International Atomic Energy Agency Specialist Meeting on 'Experience and Improvements in Advanced Alarm Annunciation Systems in Nuclear Power Plants', Chalk River, Canada: 1996 September 17-19.

DARLINGTON ANNUNCIATION: USER INFORMATION NEEDS, CURRENT EXPERIENCE AND IMPROVEMENT PRIORITIES

T. LONG
Operations Group,
Darlington Nuclear Generating Division,
Ontario Hydro,
Bowmanville, Ontario, Canada, L1C 3W2

E.C. DAVEY
Control Centre Technology Branch
AECL, Chalk River Laboratories
Chalk River, Ontario, Canada, K0J 1J0

ABSTRACT

The Darlington Nuclear Generating Station (DNGS) is located approximately 40 kilometers east of Toronto, Ontario on the coast of Lake Ontario. The station consists of four 935 MW(e) pressurized heavy water CANDU type units with a nominal power output of 850 MW(e) per unit. The station was designed and is operated by Ontario Hydro and provides electricity to meet the commercial, industrial and residential needs for 3 million people. Units 1 and 2 began commercial operation in 1990, followed by Unit 3 in 1991 and Unit 4 in 1992. Since commissioning in 1991, the station has continually achieved annual production of greater than 80% of capacity.

At Darlington, as in most other industrial enterprises, the plant annunciation systems play a key role in supporting operations staff in supervising and controlling plant operations to achieve both safety and production objectives. This paper will summarize the information needs of operations staff for annunciation of changing plant conditions, describe the operational experience with current plant annunciation systems, discuss areas for annunciation improvement, and outline some of the initiatives being taken to improve plant annunciation in the future.

1. INTRODUCTION

Operations staff at the Darlington nuclear power plant must assimilate and understand information from many sources to effectively manage plant operations. Over the life of the station, there has been an on-going evolution of operational practice and use of plant information systems to better support operational objectives. This evolution has been driven by:

- improvements to the understanding of the information needs of operations staff in support of basic plant operation,
- the creation of new information needs in response to new production and/or safety compliance needs,
- refinement of the information processing and display capabilities of existing control room information systems, and
- the introduction of new information system capabilities through retrofit systems.

The use and refinement of the control room annunciation systems has been part of this evolution.

The following sections will summarize the information needs of operations staff for annunciation of changing plant conditions, describe the Darlington operational experience with current plant annunciation systems, discuss areas for annunciation improvement, and outline some of the initiatives being taken to improve plant annunciation in the future.

2. INFORMATION NEEDS OF OPERATORS FOR ANNUNCIATION

2.1 Plant Supervisory Control

Within Ontario Hydro, the authorized nuclear operator (ANO) is assigned full responsibility and authority to control all aspects of unit operation within administrative limits. The ANO is assisted in this role by other members of the shift team, maintenance and engineering staff, and station management.

To achieve specific safety and production objectives, most middle and lower level plant functions have been highly automated. Even so, functions are rarely allocated exclusively to automation exclusively. In most cases, the performance of every function is shared between automation and humans on some basis (e.g., Operators establish setpoints for processes and perform general process surveillance on a periodic basis. Automation provides continuous control of process values to setpoint and immediately alerts operations staff to discrepancies in operation).

To carry out their responsibility, meet production and safety goals, and work effectively with automated systems; operators must be supported by information and control systems that allow them to actively supervise a highly automated process system, be responsively informed of off-normal conditions, and have the capability to intervene and substitute compensatory functions if automated functions should fail. Thus, successful supervisory control requires the co-operative control and monitoring of plant functions by both operators and automation [1].

In addition to direct supervision of unit operation, operators are expected to perform additional duties in support of station operation. The overall responsibilities of a control room operator can be classified into seven broad task areas:

- establishing and effecting operational objectives, both safety and production, for the shift (planning),
- developing and maintaining plant awareness (monitoring),
- handling plant disturbances and transients,
- controlling the plant state,
- supervising work protection and work control,
- maintaining plant availability (directing maintenance), and
- supporting administrative activities.

