SHORTER OUTAGE EXPERIENCES WITH PWRS IN JAPAN

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ABSTRACT

This paper summarizes the mission of a Mitsubishi Heavy Industries Co., Ltd. (MHI) in-house project team and the results of implementing shorter outage durations for operating PWRs in Japan. The project team was formed to develop integrated action programs aiming to achieve performance goals for shorter outages. Major tasks of the project team were to develop outage performance goals based on benchmarking operational and outage related statistics, and to develop packages of recommendations for outage enhancement covering field procedures, tooling improvements, etc. Optimization studies for maintenance tasks, including inspection, repair and routine overhaul of components, were also carried out.

This paper also highlights the actual results of efforts obtained to date at some selected operating plants.

INTRODUCTION

The availability factor for Japanese nuclear plants continues to be approximately 80%, and they also maintain very high reliability factors with very low trip rates. Current attention, however, is on higher operating and maintenance costs compared with those of other countries. So, reduction of operating and maintenance (O&M) costs is one of the vital issues for the survival of the nuclear energy option.

In order to improve the current economics of operating nuclear power plants in Japan, various types of effort have been carried out jointly with utility companies and industries, such as the original equipment manufacturers (OEM). In order to achieve the overall goal, and to help and support utility customers, systematic and integrated programs have been developed by MHI to improve the reliability and availability of operating PWRs in Japan.

The challenge of achieving shorter outages is one of the key program elements of a fully integrated program of activities being implemented enthusiastically and jointly with plant operators and constructors. The key driving forces behind achieving shorter outages are the leadership role provided by MHI's in-house project team, and the active partnership between utilities and vendors.

INTEGRATED ACTION PROGRAM FOR IMPROVED ECONOMICS FOR OPERATING NUCLEAR POWER PLANTS

In order to support utility customers, MHI as a reactor system supplier and service company, has developed its own program which consists of five target elements such as reduction of annual inspection outage duration, elimination of unplanned shutdowns, realization of longer operating cycles, improvements in power efficiency, and extension of plant service life.

A special project team was formed, and began its mission in June, 1995, to promote the five above-mentioned target elements. Three task teams were created under the project team for the designated target goal of reducing annual inspection outage durations. The first task team, named the work improvement team, comprised specialists in nuclear plant construction and field service to optimize the field activities. The second team, named the equipment improvement team, was made up with equipment design engineers to improve plant facilities, equipment design, and tooling. The last team, named the outage engineering team, comprised engineering department specialists to optimize the extent and frequency of equipment overhauling, inspection, etc. Joint project meetings have been held periodically to integrate, coordinate and unify the outcomes of each team's tasks.

BENCHMARKING TO DEVELOP PERFORMANCE GOALS

In order to develop new goals for outage performance, a systematic effort to evaluate and analyze operational and outage statistics data obtained to date, from both domestic and world experience, has been carried out for benchmarking purposes.

A survey revealed that current annual inspection outage tasks had basically been executed with iterated planning based on previous performance. That is, improper or excessive schedule margins to recover from contingency, inefficient field work density due to breaks for lunch and rest, less smooth and less timely hand-off, and less flexible outage management for unplanned field events or tasks.

Benchmarking was performed based on evaluations of actual outages, schedules and the performance of overseas plants. In order to learn from overseas practices, and to witness and gather information, MHI dispatched several outage engineers to the U.S. and Germany for approximately 400 man-days.

It was important to determine reasonable target goals for tasks, such as breaker to breaker 45-day outages as step 1, and then 39-day outages as step 2. The goals and benchmarking data are shown in Figure 1.

(   ) indicates days

	C/V Purge	**R/V Opening**	**Fuel Unloading**	**Primary System Valve, Pump Inspection**	**Fuel Reloading**	**R/V Closure**	**RCS Leak Test**	**Start up**
Step 1 45 days	(2.0)	(4.0)	(3.0)	(13.0)	(4.0)	(5.0)	(3.0)	(11.0)
Step 2 39 days	(1.0)	(4.0)	(3.0)	(11.5)	(4.0)	(5.0)	(1.5)	(9.0)

Figure 1 Goal and Benchmarking Data

It is also important to fix the scope of maintenance work to be done during outage periods to ensure safe and reliable operation following the completion of designated shorter outages. It has been the practice in Japan for a long time to pay special attention to voluntary-based preventive maintenance activities, , and there is some room to optimize this maintenance to provide shorter outages.

