

CANDU MAINTENANCE CONFERENCE 1987

THE MAINTENANCE FUNCTION AT THE BRUCE HEAVY WATER PLANT (BHWP) OF ONTARIO HYDRO

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1.0 INTRODUCTION

1.1 An Overview of the BHWP

I would like to begin my paper today by presenting an overview of the operation of the Bruce Heavy Water Plant. This overview will contain a brief history of the BHWP as well as a short description of the process that is used.

1.1.1 A Brief History. In 1967 Atomic Energy of Canada Ltd. (AECL) decided that a plant to produce heavy water in Ontario was required to meet the expanding needs of the Candu Nuclear Industry. AECL was the initial owner, The Lummus Company was contracted to design and construct the plant and Ontario Hydro was contracted to commission and operate it with a view to purchasing the plant, after successful commissioning. The plant, built at the Bruce Nuclear Power Development Site, on the Shores of Lake Huron, was called the Bruce Heavy Water Plant.

The original plant, Plant A was built between 1968 and 1971. During the next two years Ontario Hydro successfully commissioned Plant A and placed it in service. They purchased it in 1973.

The projected need for additional nuclear power in 1973 resulted in an announcement to expand the Plant to B, C and D. The construction of Plant B started in 1975 and Plant D in 1976.

In 1979 a reduction in the projected demand for energy resulted in only Plant B being completed. It was placed in service in 1981.

In 1984 a further reduction in the demand for heavy water for the nuclear power industry, resulted in Plant A being shutdown and mothballed. Today, having been declared surplus, it stands silently awaiting disassembly. It produced 6833 Mq. of heavy water (D₂O) in it's twelve year life.

A summary of the history is shown in Figure 1.

1.1.2 The Process. The BHWP was originally designed to extract 96.6 kg/hour of 99.77 molecular (mol) % D₂O from Lake Huron. During operation this figure was uprated to 105.6 kg/hour. The concentration of heavy water occuring naturally in Lake Huron is 148 parts per million (ppm). Approximately 19% (27ppm) of this heavy water is extracted by the Plant, the rest (approximately 121ppm) is returned to the lake.

D₂O is produced from ordinary water by a two step process as follows:

Step 1. In the first step the Enriching Units extract deuterium from the treated lake water and provide a 30 mol % D₂O stream to the Finishing Unit. This is accomplished by a process called the Girdler-Sulphide process which

Figure 1: Brief History of the Bruce Heavy Water Plant

<u>Year</u>	<u>Events</u>
1968 - 1971	Plant A was built.
1971 - 1973	Ontario Hydro commissioned Plant A and placed it in service.
1973	Announcement to expand to BHWP B, C, and D. Ontario Hydro purchased Plant A.
1975 - 1978	Plant B was built.
1978 - 1981	Plant B was commissioned and placed in service.
1976	Construction of Plant D started.
1979	Announcement to stop and store Plant D.
1984	Shutdown and mothballed Plant A.
1986	Plant B produced 99.999 mol.% D ₂ O for marketing purposes. Normal production is 99.92 mol.% D ₂ O.
1987	Plant B is operating satisfactorily.

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is a dual temperature isotopic exchange process using water and Hydrogen Sulphide (H_2S) as process fluids. The principle utilizes the fact that deuterium tends to concentrate in the water at a low temperature but tends to concentrate in the H_2S gas at an elevated temperature as illustrated in Figure 2.

The process is carried out in three stages in a number of large, trayed towers. The first stage consists of three parallel sets of towers, with a single second and third stage. Each of the stages has a hot and cold tower section. While treated water flows down the tower the H_2S gas is blown up through the perforated trays and bubbles through the water on the tray, promoting the necessary intimate contact. The first and second stages physically have their cold sections on top of their hot sections, permitting the two to share a common pressure vessel. The third stage has physically separated hot and cold sections.

