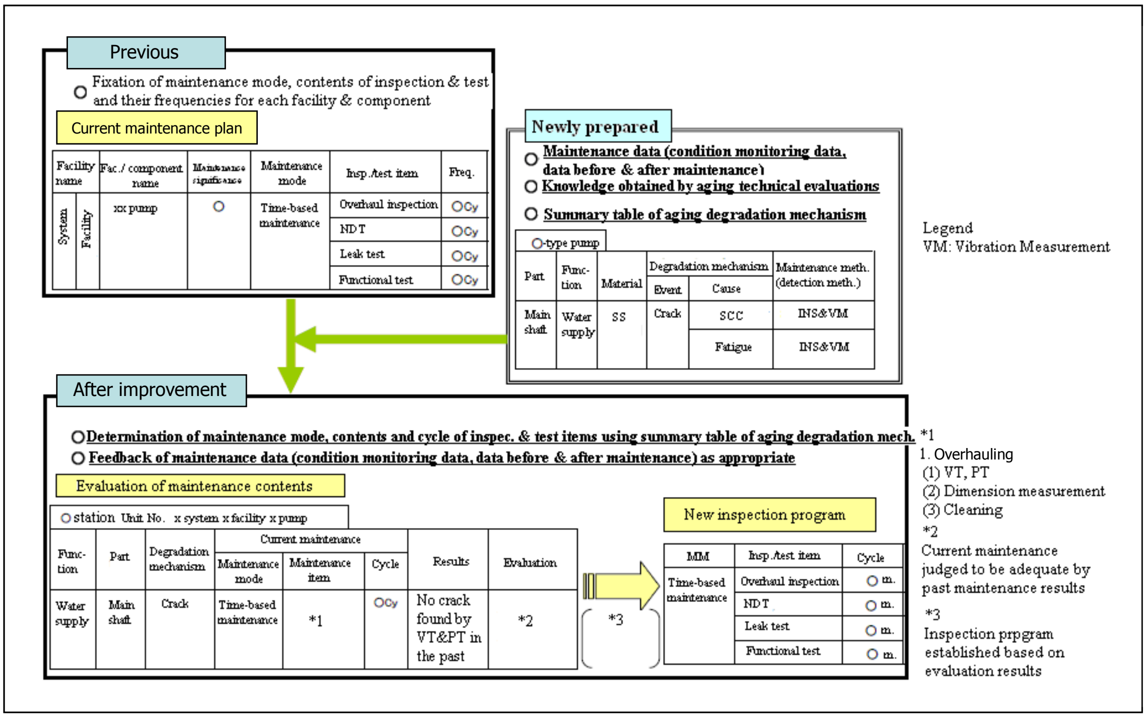


Fig. 3-3 Improved inspection plan using the summary table of aging degradation mechanism

3.3 Continuous maintenance improvement by implementation of periodic evaluation on the maintenance effectiveness

Under the New Inspection Program, the effectiveness of the maintenance activities is assessed up to the previous operating cycle at each operating cycle, and lessons and matters to be improved are fed back to the next Maintenance Program. By so doing continuous improvements in the maintenance activities are promoted. For maintenance improvement activities, feedback of the past incident experiences, evaluation results in the light of MIMAs, results of component condition monitoring using component diagnostic technology, and information on components before maintenance during overhauling are also utilized.

Moreover, focusing on degradation on a part-by-part basis, degradation progression in the preceding cycle, degradation progression of similar parts under similar environments, test results such as durability tests of the part are used to establish the optimum inspection method, interval and frequency. With these arrangements, the latest knowledge including the performances of other plants is always reflected in maintenance activities, and incidents due to aging degradation and malfunctions caused by undue changes in the state are expected to be reduced.

Table3-1 shows examples of being reflected in the Maintenance Plan based on the assessments on the maintenance effectiveness.