ACTIVITIES DONE BY THE WORK IMPROVEMENT TEAM

Planning

The role of the work improvement team was to optimize field activities such as work procedures, work methods, the work environment, etc. First, an action plan was established to investigate current annual inspection outage activities and schedules. Every critical path work item, and sub-critical path work item was evaluated, including analyses of loss of time and field work density.

Results

The investigation revealed the actual time that was required to execute each activity, and the work flow. In Japan, shifts of 2-10 hours' duration have been adopted for critical path activities. Also, field work has been stopped for breaks at lunch and for afternoon rest. One conclusion is that 24 hours of continuous work is effective in minimizing loss of time and eliminating idle time. Major points are discussed below.

Optimization of Field Crew Organization and Shift Formation

Japanese Labor Law restricts working hours in a controlled area to less than 10 hours a day. So, more than three shifts are required to cover a 24 hour period. We decided to use four shifts to cover 24 hours. The advantage of 24-hour non-stop work was estimated to be a total reduction of 195 hours for the critical path tasks of reactor vessel head opening, fuel unloading, reloading, and reactor vessel closure work.

Rationalization of Work Sequence

Parallel work processes were fully adopted in several work activities. Preparation for and completion of each activity was done in parallel with the next job with similar priority. In addition, over-head work was allowed if it was not just above the head, but on a different side of reactor vessel Next, it was decided that in-core thermocouple cono-seal housing disassembling would start immediately if the water level was lowered to the reactor vessel flange level. The total effect of the above-stated improvements in procedure are estimated to have saved 25 hours for reactor vessel head opening and closure, and for work related to fuel unloading and reloading.

Contingency Planning

Extensive contingency planning had been done to prepare for unexpected events. The lack of spare parts for disassembled components, or the breakdown of refueling tools and equipment causes delays to annual inspection outage schedules. The spare parts list for plant components was reviewed carefully. Overhauling of tools and equipment was planned to be done in advance of the refueling shutdown, especially overhauling of fuel handling system equipment, which was done in detail.

ACTIVITIES DONE BY THE EQUIPMENT IMPROVEMENT TEAM

Planning

The role of the equipment improvement team is to improve the plant facilities, equipment design, and tooling. The equipment improvement team also investigated the actual annual inspection outage schedules from the view point of the time required for each job activity on the critical path. The job activities requiring a long durations were the targets for improvement.

Results

The investigations were mostly done on reactor vessel head opening and closure work, and fuel handling work. The following job activities which require relatively long durations were picked up:

- Steam generator tube eddy current testing (ECT)
- Reactor vessel head stud removal and installation
- Reactor cavity seal ring installation and leak test
- Full length RCC drive shafts unlatching and re-latching
- Fuel unloading and reloading

An action plan was established to develop equipment and tools for improving these job activities.

Improved ECT system

Currently MHI has developed an ECT system with a tube sheet walker-type robot and dual probe pusher. In Japan, the entire length of tube in every steam generator is required to be inspected by eddy current testing, which requires ten days to two weeks, depending upon the numbers of tubes inspected in detail above the tube sheet. MHI has started to develop a four-probe intelligent robot ECT system. (See Figure 2). The effect of adopting this ECT system was estimated to be a 5-day reduction for the ECT of all tubes.

