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BURNUP CREDIT IMPLEMENTATION PLAN AND PREPARATION WORK AT JAERI

Y. NOMURA
Japan Atomic Energy Research Institute Tokai-mura,
Ibaraki-ken

K. ITAHARA
Japan Nuclear Fuel Limited Aomori-city,
Aomori-ken

Japan

Abstract

Application of the burnup credit concept is considered to be very effective to the design of spent fuel transport and storage facilities. This technology is all the more important when considering construction of the intermediate spent fuel storage facility, which is to be commissioned by 2010 due to increasing amount of accumulated spent fuel in Japan. Until reprocessing and recycling all the spent fuel arising, they will be stored as an energy stockpile until such time as they can be reprocessed. On the other hand, the burnup credit has been partly taken into account for the spent fuel management at Rokkasho Reprocessing Plant, which is to be commissioned in 2005. They have just finished the calibration tests for their burnup monitor with initially accepted several spent fuel assemblies. Because this monitoring system is employed with highly conservative safety margin, it is considered necessary to develop the more rational and simplified method to confirm burnup of spent fuel. A research program has been instituted to improve the present method employed at the spent fuel management system for the Spent Fuel Receiving and Storage Pool of Rokkasho Reprocessing Plant. This program is jointly performed by Japan Nuclear Fuel Limited (JNFL) and JAERI.This presentation describes the current status of spent fuel accumulation discharged from PWR and BWR in Japan and the recent incentive to introduce burnup credit into design of spent fuel storage and transport facilities. This also includes the content of the joint research program initiated by JNFL and JAERI. The relevant study has been continued at JAERI. The results by these research programs will be included in the Burnup Credit Guide Original Version compiled by JAERI

1. INTRODUCTION

Recently, it becomes evident that light water rectors (PWR and BWR) are continually operated to generate electric power in the long run in Japan, and the exhausted spent fuel is more and more accumulated. Most of spent fuel is now stored at on-site wet storage pools, and partly at on-site dry storage facilities such as that for the Fukushima Daiichi NPP. Some of spent fuel has been transported to overseas reprocessing plants to extract valuable plutonium as a new fuel material. In anticipation of lack of storage capacity in the next few decades, an off-site intermediate spent fuel storage facility has been decided in operation from around 2010. In addition, the first domestic commercial reprocessing plant is now under construction and it is expected to begin operation from 2005.

In Japan, it is traditional to assume a fresh fuel assumption in criticality safety assessments for spent fuel transport and storage, resulting in an excessive safety margin taken in the facility design. As an exception, burnup credit for uranium and plutonium composition is only taken in the design of the Spent Fuel Receiving and Storage Building of Rokkasho Reprocessing Plant (RRP).

In consideration of the above situation, new challenges have emerged to take burnup credit into criticality safety assessments among utilities and related industries for pursuit of economical design and handling of spent fuel storage and transportation with adequate safety margin ensured. It is all the more evident to note that the 1996 IAEA regulation shall be introduced into the national transport regulations early next year (2001), in which the implementation of burnup credit has been clearly related.

2. PREPARATION WORK FOR BURNUP CREDIT GUIDE PUBLICATION AT JAERI

At Japan Atomic Energy Research Institute (JAERI), studies have been made to develop and prepare criticality safety methods and data together with useful knowledge and information for use in design and licensing of nuclear fuel cycle facilities. Since the first version of Nuclear Criticality Safety Handbook in Japan was published in 1988 [1], works had been continued to prepare the second version of the Handbook, which was recently completed and published in 1999 as a style of JAERI report [2]. In this work scope, study on burnup credit analyses and preparation of spent fuel isotopic composition data for validation of depletion calculation codes have been made to provide useful data and methods for burnup credit implementation in Japan. For example, a more detailed depletion analysis code has been developed [3], and a lot of spent fuel composition data have been measured and collated from open literatures to make an internationally available database [4]. Fig.1 shows the results of criticality safety assessments applied for PWR spent fuel assemblies stored in water pool to illustrate how much of spent fuel can be stored and increased with increased burnup. Moreover, destructive measurements have been performed to obtain uranium and plutonium compositions of LWR spent fuel rods for use in validation of depletion calculation code.

