Plant lifetime of nuclear power plants and regulatory limits in Japan

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Abstract: The plant lifetime management of nuclear power plants (NPPs) in Japan is described in this paper with the regulatory restriction over 40-year operation. The actual plant life and operating period assumed during the design and construction phases are first discussed, and then the measures and principles are examines to ensure safety at NPPs. Better regulations and its practice are discussed for the long-term operation of NPPs over 40-year operation, by taking into account of global standards and the back-fit system. Lastly several regulatory improvement in Japan are proposed so that the NPPs can be safely operated beyond 40 years through inspections, appropriate repairs, and component replacement on the basis of the results of degradation evaluation and by means of appropriate back-fitting.

Keyword: plant lifetime; ageing management; back-fitting; nuclear regulation

1 Introduction

Japan's Nuclear Reactor Regulation Act, which was amended in 2012 in the light of severe nuclear accident at the Fukushima Daiichi Nuclear Power Plant, provides that the country's nuclear power plants (NPPs) are allowed to operate for up to 40 years. This act also stipulates that the operating period of 40 years can be extended to 20 years with the approval of the Nuclear Regulation Authority. This amendment was supported by majority of the Diet (parliament). However, according to minutes of the meeting of the Environmental Committee of the House of Councilors during the 180th Diet session when this amendment was discussed, it can be said that the 40-year operating period was selected as a politically judged condition which lacks the firm technological basis and rationale [1].

To examine the feasibility of light water reactor plant design, aging degradation evaluation of the main components is conducted by assuming a particular operating period as one of the evaluation criteria. In Japan, such evaluations have previously been undertaken by assuming a 40-year service life. Such a period was considered as highly appropriate in terms of design, and acceptable with respect to taxation at the time of the plant construction. However in actual operation, such evaluations should be performed by assuming much longer operating periods than 40 years by taking into account of the satisfactory operating performance of the real NPPs in the well-developed countries as in Japan. In fact, many plants with proven long-term integrity have been permitted to continue operating for at least 60 years, and the regulatory process for permitting 80-year operation is currently under discussion in the United States.

It is an international recognized common sense to permit the extension of the operating period of NPPs beyond 40 years, if the long-term integrity of the plant components can be technically demonstrated. This is based on the universal principle that the condition of systems, structures, and components (SSCs) should be determined by the results of inspection. The integrity of the SSCs is technically evaluated from the results of those inspections, and the service life of all SSCs, including NPPs, is determined based on the results of evaluation of the integrity of the SSCs.

However, the operating period of NPPs in Japan is limited to 40 years by the Nuclear Reactor Regulation Act, without knowing internationally recognized practice. In addition, the 40-year limit to the operating period of NPPs denies the principle of management of artifacts. Therefore, it may also lead to various problems as described below in the subsequent parts of this paper, where problems and the solutions will be

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discussed with regards to the regulatory limitations of the service life of NPPs in Japan.

2 Plant life and operating period assumed in design and construction phases

2.1 Plant life and operating period assumed for earlier NPPs

2.1.1 Practice taken by Japanese regulation and industries

The design of earlier NPPs in Japan was evaluated at the time of the plant construction by assuming a certain operating period such as 40 years. This operating period was used when designing the reactor pressure vessel and other important components to assess the accumulation or development of aging degradation and that the period was also employed to ensure the validity of the design and maintainability of the components. It was not intended to represent the plant life.

Generally, the actual accumulation of aging degradation in components is not as extensive or is slower than that assumed in the design. Accordingly, it was understood during the design and construction phases of earlier NPPs that the plant as a whole would be very likely to function well beyond the operating period which was assumed in the initial design evaluation. This effect of longer functioning was considered to be brought by many factors; (i)implementing preventive maintenance by using the knowledge gained from operating experience, (ii)experiments and research, and (iii)maintenance activities such as replacing components according to their degree of aging degradation.

As described below, this situation is reflected from the fact that approximately 15 years after the earlier NPPs began operating in Japan, the development of life extension technology was initiated under the assumption of a plant life exceeding 40 years.

2.1.2 Practice taken by oversea countries

(i) Recommendation by International Atomic Energy Agency

The authors of this paper reviewed the documents related to this issue published by the International Atomic Energy Agency (IAEA). In some of those documents, they found articles about the plant operating period. Below is one of the articles.

INSAG-14 [2], published by the IAEA in 1999, states that NPPs that started operation in the 1970s and 1980s were generally designed for 30–40 years operation. However, it notes that some organizations examine the possibility of extending the life of some plants to 45, 50, or 60 years.

(ii) Practice in the United States

In the United States, the licensed period of NPP is maximum of 40 years. However, this licensed period may be renewed upon expire. Although there is no limit on renewing the operating period under the Atomic Energy Act, the US Nuclear Regulatory Commission (NRC) currently adopts the extension limit of 20 years.

According to the Federal Register dated December 13, 1991, the original 40-year operating license by NRC is based on the description when the License Renewal Rule was developed. The Department of Justice and the Electric Utilities Association supported the 20-year extension of the initial license period from the perspective of antitrust consideration. However, electric utilities claimed that a longer license period would be necessary for depreciation of an NPP. Congress therefore decided on the 40-year limit.