The gas and water in the middle of the first stage tower have the highest D_2O concentration (600ppm) and it is from here that a stream of gas is moved forward to the second stage. A similar exchange process takes place in the second and third stage towers, with the gas leaving the middle of the second stage with a concentration of 0.24 mol % D_2O , and water leaving the bottom of the third stage cold tower at 30 mol % D_2O .

Step 2. In the second step of the process the water at the bottom of the third stage is fed to the Finishing Unit where, in a vacuum distillation process, D_2O is produced at a concentration of 99.77 mol % or higher.

Each Enriching Unit holds approximately 550 Mg of H_2S . The gas in the depleted water, or other waste streams, is recovered and returned to the process. The concentration of gas in the Plant effluent is reduced to less than twenty (20) ppb in the Enriching Units and is further diluted before being returned to Lake Huron.

D_2O , being a prescribed substance, comes under the Atomic Energy Control Board Regulations. As such the AECB issues Ontario Hydro with an Operating Licence to operate BHWPF.

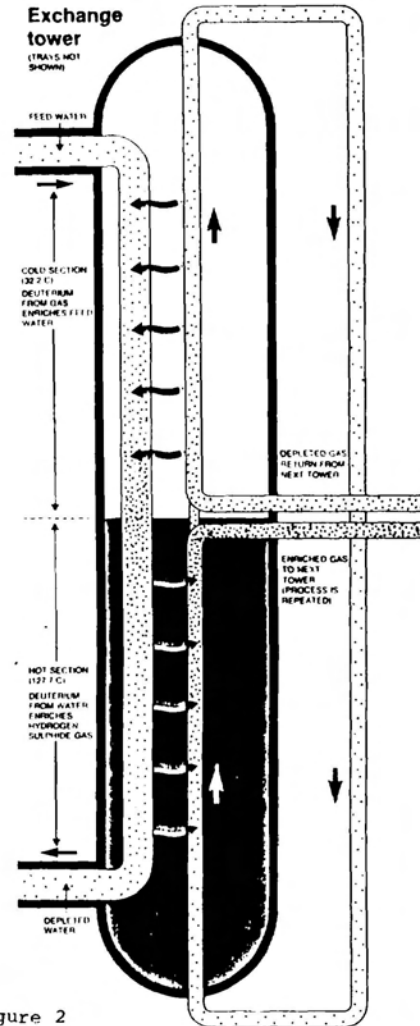


Figure 2

1.2 The Equipment at BHWPF

Some of the equipment at BHWPF is large by chemical plant standards. Most of it is situated outside, so maintaining it during the winter months in subzero temperatures, is very difficult and time consuming.

Typical components of one of the Plants at BHWPF include:

- 16,500 valves of sizes up to 1.2 m.
- 116 heat exchangers, the majority of which are 13 m long and 0.92 m in diameter.
- 19 compressors, the biggest being on the first stage tower system, which moves 2000 Mg of gas/hour and is driven by a 6900 HP motor.
- 26 towers, the largest being the first stage towers which are 83 m high, 9 m in diameter with a wall thickness of 6 cm. They contain 147 trays.
- 40 tanks and vessels.
- 230 pumps.
- 2 flare stacks whose's top sections require replacing every 10 years.

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- 596 control valves of various sizes up to 1.1 m.
- The Electrical distribution system is 13.8 KV to 600 VAC Class IV and Class III, (8 separate substations).
- 1700 process instrument loops.
- 200 air operated motorized valves, (isolation circuits).
- 86 H₂S in air monitors, (perimeter and area safety systems).
- 6 inverter/rectifier/static transfer switches, (Class II).
- 10 125VDC battery banks and switch gear, (Class I).
- 2 programmable controller loops.
- 1 plume plotter, (computerized system).
- 865 electric tracers.

to put the Maintenance Unit under one Unit Head. Technical Superintendents are assigned to this position for about four (4) years.

Today, the Maintenance Unit organization as is shown in Figure 3.