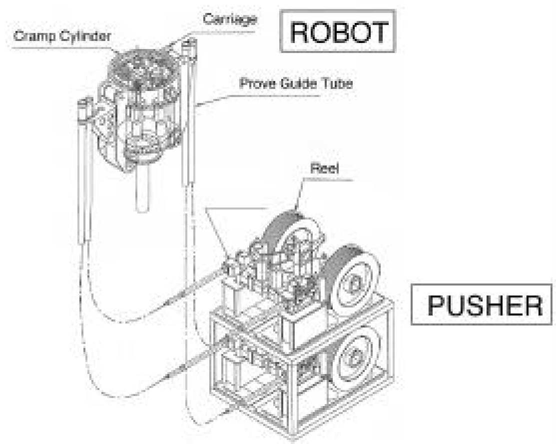

Figure 2 4-Probe Intelligent Robot ECT SYSTEM

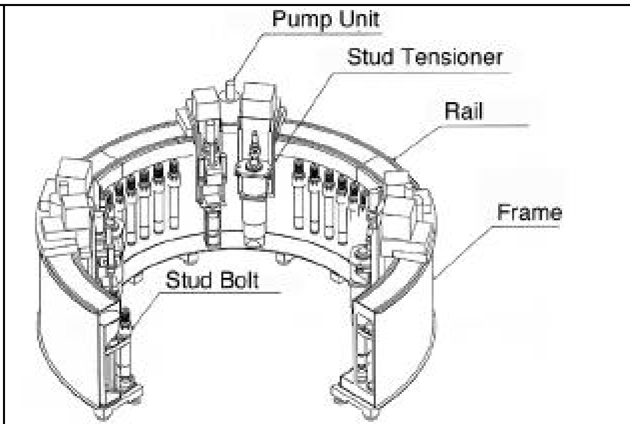

Figure 3 BTM

Bolting and Tensioning Machine (BTM)

Most Japanese plants are equipped with an automated tensioning system (ATS), which enables automatic movement of stud tensioners, automatic tensioning/de-tensioning and automatic measurement of stud elongation. Removal and re-installations, however, are done one by one, lifted by a polar crane. The development of stud handling equipment was started immediately. This bolting and tensioning machine is composed of four segments and is assembled on the reactor vessel flange. This BTM enables stud screwing/unscrewing and stud storage, as well as the function of automated tensioning system (ATS). The effect of this BTM is estimated to be an 18-hour reduction for reactor vessel head opening and closure (See Figure 3)

Permanent Cavity Seal

MHI has improved the pushing pad structure of the reactor cavity seal ring to make up an easy handling structure without bolts. However, setting and leak testing of the reactor cavity seal ring requires a long time. So, MHI has started to study the development of a permanent cavity seal (See Figure 4). ?The improved characteristic of this permanent cavity seal is found in the revised location where the air outlet leads to NIS junction box opening. The consequence of this improved permanent cavity seal is estimated to provide a 5-hour reduction for reactor vessel head opening duration.