The Fact Sheet on the NRC website about license renewal states: “Economic and antitrust considerations, not limitations of nuclear technology, determine the original 40-year term for reactor licenses.” It also specifies: “However, because of this selected time period, some systems, structures, and components may have been engineered on the basis of an expected 40-year service life.”

Another NRC website titled “Why 40 years?” explains: “The Atomic Energy Act was modeled after the Communications Act of 1934 under which a license of up to a few years to operate a radio station was granted and a license renewal was granted if the licensing requirements were met. By the similar way, the Atomic Energy Act granted a license renewal to a

NPP. The Congress chose a 40-year license for NPPs because the cost of a power plant can be normally recovered by the profit by electricity rates over this period. The 40-year license period is not based on safety, technical or environmental considerations."

(iii) Practice in other industries

Fossil fuel power plants and chemical plants are operated under the assumption that they can fulfill function for a period of over 40 years if their safety can be demonstrated. Such demonstration demands proper undertaking of inspections, degradation evaluations, and maintenance activities such as repairs, with focusing on aging degradation in any components that are subject to preventive maintenance, *e.g.*, fatigue and creep.

2.2 Recognition of plant life after accumulated operating and maintenance experience

2.2.1 Recognition before 30 years of operations of earlier NPPs

Since ca. 1976, electric utilities and plant manufacturers around the world have actively engaged in the investigation on the mechanism of aging degradation, advancing measures against aging degradation, and developing methods to replace large components. Those entities that have been performed so long time by the collaboration of academia, industry, and government in research and development on long-term problems common to electric utilities are all listed in **Table 1.** All the results of these research activities and developments revealed that a plant life extension of the existing NPPs could be possible if proper maintenance as repair and replacement would be performed in a timely manner.

As noted in Table 1, about 15 years after the earlier NPPs began operations around 1970, industry and governments undertook various research activities by assuming that the plants would function beyond the 40-year operating period. That assumption was made by the evaluation of the integrity of components at the time of plant construction.

2.2.2 Reason for developing a framework for technical evaluation of plant life management

A framework for technical evaluation of plant life management was created and developed in such countries as the United States and United Kingdom, where commercial operation of NPPs started quite early. This framework was formulated under the assumption that the NPPs would function beyond the 40-year operating period, which was assumed during the evaluation at the time of plant construction. In the United States, the license renewal rule of the NRC was developed in December 1991; it was partially amended in May 1995. The Calvert Cliffs Nuclear Power Plant and Oconee Nuclear Power Plant renewed their operating licenses for the first time in May 1998.

To manage the aging degradation associated with long-term operations, NPPs overseas have been performing such operations as license renewal or technical evaluation conducted every 10 years—rather than applying a uniform limit on the operating period of all plants. As a result, in the United States as of the end of December 2014, 92 of the 99 operating reactors, which accounts for more than 90% of all operating reactors, applied for license renewal to allow for 60-year operation. Four of the remaining seven reactors are scheduled to apply for license renewal, and three of the reactors are relatively new. The operating licenses of 73 reactors have been renewed to allow for 60-year operation.

In Japan, being aware of the importance of performing appropriate maintenance activities, electric utilities began studying the aging management of light water reactors in ca. 1990. Their long-term R&D efforts on ageing maintenance can be summarized as shown in Table 2. As seen in Table 2 for the part of April 1994, the necessity of aging management was cited in the interim report of the Nuclear Energy Subcommittee of the Advisory Committee for Energy. As a result, a study of aging management in Japan was initiated and implemented in two phases. The results of these activities revealed that the continued operation of the earlier NPPs beyond 40 years could be possible if proper maintenance as repair and replacement is performed in a timely manner.

2.2.3 Recognition after introduction of new regulatory standards

As noted in Chapter 1, Japan's Nuclear Reactor Regulation Act which was amended in 2012 describes that all NPPs in Japan are allowed to operate up to 40 years, although the operating period can be extended to 20 years only with the approval of the Nuclear Regulation Authority (NRA).

The NRA published "The Standards for Review of the Operating Period of a Commercial Nuclear Power Reactor" in November 2013. This issued standard was to cover the procedure for extending the operating period of NPPs. It required a regulatory process for all construction plans for modifications required to meet the new regulatory standards. Following the results of aging degradation evaluation, the reactor and other components had to meet specific requirements for an extension of the operating period.

The NRA released "The Guide to an Application for Approval of an Extension of the Operating Period of a Commercial Nuclear Power Reactor," which was amended in August 2014. This guide was issued to specify inspection requirements such as (i) 100% ultrasonic testing of the reactor pressure vessel in the core region (base metal and welds) with a focus on neutron-irradiation embrittlement, and (ii) surface inspection with a focus on fatigue of the primary coolant nozzle corners (feedwater nozzle corners). These were cited as detailed requirements for "the inspection (special inspection) performed to evaluate the aging degradation of the nuclear reactor and other components associated with operation before the submission of the application."

