Canadian Nuclear Society
Fourth International Conference on CANDU Maintenance
Toronto, Canada
November, 1997

Darlington Station Outage - A Maintenance Perspective

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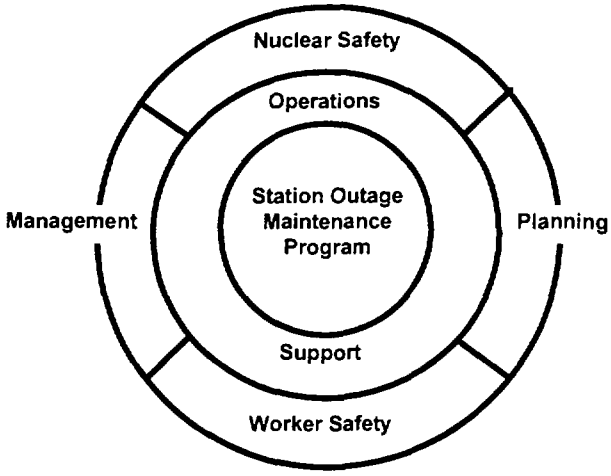
Summary

Ontario Hydro's Darlington Nuclear Generating Station (4x881MW(e)net) has carried out its first station outage since full commercial operation. The outage presented challenges to the organization in terms of outage planning, support, management, and safe execution within the constraints of schedule, budget and resources. This paper will focus on the success of the outage maintenance program, identifying the major work programs -- a Vacuum Structure and Containment Outage, an Emergency Service Water System Outage, an Emergency Coolant Injection System Outage, Intake Channel Inspections, Low Pressure Service Water Inspections, and significant outage maintenance work on each of the four reactor units. Planning for the outage was initiated early in anticipation of this important milestone in the station's life. Detailed safety reviews -- nuclear, radiation, and conventional -- were conducted in support of the planned maintenance program. System lineup and work protection were provided by the Station Operator work group. Work protection permitry was initiated well in advance of the outage. Station maintenance staff resources were bolstered in support of the outage to ensure program execution could be maintained within the schedule. Training programs were in place to ensure that expectations were clear and that high standards would be maintained. Materials management issues in support of maintenance activities were given high priority to ensure no delays to the planned work. Station management review and monitoring in preparation for and during the outage ensured that staff priorities remained focused. Lessons learned from the outage execution are being formalized in maintenance procedures and outage management procedures, and shared with the nuclear community.



1. Introduction

The Darlington Nuclear Division Station Outage Program was comprised of 7 distinct projects:

- Vacuum Structure (VS) and Containment inspections and maintenance.
- Unit 0 common non-Containment systems maintenance.
- Unit 1 outage.
- Unit 2 outage.
- Unit 3 outage.
- Unit 4 outage.
- Fuel Handling (F/H) systems maintenance.

An overview of this program is shown in Figure 1-1. To facilitate planning, the outage was divided into 5 phases:

- Phase 1: Pre-Requisites.
- Phase 2: Unit Shutdowns.
- Phase 3: VS and Emergency Service Water System (ESWS) outages.
- Phase 4: VS, Containment and Emergency Coolant Injection System (ECIS) Outages
- Phase 5: Unit Startups.

The Station Outage Leadership Team coordinated the program, emphasizing public and employee safety. The team was assisted by the Unit 0 Outage Team (concentrating on VS and Containment specifics) and the Station Outage Integration Team (dealing with integration issues between the projects).

Darlington staff were committed to completing the Station Outage safely, on time and on budget in the face of new challenges:

- A volume of work never undertaken before in an outage at Darlington Nuclear.
- Work never performed before at Darlington.
- The need to integrate all work being performed in the station into a single program.

2. Maintenance Overview

Table 2-1 outlines the major work programs undertaken during the Station Outage.

To support this, maintenance staff were divided into teams, each provided with solid supervision and backfilled with temporary labour whenever necessary. In general, these teams operated on an X-Y schedule (10h shifts - days or evenings, 6 days a week), with overtime making these extended work weeks possible. Normal staff complement was maintained for the duty crews.

Operator support, primarily for work protection, was also provided by similar teams, operating around the clock in Unit 0, and on days (7 days a week) on the reactor units. Hours of work rules were relaxed temporarily to allow for this enhanced coverage.