Basically BHWP uses a day based, area orientated maintenance organization, with a maintenance services crew providing those services that we consider best supplied by the departmental organization, e.g., a vibration monitoring and analyses service. The geographic layout of the shops dictates that we work from three different locations.

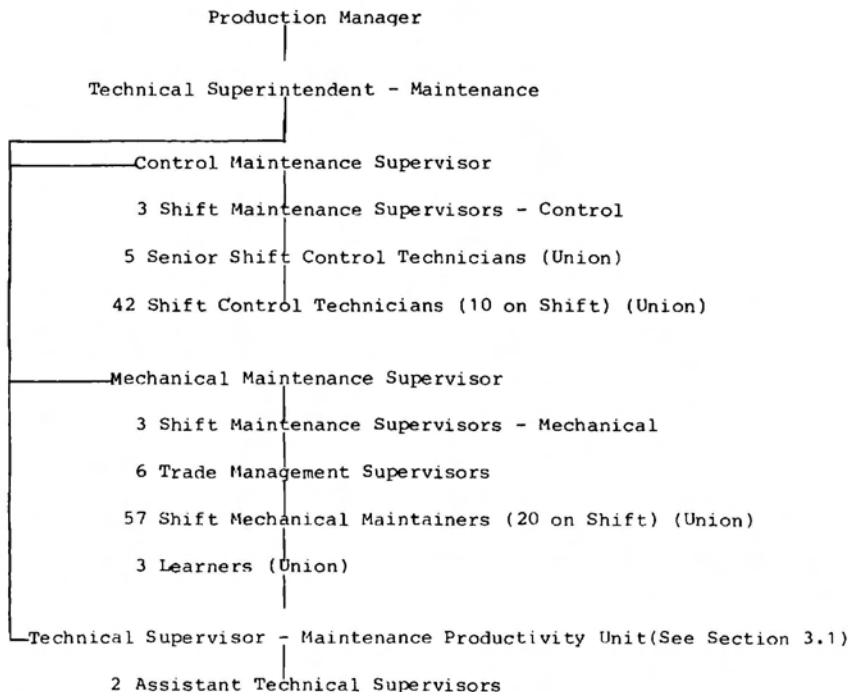
1.3 The Maintenance Unit Organization

From 1971 to 1975 most maintenance was performed on shift, with the Control and Mechanical Maintenance Supervisors reporting to the Production Manager. When Plant B was being commissioned, the Plant A organization remained basically the same, but the Plant B Control and Mechanical Maintenance Supervisors reported to two Commissioning Superintendents. This organizational structure was not considered satisfactory.

The shift maintenance complement provide a Plant wide maintenance service. The Central Maintenance Facility, which is available for use by all Departments on Site, supplies the BHWP with specialized services such as the overhaul of relief valves. The BHWP Technical Section provides all the engineering for maintenance problems.

In 1978 the position of Technical Superintendent - Maintenance was introduced to the BHWP Production Section. This position was created to provide improved program management and

Figure 3: The Maintenance Unit Organization
(1987)



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2.0 THE MAINTENANCE UNIT'S MANAGEMENT FUNCTIONS

2.1 The Management Process

The Unit's Management Process defines the Mission Statement, the Key Result Areas and the Targets. These are explained below.

The goal of the Maintenance Unit is to provide a maintenance service at BHWP that achieves specific targets for:

- Employee and public safety
- Environmental protection
- Product quality (Reliability)
- Product cost and
- Human Resource development.

These are called the five BHWP Key Result Areas (KRA's).

The Key Result Areas for the Maintenance Unit are found in the Unit's annual Reference Plan. This document contains a number of Target Record Sheets (See Appendix 1). The Target Record Sheet, for each KRA, contains a KRA statement, a set of Targets, Measurement Methods and Plans of Activities. The performance of the Unit is judged against how well we accomplish the annual Reference Plan. Performance is formally reviewed quarterly with the Production Manager.