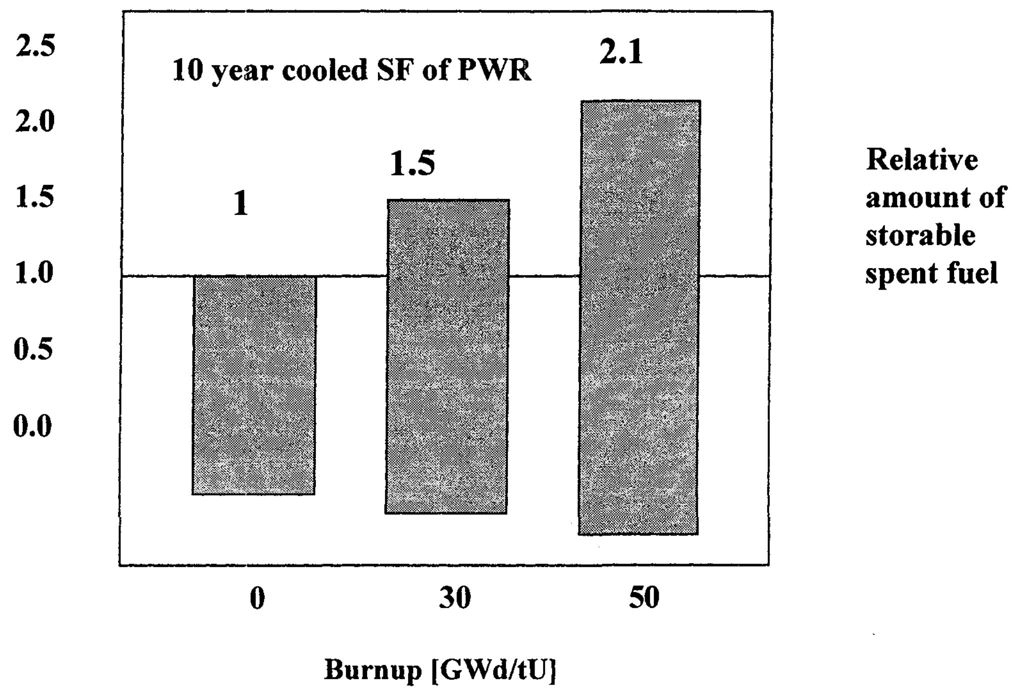

FIG. 1. Relative increase of storable spent fuel amount.

A draft of Japanese Burnup Credit Guide Original Version is now under preparation and submitted for strenuous and ardent discussions of Japanese specialists and experts in the meetings of the Criticality Safety Experiment Data Review Working Group organized by JAERI. This Original Version is expected for use in preparation of documents for licensing safety review and in safety evaluation not only for spent fuel transport and storage but also for spent fuel dissolution at reprocessing facilities. Studies for burnup credit implementation in Japan are to be performed at JAERI by reciprocal exchange of relevant information and cooperation with national and international industries and research organizations as shown in Fig.2. Since measurement data on spent fuel isotopic composition especially for fission products are generally scarce and difficult to obtain, these cooperation scheme is considered to be vital to achieve the task successfully.