Similarly, the NRA published "The Guide to the Aging Management of a Commercial Nuclear Power Reactor Facility" in June, 2013. Major changes from the previous technical evaluation for plant life management includes the following items: (i) permanent facilities for coping with various types of severe accidents, (ii) managing the scope of evaluations, and (iii) properly reflecting results of special inspections and technical evaluations for plant life exceeding 40 years of operation.

2.3 Current regulatory systems and measures in Japan for plant life management

In addition to the existing regulatory systems for plant life management, a new regulatory system for extending the operating period of NPPs was established. Following the accident at the Fukushima Daiichi NPP, the new regulatory standards impose very strict design requirements for external events which include tsunamis, earthquakes, tornadoes, fires, and floods. The new standards require the installation of facilities, establishing an emergency response organization, formulating procedures for coping with various severe accidents, and imposing strict requirements on the technical evaluation of plant life management. The standards include an evaluation of aging degradation in permanent facilities for dealing with severe accidents.

The aim with the current regulatory system for plant life management in Japan can be summarized as follows: (i) to conduct a technical evaluation of aging degradation in components every 10 years after 30 years of operation by assuming an operating period of 60 years (as was previously the case), (ii) to develop a long-term maintenance plan, and (iii) to obtain approval from the NRA for changes in the technical specifications related to operation. After the approval for extending the operating period, the NRA requires evaluation after 30, 40, and 50 years of operation.

In the above stated regulatory system for extending the operating period of NPPs which was introduced with the new regulatory standards, the permissible operating period of plants is uniformly limited to 40 years after the start of operation. The operating period can be extended for up to 20 years only after approval by the NRA before expiration of the license. The application for extending the operating period has to be accompanied by the results of the special inspection of the reactor pressure vessel and technical evaluation of plant life management as well as the long-term maintenance plan for the extended period.

The new regulatory standards and regulatory system for plant life management were developed in full consideration of the experience with the accident at Fukushima Daiichi NPP. Aging management takes place on a continuous basis and consists of assessing the aging degradation of components using up-to-date findings. Existing maintenance activities are reviewed, new plant maintenance programs are then developed, implemented, and reviewed if necessary. This is believed to be an effective way to ensure the safety of long-term operation of an NPP. It is thus important to perform safety improvement activities thoroughly in accordance with the regulatory system to assure that plant life management and the new regulatory standards are maintained from a long-term perspective rather than uniformly limiting the operation period of all plants to 40 years.

3 Measures and principles to ensure safety of NPPs

3.1 Design, management, and regulatory standards to ensure safety

3.1.1 Safety design and aging management

Technology develops rapidly. After a plant is constructed using the latest technology available at the time, technology continues to improve and important knowledge is accumulated. Thus, even a plant which had built by utilizing the latest technology and knowledge will start to become obsolete as soon as plant construction is completed. If an accident or serious problem occurs in any NPP in Japan or overseas after operation begins and if the knowledge or lessons thereby learned are important for the safety of such plants, then existing regulatory standards may change or new ones become established.

Generally, if the regulatory standards are revised, the revised standards are applied or back-fitted to existing operating plants. This may require changes in safety design and maintenance which are two key elements in determining plant safety. Safety design may require a modification of existing components or facilities. In some cases, it may not be easy to make such modifications. In such an event, safety assessment or risk assessment is required. Even if a plant cannot be properly back-fitted or if it fails to meet the requirements of the new regulatory standards, it may still be judged as having adequate safety from the latest technological perspective if some changes have been made to plant systems or it has been possible to enhance human performance there. In such a case, it would be reasonable to approve continued operation of the plant even though it fails to meet the new regulatory standards.

Regulatory standards are extremely important for promoting the peaceful use of nuclear energy and are based on ensuring safety. The most effective means of guaranteeing safety is considered to involve setting an appropriate regulatory hurdle to prevent accidents, to promote continuous enhancement of safety by improving plant systems, and incorporating safety culture. The regulatory hurdles need to be set high to secure safety. However, to promote the peaceful use of nuclear energy and contribute to improving public welfare and living standards, it is necessary to place the regulatory hurdle as low as possible. A good balance is therefore required between the two contradictory requirements. That is why developed countries have made ongoing efforts to set the regulatory hurdles at appropriate level based on an imaginative approach and using the latest technological findings.

From this perspective, it is extremely important to develop a rule for back-fitting in a reasonable manner. This is because even an NPP built by using the latest technology and knowledge will start to become obsolete as soon as construction is completed. Therefore all plants will face the situation whereby they have to be back-fitted to meet new regulatory standards. It is important therefore that the regulatory standards should be the minimum requirements to ensure safety. The purpose of the back-fitting should be to fulfill the level of safety required by regulations—not to require that all operating plants meet the regulatory standards.

3.1.2 Significance of 40-year design

(i) Definition of plant life

The economic efficiency and safety of a plant have a decisive influence on the continued existence of that plant. If the economic efficiency falls below a certain level, the plant cannot survive. Likewise, its survival is threatened if safety level drops below a certain level. From this perspective, the authors of this paper would like to introduce major factors that determine the life of a plant as depicted in Fig. 1. It is straight forward for you to see what the authors of this paper would like to tell from Fig.1 that the limit of the plant life would be determined by either of the both factors of physical and economical situations caused by ageing degradation which make it impossible to replace or modify the components to use the plant further. The authors of this paper would like to extend the relevant arguments in the subsequent two subsections.