Table 3-1 Examples of being reflected in the Maintenance Plan based on the assessments on the maintenance effectiveness

Information used for assessment	Assessment results	Measures
Monitoring results on MIMAs	They are below the target values and so, improvements are required.	Change in maintenance methods and inspection intervals
Data before check and maintenance	Degradation progression is faster than originally expected.	Shortening of inspection intervals
	Degradation progression is slower than originally expected or not observed.	Review to identify any other degradations to determine inspection interval.

3.4 Suppression of accidental failures by upgrading checks and monitoring during plant operation

Maintenance activities during plant operation include periodic operation tests, walkdowns, etc. As shown in Fig. 3-4, component conditions are judged by senses for abnormal noise, foreign odor, heat generation, etc., depending on experiences of inspection engineers. In the New Inspection Program, such walkdowns and monitoring are still important, but it has become possible to detect an indication of condition change by actively adopting new condition monitoring using equipment diagnosis technologies, such as vibration diagnosis, oil analysis, and infrared thermography. For example, it has become possible to detect anomalies, such as wear of rotating components and heat generation of terminals, at an early stage and repair them before their failures by applying vibration diagnosis technology to water pumps or by applying infrared thermography detection technology to power supply equipment, etc. Making use of such technologies, it becomes possible to detect indications of accidental failures at an early stage, which cannot be prevented only by periodic overhauling. An example of monitoring rotating equipment using a vibration diagnosis technology is given in Figure 3-4. Other effective diagnostic technologies are shown in Table 3-2.

Noise check
by stethoscopic rod

This check depends on a human sense.
Distinctive noise can be detected, but it depends on the local environment and noise trend cannot be detected.