The Control and Mechanical Maintenance Supervisors and the six Shift Maintenance Supervisors also have individual annual Reference Plans.

Targets from the annual Reference Plan are used as Maintenance Performance measures. These include:

- Cost of maintenance/kg of D₂O produced.
- Production loss attributable to defective maintenance.
- Compliance to the weekly plan.
- Actual costs against budget.
- Benefit/cost ratio for the Maintenance Productivity Unit.

2.2 Performance Reviews

Each month the Managers, Section and/or Unit Heads undertake performance reviews at BHWP. These reviews normally takes about an hour and provide the reviewer with the opportunity to delve into any specific aspect of, for example, the maintenance function that the reviewer wants to verify. A short memo records the discussions and any actions arising.

For 1987 some performance review topics for the Unit have included the following:

- Review of BHWP crane maintenance records.

- Review of the Unit's last twelve months' use of our thermography equipment.
- Review of a random sample of equipment history records for compliance to procedure.
- Review of the shift maintenance log book for conformance and action follow-up.
- Review of a sample of Control Maintenance work reports for compliance to procedure.

The status of actions resulting from the performance reviews is reported on by the Section or Unit Head at the end of the year.

2.3 Plans and Work Execution

The Planning Section provides the following plans to assist the Maintenance Unit.

- The three month plan.
The weekly plan for the operating and maintenance activities.
- A daily shift maintenance plan, which identifies work for the Mechanical Maintainers on shift.
- Outage plans.
- Special plans for unique jobs.

The Maintenance Unit contributes to the preparation of these plans.

All work executed at BHWP is authorized by one of the following documents.

- A Deficiency Report (DR).
- A Minor Work Order (MWO).
- A Preventive Maintenance call-up (PM call-up).
- A Proposed Change (PC) (an engineering document).

At the present time all maintenance work is charged to a recognized job number, the DR number or the PC number.

2.4 The Work Management System

Our present computer capabilities, pertaining to the maintenance function, can be summarized under the following three headings. The information is contained in more than one computer system and cannot always be integrated.

- Work Management
 - Pre outage planning and monitoring critical path activities during a unit or system shutdown.
 - Deficiency Report status and backlog of available work.
 - The preventive maintenance program.

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- Materials Management
 - Material specification lists for most equipment.
 - Bills of materials.
 - Ordering of materials.
 - Reservation of material for specific jobs.
 - Material costs and stock levels.
- Monitoring System
 - Estimated and actual hours worked, material costs and total costs of repair by DR, MWO, and PM program.
 - DR history, which can be sorted a number of ways to give individual equipment maintenance history, or maintenance history by group of equipment, e.g., pumps. This history search can be supplemented by reviewing the equipment files.

A fully intergrated work management system will combine all these, and other systems, into one intergrated computer system.

3.0 OTHER MAINTENANCE UNIT FUNCTIONS

3.1 The Maintenance Productivity Unit

The Maintenance Productivity Unit (MPU) was introduced to our Maintenance organization in 1978. It's Mission is to:

- Reduce the cost of producing heavy water by developing solutions to immediate and long term maintenance problems. This is done by supplying specialized engineering support in the areas of consulting, industrial engineering and maintenance methodology.
- Provide information and analysis to the Technical Superintendent - Maintenance and the Maintenance Supervisors so that they can more effectively carryout their responsibilities.

Since 1978 the MPU has saved Ontario Hydro a considerable sum of money. A list of some of the major projects accomplished is shown in Figure 4. We use the criteria of comparing the benefit the MPU has achieved, when projects are implemented, against the labour cost of their development. Our benefit/cost target is > 2:1. Most project's benefits are credited for up to a 36 month period following the introduction of the project. With the exception of one year, we have achieved our benefit/cost ratio target.

Not all studies that we undertake save us money. One engineer spent approximately two (2) months reviewing our Shift Mechanical Maintainer needs, similar to the study we completed on our Shift Control Technician needs. At the end of the study we concluded that the number of Shift Mechanical Maintainers employed was appropriate. We claimed no cost savings as a result of this project.