(ii) Consideration of aging degradation in plant design

Thereafter, based on detailed actual operational data after the start of operation and on inspection results, the progress of aging degradation is evaluated again to ensure the integrity of components. If the evaluation results show that some measures are required, the components are updated or modified as far as physically or economically possible to allow continued operation. This principle is widely accepted both in Japan and foreign countries in all industries.

(iii) New knowledge or regulatory standards and plant life

Revising regulatory standards simply based on the current technological findings can bring about a detrimental effect on plant life. For example, if an attempt is made to modify a component or system to meet new regulatory standards, the modifications may not be possible physically or economically. That could result in closure of a plant.

The important point to consider here is, as described above, even a plant built using the latest technology and knowledge will start to become obsolete as soon as plant construction is completed. Therefore, if the regulatory standards are revised in line with the current technology, it is necessary to return to the perspective of plant safety without being bound by the requirements of regulatory standards. This is because what is required of a plant is to ensure that safety exceeds a certain level—not to meet the requirements of regulatory standards. This is what is required by the Atomic Energy Act and the Nuclear Reactor Regulation Act.

In accordance with the above considerations, there are many situations where a decision has to be made as to whether new regulatory standards should be back-fitted to the existing plants. Such decisions are very important to guarantee safety. Therefore, it is necessary to clarify the specific cases where back-fitting is required to meet new regulatory standards as well as the scope, method, and criteria for effective back-fitting.

3.2 Back-fitting method to meet regulatory standards

3.2.1 Principles in the United States and Europe

(i) Back-fitting method in the United States

The authors of this paper investigated the method of back-fitting to meet new regulatory standards in the United States. The back-fit analysis method employed by the NRC is as shown in **Fig. 2**.

(ii) Back-fitting method in Europe

The authors of this paper examined back-fitting method in the UK, France, and Germany. Those countries have the similar procedure as that by NRC, although not shown here.

3.2.2. Back-fitting in Japan

There had been no legally stipulated regulation method of back-fitting in Japan, except for the earthquake resistance. In the light of bitter experiences of several big earthquakes since Kobe earthquake occurred in 1995, a review has been made of the integrity of plant systems vital to safety, and measures have been developed and adopted as necessary as possible. To ensure the integrity of plants, the government has used a regulatory system—the so-called back-check system—to confirm the integrity of systems important to safety.

However, following the introduction of the new regulatory standards in July 2013, requirements for back-fitting were implemented in Paragraph 3-14[1] and Paragraph 3-23[2] in Article 43 of the Nuclear Reactor Regulation Act. Consequently, back-fitting is always required, regardless of when a plant's construction permit was issued. Particular problems

[1] It requires that the licensees shall maintain their plants to meet the NRA technical standards.

[2] It says that the NRA has the legal right to order the licensees to take actions necessary to meet the NRA technical standards and rules.

in this regard are the criteria for back-fitting and its timing. In the United States, prompt back-fitting without consideration of cost is required only if it is necessary to provide appropriate protection of the public. Other considerations involve comparing the cost of modification and the benefits to improved safety and determining whether back-fitting is actually required. When ordering back-fitting, the NRC requires that electric utilities should submit their responses and the implementation plan. The NRC also provides a grace period, taking into account of the time necessary to implement the measures with allowing the back-fit process to be undertaken without causing a plant shutdown.

It is important always to maintain and improve safety. It is also necessary to design a back-fit system that incorporates scientific rationality, for example, by evaluating the contribution of back-fitting to improving plant safety as a whole and its cost-effectiveness. This should be based on the back-fit rule as are implemented in the United States and other countries. The scientific and technological approach should be implemented so that the utilities can determine whether to apply the back-fit rule, the scope and method of application, and the grace period.

4 Ideal management of NPP facilities

4.1 Structure to ensure nuclear safety and its components

Nuclear safety is ensured by two systems: (i) plant system, consisting of mechanical, electrical, control, and civil engineering and construction components, and (ii) human system to operate the plant system [4]. The requirements of the both systems with their roles for safety can be described as shown in Fig. 3.

The plant system incorporates safety design considerations to provide the system of higher reliability such as with regard to redundancy, diversity, and independency, with the measures to prevent human error, by the introduction of fail-safe, foolproof, and interlocking measures. These design considerations encompass both external and internal events. The system is designed to ensure reliability or safety beyond a certain level as long as the system functions in accordance with the plan.

Under normal conditions, the human system manages safely and steadily the plant system by performing activities, such as operation and maintenance, while under the design conditions on a planned basis and maintains production. Even with abnormal events or an accident due to an internal event such as component failures, or an external event such as an earthquake or tsunami, the human system performs emergency response operations to shut down the plant system safely and keep the plant condition under control while ensuring safety. Thus, nuclear safety is ensured by a combination of the safety functions of a plant system and the actions of a human system.