Current operational experience and former studies [2,3] indicate that more than 80% of the operator's time on shift is occupied by tasks other than those involved with direct process supervision and control of the unit. Even during instances when the unit is directly monitored, it is only practical for operators to maintain an awareness of a very small subset of the available plant parameters. Consequently, operators depend on the plant annunciation systems to alert them to plant changes requiring intervention and to assist them in maintaining an up-to-date awareness of all important changes in plant conditions.

2.2 The Role of Annunciation

The role of annunciation is to ensure that control room staff are promptly alerted to and supported in their response to important changes in device, equipment, system or plant conditions that may impact on operational goals. In fulfilling this role, annunciation must perform three functions:

- detect and may predict the occurrence of plant changes,
- alert users to plant changes important for the current operating situation such that:
  - only operationally relevant plant changes are annunciated
  - the demands imposed on user's attention to recognize the plant changes fits with the demands of other concurrent control room tasks, and
- points users to additional plant information to understand and respond to the changes [4,5].

There are two kinds of changes in plant conditions that the annunciation should alert operators to:

- *Fault alarms* - challenges to current operational goals that represent potential or current problems in the plant (e.g., process disturbances or equipment faults), and

- *Status alarms* - changes in equipment, system or plant conditions that do not represent a challenge to current operational goals (e.g., confirmation of the completion of an automatic action).

Operators require timely information on both types of plant changes. Information on impending and current problems is required so operators can interpret what operational goals are challenged, and plan and prioritize compensatory actions. Information on other changes in plant conditions (i.e., not problems) is required to maintain an up-to-date awareness of the plant configuration. Such an understanding is essential for planning and prioritizing the response to impending or current problems (i.e. faults).

2.3 Situations To Be Supported

The annunciation system must support operators during all phases of plant operations. As a result, the annunciation system must successfully perform its functions across a wide variations in the rate of alarm generation/clearing and number of alarms active and across a wide variation in plant modes. A summary of the alarm state characteristics representative of different operating conditions and operational emphasis at the Darlington plant is provided in Table I [6]. Both typical and extreme values are shown to indicate the range of alarm state characteristics that must be accommodated.

TABLE I. ALARM STATE CHARACTERISTICS BY OPERATING PHASE

Operating Condition	**Rate of Alarm State Changes**		**Number of Alarms Active**	
	Typical	Extreme	Typical	Extreme
Stationary Conditions				
Full power operation	< 3/min	> 20/min	< 10	> 50
Shutdown	< 5/min	> 20/min	> 40	> 150
Changing Conditions				
Startup	> 5/min	> 50/min	< 40	> 150
Shutting Down	> 5/min	> 50/min	<50	> 300
Outages	< 5/min	> 20/min	> 150	> 250
Upsets (0-3 min)	> 50/min	>200/min	> 200	> 1000
Upsets (>3 min)	> 25/min	>100/min	> 150	> 800

2.4 Users to be Supported

In all operating phases, the ANO is the primary user of the annunciation system. Under normal operating conditions, the ANO is assisted by one additional person (a Supervised Control Panel Operator or SCPO) who is trained in monitoring the unit and

alarm interpretation but is not permitted to undertake control actions. The SCPO may independently use information from the annunciation system as part of his/her normal duties associated with work control, system surveillance and system testing.

During plant upset conditions, additional staff join the unit crew to respond to the upset. Two ANOs from adjacent units, if available, join with the unit ANO and assist with stabilizing the unit under the unit ANOs direction. In addition the Shift Supervisor joins the response team to oversee response activities and provide an independent assessment of plant overall safety state. All of these individuals rely on information from the annunciation system to support their response activities.

2.5 Annunciation Information Needs

Information provided by the annunciation system should be designed to support operators in their tasks with respect to achieving operational safety and production goals. These tasks include maintaining plant awareness, interpreting alarms, diagnosing problems, and planning, prioritizing and effecting a response to problems; as well as for normal control activities. The following characteristics represent desirable properties of annunciated information:

Detection

- Detect all changes important to the achievement and preservation of plant operational goals

- Time-stamp all changes whether relevant or irrelevant to support both control room diagnosis and later off-line analysis.