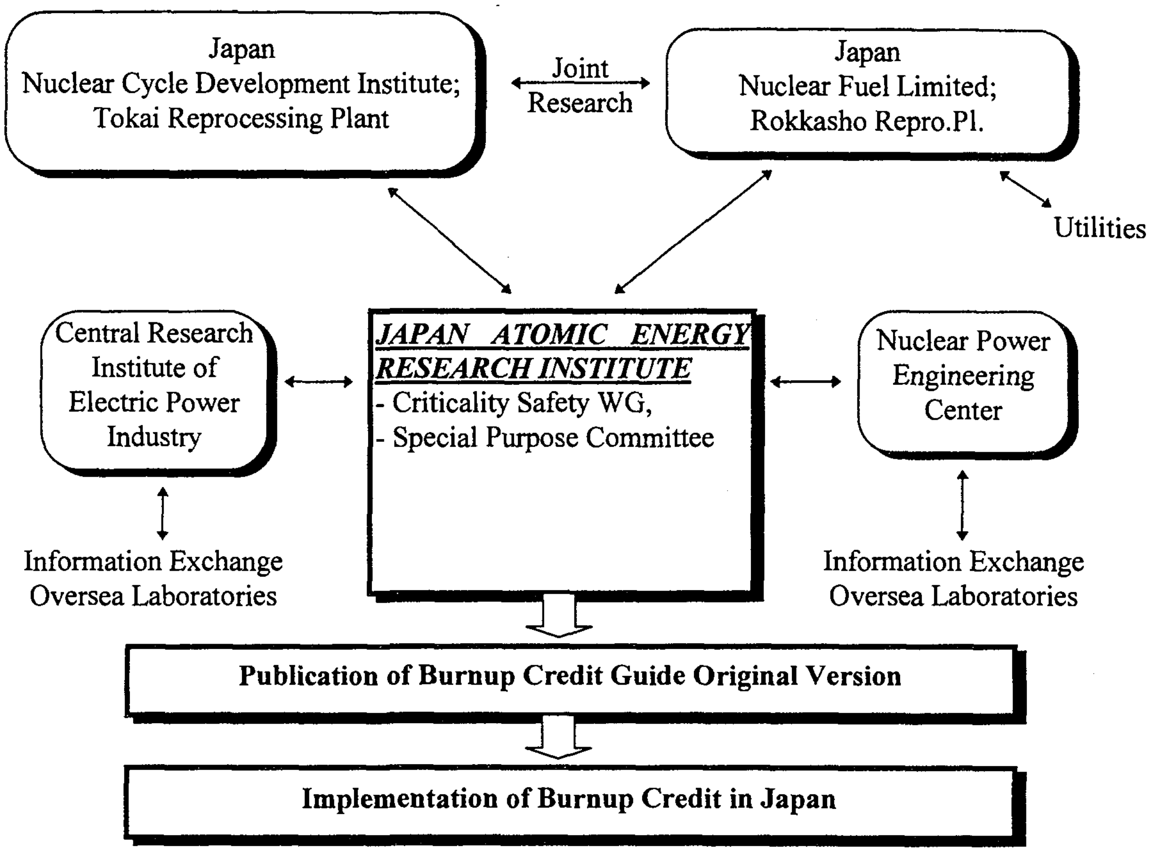

FIG. 2. Scheme for burnup credit implementation in Japan.

3. RESEARCH COOPERATION WITH JNFL ON BURNUP CREDIT IMPLEMENTATION

3.1. Burnup Credit Design Adopted in RRP

In the Spent Fuel Receiving and Storage Building of RRP operated by JNFL (Japan Nuclear Fuel Limited), spent fuel as carried in is firstly stored in the Spent Fuel Temporary Storage Rack designed to accept spent fuel with the maximum uranium enrichment of 5wt%. This specification is universal for the initial UO2 fuel composition of PWR or BWR in Japan. Then, the spent fuel is classified by its residual uranium enrichment determined by burnup measurement into the low (less than 2 wt% 235U) and the high (less than 3.5 wt% 235U) categories. Because the fact shows that most of the spent fuel assemblies exhausted from Japanese LWR have residual uranium enrichment less than 2 wt% 235U. Subsequently, each spent fuel assembly is stored separately in the differently spaced storage racks corresponding to the classification. The correlation of residual uranium enrichment of spent fuel with its averaged burnup is shown in Fig.3. The storage racks have been constructed by robust structure maintaining an appropriately designed spacing between spent fuel assemblies so that criticality accident is not considered to happen due to deformation of storage racks.

