Study on the life determination and extension methods of life-limited items of Nuclear Power Plant (Based on EPRI NP-6408)

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1. Introduction

In order to operate nuclear power plants and related facilities safely from the risk of accidents, proper maintenance is essential at the right time. Proper maintenance, whether it is due to a breakdown or to prevent breakdowns, is the most important measure to ensure the safety of a nuclear power plant. For maintenance, various factors such as manpower, equipment, time and money parts are introduced. Among them, the use of appropriate parts is the most fundamental factor.

Korea, meanwhile, used the QAP-1 of KEPIC[1], Korea Electric Power Industry Code, which cited the American Society of Mechanical Engineers ASME NQA-1[2], which is the technical background of the US 10 CFR Part 50 Appendix B[3]. As the requirements of the quality assurance of the facility, and the content of "Requirement 8 Identification and Control of Items" is applied as a requirement to secure the use of the above-mentioned suitable parts. The requirements of Chapter 8 of KEPIC QAP-1 are as follows.

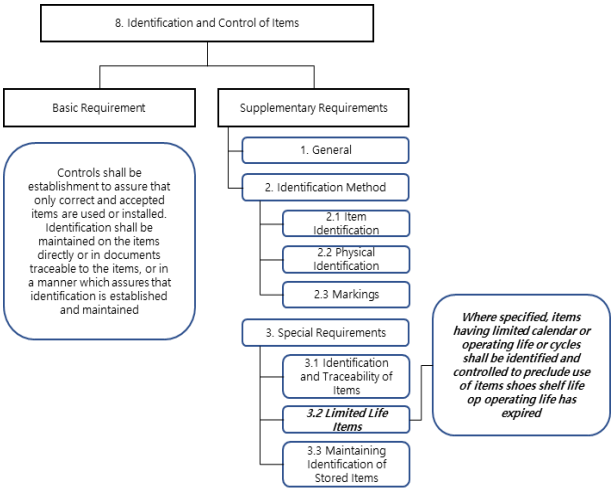


Fig.1. Requirement 8 Identification and Control of Items

Looking at the content of the requirements, reference is made to lifetime limited items as special requirements in the supplementary requirements, which require that items that have a limited lifetime in their stored devices or parts are identified and managed so that they will not be used after their lifetime have. According to the requirements of KEPIC, it is inevitable to dispose of items that have reached the end of their life due to the efficiency of operation of nuclear power plants, the occurrence of unplanned maintenance, it is a difficult choice. In addition, a lot of research has been done on how to evaluate the life span of a device or a component. Based on this, if it is technically justified, it will be possible to extend the life of the storage item and save a lot of cost and time. You will be able to make an effect. The regulatory body of nuclear power in Korea also judges the appropriateness of the management suitability and life extension judgment of the storage items of the nuclear power plant through regulatory inspection. However, there are still some unsatisfactory or technically unsatisfactory parts, and the relevant findings and recommendations derived from the quality assurance inspection over the past four years are as follows: [4], [5],[6],[7]

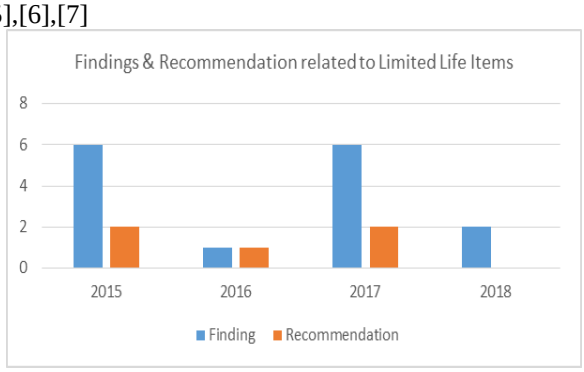
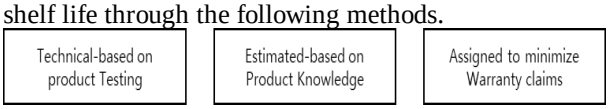


Fig.2. Findings & Recommendation related to limited life Items

2. Shelf Life Evaluation

2.1 Life Evaluation Criteria

Many industries, including space, defense, and aviation, have been studying shelf life determination or life extension for shelf life items and have proposed shelf life through the following methods.