- Distinguish between alarm conditions that represent true plant changes and those that represent instrumentation failures.

Relevance Determination

- Base the determination of the operational relevance of plant changes on:

    - the physical state of the plant, systems and equipment, and

    - the transient state of the plant, systems and equipment (e.g., do not annunciate changes that are expected to occur briefly during a transient unless they are still present when they would be expected to have returned to normal).

Alerting

- Annunciate all plant changes relevant to the achievement of plant operational goals for the current operating situation:

    - DO NOT annunciate any plant changes that are irrelevant (i.e., those that are either expected or unimportant) to the achievement of plant operational goals for the current operating situation, and

    - Make information on all plant changes, including detected irrelevant changes, accessible on demand.

- Match the demands for operator interaction with the annunciation system with the demands of other tasks in the control room.

- Annunciate relevant plant changes with both discrete and easily identifiable "audible" and "visual" presentation components.

- Annunciate as "Expected but not occurred" fault alarms, those plant changes expected to occur during a particular event or transient or after a particular operation (e.g. a reactor trip) that do not actually occur.

Display

- Display plant changes in a manner consistent with human perceptual and cognitive capabilities to effectively use the information while simultaneously attending to other tasks.

- Display plant changes (e.g., fault alarms) in a manner such that their priority with respect to the operational goals for current equipment, system and plant state is obvious to the operator (i.e. present plant changes consistent with the plant situational context).

- Organize the presentation of plant changes consistent with the way operators use the information (e.g., separate fault from status alarms to simplify plant fault state determination, organize fault alarms by priority consistent with way operators order their response to problems and organize status alarms in a chronological time sequence to give the operators a picture of the evolution of the change in equipment, system and plant state).

- Display plant changes such that any new alarms, any return to normal alarms, any unacknowledged alarms and any acknowledged alarms are easily visually discriminable.

- To improve display efficiency, dynamically replace multiple individual alarms representing the same alarm condition in different information channels with a single higherevel message that conveys all of the pertinent information that would have been obtained from each of the individual component alarms (i.e., alarm coalescing).

- Continuously display the current number of relevant and irrelevant fault alarms to assist operations staff in maintaining overall plant state awareness.

- Continuously display the current “plant mode” on all annunciation CRT screens to assist operations staff in maintaining overall plant state awareness.

- Provide at the operator's desk direct access from primary alarm displays to supporting information on each alarm (e.g., instrument source, conditioning factors, alarm response procedures). All of this should also be easily accessible for the annunciator window tiles.

- Provide operator customizable views of both the current and past alarm state of the plant to support alarm interpretation, upset diagnosis and display support for specific control room tasks (e.g., the ability to look in history for a particular alarm or group of alarms and their chronological evolution and the ability to look at all current alarms; whether relevant or irrelevant in various configurations of a current alarm summary).

- The physical configuration of the annunciation CRT display hardware should support BOTH the manner in which the ANO operates normally (alone) and the way the ANOs operate as a team during a transient.

Control

- Provide at the operator’s desk console, a simple means to alter alarm setpoints and/or alarm jumper status; using proper station change control procedures.

Consistency

- There must be clear, understandable, defendable, documented, consistent methodologies (with rationale) for each of the following:

    - CRT and Window annunciator tile message texts,
    - Use of colour (for CRT annunciation and Window annunciator tiles),
    - Use and selection of alarms requiring Window annunciator tiles,
    - Abbreviations and acronyms, and

- Hysteresis and deadband determination.

- The separate annunciation systems that are used for shutdown system one and shutdown system two should operate consistent with normal annunciation system (i.e. should reflect all of the listed features and requirements from Section 2.5 “Annunciation Information Needs”).