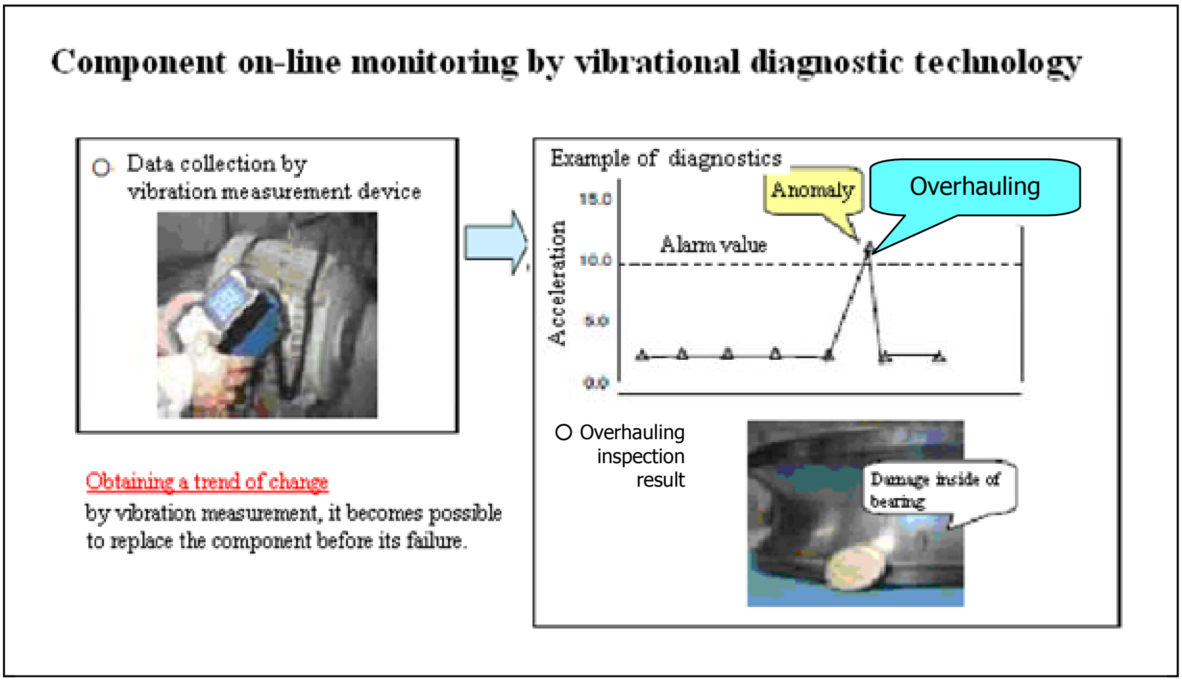


Fig. 3-4 Vibration diagnosis and monitoring technologies for rotating equipment

Table 3-2 Effective diagnostic technology

Equipment Diagnostic Technology	Subject Component	Detectable Event
Vibration diagnosis for rotating equipment	Rotating equipment, such as pumps, motors, fans, and compressors	• Wear, cracks, contacts, and poor balance etc. of rotating equipment (shafts and impellers) • Bearing damage, lubricant shortage, etc.
Lubricant diagnosis	Pumps, motors, fans, compressors, turbines, generators etc.	• Lubricant degradation • Anomaly of bearing slide member
Infrared thermography diagnosis	Power supply equipment, switchyards, rotating equipment, etc.	• Anomaly of terminals (identification of heat generating locations and temperature distribution) • Temperature anomaly of bearing
Wall-thickness diagnosis by radiation	Components, piping etc.	• Wall thinning events on internal and external surfaces of components, piping etc.

3.5 Establishment of improvement target by MIMAs

Licensees establish the MIMAs in order to continuously improve maintenance activities and perform their evaluations. The MIMAs are used as a "measure" to objectively assess the performance of maintenance activities and make the effects and weaknesses of the maintenance activities "visible." The management indicators and their target values are set up as MIMAs for each system, focusing on important structures, systems, and components with important "functions," such as "to shutdown," "to cooling" and "to confine" from the viewpoint of reactor safety. For the maintenance items that do not satisfy the target values, utilizing root cause analysis methods, their weaknesses and shortcomings, work environment factors (i.g. work place is too tight to use proper tools, etc.) and organizational factors (no adequate working hours) are identified. In addition to the improvement in maintenance methods or clarification of technical issues, reduction in the occurrence of incidents due to human errors is expected.

Examples to utilize MIMAs are given in Figure 3-5.

<< Visualization of maintenance activity performance>>

Establishment of MINAs: to visualize the effects and weaknesses of maintenance activities by establishing management indicators and their target values

Example of MIMAs

	MIMAs (example)	Purpose
Entire plant	Number of unscheduled reactor automatic shutdowns	To monitor the occurrence of failures which affect plant operation
	Number of unscheduled power changes	
	Number of unscheduled actuations of engineered safety feature (backup equipment)	
Each system	Preventable failure (Number of failures which could have been prevented with appropriate maintenance)	To directly measure whether maintenance is adequate by measuring the number of failures resulting from inadequate maintenance
	Non-stand-by time (Time from the occurrence of a failure to its restoration regarding emergency systems)	To monitor recovery time, since shortening recovery time is important for the emergency system in terms of safety.

Example of Assessments

System	Required functions	Management indicators and their target values	Basis	Assessment results	Necessity of mainte-nance plan review
Residual heat removal system	Core cooling function Function to confine radio-active material	Preventable failure: less than once / cycle Non-stand-by time: less than 120 hours / cycle	Preventable failure Failure probabilities of pumps and valves representative to the system are less than 1.0×10^{-3} (failure/demand) Non-stand-by time The allowable standby exemption times for components provided in the Fitness-for-Safety Program are different. A half of the smaller value (ten days) is conservatively used. In this case, an increment in the conditional core damage probability is zero and less than the value currently referred to in the U.S.	Results of this operation cycle Preventable failure 0 time Non-stand-by time 0 hour	No

Figure 3-5 Utilization of MIMAs

3.6 Establishment of the Maintenance Plan

The Maintenance Plan is required to include the following three requirements. Further improvement in safety is expected by establishing the Maintenance Plan that integrates these factors.