MIL-HDBK-695C [8] and MIL-STD-1523A [9], which are the defense standards for these methods, cover the shelf life of rubber products and elastomeric products, it contains in-depth research on how to estimate life span and is widely borrowed from other businesses. In

the nuclear industry, EPRI Technical Report NP-6408 [10] was presented as a guidebook by EPRI, the US Electric Power Research Institute, taking into consideration the methodologies presented in the aforementioned standards and the characteristics of the nuclear industry. In this paper, the method presented in NP-6408 will be introduced and the storage life evaluation and extension method will be discussed.

2.2 Analysis of EPRI NP-6408

2.2.1 Configuration of Report

First of all, this guidebook describes the presumed assumptions and precautions for deriving the methods presented in this guide, and suggests five ways of evaluating the shelf life by analyzing factors affecting the shelf life have. In addition, after the shelf life has been derived, how the packaging or storage environment affects the presented shelf life is classified by materials. Finally, report have presented the general shelf life for each item category and application that can be applied to a comprehensive shelf life program.

2.2.2 Analysis of shelf life evaluation method

The core contents of this guidebook are five ways of evaluating storage life. Before introducing the five methodologies, the guide outlines the overall process for life limited items to be used in power plants as shown below. As shown in the diagram, this guide also basically means that lifetime extension is not acceptable. I will discuss lifetime extension later.

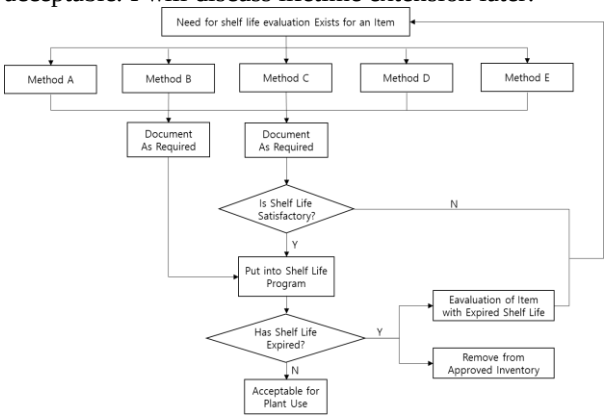


Fig.3. Shelf Life Methodology Schematic(NP-6408)

Each of the methods named from Method A to E is briefly described below.

a) ***Method A*** - Manufacturer's Recommendation.

This method can be used when the manufacturer presents the shelf life. This method is assumed to be the first method of A because it can be said that the user or the buyer can be the most reliable way to establish the shelf life without special effort and analysis. Note, however, that the manufacturer's recommendation may be accepted if it is empirically or experimentally determined, but if it is based on MIL-HDBK-695C or is related to the warranty, it may be set to a longer life there will also be.

b) ***Method B*** – Natural Aging Data

The natural aging method is to set the critical property of the item to establish the method that can derive the permissible value of the element, then set the actual use environment, periodically test the critical property. To set the storage lifetime based on the data. This method is experimental data based on the actual use environment, so it can be said that it is highly reliable. However, since it takes a long time, there is a disadvantage that it cannot be used immediately unless the result is obtained in advance. In addition, the guide suggests that this method should be tested on a case-by-case basis, so that the use of practical data may be limited if the finished results do not fit the environment and reality to be used.

c) ***Method C*** – The Arrhenius Method

There are several theoretical models describing material degradation, which are described in detail in EPRI Report NP-1558 [11]. The US Nuclear Regulatory Commission (NRC) has introduced the Arrhenius model as a method of accelerated life testing allowed in Regulatory Guide 1.89 [12], a regulatory standard for environmental qualification, for electronic components that have a significant impact on safety. The main premise of the method C method is that the verified life through the Arrhenius method can be used to determine the shelf life.

d) ***Method D*** – Accelerated Aging.

The method through the accelerated aging test is basically the same as the method through the natural aging test of Method B. However, in order to perform accelerated aging test, it is necessary to apply activation energy to the parts and materials that are responsible for the main functions of the device or parts. Activation energy refers to the minimum energy required to cause a chemical reaction and determines the shelf life based on the results of how the activation energy of the material changes in harsh environments such as high temperatures.

e) ***Method E*** – Appendix B of Guidelines.

Appendix B of this guide shows the typical shelf life for 70 representative materials. The proposed storage lifetime is divided into manufacturer‘s recommendation(Mfr), Arrhenius method(Arr) or natural degradation(Nat), and the proposed storage life is generally available(Gen), and whether it should be used specifically according to the material of the subcategory(Spec).It is also divided into whether it is set on the basis of the assembly installed (I) or not (N).