While not an operational information need, there is a clear requirement to have an effective and responsive means for effecting changes to annunciation systems so that the systems can be kept up to date with station operational needs. Factors that initiate the need for annunciation system changes include changes in production goals, regulatory requirements, technology or operating experience. The following characteristics represent desirable properties to support change:

- Provide effective information management tools to allow annunciation system software and hardware upgrades and changes to be made easily in a cost efficient manner; and consistent with station change control procedures. The kinds of changes to be accommodated include:

  - new alarm creation and alarm deletion,

  - changes to alarm text or logic,

  - changes in plant mode specification (e.g., determining parameters),

  - changes in relevance determining factors, and

  - changes in priority determining factors.

3. DARLINGTON ANNUNCIATION EXPERIENCE

3.1 Facilities and Functions

The Darlington control room contains separate control areas for each of the four reactor generating units, common services (e.g., electrical supplies), and on-power fuel handling systems. This has resulted in a division of alarm management responsibilities and the need for co-ordination of alarm management activities between staff supervising different control areas. The remainder of this paper will focus on alarm management associated with the operation of each reactor generating unit.

The control area for a Darlington generating unit includes both panel and console displays and controls (see Figure 1). The panels are organized on a system-basis and each panel contains annunciation indicators at the top and conventional indicators (e.g., edge

meters, status lamps), computer displays, and equipment controls (e.g., handswitches and analog controllers) throughout the balance of the panel area. The operator desk console area provides four computer-based displays to support integrated supervision and control of the unit. Operators use the computer displays as their primary source of information during supervision of stable plant operation and execution of startup, shutdown and power-change maneuvers [7].

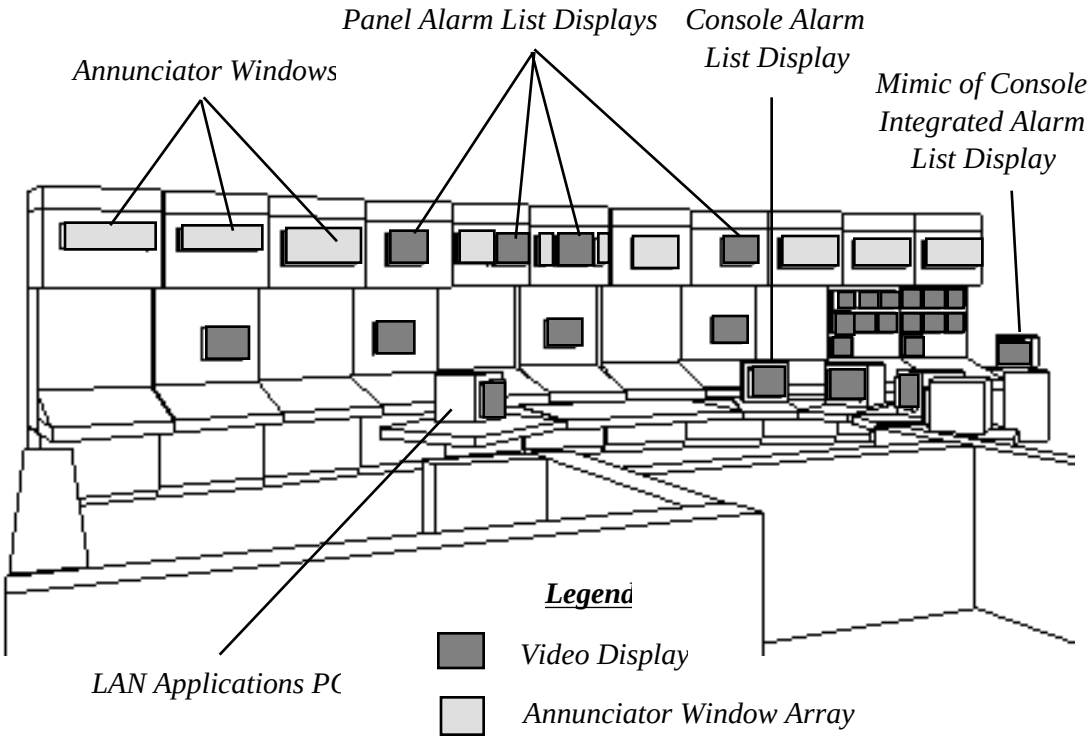

FIGURE 1: Darlington Generating Unit Control Area

There are two sources of annunciated information within each unit:

- computer-generated alarms displayed within panel and console displays, and
- alarms displayed on annunciator tiles at the top of each panel.