- Check plan to examine equipment conditions by overhauling of components
- Repair, replacement, and modification plan to maintain and improve equipment conditions
- Special maintenance plan to be set up during long-term plant outage

These plans must be established as follows.

a) Check plan to examine equipment conditions

An appropriate maintenance plan should be developed based on the assessments on the effectiveness regarding check methods such as overhauling, leakage tests, functional and performance tests, as well as inspection frequency. In this plan, maintenance due to equipment conditions (condition-based maintenance) which utilizes "equipment diagnosis technology" should be adopted in addition to the maintenance with periodic overhauling on its basis (time-based maintenance).

b) Repair, replacement, and modification plan

A plan should be established, with clarifying their contents and reasons, to be able to systematically perform repairs, replacements and modifications based on aging and the latest knowledge.

c) Special maintenance plan

As measures to improve safety, a power plant might be shut down for a long period of time to extensively replace equipment and components and/or to modify safety-related systems. When performing such maintenance activities different from ordinary ones, it is necessary to establish a special maintenance plan. The plan should be established considering equipment conditions and progress in checks. In the plan, contents such as identification of equipment conditions, confirmation of equipment activation in the commissioning before plant reoperation and monitoring after reoperation, as well as reasons why activities are different from the ordinary maintenance should be described.

The maintenance activities are performed in accordance with the characteristics of each power plant by assessing the maintenance effectiveness and feeding the assessed results back to the Maintenance Plan. Skilled work force and reduction in radiation exposure are secured by equalizing maintenance activities during operation and during plant outage through the utilization of condition monitoring during operation.

These measures are expected to contribute to higher reliability of maintenance activities.

A manpower distribution required for periodic licensee's inspections is shown in Figure 3-6. This figure provides insight into the necessity of equalizing maintenance activities.

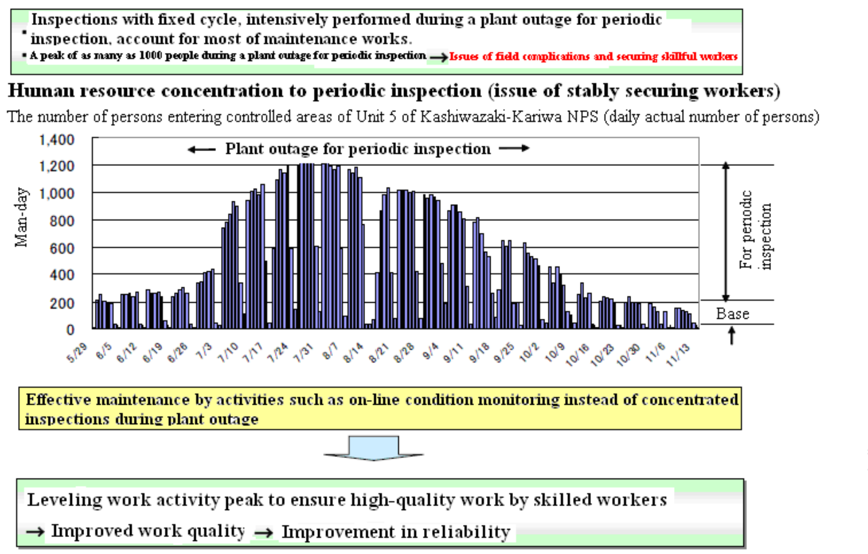


Figure 3-6 Manpower required for periodic licensee's inspection and necessity of securing human resources

4. Aging Management in the New Inspection Program

For the Aging Management of plants, it is currently mandatory for licensees to perform the technical evaluations on aging[*1] at the point before their plants exceed 30 years after commissioning according to the Reactor Regulation Act, and NISA reviews the adequacy of the technical evaluations on aging and long-term maintenance plans[*2] submitted by licensees. This current regulatory framework for the Aging Management mandatorily applies from now on, but the following two items are added in order to further strengthen the Aging Management.

- Ten-year maintenance management policy based on technical evaluations on aging (long-term maintenance management policy) should be described in the Fitness-for-Safety Program as a matter of approval by NISA. NISA reviews more closely the adequacy of Aging Management by licensees.
- Licensees' specific maintenance activities of each operating cycle according to the long-term maintenance management policy are to be provided in the licensee's "Maintenance Plan", and NISA reviews them in advance and checks its implementation status and results during the Safety Fitness Inspection and the Periodic Safety Management Review.

