EQUIPMENT PRESERVATION FOR A 4-YEAR OUTAGE OF PICKERING NGS UNITS 1 AND 2

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ABSTRACT

During the Pickering NGS Units 1 and 2 outage it was necessary to place systems in a state which would inhibit equipment degradation. This state is collectively known as "lay-up".

The objective of this report is to transmit details of the organization to implement and maintain lay-up, and to report on problems and their solutions.

Lay-up conditions for major systems are described.

The lay-up techniques used during the retubing outage were successful, with little evidence of equipment degradation. Recommendations for similar applications of lay-up in the future are given.

INTRODUCTION

Pickering NGS Units 1 and 2 were shut down on November 13, 1983 and August 1, 1983 respectively. The decision to change reactor pressure tubes was made in March 1984. It was clear that several years would elapse before these units could be returned to power. Therefore, steps had to be taken to prevent deterioration of the plant - and especially of the pressure envelope - so that it would be fit for extended service on completion of retubing. The shutdown period eventually extended into four years. This report describes the program, and its results, used to preserve equipment during this time.

The program under which these steps were defined and implemented was known as "lay-up" and was a component of Pickering Upgrading (Pick-Up) Program.

The objectives of lay-up were defined as:

- place equipment into a protected state safely, effectively and economically

- maintain protective conditions throughout the outage period

- ensure equipment could be efficiently restored to reliable service

- minimize exposure of equipment to conditions other than the protected state during maintenance and inspections.

The purpose of this paper is to present the experience gained during this period and to identify some of the difficulties, pitfalls and successes encountered, for reference under similar future circumstances.

The thrust of this report is directed at organizational and operational problems.

ORGANIZATION

A number of organizational elements had to be brought together for effective lay-up program. The following departments were involved.

- Central Nuclear Services (CNS) - whose function is to provide specialized services and advice to all Ontario Hydro nuclear generating stations. The Chemistry Section of CNS had the task of:

- researching and recommending the lay-up method to be used on the various systems and components

- specifying the desired values of chemical parameters

- assisting the station staff in the event of difficulties.

- The Commissioning Section at Pickering NGS had the primary responsibility for securing the implementation and maintenance of lay-up. This site organization was responsible for ensuring Pickering NGS Units 1 and 2 were available to operate safely and reliably after reactor retubing.

- The Production Section at Pickering NGS had the responsibility for all field work involved with implementation and maintenance of lay-up, in accordance with priorities specified on the daily work plan.

- Special mention must be made of the key role of the Chemistry Unit at Pickering NGS. This was the unit responsible for defining sampling frequencies, method of analysis and reporting and review of the results.

Organization of these groups operated via the following mechanisms:

- A lay-up coordinator was appointed. His tasks were to be familiar with system status at all times and to instigate corrective actions when required.

- The Station Chemist was instructed to review, on a weekly basis, the chemical condition of all systems. A continuous record of sample results was kept on a computer.

- The Duty Shift Supervisor had immediate responsibility for preserving the desired system condition.

- A "system responsible engineer" was appointed for each of the systems under lay-up. He had to prepare work plans and operating memos specifying in detail the system configuration and operation required for effective lay-up. A list of systems and the "system responsible engineers" was published.

IMPLEMENTATION OF LAY-UP

Initial Phase

Pressure tube failure in Unit 2 occurred on August 1, 1983, but it was not until March 1984 that a decision was made to retube reactors 1 and 2 with the consequent unit outage of several years duration. The lay-up program therefore, was not defined until the summer of 1984 and its implementation commenced in earnest in the Fall.

In the interim, ie, from August 1983 until the Fall of 1984 steps were taken by Pickering Operations, to protect equipment from deterioration.

Typically service and auxiliary systems, whose operation is not dependent on unit power level were kept in service.

For other systems, such as

- heat transport
- feedwater
- steam and boilers

standard provisions were made to minimize deterioration.

For example:

- Circulation and purification was maintained for heat transport system, as required for cooling of fuel.

- Boilers were filled with hydrazine treated water and N_2 blanket was eventually applied to main steam piping, but there was no provision to circulate the water.

- Turbine and generator were continuously purged with warm air and routinely rotated.

These were the steps normally taken during outages of several weeks duration. They are adequate in the short term, but lack the more elaborate preparation and controls of the formal long-term lay-up program.

Long-term Lay-up Phase. When long term lay-up was decided upon (March, 1984) the following sequence of events occurred:

- CNS prepared chemical specifications (June, 1984)

- Pickering Engineering Department engineered boiler recirculation system, which was put in service on Unit 1 in February, 1985

- station reference plan was issued defining lay-up responsibilities at the station

- list of "system responsible engineers" was published

- lay-up coordinator was named and lay-up committee formed. The committee held its first meeting on October 4, 1984.