Major projects were also supported, around the clock if necessary, by dedicated facilitators normally originating from the Technical Section.

This staffing approach is summarized in Figure 2-1.

3. Success Story

Awareness of Nuclear Safety

Nuclear safety was maintained as a fundamental focus throughout the planning and execution stages of the outage. From upper management to the shop floor, expectations were made clear with respect to nuclear safety. Fundamentals were reviewed and pre-job briefings provided immediate reinforcement of nuclear safety issues associated with the conduct of field modifications and maintenance.

The Operations Manager provided "the 10 commandments of the outage", to clarify his expectations of staff. The first commandment was to "Think Safety Culture" - nuclear and employee safety first in every endeavour.

The success of the nuclear safety program during the outage was evident in the performance indicators supporting nuclear safety.

There was one Operating Policy and Principle (OP&P) non-compliance during the outage:

- Addition of unpoisoned D_2O to the Unit 4 moderator system while in a Guaranteed Shutdown State (GSS).

In total, sixteen reportable events occurred during the outage, none of which were due to the unique nature of the outage. The maintenance-activity-related reportable events during the outage were:

- Pinhole leak identified in a valve weld.
- HTS relief valve not properly calibrated.
- Instrument Air system backup air receiver inadequacies.
- Unapproved door seals on steam protected rooms.
- Contaminated material found in scrap metal bin.

Given the volume of work planned and executed, and considering the degree of discovery work in the outage, these results were considered reasonable. There is however, considerable room for improvement in the nuclear safety

aspects of work execution. A true success would be a station outage with no reportable events. Work is progressing in this area as part of the station's maintenance improvement programs.

Awareness of Employee Safety

Briefing of employees by the first line supervisor was the single most effective means of increasing awareness of radiation and conventional safety.

Consistency was achieved through the use of Task Safety Analysis (TSA), prepared during the planning phase of each job to detail all safety concerns and precautions associated with that job.

Operating Experience (OPEX) was communicated to all staff through the 'Safety Pause', a weekly briefing session where recent events were reviewed and a consistent message was communicated station-wide.

Surveillance in the field was performed independently by:

- The Safety Team, consisting of Joint Health and Safety Committee members supervised by Station Outage Management.
- The Conventional Safety Section
- The Radiation Protection and Health Physics Sections.

Findings were compared daily and resources were combined as necessary to resolve issues quickly.

Considering the volume, novelty and complexity of the work being performed, there is a clear indication of improved performance at Darlington:

- 1 Lost-Time Accident attributable to the Station Outage (a back injury in the pre-outage phase)
- 0 High-MRPH (Maximum Reasonable Potential for Harm) accidents.

Nevertheless, there were many near-misses, particularly related to body mechanics, and four license non-compliances, all associated with radiation protection:

- Incorrect classification of a radioactive shipment.
- Contaminated material found in a scrap metal bin.
- Evidence of beverage consumption in radiological zone 2.
- Evidence of food/beverage consumption in a non-zoned area of the operating island.

Awareness of Plan

The Operations Manager's second commandment was "Plan the Work and Work the Plan". This concept, along with "Think Safety Culture", was paramount to the successful planning and execution of the outage.

The challenge of integrating all projects into a single plan and to have it used effectively in the field, was met through the cooperation of all groups.

At the individual project level, as few changes as possible were made to the outage planning approach used in previous single-unit outages. Individual project schedules were issued on a daily basis, within the framework of a key plan, produced by the Unit 0 Planning Section. This key plan contained all the necessary integration information needed to synchronize all projects:

- Outage Organization and Phone Numbers
- Station Outage Overview
- Inter-Unit Coordination Diagram
- Individual Project Overviews
- D2O Inventory Management
- Nuclear Safety Overview
- Shared Resources (eg, MOVATS, Scaffolds)

Figure 3-1 depicts this daily plan structure, while Figure 3-2 outlines the daily planning and integrating routine put in place to arrive at a quality product.