[*1]: Technical evaluations on aging: to select the anticipated degradation events on major structures and components of a nuclear power facility, to perform their technical evaluations based on the latest technological knowledge and the past operating records, etc., and to establish additional maintenance measures at the point before the nuclear power facilities exceed 30 years after commissioning

[*2]: Long-term maintenance: ten-year program on the measures to be additionally carried out as the Aging Management according to the technical evaluations on aging

Comparisons between the previous program and the New Inspection Program are given in Table 4-1.

Table 4-1 Comparisons of regulation on Aging Management of plants between the previous program and the New Inspection Program

Previous program	New Inspection Program
Licensees are to report technical evaluations on aging and long-term maintenance plans to NISA.	Long-term maintenance management policy and technical evaluations on aging are required to be described in licensee's Fitness-for-Safety Program, and NISA authorizes them after reviewing their adequacy.
Licensees are to report the implementation status of long-term maintenance plans at the end of periodic inspections of each operating cycle.	At each operating cycle, licensees are required to describe the implementation plans in accordance with long-term maintenance management policy in the Maintenance Program and submit them to NISA, and the Government reviews them in advance. NISA checks on their implementation status and results through the Periodic Safety Management Review, etc.

Aging degradation starts with power plant operation. For degradation events of which appropriate monitoring is considered necessary before 30 years after commissioning among aging degradation events, trend monitoring according to degradation characteristics based on the summary table of aging degradation mechanism is performed without fail to enhance the Aging Management. Also at the power plants which have exceeded 30 years after commissioning, since their functions and performance have been checked by periodic inspections etc. from the beginning of operation and preventive maintenance measures, such as introduction of the latest technology and replacements with new materials, have been taken, the original functions and performance as overall nuclear power plants have been maintained. Table 4-2 shows examples of the typical preventive maintenance measures taken in the course of 30 years after commissioning at the nuclear power plants which have undergone technical evaluations on aging.

Table 4-2 Examples of typical preventive maintenance measures

Type of power plant	Maintenance item	Means of maintenance: Replacement using new materials	Means of maintenance: Application of new technologies	Contents of maintenance
BWR	Replacement of recirculation piping Replacement of core internals	√		Replacement using the material with high resistance to stress corrosion cracking (low-carbon SUS material)
	Shroud support welds		√	Suppression of occurrence of stress corrosion cracking by residual stress mitigation technologies (peening work etc.)
	Hydrogen injection		√	Replacement of SG heat transfer tubes with those made of material with high resistance to stress corrosion cracking (Alloy 690)
PWR	Replacement of Steam generator (SG)	√		Suppression of occurrence and growth of stress corrosion cracking by improvement of the corrosive environment by hydrogen injection
	Improvement of secondary system water quality	√	√	Employment of all volatile treatment (AVT) using ammonia and hydrazine instead of phosphate treatment for prevention of SG heat transfer tube corrosion
	Replacement of reactor vessel upper head			Replacement of upper head nozzle material with the material having high resistance to stress corrosion cracking (Alloy 690)

As shown in the data of Figure 4-1, such preventive maintenance measures have contributed to the safe operation of power plants: the unscheduled shutdown rate per one plant, which is the sum of the number of unscheduled shutdowns at a given fiscal year from the beginning of commissioning (1970) to 2004 divided by the number of plants for 9 power plants with operating lives around 30 years, does not indicate a trend of increase as their in-service periods get longer.

