MANAGEMENT FOR PREVENTIVE MAINTENANCE AND SAFE OPERATION OF A HOT LABORATORY

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ABSTRACT

In order to develop fuels and materials for fast reactors, five hot laboratories are now in operation at the Oarai Research and Development Centre. More than 30 years have passed since the first hot run of these facilities was started, and during this time it has been indispensable to maintain the principal equipment for continuous safe operation.

In 2003, a new safety review method was developed by modification of periodic safety review tools applied to preventive maintenance for Japanese commercialized power reactors. The most important features of several safety assessment tools as well as experiences obtained during operation of the hot laboratories were reflected in the method. Effective repair or replacement of equipment before malfunction has been possible and the priority for preventive maintenance could be appropriately determined for stable management of hot facility operations by using the developed method.

1. Introduction

In the Oarai Research and Development Centre (ORDC) of the Japan Atomic Energy Agency (JAEA), five facilities, as a hot cell complex, are now in operation mainly for performance of post-irradiation examinations (PIEs) of fast reactor fuels and materials. The design concept of the cell facilities was strongly linked with the experimental fast reactor Joyo and many radioactive materials and irradiated fuel components have been handled. However, more than 30 years have passed for all facilities since hot operations were started, and aging degradation must be considered. Therefore, it is indispensable to perform effective maintenance for the principal equipment, such as electronic devices, manipulators, in-cell cranes and ventilation systems to maintain safe operation. The concept of effective maintenance should include two points.

(1) Regularly evaluation of the soundness for each piece of equipment installed in the facility.

(2) Complementary preventive maintenance based on periodic safety review.

In 2003, research work was launched in JAEA to develop a new safety review method for the hot laboratories based on a previously developed safety review method for Japanese commercialized power reactors. . The new method for the hot laboratories was intended to reflect the most important features of several safety assessment tools as well as experiences obtained during operation of the hot laboratories over 30 years. Moreover, Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) were utilized to expand applicable fields. The primary feature of this method is that the safety level for each piece of equipment is decided and expressed numerically by using such factors as “risk point until malfunction”, “validity of the performance indicator”, and “compliance issue for regulation”. Consequently, the levels are classified into 7 grades, that is, evaluated safety grades.

Based on the evaluated grades, effective repair or replacemnet of equipment before malfunction would be possible, and the priority for preventive maintenance would be appropriately determined for stable operation of these hot facilities. The system underwent inplementation tests from 2003 through 2007 and has been operated officially since then. In this paper, the new safety review method and what it has achieved to date are described.

2. Description of hot cell complex

The hot cell complex for fast reactor fuels and materials has been operated at the ORDC and includes five facilities: the Fuel Monitoring Facility (FMF), the Alpha-Gamma Facility (AGF), the Plutonium Fuel Research Facility (PFRF) and two Materials Monitoring Facilities (MMF-1 and 2) [1].

The FMF is located adjacent to the experimental fast reactor Joyo and it started operation in November 1978. Nondestructive examinations of fuel subassemblies, such as X-ray CT, radiography and dimensional analysis, are carried out in this facility, in addition to some destructive examinations of fuels, cladding and so on. The selected pins and materials, are sectioned to the appropriate size at the FMF, and then sent to the AGF and the MMFs for further detailed examinations. The FMF is composed of the main concrete cells, examination cell, decontamination cell and clean cell. The shielding capability of the walls allows the examination of fuels and materials of $6x10^{16}$ Bq for gamma rays as an example.

The AGF has been operated successfully since October 1971. The main roles of this facility are to carry out the physical, metallurgical and chemical analyses of irradiated plutonium-bearing fuels. Some of the hot cells have been refurbished to fabricate remote-handling of americium- (Am-) containing mix oxide (MOX) fuels. The main functions are to evaluate the fuel burn-up, physical properties, and chemical composition of minor actinides (MA) elements in MOX fuel. The inner box-type cell is characteristically used in this facility, in which stainless steel movable boxes are installed in radiation shielding such as concrete, lead, etc. to provide air tight cells for experimental work. Installation of an MA-containing fuel fabrication apparatus was completed in 1998. The fabrication test for MOX fuel containing 5% Am has been conducted since 2001 to 2005.

The MMFs have been operated since 1973 to handle reactor materials. Mechanical and physical examinations are conducted on core materials, structural materials and control rod materials irradiated in several fast reactors. Structural materials irradiated in the Japan Material Testing Reactor (JMTR) are also examined. The main functions of the MMFs are evaluation of irradiation effects on mechanical properties, physical properties, and microstructures of reactor materials. There are two areas, MMF-1 and MMF-2. MMF-1 has six concrete cells (one is located in the basement of the 2-story building) and two lead cells. MMF-2 has four concrete cells and one iron cell. One of the concrete cells is divided into two parts by a stainless steel wall. A transmission electron microscope with acceleration voltage of 400keV is provided to evaluate microstructures of core materials.

The PFRF is used for development of advanced fuels focused on the use of plutonium, such as nitride and metallic fuels, and it can only be operated for unirradiated materials. Its main devices for treatment of nuclear materials are glove boxes.