With the outage complexity requiring the introduction of five separate "phases", each with its own set of restrictions and rules, it was necessary to ensure that work was planned and executed in the correct order within the correct outage phase. Outage phasing was characterized on all outage planning logic, daily outage plans, etc, with STOP signs to delineate a Change of Phase. A Change of Phase Meeting was held in advance of each change of phase to provide assurance to the Operations Manager that work required for completion in one phase was performed successfully, that prerequisite unit/system alignment for the next phase was complete, and that Work Plans, operating instructions and material requirements for the subsequent phase were in readiness for the transition.

4. Factors Contributing to Success

Strong Nuclear Safety Support

Nuclear Safety considerations drove the outage from early planning, through execution, and post-outage reviews. Nuclear oversight aspects of the outage are summarized in Table 4-1.

From the initial planning stages, operating experiences from earlier outages at Darlington and other station outages at Ontario Hydro sites were reviewed and lessons learned were built into the planning program. Involvement of staff at all levels was solicited. The Station Outage Leadership team also drew on this wide experience base for nuclear safety planning. A series of Nuclear Safety review meetings were held in advance of the outage to provide assurance that nuclear safety issues were adequately addressed (Figure 4-1). This included a Station Outage Internal/External Review Meeting where staff from all other Ontario Hydro sites, other Canadian nuclear sites, the CANDU Owners Group, WANO representatives, and various support companies/organizations were invited to participate.

Planning for the outage was built upon a fundamental expectation of compliance with OP&Ps and procedural adherence. Reviews of operating instructions and workplans by the executing organizations, by line management, and by Nuclear Safety staff ensured that these expectations could be met.

The division of the outage into its 5 phases further contributed to its success. A Nuclear Safety Planning Restrictions and Prerequisites chart was prepared to succinctly communicate the particular requirements of a particular outage phase. Figure 4-2 is an extraction from the Nuclear Safety Planning Restrictions and Prerequisites chart for illustrative purposes. Again, the STOP signs are utilized to ensure that work does not progress from one phase to the next without adequate reviews and approvals. These prerequisites and restrictions were translated to formal outage plans, operating instructions, and workplans for field execution.

During the outage, nuclear safety and work progress were reviewed daily, at unit-specific planning meetings, the Station Management Team meeting, the Nuclear Safety Oversight meeting and the Station Outage Integration Meeting (Figure 3-2). The latter was the final vehicle for communicating nuclear safety issues to the maintenance coordinators, who in turn would brief their staff.

Operational Decision Review Panel (ODRP) meetings were developed during the outage to aid in the resolution of Nuclear Safety issues and provided a structured forum for presentation and review of solutions to significant problems/issues and for station upper management decision making.

Throughout the outage, field staff were encouraged to maintain a questioning attitude. Instances where this questioning attitude was able to identify and correct a potential event with negative consequences were celebrated in the daily/weekly outage news updates.

Staff reviews of the outage after its completion have been conducted with operating experience being built into station outage planning procedures and shared externally through formal OPEX programs.

Employee Safety Buy-In By All

Employee safety was at the forefront of all discussions from the very start, with representatives from Maintenance, Operations, Conventional Safety, Radiation Protection, Health Physics and Joint Health & Safety on the Station Outage Leadership Team. Emergency Response also played an important role.

During the pre-outage phase, these people were constantly on the lookout for knowledge and experiences from other locations within and outside Ontario Hydro. They were instrumental in the development of access strategies and associated rescue plans for the Vacuum Structure and other locations. They also ensured that the correct procedures, tools and human resources were in place to ensure success.

Many employees were briefed by their peers in special safety meetings dealing specifically with outage issues.

During the outage, the thrust was on self-checking, attention to detail and procedural adherence in all work undertaken.

Extraordinary Effort By All

A limit was placed on hiring of temporary staff to ensure that they were adequately supervised in the field. This forced permanent staff into working longer hours. This situation was maintained throughout the outage without any detrimental effect on safety and performance, to the credit of all staff.

Noteworthy contributions were also made by:

- Technical support staff, including the coordination of major projects by the facilitators.
- Clerical support, including documentation updates at phase changes and duplicating of daily plans.
- Shift Supervisors

- The Safety Team.
- The Management Team.