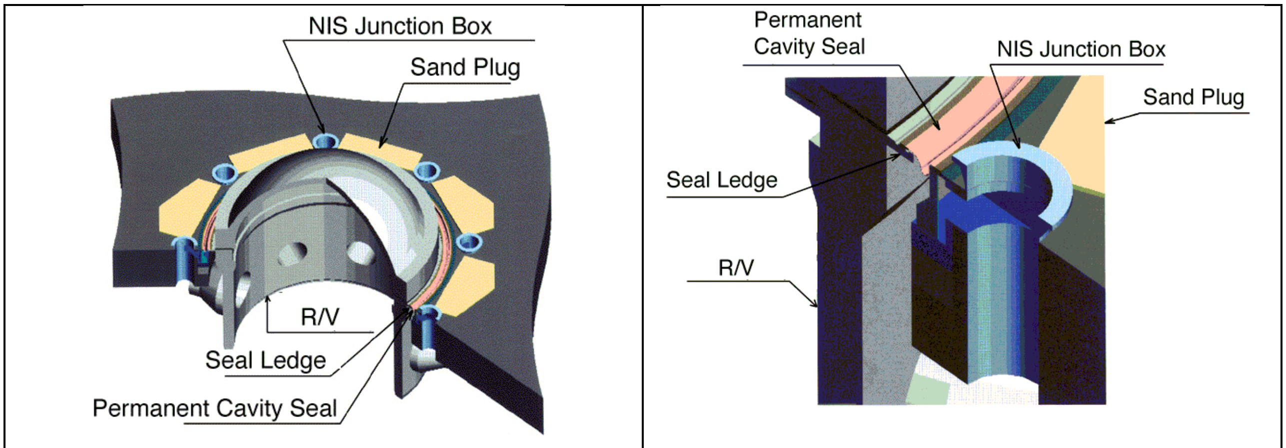

Figure 4. Permanent Cavity Seal

Multiplication of F/L RCC Drive Shaft Handling Tool

The latching and re-latching operation itself does not take a long time, but if the plant is a four-loop plant, the number of F/L RCCs is 49. Therefore, the total time taken for all RCCs is simply increased 49 times. MHI has studied several options. One is to handle all drive shafts at a time. Another is to handle several drive shafts at once. The equipment can be designed and manufactured, but were expected to have difficulty with the stacked drive shaft latch button. Finally MHI decided to apply two handling tools at a time. The effect of this duplication of tools is estimated to reduce reactor vessel head opening and closure duration by 4 hours.

Faster Fuel Handling System Equipment

The speed of fuel handling system equipment in Japanese plants is restricted to avoid damage to fuel assemblies. That is, MHI used to experience several corner grid failures. Recently, the integrity of fuel assemblies has improved enough to increase the speed of the fuel transfer system. An example of improved specification for fuel handling system equipment speed is shown in Table 1.

The effect of speeding up fuel handling equipment, including off-index unloading and reloading, was estimated to provide a 26-hour reduction for fuel unloading, reloading work.

Table 1 Improved specifications for fuel handling system equipment speed

Equipment name	Portion	Current spec.	Improved spec.
Manipulator crane	Bridge	18/6/3/0.9	18/9/6/0.9
	Trolley	6/4/2/0.3	9/4/2/0.5
	Mast hoist	6/4.2/1.8/0.6	9/6/2.1/0.9
Fuel transfer system	Conveyer car	6.2/3.1	9.3/3.1
	Lifting	25 sec.	
Spent fuel pit crane	Bridge	12/9/6/0.	18/12/9/0.9
	Trolley	12/9/6/0.6	18/12/9/0.9
	Mast hoist	4.2/2/0.9	6/3/0.9

Off-index core unloading, reloading

Off-index core unloading, and reloading avoids interference between fuel assemblies because the fuel assembly is handled apart from fuel assemblies in the core. Therefore, the speed restriction at core entrance region could be deleted. Thus, the time in the slow zone can be saved and cycle time for unloading, reloading can be reduced.

ACTIVITIES DONE BY THE OUTAGE ENGINEERING TEAM

Planning

The role of the outage engineering team is to optimize the extent and frequency of equipment overhauling and inspection, etc. The outage engineering team investigated the details of overhauling and inspection.

Results

Several opportunities for improvements were pointed out. The application of rotational spare parts, alternation of the reactor coolant system integrity leak test , and reduced extent and frequency of outages were all evaluated.

Rotational Spare Parts

Disassembling, parts maintenance and inspection, and reassembling work takes a long time. A method for exchange of complete equipment pieces (or several parts) instead of disassembling, parts maintenance, inspection and reassembling has been effective in reducing time for maintenance. This rotational spare parts method is especially effective for reactor coolant pump internals, sea water pumps, and diesel generator engine parts which are on the critical path or sub-critical path. A balance between the cost of additional capital equipment and outage time costs must be considered for each case.

Alternation of Reactor Coolant System Integrity Leak Test Condition

The Japanese annual inspection code requires reactor coolant system integrity leak tests at cold solid conditions. MHI evaluated the inspectability at a hot standby condition and started negotiations with utility companies and with the government's Ministry of International Trade and Industry (MITI) to approve the method of testing.

Inspection and Overhauling Frequency

Both diesel generator engines are required to be overhauled and inspected annually in Japan. This work is on the sub-critical path on the annual inspection schedule. MHI evaluated the parts life and performed FMEA on the diesel generator engine parts. The evaluation revealed that the overhauling frequency would allow the interval to be increased two times longer than the current frequency. Hence, overhauling of one diesel engine could be eliminated in the future.

RECOMMENDATION PACKAGE FOR SHORTER OUTAGE ENHANCEMENT

MHI's in-house project team has developed recommendation packages based on extensive benchmarking, internal in-depth review of past experiences of good practice, and lessons learned from participating over two hundred times in outage management of Japanese PWRs.