4.2 Aging degradation management and safety based on maintenance activities

If a plant system would be degraded, maintenance is the activity by which the human system would serve to repair the plant system and to prevent any resulting reduction in function. Maintenance is an activity that involves the following cycles: (i)planning inspection or monitoring of a target component (P) based on predicting the initiation and progress of aging degradation, (ii)implementing an inspection or monitoring plan (D), (iii)evaluating the results of implementing the inspection or monitoring plan (C), and (iv)taking corrective measures for the component as required (A). This constitutes the PDCA cycle for maintenance. [4]

As noted above, maintenance involves checking the condition of a plant's components and buildings by using an inspection or monitoring technique. Maintenance predicts and evaluates the progress of aging degradation associated with subsequent operations of the plant by using aging degradation evaluation techniques. Based on those predictions and evaluations, maintenance determines whether or not to continue operation of the plant, and it takes corrective measures when and where necessary. Maintenance is a universal activity and is commonly performed in general industrial plants as well as in NPPs. Maintenance activities are repeated during the life of a plant to preserve the integrity of the individual equipment and the whole system.

5 Proposed improvements for better regulation

5.1 Problems from the perspective of desirable regulation and proposed improvements

5.1.1 Removal of 40-year limit on operating period

In Japan, the current system limits the operating period of all NPPs to 40 years. However, this is inappropriate from a scientific and technological perspective as well as with respect to global trends. The Nuclear Reactor Regulation Act should be amended and the associated regulatory system revised.

5.1.2 Accepting application for extending the operating period

The authors of this paper believe that it should be permissible for an application to be made to the NRA to extend the operating period of an NPP beyond 40 years of operation. If reviewing such an application proves to be too time consuming, rules should be specified to allow continued operation, provided that an electric utility demonstrates the integrity of the plant based on inspection and evaluation.

5.2 Problems with the regulatory process and proposed improvements

5.2.1 Application period for approving extension of the operating period

The authors of this paper believe that the same application procedure as that practiced in the United States should be employed in Japan for extending a license to NPPs. There, the application period for extending the license is such that the application may be made at an early stage several years before the operating period expires to permit early review in the approval process.

5.2.2 Expiration of plant license while applying for extension

The authors of this paper believe that the regulatory process should be changed for the NPPs where an application for extending the operating period has already been submitted and is under review. It should allow the review process to be continued and the operating period extended even if the 40-year period of operation has been exceeded during the review process as long as the applicant can demonstrate the safety of his plant in the extended period.

5.2.3 Proposed improvements in the regulatory system for approving extension of operating period

The authors of this paper believe that the procedures in the regulatory system for approving extension of the operating period of NPPs should be improved as described in the subsequent paragraphs of this subsection.

1) The period during which an application for extending the operating period can be submitted. It should be changed so as to allow application submission more than several years before the end of the 40-year period. (This requires revision of the Ministerial Ordinance for Commercial Power Reactors.)

2) In conjunction with this point, it should be possible for the NRA to review an application to approve extension of the operating period and expeditiously issue an approval according to the progress of the review process.

3) There should be a provision for plants applying for extension of the operating period, whereby the review process by the regulatory body should be continued beyond the 40-year period. It should be possible for the approval procedures to be completed even when there is a delay in the review process and it is not finalized before the end of the 40-year period. (This requires revision of the Nuclear Reactor Regulation Act.)

4) Changes should be made so that completion of procedures to approve a construction plan in compliance with the new regulatory standards is independent of the requirements for an application to extend the operating period. (This requires revision of the regulatory review criteria.)

5) The grace period for plants that have reached or are nearing the end of the 40-year operation period should be extended. (In addition to other steps, this requires revision of the Act for Establishment of the Nuclear Regulation Authority.)

6) The regulatory system for approving extension of the operating period should be made more effective and efficient by eliminating provisions that also exist

in the regulatory system for plant life management.
7) It would be appropriate to conduct the special inspection under the regulatory system for plant life management. This means the current regulations should be changed so as to allow it.

5.3 Technical problems in the special inspection for extending the operating period

The relationship between the special inspection for extending the operating period and the technical evaluation for plant life management and in-service inspection should be clearly defined. In this respect, the following points should be clarified:
1) Level of aging degradation which may occur in the components selected as targets of the special inspection.
2) Inspection method adopted in the special inspection.
3) Necessity or technical reasons for the special inspection.

5.4 Proposed improvements in the back-fit rule

In Japan, the contribution of back-fitting to enhance safety as a whole and its cost-effectiveness should be evaluated by using a scientific and technological approach. It should be based on the back-fit rule adopted in the United States and other countries. The back-fit rule in Japan should be revised to allow for the scope and method of application and the grace period to be specifically determined based on the evaluation.

6 Concluding remarks

Industrial facilities are generally inspected and evaluated for aging degradation. The results of the inspection are examined, and corrective measures, including repairs, are performed as necessary. New knowledge may be gained from the operating and maintenance experience in addition to experimental and research results. The facility improves through that knowledge, and it continues operations by ensuring the required safety. It is a widely accepted principle that as long as the aging degradation of the facility is well controlled and its safety assured, the facility can be used to serve society with no limit on its operating period. Independent of the type of industrial facility, this universal principle and approach is adopted both in Japan and overseas countries.