Excellent Participation of Employee Reps

Employee representatives made important contributions in all aspects of the outage:

- Member of the Station Outage Leadership Team.
- Resourcing.
- Jurisdictional decisions.
- The Safety Team.
- Roll-out of information to staff.

Again, an open, positive relationship between management and the unions proved to be an important contributing factor to the success of the Station Outage.

Other Factors

Other factors worth noting include:

- Good planning on the units, with improved control over emergent work.
- Good integration of the projects into a single program, with personnel at all levels well focused.
- Excellent supervision of the trades in the field.
- Defense in depth in all areas, be it technical support, nuclear safety, employee safety.
- Excellent operator support, when taking into consideration the shortage of Operator staff at Darlington.
- State-of-the-art communication systems in the Vacuum Structure, involving the use of companion telephones.

5. Conclusion

The outage performance in relation to the measures, indicates that the 1997 Station Outage at Darlington was successful. The only indicators to be challenged, were the duration and cost of the outage, mostly due to the Shutdown System Trip Window issue, which evolved during the outage.

However, there is room for improvement in all areas, and some key recommendations are given below.

Higher Priority Sooner

Good preparation is essential to an outage program of this complexity. At Darlington, work began on a small scale some 16 months prior to the outage. Due to the heavy outage load in 1996, and to other station priorities, very little attention was paid to the pre-outage phase until January 1997, when the outage was only 4 months away.

For a subsequent station outage, it is recommended that a full 18 months of preparations be considered, along with sufficient priority to mobilize staff to focus on the project.

Work Plans Sooner

Work Plans are the basis for good job assessment. This ensures that the right material is ordered, the necessary resources are secured and that the supporting documentation is ready (eg, TSAs).

It is clear that in future outages, Work Plans must be issued to the field much sooner. This can be achieved through sound outage management, where clear milestones are defined, that people are held accountable to meet.

Also, the Work Plan as it stands at Darlington, is too inflexible, and for that reason, is likely to change dramatically as new outage management techniques are implemented.

More Resources

Resources were limited for this outage at Darlington, for a number of reasons:

- Operators were short in numbers and qualified assistance was not available from other stations.
- Jurisdictional decisions restricted the use Building Trades Union (BTU) staff.
- A number of large jobs (eg, turbine outage), traditionally performed by contractors, were taken over by Darlington staff.
- Temporary staffing was limited to 100 people to ensure adequate supervision.

Thus, staff worked extensive overtime, at a significant cost, and with the increased risk of errors due to fatigue.

Future resourcing considerations should include bolstering our Operator numbers (already under way with Nuclear Recovery), and reviewing Darlington's position with respect to Union jurisdictions and the use of contractors for specialized work.