3. Application

3.1 Current Status

As stated above, the items on the shelf life of the items have been steadily derived through regulatory inspections, and the distribution of the findings by each type is as follows.

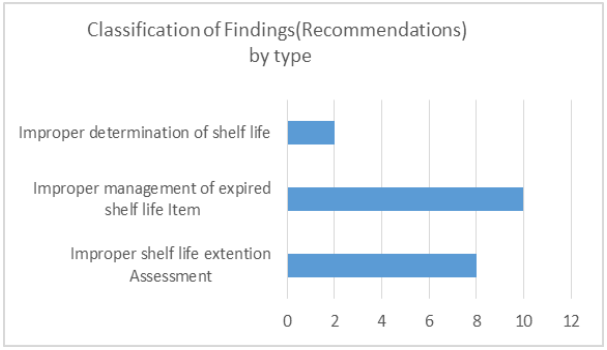


Fig.4. Classification of Findings(Recommendation) by type

As shown in the above table, it is known that the lifespan limitations of most of the Korean power plants are extended after their lifetime, and the evaluation methods and management methods for them are not clearly established. Another interesting point is how to set the life span. This can be divided into two parts: one is how to set the lifetime of the first item when it is stocked, and the other is how to reevaluate the lifetime of the item that has reached its lifetime. Therefore, the problems associated with the management of life-limited items of nuclear power plants can be roughly divided into two categories.

1. How to extend the life of items with limited life
2. Establishing the initial life-time setting method for new items

We will propose an application method based on EPRI NP-6408, which is discussed in this study, on the two previously derived problems. The first is to establish a method to extend the life of products with limited life. The guide suggests three ways to extend the life of products with limited life.

a) ***Method A through E***

When using this method, the evaluation results must be documented.

b) ***Procurement in Appendix C***

You may need to use an expired item immediately. In this case, the method discussed in Appendix C can be used. Because Appendix C can be used to prove that items that may affect the service life of the item have not deteriorated during the storage period.

c) ***Reduction of service or qualification life***

The Arrhenius method and the activation energy activation energy lifetime extension method can be used to extend the lifetime of materials other than liquids and semisolids. The use of this method requires that there be available data and a close cooperation between the material management and engineer departments.

The method (c) of the above method may be difficult to apply to the current reality, and the method of (a) or (b) may be an applicable method. The following is a method of determining the life of the first item to be received. It is not necessary to mention here again, since the five methodologies introduced in this paper can be used to determine the life of the first item to be received. However, there are several important considerations to determine the life of the items received.

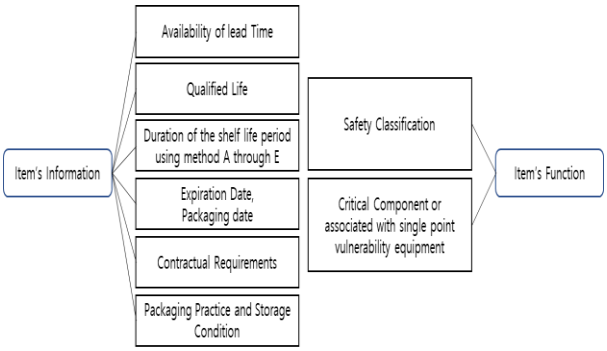


Fig.5. Information and Function-specific Consideration when determining the initial shelf life

When determining the life span of an incoming item, we must consider the above before simply relying on five methodologies. In particular, it is important to note that the first consideration, the actual completion of the finished product by the actual supplier or manufacturer, is more important, and that if the cure date is unclear, the actual storage life may be reduced by more than 50%.Therefore, the starting and ending points of storage life must be technically clear.

4. Conclusion

We will use the contents of EPRI NP-6408 as a basis for judging the life-time of life-limited items of various devices and components in the course of operating and maintaining nuclear power plants. As one of the quality assurance requirements to secure the safety of nuclear power plants, the storage life management of items is an important requirement to be dealt with. It is not merely to extend life by mechanical judgment using guides, Based on the various constraints and engineering evidence presented in the guide, the life span of the item should be determined. In addition, the guide requires that the contents be used as basic data for judging according to each circumstance rather than as an absolute standard. Therefore, it is necessary to carry out steady research in order to establish a more practical and clear storage life in cooperation with operators, suppliers and academia, will be.

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