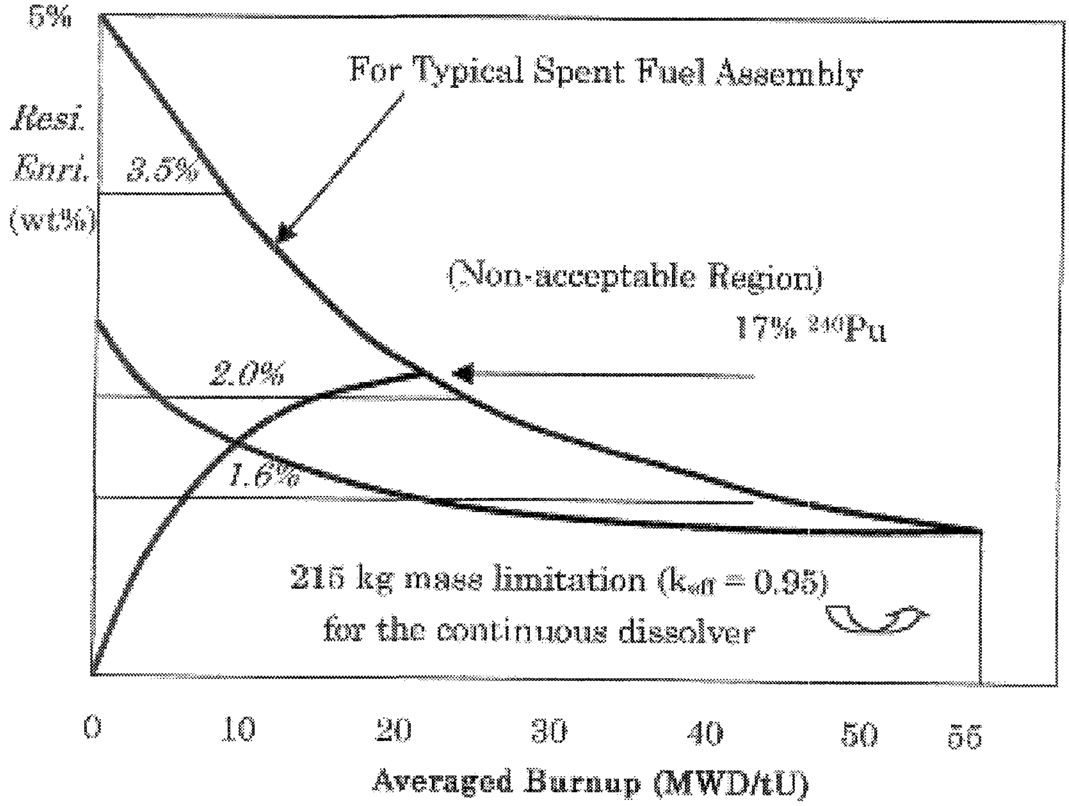

FIG. 3. Correlation of uranium residual enrichment with assembly averaged burnup for spent fuel.

On the other hand, criticality safety design of the continuous dissolver adopts burnup credit so as to keep the multiplication factor less than 0.95 by a combination of burnup and initial uranium fuel enrichment. Consequently, any spent fuel burned up to less than that corresponding to keff = 0.95 curve such as shown in Fig.3 has to be treated with soluble neutron absorber (gadolinium) mixed in the dissolution process. If the effects of fission products could be taken into account for the burnup credit design of the dissolver, the use of extraneous neutron absorber would be avoided to bring an economic and safety merit to the design and operation. Studies have been continued to realize such a technical breakthrough.

As for the processes for spent fuel receiving, storage, sheering and dissolution, criticality safety control is based on specification of one spent fuel assembly. On the other hand, criticality safety control for the following process such as separation and purification is based on whole amount of solution held in the Accountability and Adjustment vessel which should be processed in one day or so. In the latter process region, vessel designs and their operation are based on liquid isotopic composition to secure criticality safety. The operation control is made by keeping the uranium enrichment to be less than 1.6 wt% 235U and the plutonium ratio to be 240Pu more than 17 wt% which is assured by sampling liquid and its measurement made in the accounting vessel. By this isotopic composition control, vessel geometry can be made favorable from the criticality safety point of view in combination with the restriction of fissile fuel concentration.

3.2. Implementation of Burnup Credit at RRP

Presently, calibration tests have been finished for the burnup monitor in anticipation of full-fledged receiving of spent fuel assembly hereafter. However, in consideration of long termed operation of spent fuel receiving and storage, a lot of problems have been pointed out concerning operation and maintenance of the burnup monitor from effective and economical operation point of view. Namely, the current usage of the burnup monitor is based on an excessive safety margin assigned to the measurement, and needs significant maintenance work to keep its reliability. These situations would be surely improved by employing alternative methods such as resorting to burnup data supplied by reactor core management.