3. Methodology of safety review for hot laboratories

3.1 Definions of safety grade

Safety grades are defined in order to regurarly check the soundness of all equipment. There are 7 grades combining three evaluation factors, risk point, performance indicator and compliance issue (illegality). Table 1 shows the defined safety grades and evaluations corresponding to the levels.

Table 1 Defined safety grade and its measures

Evaluated safety grade		Measures
A	AA	No risk, or problem (malfunction) is completely solved
	A	Low risk, no needs for preventive maintenance
B	B	Low risk, needs preventive maintenance based on PI
	B-	Low risk, needs preventive maintenance
C	C	Intermediate risk, needs earlier preventive maintenace based on PI
	C-	Intermediate risk, needs immediate preventive maintenance
D		High risk, needs immediate direct repair or replacement and report to government

3.1.1 Risk point

A cause which leads to malfunction for each piece of equipment, namely risk point (RP), is extracted by considering radiation damage. The RP also should contain not only tangible matters which clearly exist, but also latent risk expected from aging degradation of equipment.

As the first step, the RP is expressed numerically in the range from 0.5 to 100 by the multiplication of the following three point values. The point values are marked within a designanted range followed by the influence on the RP.

i) Possibility of malfunction based on current operating conditions: 1.0 - 10.0

ii) Passage of time within the term of aging degradation: 1.0 – 10.0

iii) Need for preventive maintenance: 1.0, no need for preventive maintenance or low influence: 0.5

After multiplication of the above three point values was carried out, the RP was categorized into three ranks of A, B, and C describing the need for taking measures as preventive maintenance (Table 1). The categorization was based on the many experiences obtained in operating the hot laboratories for over 30 years.

A: ≤ 4.0 : Total risk is very low, and continued soundness for each piece of equipment could be confirmed.

B: 4.0 – 40.0 : Although it is thought that the continued soundness is confirmed, attention should be paid to the RP for preventive maintenance.

C: ≥ 40.0 : It is thought that the soundness is kept, however, earlier than expected, or immediate maintenance, is needed.

Category D shown in Table 1 is not expressed by using marked RPs, and it is judged by compliance with regulations as described later.

3.1.2 Performance indicator

A performance indicator (PI) is defined as an index to predict the term of validity until a piece of equipment malfunctions. After the applicability of the PI to the target equipment and its quantitativeness are evaluated, the point values of the PIs are marked in the range from 1.0 to 10.0 in proportion to the extent of their applicability. Judgement is made as to whether to apply prediction of the term validity, at the minimum, the PI value should be more than 4.0.

3.1.3 Illegality

It is important to observe regulations on operation of all equipment from the viewpoint of compliance with related laws. Therefore, several possibilities affecting illegality (IL) by equipment malfunction have to be considered. The possibility should be expressed numerically for evaluation of safety level; point values of the ILs are marked as 1.0, 7.0 and 10.0 according to their increased possibility. In this case, the regulations include all related Japanese laws, manuals and instructions within JAEA. If it is clear that there is an IL to Japanese law, the point value is 10.0. When immediate repair or replacement for the equipment is considered from the viewpoints of JAEA regulations, the point value should be 7.0. The point value of 1.0 means there is no IL.

3.2 Safety level and related evaluation factors

Table 2 shows the relationshop between safety grades and the three evaluation factors.

The safety grades of AA, A, B and B- are regarded as those in which safe operation can be continued with low risk. However, in particular B and B- cases, preventive maintenance should be planned. In the meantime, safe operation might be kept without major problems in the case of C and C- when the safety review is applied. However, in order to continue safe operation, early or immediate maintenance work should be performed within the business year.

Table 2 Defined safety grades and evaluation factors

Evaluated safety grade		Risk point (RP)	Performance indicator (PI)	Illegality (IL)
A	AA	No risk	No risk	1.0
	A	≦4.0	-	
B	B	4.0 - 40.0	4.0 - 10.0	1.0
	B-		≦4.0	
C	C	≧40.0	4.0 - 10.0	1.0
	C-		≦4.0	
D		-	-	7.0

4. Example safety review

An example safety review for actual equipment is introduced here.

Figure 1 shows a photograph of the glove box installed in a hot laboratory. Air pressure in the room is a negative 50 Pa relative to atmospheric pressure, and the inner pressure of the glove box is a negative 300 Pa relative to the room pressure to prevent leakage of nuclear materials. These negative pressures are produced by the ventilation system. In order to isolate the room negative pressure from minute changes of atmospheric pressure, exhaust and intake air are controlled by the damper shown in Fig.2. This damper is driven by a cylinder system. Malfunction of the cylinder could result in an accidental leakage of nuclear materials. This damper has a rubber diaphragm structure and is run by pressurized air; therefore aging degradation of the diaphragm is an important point. This damper was selected as one device which must be evaluated for safety review. Final estimated point values of RP, PI and IL were 20, 4 and 1 points, respectively. The safety grade of this damper was classified as B. This was no need to repair or replace it; however, a spare damper was prepared as a preventive maintenance measure. In this case, since PI was estimated as 4, checking of the cylinder was continued. As a result, minute leakage of air was found to occur from the diaphragm and effective replacement could be done smoothly while the risk was still low.