Japan's Nuclear Reactor Regulation Act, as amended in 2012, limits the operating period of NPPs to 40 years in the absence of other provisions. NPPs in Japan are thus based on a very unusual principle compared with the situation overseas. This "unusual" amendment was proposed and introduced by Diet members and approved by the Diet. The 40-year limit was politically determined, and it lacks a scientific and technological basis. The life of industrial facilities should be determined using scientific, technological, or economic standards. As described in this paper, the politically based 40-year limit on the operating period of NPPs in Japan may be the political compromise on the safety of NPPs from social point of view. However, it may prevent proper utilization of Japan's assets and place the resulting burden on the public.

The objectives of Japan's Atomic Energy Act and the Nuclear Reactor Regulation Act are stated as follows: to utilize nuclear energy with ensured safety to secure future energy resources; to achieve progress in science and technology and promote industry; and to contribute to improving human welfare and public living standards. As long as the safety of NPPs is maintained based on the spirit of the law, they should be allowed to operate to serve society.

List of acronyms

BWR Boiling water reactor
ECT Eddy current test
IAEA International Atomic Energy Agency
IASCC Irradiation assisted stress corrosion cracking
METI Ministry of Economy, Trade and Industry
MITI Ministry of International Trade and Industry
NDE Non-destructive examination
NPP Nuclear power plant
NRA Nuclear Regulation Authority
NRC Nuclear Regulatory Commission
PTS Pressurized thermal shock
SCC Stress corrosion cracking
SG Steam generator
UT Ultrasonic test

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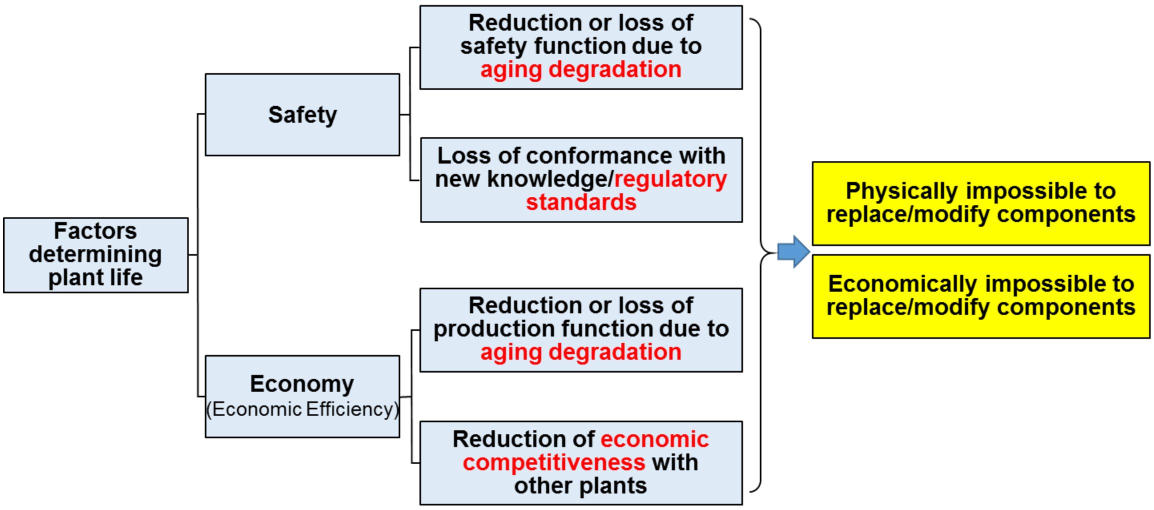


Fig. 1. Factors determining plant life.