Actions assigned at this meeting were to implement:

- mechanical modifications, such as temporary piping and removal of valve internals.

- special operating procedures to circulate and periodically replenish lay-up fluids.

- instructions to chemical technicians with respect to sampling method and schedule.

The subsequent monthly review meetings and actions arising from them were the main mechanisms for long-term implementation and control of lay-up. The following were routinely reviewed.

- status of each system, ie, work underway, portions of system out of lay-up and why.

- chemical condition of each system

- performance of sampling

- plans for the coming month, such as:

- maintenance or other major work scheduled

- corrective actions arising out of review of the above

- special reporting requirements.

The meetings were attended by Pick-Up superintendent, Production representative, system responsible engineers and chemistry section staff from Pickering NGS and CNS. They were chaired by lay-up coordinator.

Lay-up States. These were:

- system in operation (eg service water)

- system dry with N_2 blanket (eg main steam piping)

- system dry with warm air blanket (eg turbine and auxiliaries)

- system wet with hydrazine treated water (eg feedwater piping)

Systems were put into one of these states as follows:

Heat Transport. This was divided into two portions:

- the lower, comprising the pressure tubes, end fittings, feeders and headers was kept dry in air as part of the retubing operation

- the upper part, comprising of all the piping, in the boiler room was kept under N_2 blanket.

The application, maintenance and sampling of this N_2 blanket was quite difficult because of complexity of the piping and the need to periodically open it up for maintenance. Elaborate valving set ups and purging sequences were necessary to ensure that all air has been evacuated from the system.

Moderator. This system was filled with demineralized H_2O and kept in operation, by running at least one circulating pump and purification circuit.

Main Boiler (Secondary Side) and Steam Piping. The secondary side of main boilers was to be protected by demineralized water with hydrazine added. In order to assure good chemical control it was decided to install a temporary circulation system to be run continuously. Prior to its installation and operation in February 1985, the boilers were filled with stagnant water, which was changed from time to time as dictated by declining hydrazine concentration. When required, the boilers were drained to the lake through blowdown piping. Considerable difficulty was experienced during the winter because of freezing of blowdown lines due to passing valves.

Several months after the installation and start up of the temporary water recirculation system, ie, in July 1985, satisfactory hydrazine concentration could not be maintained due to it being converted into ammonia. Boilers had to be drained every few days.

Efforts were made to determine and eliminate the cause of this reaction, as follows, all to no avail:

- tightening of flanges and installation of blanks to eliminate air ingress
- system field checked to ensure no inadvertent connection existed
- lay-up history was reviewed in detail
- search of literature conducted by CNS

The causes of this ammonia production are not yet fully understood, but suspicion is directed at the hard sludge pile which has accumulated on the tubesheet, up to a maximum depth of 40 cm.

The details of reaction taking place and the investigation into this phenomenon are reported in reference (1).

As the result of ammonia production and the difficulty of maintaining satisfactory hydrazine concentration, the control parameter was changed from hydrazine to dissolved O_2 concentration. Permissible concentration of ammonia was also limited.

An on-line dissolved O_2 analyzer was installed and O_2 levels well below the specified values were maintained by periodic additions of small amounts of hydrazine.

In order to eliminate the possibility of stagnant air accumulating at the water-gas interface in the boilers, nitrogen gas was fed into water. It bubbled to the surface and then into the main steam piping. No difficulty was experienced maintaining adequate N_2 concentrations in the main steam piping.

TABLE 1: CHEMICAL SPECIFICATIONS

	Original	New	
		Objective	Limit
Hydrazine	50-100 mg/kg	50-75 mg/kg	50-200 mg/kg
Dissolved Oxygen	-	50 mg/kg	200 mg/kg
Ammonia	-	100 mg/kg	1000 mg/kg
pH	9.0 to 9.5	9.0 to 10.5	9.0 to 11.0

Condensate and Feedwater. The deaerator, condensate and feedwater piping was filled with hydrazine solution which was circulated weekly using auxiliary feedwater pump. Temporary piping had to be installed to permit circulation during retubing of the main condenser. The condensate storage tank was filled with dry air. Low pressure feedwater heaters were periodically flushed using deaerator water.

Other Systems. They were put into lay-up as follows, with no difficulties being experienced:

- turbine and auxiliaries - dry with warm air blanket
- generator and auxiliaries - dry with warm air blanket, except when undergoing maintenance
- recirculated water - in service
- liquid zone control - in service
- lubricating oil - rust-inhibiting agent added
- fuel handling and auxiliaries - drained and dried
- boiler blowdown - part of the main boiler circuit

PROBLEM AREAS AND DIFFICULTIES

There were a number of difficulties associated with implementation and maintenance of lay-up.

These can be divided into:

- organizational
- logistic
- technical.