Figure 4: A List of Some Major Projects Accomplished by the Maintenance Productivity Unit

<u>Project</u>	<u>Benefit Per Year (k\$)</u>
Introduction of the maintenance coordinator	336
The procurement of a versalift (mobile crane)	282
Elimination of most work protection delays	216
Modification of the overhead cranes for pumps P106/P107	103
Improve steam trap maintenance efficiency	237
Review of shift control technician needs	200
Review of BHWP's transportation needs	64
Introduction of the vibration data collector.	44

Besides working on projects, the MPU supplies the Maintenance Unit, and others, with important information on costs of maintaining equipment at BHWP. The MPU produces the Maintenance Unit Monthly Report which contains cost data and other statistics on the effectiveness of maintenance, e.g., statistics on welding performance and the effectiveness of the vibration Monitoring Program. The index is shown in Appendix 2.

The MPU has, as one of it's projects, co-ordinated the development of our Standard Hours Manual. This Manual breaks down a job into it's basic activities, and details a labour requirement, and a duration, for each one. It also specifies material requirements and special tools. It contains detailed information on most equipment at BHWP and is used extensively by the Maintenance Co-ordinator (see below) for DR package preparation. It is about 85% complete.

3.2 The Maintenance Co-ordinator Position

In 1982 the position of Maintenance Co-ordinator was introduced to the BHWP Maintenance Organization. This came about as a result of discussions with a maintenance efficiency consultant named Borden Coulter of the Emerson Consultants Inc. of New York.

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One function of the Maintenance Co-ordinator position is to provide complete Deficiency Report (DR) work packages, for identified deficiencies for the Control and Mechanical Maintenance Work Units at BHWP. An equally important function is to provide maintenance management input to Engineering when they are contemplating changes to the plant.

The Maintenance Co-ordinator position has always been filled by the first line supervisor because:

- We require go/no-go management decisions to be made during the DR assessment process.
- We require a position for the development of first line supervisors.
- We require the Maintenance Co-ordinator to directly supervise a field crew when the need arises, e.g., to fill in for vacation relief, sickness or increased work load.

The Maintenance Co-ordinator's main activities include the following:

- Initially reviewing the DR, to become familiar with the problem and the proposed solution.
- Making a field trip to see the exact location of the deficiency and to assess the need for such things as scaffolding, insulation removal, and special equipment such as lifting gear and tools.
- Providing a supervisory assessment on the best way to do the job and preparing a package to resolve the deficiency which could include obtaining such things as bills of material, drawings or sketches, engineering input and procedures.
- Estimating material and labour requirements.
- For unusual jobs, informing Maintenance supervision of the problem and the solution.
- Reviewing a sample of completed DR's for comparison of actual costs against estimate.

The Maintenance Co-ordinator is an essential position in our organization and has the authority to determine how the job is to be done. A good theoretical and practical knowledge of the equipment is required, along with the ability to come up with the best solution in a short time. Being able to cooperate with, and influence, other people is also required.

Maintenance DR's are assessed by our three Maintenance Co-ordinators, and approved by cost controllers, before execution in the field. Having a complete work package, when the job is scheduled in the field, enables the tradesperson to spend more time on the tools, and allows first line supervisors more time to perform direct supervision in the field.

The Maintenance Co-ordinator uses our Standard Hours Manual to assist in estimating time, material and special requirements, for DR package preparation.

4.0 THE BHWP PREVENTIVE MAINTENANCE PROGRAM

An important goal of the BHWP is to provide safe, reliable, economic and environmentally acceptable operation. In support of this goal BHWP carries out specific routine activities that are primarily preventive in nature. The Preventive Maintenance (PM) Program is in place to initiate such activities and provide feedback on compliance.