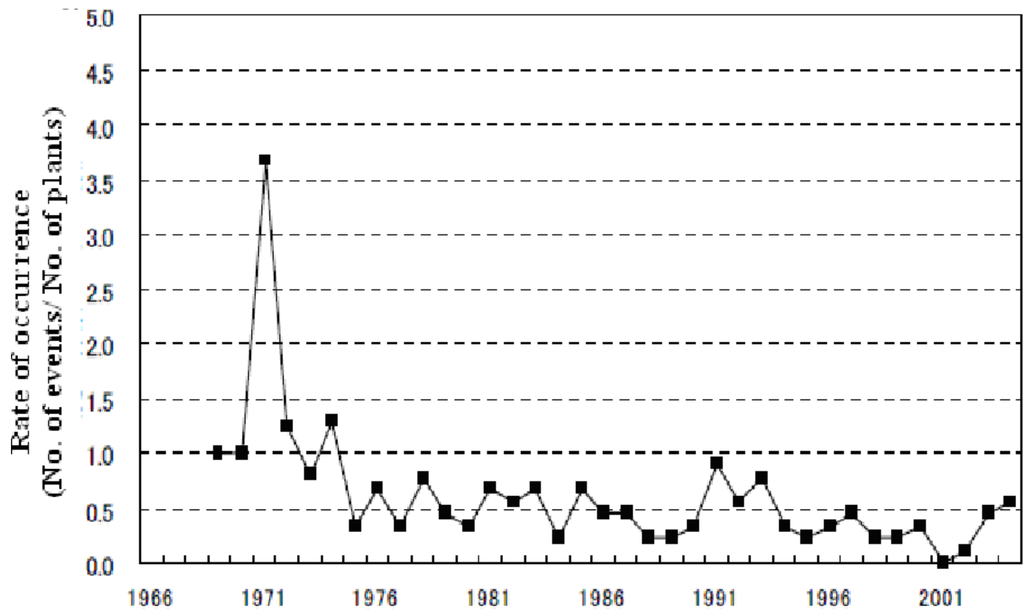


Figure 4-1 Trend of unscheduled shutdown rate

(The unscheduled shutdown includes both of manual and automatic shutdowns.)

5. Efforts to improve inspection effectiveness by comprehensive evaluation of each power plant

In order to raise the licensees' level of ensuring safety, implementation of the following comprehensive evaluation and inspection is considered necessary for each power plant .

- Licensees are to present indicators to exactly represent the safety performance of power plants, and to use them after receiving evaluation from NISA.
- Licensees are to use a method for determining the safety significance of the matters pointed out during inspections.
- With these, the comprehensive evaluation of each power plant is to be performed, and the results are to be used for effective implementation of inspections.

Major efforts are specifically discussed below.

5.1 Evaluation of performance indicators (PI evaluation) (PI: Performance Indicator)

The purpose of PI evaluation is that NISA judges whether fitness-for-safety activities of a power plant have been appropriately performed using objectively measurable indicators, and evaluates the presence or absence of degradation and the levels of the fitness-for-safety activities, etc. based on reference values (thresholds). For indicators for PI evaluation, the following specific indicators have been established as the goals which power plants should achieve, after investigating examples in foreign countries.

- Operation management and maintenance management

1) Number of unscheduled automatic and manual scrams per 7,000 critical hours
2) Number of unscheduled power changes per 7,000 critical hours
3) Number of unscheduled scrams which accompany a loss of normal heat removal function
4) Rate of safety system inoperability time (number of cases exceeding the reference rate)
5) Number of failures of safety system function
6) Leak rate from reactor coolant system (number of cases exceeding the reference value)
(7) Concentration of Iodine 131 in reactor coolant (number of cases exceeding the reference value)

- Radioactive waste management

8) Number of excessive releases of radioactive waste
9) Number of events with a loss of monitoring functions during a release of radioactive waste

- Radiation control

  10) Maximum individual radiation dose (number of cases exceeding the reference value)
  11) Number of excessive radiation effects occurred

The Categories for PI evaluation are established as the following four Categories, considering consistency with the evaluation Categories in the Significance Determination Process (SDP) mentioned later and the evaluation Categories in the comprehensive evaluation of safety activities, and the concept of the Reactor Oversight Process (ROP) of nuclear power plants adopted by the U.S. NRC.