Figure 1-1
Station Outage Overview

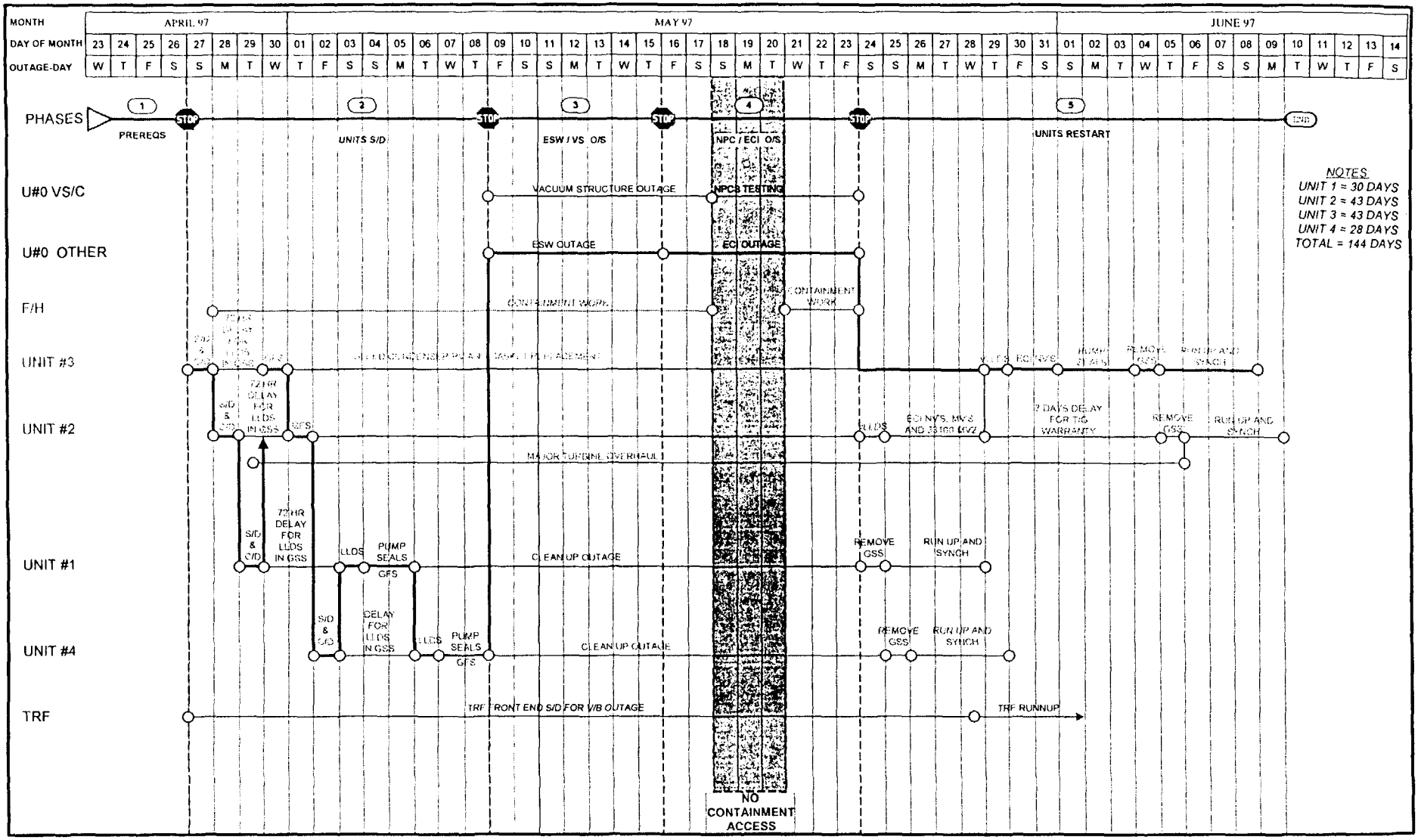


Table 2-1
Outage Work Program

Project	*Scope*	*Expended Person-hours*
VS/Containment	• Vacuum Structure(VS) & Containment inspection, repairs & testing. • Vacuum, Dousing Water & Emergency Filtered Air Discharge. System (EFADS) valve repairs.	15, 300
Common Systems	• Emergency Service Water System (ESWS) valve repairs • ESWS pump well inspections and cleaning. • Emergency Coolant Injection (ECIS) valve repairs.	10,800
All Reactor Units	• Mandatory callups and repairs. • Shutdown Cooling System (SDCS) motorized valve MOVATS • Low Pressure Service Water (LPSW) pump well inspections, repairs and cleaning. • Electrical Class III Transfer Scheme tests.	
Unit 1	• Heat Transport (HT) pump seal replacement. • Generator slip ring grinding.	25,100
Unit 2	• Major turbine overhaul • Reactor Inlet Header (RIH) ECIS non-return valve inspections	50,200
Unit 3	• Digital Control Computer (DCC) software shipment XY18 installation. • Adjuster rod re-configuration. • Bleed condenser relief valve replacement. • HT pump seal replacement. • Reactor Outlet Header (ROH) ECIS non-return valve inspections	29,400
Unit 4	• HT pump seal replacement. • Bleed condenser top cover modifications and gasket replacement.	17,200
Fuel Handling	• Mandatory callups and repairs. • Computer system upgrades. • Power track inspections.	5,000
TOTAL		**153,000**