Organizational Problems

The problem was slow implementation of lay-up.

The station had to operate under the following set of priorities:

- service and maintain operating units, including planned outages

- complete commissioning of Units 5 to 8

- retube reactors 1 and 2

- carry out Pick-Up program on Units 1 and 2.

Since lay-up was part of Pick-Up, it was difficult to argue convincingly about the need to assign scarce resources to it. Nevertheless, lay-up did move ahead especially in areas where serious deterioration would have grave consequences, such as boilers and heat transport system.

The Production and Technical Sections accounted for most of the delays. While everyone agreed on the need for lay-up, resources, ie, manpower, were not made available to do the necessary work. It must be emphasized, that this was because of the many urgent and pressing demands made on Pickering NGS, only a few of which could be satisfied at any one time. Hence, there was a constant struggle and discussion about the relative priorities of various conflicting demands, with lay-up often being delayed.

A lesson for the future should be drawn here. The delays, frustrations and arguments would not arise had there been a dedicated crew assigned to Pick-Up.

Logistic Problems

Maintenance of lay-up conditions was seriously affected by the need to provide isolation and work protection for inspections, modifications and maintenance.

The major items affecting lay-up were.

Retubing of main condenser, which affected lay-up of feedwater and condensate as well as the N_2 blanket of the main steam piping. Temporary lines had to be installed to maintain lay-up on feedwater, and special precautions had to be taken to ensure that N_2 will not find its way into the condenser. Until these were provided, N_2 make-up to main steam pipes had to be isolated while work on the condenser was in progress.

Detailed inspection of main heat transport pumps necessitated removal of N_2 blanket from one heat transport system loop.

Major modifications and repairs in the deaerator and the condensate storage tank required removal of N_2 blanket.

Regular rotations of turbine generator, scheduled every two weeks were difficult to execute due to work underway on the turbine/generator and the lubricating system.

Inspections of feedwater heaters, both high and low pressure required temporary removal of hydrazine treated water.

Technical Problems

In a few cases, incorrect lay-up has resulted in damage to equipment.

The inside of the tubes of high pressure feedwater heaters were found covered with loose deposit consisting of about 85% copper. The tubes are copper-nickel alloy and it was clear that this deposit originated from the tubes. All high pressure feedwater heater tubes had corroded to some extent, as evidenced by the presence of this deposit, the amount of which was approximately 400 kg in the worst heat exchanger. All heat exchangers were cleaned and the tubes were inspected by eddy current technique and found to have corroded uniformly, having lost about 15% of wall thickness. No pitting corrosion was found and the heat exchangers were declared fit for service. An alternative lay-up technique, is being investigated.

End shield cooling heat exchangers had to be replaced due to tube vibration, fretting and cracking caused by incorrect operating practice as specified by lay-up. Cooling water flow was maintained on the shell side, with the tubes being empty. The tubes vibrated and fretted, with several being totally sheared at support plate. Change of operating mode eliminated this problem.

The generator was maintained dry and warm by a "belly heater" located outside and at the bottom of the casing. The heating was excessive and the paint on the inside of the generator casing peeled along the bottom 20° of the casing. Clean up and scraping of all loose paint inside the generator was necessary which turned out to be a difficult and awkward job due to restricted access and presence of an oil film.

Preventive Maintenance

The lay-up program objective was prevention of equipment deterioration. The overriding objective of the Pick-Up and commissioning program was to assure trouble-free startup and operation of Units, which has been accomplished for Unit 1. To that end a lot of inspections and preventive maintenance had been done. This work, while not strictly part of lay-up, is of interest when trying to preserve and restart a plant after a long outage and is therefore briefly reported here.

The following was done.

- All major relief valves were overhauled. Relief valves on condensate and feedwater systems would not operate properly due to accumulation of corrosion products. New valves had to be installed in a number of cases.

- Elastomers (diaphrams and "O" rings) had been changed in all major control valves and their operators. Existing elastomers were generally found in a satisfactory condition.

- All protective relays have been calibrated and reset.

- All 4 kV and 600 V breakers had been overhauled and lubricated. The original lubricant had hardened and could have impeded breaker operation.

- Numerous valve packings were inspected and found to be satisfactory, ie, not dried up. However, some of them needed tightening when pressure was applied.

- Major vertical pumps and motors, such as heat transport and moderator, had been left supported on their thrust bearings, even though the possibility of bearing indentation was considered a possibility. No damage ensued, as evidenced by bearing inspections and trouble-free startup and operation of pumps.

- All main heat transport pump seals had to be changed due to crud accumulation. This crud is thought to be the result of Candecon decontamination, rather than incorrect lay-up.

