Insight from Pilot On-line Maintenance for an Essential Chilled Water System in a Westinghouse Plant

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1. Introduction

On-Line Maintenance (OLM) means a preventive maintenance while the grid is on-line. It is widely used in many countries such as the US, France, Spain and Switzerland, to improve equipment reliability, reduce outage work activities, and improve the availability of safety systems during outages [1].

In Korea, preventive maintenance of safety systems has not been carried out. Therefore, a pilot OLM for the Essential Chilled Water System (ECWS) in a Westinghouse reactor type plant required to prepare procedures, risk assessment, performance monitoring and contingency plans. Several discussions and presentations were done to minimize any gaps in understanding between regulator and industry.

It is meaningful to implement OLM in Korea for the first time and to gain a variety of insight by preparing and performing it. This insight is discussed in this paper and will be used for the next OLM for other plants or systems.

2. Preparation and Performing of Pilot On-Line Maintenance

2.1 Scope of Work

For the pilot OLM, the ECWS was chosen because it had an adequate Allowable Outage Time (AOT) and a minor safety impact [2]. Table I shows the scope of the maintenance work for the chiller and the chilled water pump. These work items were identified based on the preventive maintenance schedule and Functional Equipment Group for an essential chiller to minimize the out-of-service time (OOST) [3].

Table I. The work items for pilot OLM

Components	Work Items
Essential Chiller	Compressor Overhaul
	Condenser ECT
	Motor Overhaul
Chilled Water Pump	Pump Overhaul
	Pump Motor Inspection
Chiller Bearing Sensor	Calibration and Check

The work was scheduled for 10 days (240 hrs) which was within 30 days of the AOT. The compressor overhaul was done by 2 shifts of the maintenance group. Skilled maintenance personnel with experience of more than 10 years and the relevant license were designated as the leads of each maintenance group for the pump, compressor and motors.

2.2 Organization and administration

A Task Force (TF) was established to prepare the procedures and documents for the OLM. The TF was then reorganized for work control during the OLM process. The site engineering director was the chief of the TF, which was composed of seven groups handling technical support, operation, work control, maintenance, risk monitoring, performance monitoring, and industrial safety including foreign material excursion control. This TF managed the work schedules, engineering issues, and troubleshooting in two shifts. Table II shows the meetings held for effective control of the maintenance.

Table II. The meetings done for on-line maintenance

Meetings	Purpose	Time to be held
OLM Kick-off	Report and share the preparedness	2days before
Pre-Job Brief	Pre-Job brief	Immediately before the work
Daily Meeting	Daily Progress Reporting	Daily
Work Control Meeting	Progress and Control	Daily
Post-Job Critique	Evaluation	Immediately after the work
Feedback	Feedback	1 week after work completion

2.3 Performance and Risk Monitoring

The Maintenance Rule (MR) can be used for the performance monitoring of SSCs which are affected by risk-informed applications. NRC Inspection Manual 9900 requires that the requirements of MR be met when taking equipment out-of-service to perform preventive maintenance during power operation [4]. In particular, the maintenance should be considered in order not to exceed the availability performance criteria, and thereby prevent the entering of the LCO unnecessarily.

The availability performance criterion of ECWS is 384 hours per 3 years. The estimated total OOST for preventive maintenance was 282 hrs, including the previous 42-hr OOST. However, this time was still within the criteria. The final OOST after the maintenance was 267.6 hrs, indicating a reduction of 14.4 hrs as compared to the scheduled duration.

The base risk of the Core Damage Frequency (CDF) and the Large Early Release Frequency (LERF) was 6.24E-6 and 6.17E-7 respectively. These figures were evaluated for the configuration without any maintenance or testing. The risk of CDF and LERF for the out-of-service of ECWS was 8.42E-6 and 7.05E-7, which were both within the 'green' color status meaning no additional actions needed to be taken.

2.4 Risk Mitigation Actions and site Walk-downs

The contingency plan was established and provided in the Main control room (MCR) and in local areas in the event of emergency. A warning tag reading "No Manipulation" was placed on the hand switch in the MCR of the stand-by ECWS and a sign reading "Do not enter" was posted on the door to this area. The system engineer carried out field walk-downs once a day with check sheets for the relevant parameters, while shift operators logged the parameters three times per shift for the central chilled water system which ran during normal operation, the stand-by ECWS, as well as the component and sea water cooling water system. The risk based on the configuration change was monitored in the work control room with risk monitoring systems which evaluated the up-to-date changes in the risk level as shown in Fig. 1.

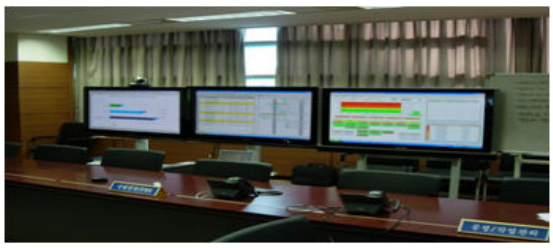

Fig. 1. Risk monitoring system in the work control room

3. Results and Insights from the Pilot On-Line Maintenance

The pressure of the compressor for the 8-hr holding test after the maintenance did not change, which indicates that the performance of the compressor was greatly improved without any leakage comparing to the previous performance. An integrity of the MCR emergency heat and vacuum system, which supplied cooling water from the ECWS, was successfully tested according to the surveillance test procedures as shown in Table Ⅲ. The duration of the work was 9.4 days, which was 8.6 days shorter than the average work duration of the ECWS over the past five years.

Table III. Test results after preventive maintenance

Test Items	Unit	Criteria	Actual
Leak test (Holding)	mmHg	< 1.27	0
Operation Tests	Hrs	> 10	10.1
MCR Temp.	℃	<25.6	24.2
Comp. Pressure	kg/㎠	5.3~8.7	6.2
Lub.oil pump △P	kg/㎠	1.41~2.11	1.75
Chiller Out. Temp.	℃	<6.7	6.5
Chilled pump flow	ℓ /sec	> 32	40

The OLM can be done by skilled and experienced maintenance workers who can focus on the work so that equipment reliability can be improved.

The sequential combination of the work schedule for all relative tasks and more effective work control process are required to manage the work and improve the work quality. The contract with maintenance works can be changed to reflect the OLM to give more flexibility regarding the use of experienced workers. Clear definitions of the exit of the LCO and the out-of-service function are required as well.

4. Conclusions

From the pilot implementation, the OLM was shown to help improve equipment reliability and performance and utilize resources in an effective manner. The actions that need to be improved for fleet-wide OLM were identified as well. Efforts to reduce the gaps in understanding and opinions between regulator and industry were made while performing this pilot implementation. These gaps were found to stem from a lack of understanding, social malaise or weak mutual trust in relationships. Research by regulator to establish guidelines or rules for OLM is in progress, and this paper and the result of the pilot implementation can help improve these rules or guidelines.

Further study and the implementation of the findings of this study and use of the insight gained would be beneficial for the effective implementation of a full-scope OLM in the future.

REFERENCES

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