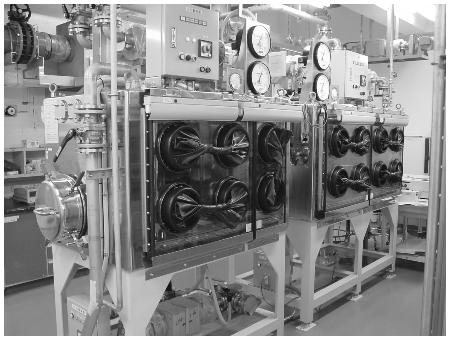

Fig.1 Glove box and ventilation system

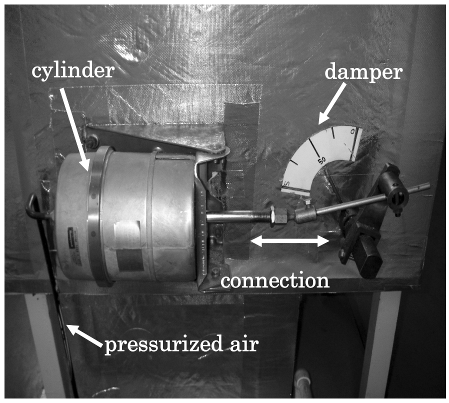

Fig.2 Photo of cylinder system for damper control

5. Results and effectiveness of the current safety review

The safety review was performed based on the evaluation of safety levels for the hot cell complex of ORDC most recently in fiscal year 2008. The total number of selected devices for the FMF, AGF, MMF (1 and 2) and PFRF were 49, 79, 151 and 93, respectively. The current status of the safety review is shown in Table 3.

Table3 Current status of safety review for hot cell complex

Evaluated safety grade		FMF	AGF	MMF(1&2)	PFRF
A	AA	6	31	90	43
	A	27	3	18	18
B	B	15	44	40	32
	B-	1	1	3	0
C	C	0	0	0	0
	C-	0	0	0	0
D		0	0	0	0

All safety grades were more than B- . This reflected the modifications made for safety based on the previous review performed in fiscal year 2007.

The safety grade of 38 devices could be raised from B or B- to A in fiscal year 2008. Figure 3 shows the number of items that were raised from a lower grade to a higher one by resolving a problem or carrying out a maintenance task based on the periodic safety review results. As far as each safety grade was concerned, C level devices were modified and all issues were solved in 2008 as shown in Fig. 4. As there are no C level devices in the current hot cell complex, the developed method was demonstrated to be effective for safety review of equipment in hot laboratories.

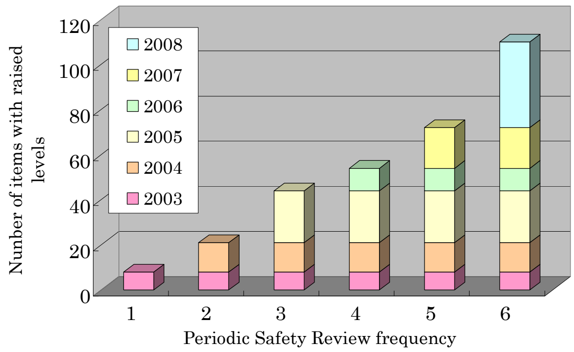

Fig.3 Evolution of safety grade by periodic safety review

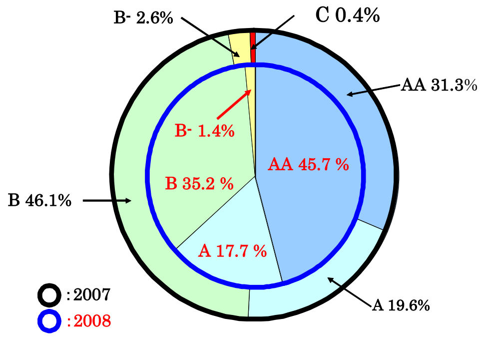

Fig.4 Modification of safety grade from 2007 to 2008

6. Conclusions

A new safety review method developed in JAEA has been implemented in five hot cell facilities. The feature of this method is that the safety grade for each piece of equipment is decided and expressed numerically by using three factors: “risk point until degradation”, “validity of the performance indicator”, and “compliance issue for regulation”.

Among the 7 classified safety levels, all equipment has achieved at least B or B- levels; these are considered as low risk and not in need of repair or replacement based on the periodic safety review. The classified levels also can be used to determine the need for continued observation depending on the selected priority. As a result, no accidents are presently expected which should contribute to raised availability of the facility operation in the future.

Reference

[1] M. Itoh; Proc. 3rd JAERI-KAERI Joint Seminar "The Post Irradiation Examination Technology”, March 25-26, 1999, pp44-52, JAERI Oarai, Japan