A cooperative research program between JAERI and JNFL has been instituted to develop procedures to take spent fuel burnup data obtained from reactor core management instead of performing measurement for spent fuel receiving in the storage racks. The following research items are now to be addressed for the 3-year cooperative work.

1. Assessment of precision of burnup data obtained from reactor core management:
    1.1. Assess precision of average burnup and axial burnup profile data obtained from reactor core management on PWR or BWR spent fuel assemblies,
    1.2. Determine the most reliable method to assess the precision in consideration of the existent data of approximately 4 % obtained by several available methods,
    1.3. Investigate reliability and representation of the axial burnup profile data of spent fuel assemblies.
2. Assessment of reliability of procedure to evaluate the fuel burnup data:
    2.1. Assess human error probability conceived in the evaluation procedure for burnup data from the reactor core management,
    2.2. Survey any evaluation procedure available in each utility company, and obtain data on its relevant human error probability,
    2.3. Check the procedure adopted by both utility and fuel vender to investigate the causes for discrepancies with burnup data evaluation, if any, and to rectify the error thus to reduce the human error probability. If the error of the burnup data be not rectified and reflected to the next cycle core management, a difference could be observed between the predicted core power distribution and the real one. If the difference could be detected by any means, one can assess the relevant human error probability in this process.
3. Work out a data transfer management system taken both by utility and consignee:
    3.1. Work out a data transfer procedure concerning spent fuel released from a power reactor,
    3.2. Work out a data confirmation procedure at the power station for spent fuel shipment and at the Rokkasho Reprocessing Plant for spent fuel receiving,
    3.3. Determine necessary conditions to confirm burnup data without using burnup monitor, such as those for the fuel rack address and the fuel ID number management at the on-site spent fuel storage rack and also for the independent double check by the operator for ID confirmation, etc,
    3.4. Survey any methods to confirm the spent fuel ID implemented in overseas facilities, and make comparison with the proposed one.
4. Assessment of reliability of the whole through data transfer management system:
    4.1. Assess human error probability conceived in the procedure concerning treatment of burnup data released from the power station, spent fuel transport, and spent fuel receiving at the RRP Storage Rack,
    4.2. Clarify the difference of reliability in determining burnup of spent fuel by the methods with and without a burnup monitor.
5. Assessment of conservatism for burnup data averaged over 50cm from the end of a fuel assembly:

5.1. Evaluate burnup data averaged over 50 cm from the end of a fuel assembly by multiplying assembly average burnup with a certain comprehensive factor,

5.2. Investigate conservatism for the above evaluation method by applying the axial burnup profile data obtained with the burnup monitor at the Rokkasho Reprocessing Plant.

6. Working out whole through logic applied to burnup credit licensing:

6.1. Work out whole through logic for burnup data acceptance procedure without using burnup monitor, which is applicable to the licensing process.

4. CONCLUDING REMARKS

It is now evident for Japan to introduce burnup credit into design and operation of spent fuel storage and transport facilities due to continual accumulation of spent fuel discharged from PWR and BWR power reactors. In the near future, more economical design and operation will be realized for spent fuel on-site storage and transportation from power reactors to RRP by implementing burnup credit methods.

These burnup credits would be firstly at the actinide only level, and partially and already introduced into the design of the Spent Fuel Receiving and Storage Building at RRP. Studies have been continued to take fission products into burnup credit evaluation to improve further economical and safety merits to the dissolver design and operation.

Recently, a cooperative research program has been instituted to study adopting burnup data supplied from reactor core management without burnup monitoring to accept spent fuel into the storage pool. Utilities also seek to the methodology to confirm burnup data without burnup monitoring for loading spent fuel to transport casks.

At JAERI, studies have been continued to develop burnup credit evaluation method including isotopic composition databases and the burnup Credit Guide Original Version is now under preparation for its publication for use in licensing reference documents and design safety evaluation. These studies have been executed under a cooperative work scheme throughout Japan to enhance reciprocal information exchange and common usage of necessary data for burnup credit implementation.

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