The recommendation packages are customized and tailored for each plant, and cover essential areas such as field maintenance crew organization and their shift formation, revised field procedures and hold points, rationalization of work sequence, long-term and short-term outage planning, facility and tooling optimization for readiness and safer activity, component modification for easier disassembly, expansion of rotational spare parts, and operational improvements in cool-down and heat-up modes.

IMPLEMENTATION RESULTS

Based on the recommendations and proposals to electric utility companies, as of September 1997, continuous 24 hour shifts were applied at seven nuclear power plants to expedite outage work. Based on the recommendations for improvement of plant facilities, equipment design, and tooling, MHI received an order from one power station to apply BTM and cavity permanent seals. Modification to refueling machines, and control programs for off-core unloading and reloading has been completed at some plants. Also, speeding up of fuel handling system equipment and other improvements such as four-probe intelligent ECT robot systems are being prepared for orders from several electric utility companies. Based on recommendations and proposals to optimize the extent and frequency of equipment overhauling and inspection, some of these proposals, such as rotational spare parts, alternation of reactor coolant system integrity leak test condition, reduction of overhaul extent and frequency, have been applied in several plants.

The total effectiveness of the proposed improvements which are contained in the recommendation packages, have been realized during actual outages.(See Figure 5). The effects obtained in these improvements was evaluated to be sufficient to achieve the 45 day, 39 day goals.

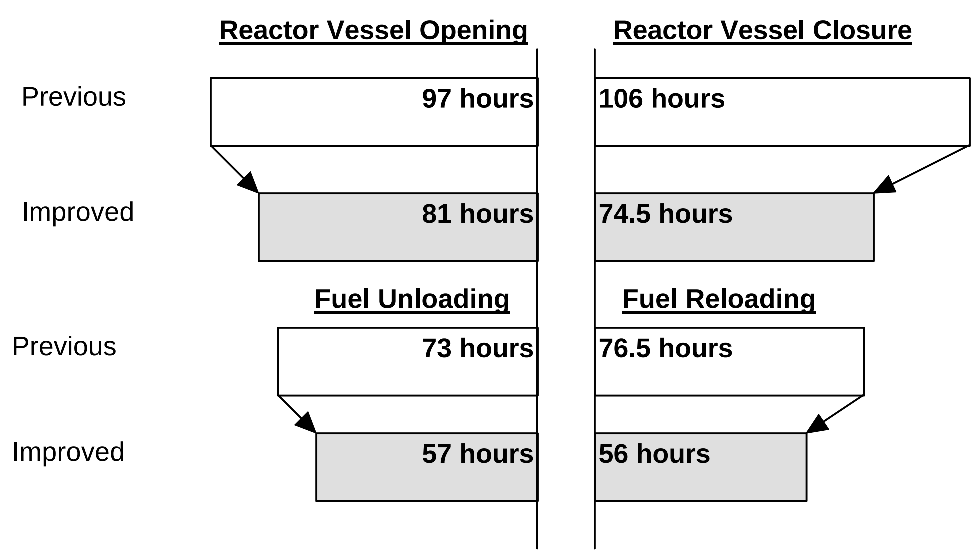

Figure 5 Summary of Actual Results at Selected NPPs

The packages also addressed indirect aspects, or surrounding supporting aspects, such as transportation to and from local hotels, communication between customers and vendors, incentives to contractors, and culture and motivation for people working at nuclear power plant sites.

CONCLUSION

Many kinds of extensive efforts to reduce annual outage durations are being carried out.

In order to support Japanese PWR utilities' policies and programs to improve nuclear economy, MHI has been committed to work toward shorter outages by means of outage engineering and outage services.

Shorter outage durations, such as 45 days or 39 days, according to the rules of the Japanese industry, requires more and more in-depth preparation, detailed planning and management for all aspects of outage, strong leadership role, family-like on-site teamwork and communications, and continued attention and concentration of the maintenance workforce.

We believe our current efforts, being conducted to achieve performance goals, will continue to result in quality services and reliable plant operating performance.