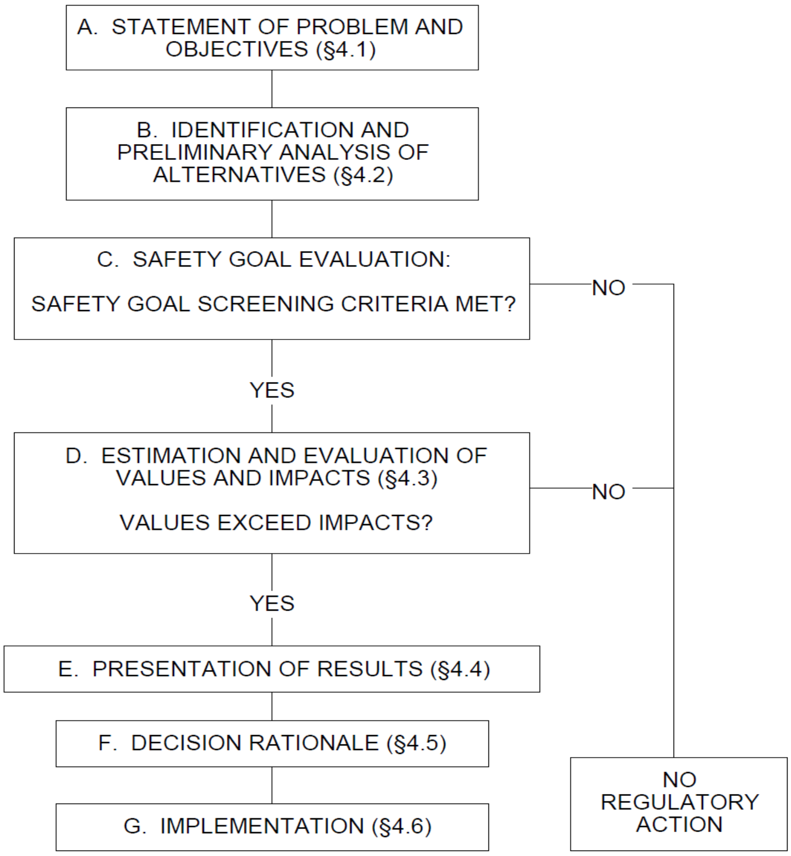


Fig. 2. Regulatory analysis for cost-justified substantial safety enhancements to nuclear power plants (Cited from NUREG/BR-0058, Rev. 4).

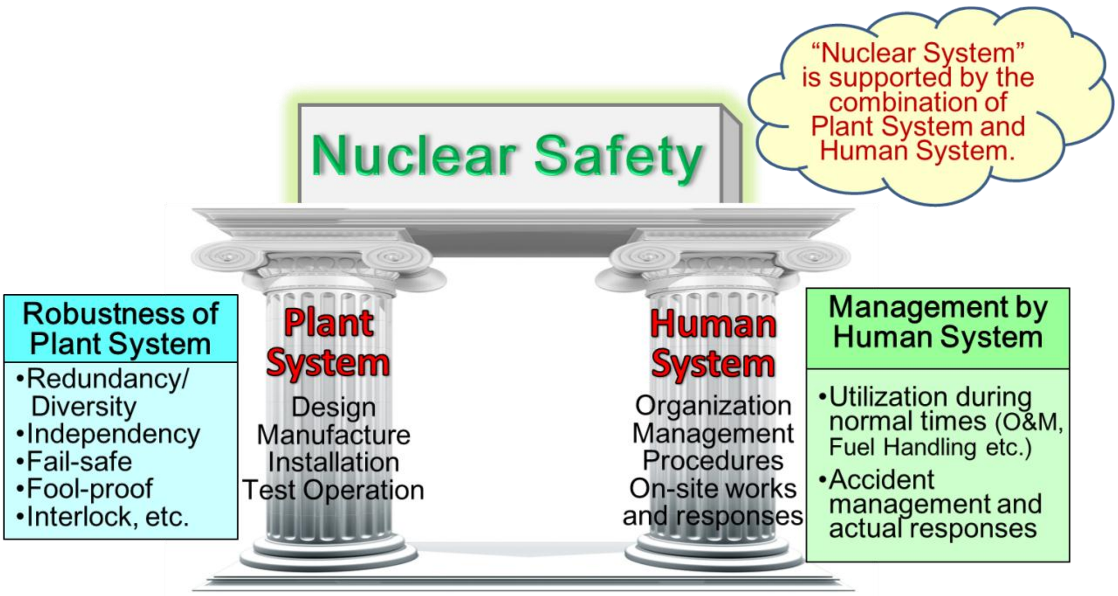
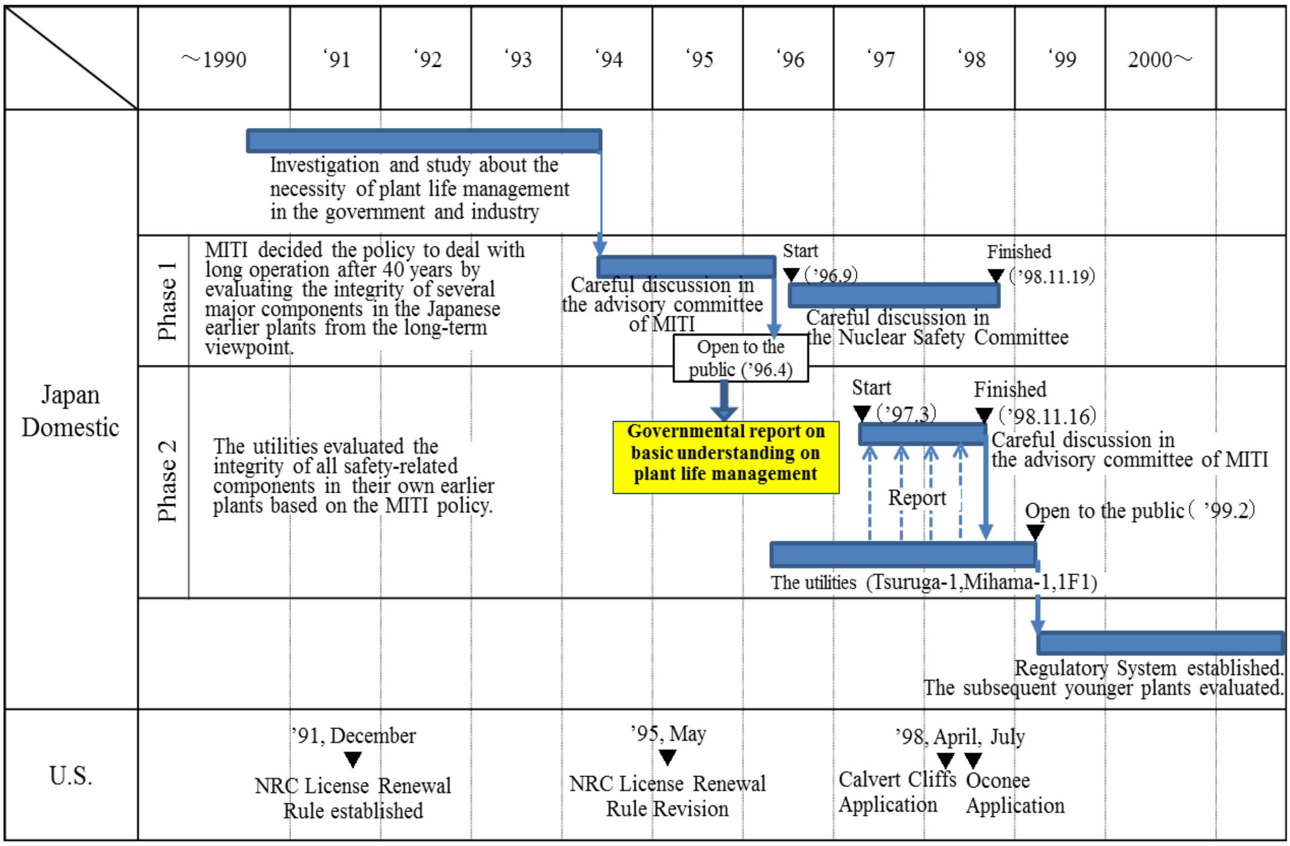