- The station cooling water intake is prone to silting. The pattern of silt deposits has changed due to non-operation of Unit 1 and 2 condenser circulating water systems, resulting in a significant build up in front of Unit 1 and 2 skimmer wall. A one week flushing operation was attempted, with partial success, to flush this silt through the condenser cooling water.

Removal of Lay-up

As the time for unit restart approached, the instruction on lay-up was revised to define responsibilities for removal of lay-up, as follows:

- Request for lay-up removal to be initiated by system responsible engineer and approved by Commissioning Section Superintendent and Technical Superintendent for Chemistry.

- Work Plans and operating instructions for removal must contain some testing and inspection requirements, to establish condition of the system with respect to deterioration and crud accumulation.

- Proposal for removal must be agreed to by:

- Chemistry Unit at Pickering NGS
- CNS Chemistry Department
- Production Superintendent

Based on these instructions, removal of lay-up was executed smoothly on Unit 1.

RESULTS ACHIEVED

The lay-up program has achieved its objectives including its efficient removal and the restoration of equipment to service. This has been confirmed by trouble-free startup of Unit 1 and by various inspections prior to startup.

There were no defects identified other than those referred to under "technical problems" which impeded or delayed Unit 1 startup, and could be traced to lay-up.

The following inspections confirmed satisfactory results of lay-up program.

- The steam drum and its "furniture" of boiler 3 were inspected and found to be in excellent condition. A program of boiler tube inspections has been conducted over the entire lay-up period. Four tubes have been removed for metallurgical examination. 40% of tubes have also been inspected by eddy current technique. No deterioration or adverse effects have been found.

- Main steam piping was visually inspected on the inside in the vicinity of steam reject valves. Ultrasonic inspections were also conducted. No deterioration was found with the inside surfaces of piping being in excellent condition.

- Heat transport piping was inspected from the pump bowl during pump dismantling and also when other opportunities such as valve modification, presented themselves. The piping was found in excellent condition.

- Another proof of satisfactory heat transport piping preservation was that the expected crud burst did not materialize on startup thus confirming existence of a good magnetite layer.

- Condensate and feedwater piping was examined whenever equipment was opened up, with satisfactory condition of inside surfaces being confirmed. Some erosion was found on heater drain and vent piping.

- Numerous heat exchangers (HXs) have been examined, both nuclear and conventional by visual and eddy current techniques, and most have been found in satisfactory condition.

- An audit of the lay-up program was conducted by CNS in November, 1985, and the follow-up review in January, 1987. The audit confirmed satisfactory application of chemical specifications and procedural controls and assessed overall performance of lay-up as "good". Table 2 illustrates chemical performance for Unit 1.

TABLE 2: CHEMICAL PERFORMANCE

		Period
	Up to Nov/85	Nov/85 - Jan/87
% of samples taken	60	91
% of data within specification	84	94

RECOMMENDATIONS

The following specific recommendations can be made for future lay-up programs.

- Assign a dedicated team of technical and production staff to implement and oversee a major shutdown, including lay-up. This group should be isolated from other station priorities and would be in a position - and be responsible for - adequately protecting the equipment throughout the shutdown.

- Assign a senior person to be responsible for lay-up and provide him with adequate resources. Lay-up should have high profile and priority. CNS and Technical Section (Chemistry) should be retained as consultants.

- Conduct orientation and awareness seminars with technical and production staff to ensure that they are aware of lay-up program and recognize its importance.

- Start sooner. We took a long time to make up our mind about lay-up. Selective lay-up, eg, to boilers, is well worth applying if the outage will last a few months. This may help to avert a lot of difficulties in the future.

- Early in the lay-up program institute a vigorous chemical control program with frequent sampling and evaluation of chemical conditions.

- Be selective in application of lay-up. Part of our problem was that initially we attempted to lay-up all systems, even though some are obviously more important than others. Future lay-up programs ought to be more selective in assigning priorities.

- A document describing organization, chemical specifications and implementation steps, and incorporating the recent Pickering NGS experience should be prepared and included in station documentation. This will greatly facilitate future lay-up applications.

CONCLUSION

In spite of delays and difficulties, the lay-up program was successful in achieving all of its objectives. Had there been a stronger organization in place, the objectives would have been achieved sooner and there would have been better assurance of equipment protection. As it was, little equipment degradation occurred.

REFERENCES

(1) GILLIES, C., HERSEY, M., MCCOOL, D., "Lay-up Chemistry during Pickering NGS Units 1 and 2 Fuel Channel Replacement", Water Chemistry and Materials Performance Conference, CNS, October, 1986, Toronto.

(2) DYCK, R.W., to K.H. Talbot, private communication March 17, 1987, Pickering file P-00772.17.

(3) UPTON, M.S., MONTFORD, B., "Assessment of Pickering NGS Units 1 and 2 Lay-up", CNS Report number CNS-1R-01800-2.