Figure 2-1
Maintenance Organization

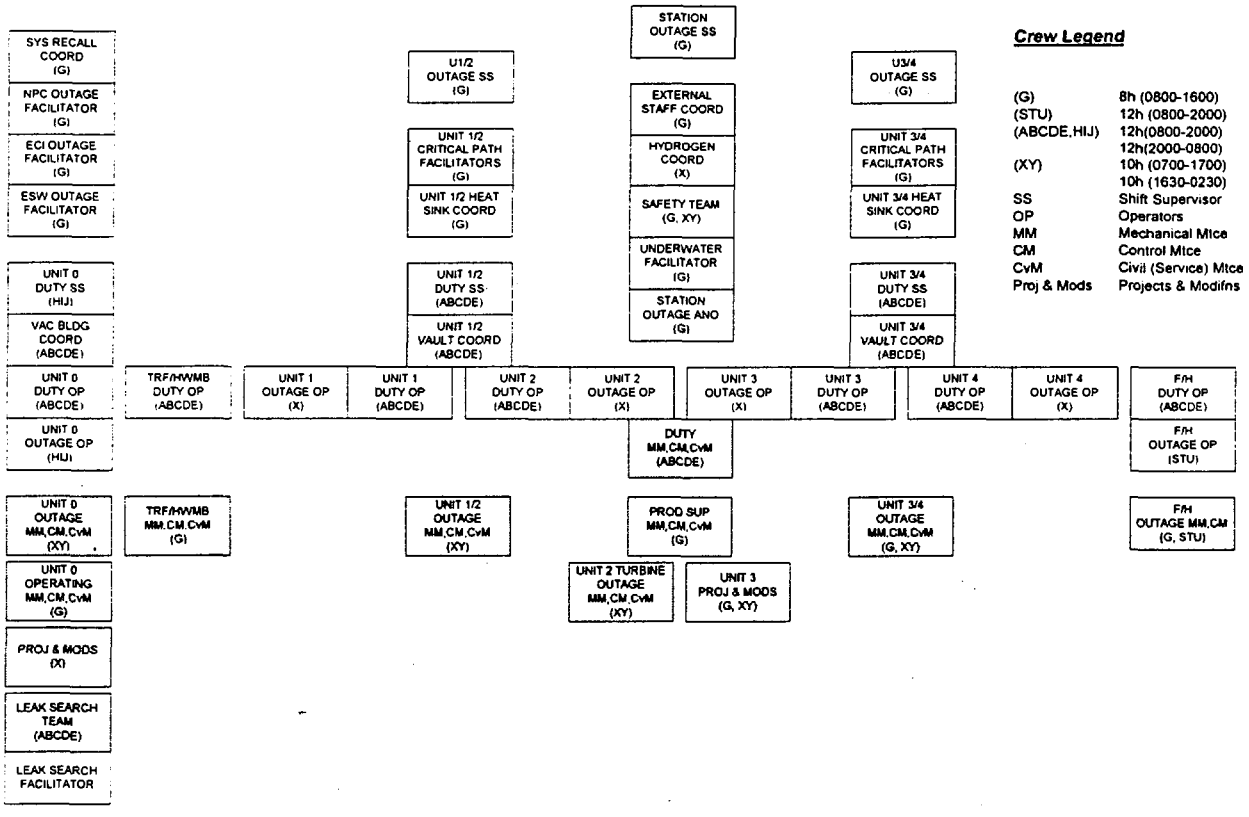


Figure 3-1
Daily Plan Structure

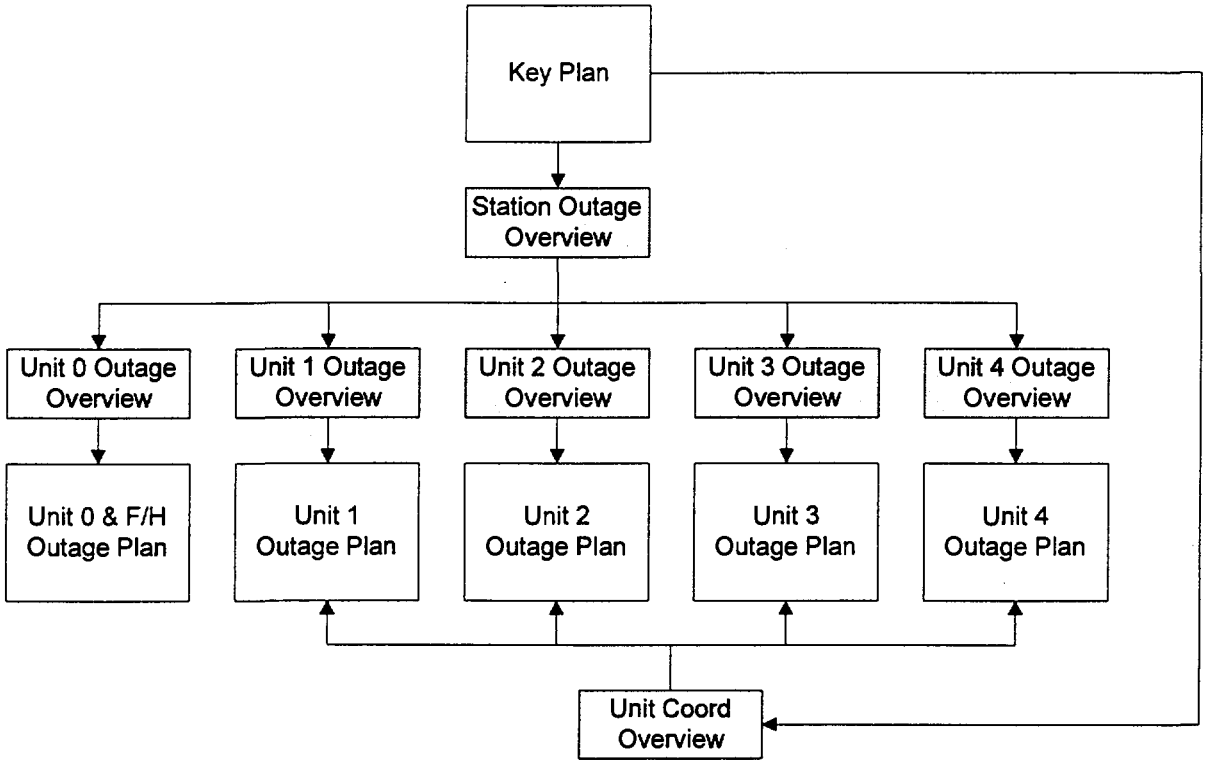


Figure 3-2
Daily Planning Routine

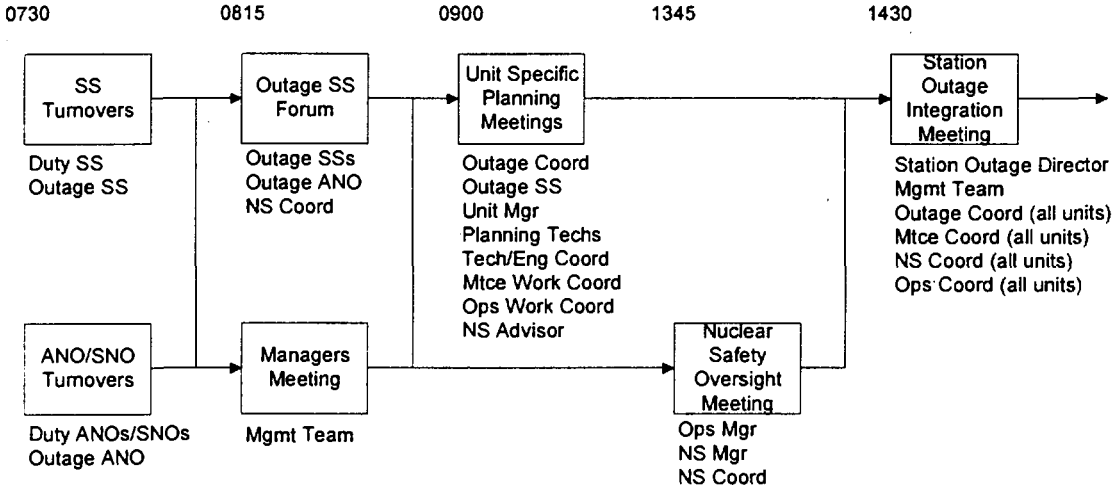


Table 4-1 DNGD 1997 Station Outage
Nuclear Safety Oversight

Program	Particulars	
Governing Documents	• OP&Ps / License • Outage Policy • Outage Procedure	• OHN Nuclear Safety Policy • OHN Risk Mgmt Policy (Draft) • Performance Objective and Criteria (PO&Cs)
Planning	• Scope Meetings • Planning Meetings • Overview for Station • Overview for Units	• Detailed Outage Plans • Darlington Outage Management System • Work Management System
Reviews	• Reactor Safety Review Mtgs • Internal/External Review Mtg • Workplan Reviews by: Supv, NSO, Outage SS, Mgr • Outage