Fig. 3. Structure of nuclear safety.

Table 1. History of major research projects on aging management in Japan

	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Research on pressurized thermal shock (PTS) of reactor vessel (Fracture mechanics test of irradiated specimen, Evaluation of reactor vessel during PTS)	■	■	■	■	■	■	■	■	■																							
Research on plant life extension (Phase II) (Fracture toughness test of aged cast stainless steel and irradiated stainless steel, Reconstitution of used specimen for measuring embrittlement of reactor vessel etc.)					■	■	■	■	■	■	■	■	■	■																		
Verification test and establishment of evaluation methodology on the integrity of cracked mechanical components (ex. piping)									■	■	■	■	■	■	■	■	■	■														
Development of NDE method of detecting fatigue crack in SG tubing and Verification test on ultrasonic test detectability and crack sizing ability relating to SG tubing										■	■	■	■	■	■	■	■	■	■	■	■	■										
Environmental fatigue tests for primary coolant components and development of its evaluation method												■	■	■	■	■	■	■	■	■	■	■	■	■								
Development of surface improvement technologies against stress corrosion cracking (SCC) for reactor internals														■	■	■	■	■	■	■	■											
Development of evaluation method of reactor vessel neutron irradiation embrittlement and primary coolant piping thermal aging														■	■	■	■	■	■	■	■	■	■									
Development of repair weld technology applicable to neutron irradiated materials including reactor vessel and internals															■	■	■	■	■	■	■	■										
Laboratory tests for acquisition of data on SCC propagation rate in Ni based alloy																		■	■	■	■	■	■									
Laboratory tests for acquisition of data on IASCC propagation rate in reactor internals and development of its evaluation method and management																		■	■	■	■	■	■	■	■	■						
Development of evaluation method of residual stress and SCC propagation in complex-shaped portion of Ni based alloy components including nozzle safe-end weld and shroud support weld																			■	■	■	■	■	■	■							
Laboratory tests for acquisition of data on safety-related cable aging degradation in thermal aging condition and thermal and irradiated aging condition																				■	■	■	■	■	■	■						
NDE tests on detectability and sizing accuracy of UT and ECT in Ni based alloy weld																				■	■	■	■	■	■	■						
NDE tests on detectability and sizing accuracy of UT and ECT in low carbon stainless steel weld																					■	■	■	■								
Laboratory tests for acquisition of data on SCC propagation in nuclear grade low carbon stainless steel																					■	■	■	■	■							
Laboratory tests for acquisition of more data on SCC propagation rate in Ni based alloy																							■	■	■	■	■					
Tests for acquisition of data necessary for evaluating fracture characteristics of Ni based alloy welded structure																							■	■	■	■	■					
Study for improving the evaluation method of reactor vessel neutron irradiation embrittlement in higher irradiation dose condition																							■	■	■	■	■	■				
Study for improving the evaluation method of fatigue and crack propagation in neutron irradiated materials which have repair weld																								■	■	■	■	■	■			
Study for evaluating the effect of neutron irradiation dose below the threshold of IASCC susceptibility on low carbon stainless steel and its weld used in BWR reactor internals																									■	■	■	■	■	■	■	

Table 2. History of the study of plant life management in Japan ascompared with U.S.A.



MITI: Ministry of International Trade and Industry
(the present METI; Ministry of Economy, Trade and Industry)