Level of Degradation	No degradation	Level 3	Level 2	Level 1
Color code	Green	White	Yellow	Red
Definition of level	Condition without degradation	Condition to show indication of degradation	Condition to show indication of significant degradation	Condition to show indication of unacceptable degradation

5.2 Safety Significance Determination Process (SDP)

The objective of SDP is to assess to what extent an individual event occurred during activities to ensure safety of operators has influenced the nuclear safety. Events which NISA found during inspections, incidents that should be legally reported to NISA, and events determined not to satisfy Limiting Conditions for Operation (LCO) provided in Fitness-for-Safety Program (LCO deviation events) are subject to SDP.

The Categories adopted in the Safety Fitness Inspection are used for those of SDP.

Category in SDP	Category in the Safety Fitness Inspection	
	Category for evaluation	Actions taken according to evaluations
I	Violation 1	Issuance of an order for plant shutdown or a directory in the name of the relevant minister
II	Violation 2	Issuance of a directory in the name of the Director-General of the Nuclear and Industry Safety Agency

III	Violation 3	Issuance of a directory in the joint names of managers for the Policy Planning and Coordination Division / Nuclear Power Inspection Division
IV	Oversight	Oversight of reactor establisher's corrective action by Nuclear Safety Inspectors

The first step is to determine whether an incident and/or an LCO deviation event that is subject to this evaluation is minor or not in terms of safety. If more detailed evaluation is judged necessary on account of possible impacts on the nuclear safety, the Category level is determined according to the Categories in the SDP.

In the evaluation, the following implications are assessed:

- "Implications for safety functions"

  It is determined that safety functions of the concerned facilities and components have been impaired or not.

- "Radiation effects on the general public"

  It is determined that a release of radioactive waste has exceeded or has been likely to exceed the limits legally specified due to a failure to comply with the Fitness-for-Safety Program.

- "Radiation effects on employees"

  It is determined that a radiation dose to employee has exceeded or has been likely to exceed the limits due to a failure to comply with the Fitness-for-Safety Program.

5.3 Comprehensive evaluation of activities to ensure safety

The purpose of comprehensive evaluation of activities to ensure safety is to comprehensively evaluate the situation of a plant by using PI and SDP, and to identify the areas to be improved in licensee's activities to ensure safety, and to apply the results to the next Maintenance Plan and inspection program planning.

It is absolutely necessary to oversee the overall maintenance activities by adding evaluations of implementation status of maintenance activities which include Aging Management and Incident Management to this comprehensive evaluation.

6. Conclusion

The adoption of the Maintenance Program and the New Inspection Program are to enhance nuclear safety. By these Programs, licensees establish a mechanism to improve licensees' maintenance activities. Licensees are required to submit a maintenance plan, the implementation results and improvement status based on the said results to NISA. NISA reviews their adequacies and orders changes if necessary.

Licensees are required to collect data on degradation of components during overhauling, vibration of pumps during operation in a scientific manner and to continuously reflect them in inspection methods and frequency, etc. These efforts are expected to prevent incidents due to aging degradation and to reduce malfunctions which could be produced by giving an unnecessary change of state to components. NISA seeks licensees to perform thorough aging management from the beginning of plant operation, based on the knowledge acquired so far on aging, by strengthening NISA's oversight to the implementation of the licensee's Aging Management.

References

1) "Searching for Scenarios to Make Full Use of Nuclear Power Plants", Asahi Newspaper dated May 22, 2009

2) "Adoption of Inspections on the Basis of the Maintenance Program", material from the Nuclear and Industrial Safety Agency, August 2008

3) Standard of the Atomic Energy Society of Japan "Standard for the Aging Management of Nuclear Power Plants for Public Hearing (revision)" (AESJ-SC-P005:200X)

4) "Summary Table of Aging Degradation Mechanism", separate attachment of Standard of the Atomic Energy Society of Japan "Standard for the Aging Management of Nuclear Power Plants for Public Hearing (revision)" (AESJ-SC-P005:200X)

5) News Release of NISA, the Ministry of Economy, Trade and Industry, December 12, 2008 "Approval of Application for Amendment in the Fitness-for-Safety Program from Reactor Establishers for the Amended Ministry Order for Adoption of the Inspection Program Based on the Maintenance Program"