Leadership Team • Planning Integration Team	• Manager Forums • Nuclear Safety Working Party • Outage SS / Outage ANOs • Nuclear Safety Coordinator • Accident Assessment • Safety Analysis (SOE)
Change Control	• Permanent Change Process • Temporary Change Notice	• Jumpers • Workplan Reviews
Heat Sink Management	• Heat Sink Strategy Document • Maximize availability of SDC • Heat Sink Coordinators (U1/2, U3/4)	• Heat Sink Operating Memo • IBIF availability as interim HS
Operating Documentation	• Operating Memos for major systems • Operating Memos for OP&Ps • Operating Memos for AIMs • Operating Memos for Startup/Shutdown	• Heat Sink Operating Memo • Operating Manual revision for some systems • Rundown Logic • Startup Logic
Training	• Training Working Party • Authorized Staff Training	• Other Operator Training
Outage Execution	• Daily Plan • Daily Planning Meetings • Reactor Safety Board • Heat Sink Strategy Board • Change of State Meetings • GSS Removal Meetings • Commitments tracking	• Outage Director / Mgr reviews • Outage SS/ANO reviews • Duty SS/ANO reviews • Nuclear Safety (NS) reviews • Vault Coordinator reviews • NS Coordinator Mgmt updates • Event Reporting Process
Post Outage	• Post - Outage Review Mtg • Post - Outage Reports	• OPEX - Build into procedures

Figure 4-1 DNGD 1997 Station Outage
Reactor Safety Review Meeting Process

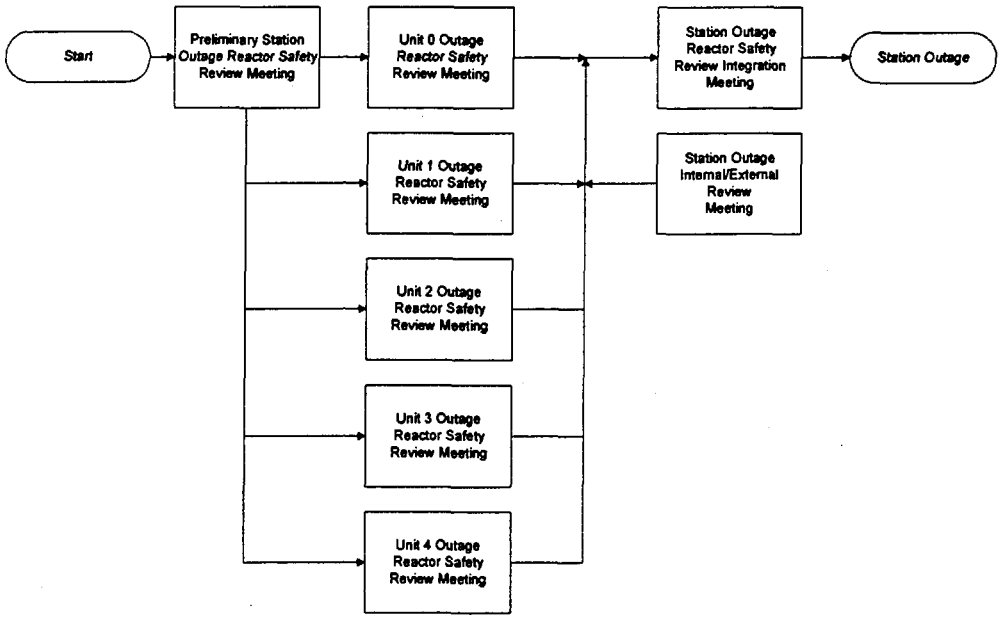


Figure 4-2

Ontario Hydro
Darlington Nuclear Generating Division
1997 STATION OUTAGE

NUCLEAR SAFETY PLANNING RESTRICTIONS & PRE-REQUISITES

(abbreviated sample for illustration)