BHWP has an effective PM program. We constantly report > 99% completion of the planned program on a monthly basis. We achieve this figure because we place high priority on completing PM callups. Only the correction of a safety hazard well pre-empt a PM callup activity.

Some of the features of our PM program include:

- One form is used to initiate new callups, or make revisions to or totally delete existing callups.
- The completed form is reviewed by Engineering and the Production Supervisor responsible for it's execution.
- The form is approved by the Cost Controller.
- Planning - schedule all callups.
 - report compliance monthly.
 - reschedule missed callups.
- All completed callups are reviewed by the Cost Controller.
- All callups are reviewed every two years to ensure their continued effectiveness.

Compliance standards for safety valves and safety equipment is > 99%, and for other callups the standard is > 90%. We have about 2300 callups.

In the Maintenance Unit, Control Maintenance spend about 44% of their productive time, and Mechanical Maintenance about 10% of their productive time, performing PM callups. Productive time is defined as annual total hours (2080) less time for vacations, statutory holidays, sickness and training. The difference in the two figures above is explained by the difference in work methods between the two work units.

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5.0 FUTURE MAINTENANCE UNIT WORK PROGRAMS

Future work programs planned by the Maintenance Unit will include:

- Assisting in the introduction of a more fully integrated work management system.
- Completing the Standard Hours Manual.
- Refining the indices for measuring the effectiveness of the Unit.
- Expanding the use of Computers within the Unit to reduce paper flow.
- Continuing to assess outside industry for new methods and equipment to increase maintenance productivity.
- Reviewing our existing Preventive Maintenance program to ensure it is producing the intended results.

I trust this paper on the Maintenance function at the Bruce Heavy Water Plant has been informative. If you have any questions I will be pleased to address them.

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APPENDIX 1

TARGET RECORD SHEET

<u>KEY RESULT AREA</u>		<u>RELIABILITY</u>	
<u>STATEMENT:</u> THE EXTENT TO WHICH MAINTENANCE PROGRAMS AND WORK EXECUTION MEETS USER NEEDS			
<u>TARGET(S)</u> TO ACHIEVE $\leq 1\%$ PRODUCTION LOSS ATTRIBUTABLE TO DEFECTIVE MAINTENANCE WORK (THERE ARE 5 OTHER TARGETS FOR THIS KRA)	PERFORMANCE		
	Q	YTD	
<u>MEASUREMENT METHODS</u> MONTHLY DERATE SUMMARY REPORT			
<u>PLAN OF ACTIVITY</u> REVIEW THE "EQUIPMENT FAILURE" CATEGORY ON D20 LOSS AND TAKE CORRECTIVE ACTION AS NECESSARY	DATE		
	SCHEDULED	ACTUAL	
	MONTHLY		MONTHLY

SUBMITTED BY: _____

APPROVED BY: _____

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APPENDIX 2

THE MAINTENANCE UNIT MONTHLY REPORT TYPICAL TABLE OF CONTENTS

<u>SECTION</u>	<u>DESCRIPTION</u>
1.0	1.1 MAINTENANCE COSTS - YTD 1.2 MAINTENANCE COSTS/Kg D ₂ O-YTD
2.0	DERATES ATTRIBUTABLE TO THE MAINTENANCE UNIT
3.0	SUMMARY OF MAINTENANCE JOBS COMPLETED BY EQUIPMENT TYPE
4.0	OTHER MAINTENANCE PROGRAMS 4.1 STEAM SYSTEM REPAIRS 4.2 PREVENTIVE MAINTENANCE 4.3 ROTATING EQUIPMENT MONITORING
5.0	MAINTENANCE COSTS BY PLANT
6.0	BHWP WELD REPAIRS
7.0	HIGHEST COST DEFICIENCY REPORTS
8.0	*MINOR WORK ORDER SUMMARY
9.0	FIRST AID AND MEDICALLY TREATED INJURIES FOR THE MAINTENANCE UNIT

*A MEANS OF CORRECTING MINOR DEFICIENCIES