The computer-generated alarm displays enable changes in the status of more than 8000 analog, contact inputs and calculated variables to be individually annunciated. Four panel displays each provide a chronological listing of alarms associated with specific plant functions, one for each of:

- heat transport, emergency coolant injection and shutdown systems,
- reactor and moderator systems,

- electrical systems, and
- feedwater, turbine and common processes systems.

Each display has a presentation capacity of about 20 messages each. If more annunciation messages are available for display at one time, the most recent messages overwrite the oldest ones, irrespective of priority or relevance.

At the console, operators can display an integrated chronological listing of the most recent alarms from all 4 panel annunciation CRTs, or view alarm histories or current alarm summaries in various configurations. Printed alarm logs are also available.

The computer-generated alarm displays were intended as the primary annunciation support for normal use. The annunciator tiles were intended as a backup system to provide more limited safety related annunciation support on the unavailability of the computer-based annunciation.

3.2 Operational Experience

Overall the computer-based annunciation system supports operations staff well in understanding the alarm state of the unit during conditions when only a few alarms are present (e.g., normal stable operation and controlled power maneuvers).

Additional support for operators in linking individual annunciation messages with support material, such as alarm response procedures, is still desirable even during normal operations. Currently the Darlington computer-displayed annunciation messages contain no basic identifying code as to the operating manual where alarm detail information can be found (see Figure 2). This presents an additional mental burden on operators and can lead to operational inefficiencies associated with access and search for the appropriate reference material.

During conditions when many alarms are active and/or the alarm generation rate is high, the computer-based annunciation displays are less useful, for example:

- irrelevant alarms routinely overwrite displayed operationally relevant alarms as result of minimal relevance conditioning.

- the chronological listing of alarms shows only the most recent alarms rather than the most important to the operating situation, and

- the indicated and fixed priority of alarms based on the full power operating state may not be appropriate for the various other non-full power operating situations.

X PHT D20 RECOVERY 3382-P1 HS OFF NORMAL
X HT PUMP 1 TRIPPED
X STEPBACK HT PUMPS TRIPPED
Y ION CHBR CH A LOG PWR RATE IRR
Y MTC HX1 OUTLET TEMP LOW
X BLEED CONDENSER PRESSURE HIGH
X SDS1 MONITOR COMPUTER MESSAGE
X CDSR COOLING SPRAY STRNR DIFF PRESS HI

Figure 2: Example of Darlington Computer-displayed Alarm Messages.

In such circumstances (e.g., upsets and outages), alternative alarm management strategies are employed.

During plant upsets, the panel and console alarm lists can be 'flooded' with alarm messages making the computer alarm displays temporarily unusable. Consequently, the station upset response strategy directs operations staff to use the backup panel annunciators to track changes in the plant safety and production state, until the demands of the transient on the ANO relax such that printed alarm summaries can be taken and carefully reviewed to identify all the relevant alarms to address. In such instances, the ANO must locate the few key relevant alarms buried within the hundreds of relevant and irrelevant alarms listed on the summary printouts. While this approach has proven operationally acceptable, it provides a much more limited indication of the alarm state of the unit and leads to delays between alarm occurrence and operations staff recognition. The annunciator tiles are limited in number (i.e., 100s versus the 1000s of potential plant CRT alarms), and primarily safety-related. Thus, they do not provide as full annunciation support associated with the production side of the plant.

During outages, several hundred or more alarms can be active and most are irrelevant or inappropriately prioritized. Again, operators must take periodic printed alarm summaries to assist in maintaining an awareness of the full alarm state of the plant.

In many operating conditions, a majority of the alarms operators are alerted to are operationally irrelevant. The presence of these alarms provide an unnecessary distraction and can further complicate the task of understanding the true alarm state of the unit. A conditioning capability exists within the computer-based annunciation program but has not been extensively utilized due to the perceived effort required to analyze conditioning relationships.

4. PRIORITY AREAS FOR IMPROVEMENT

The previous discussion has highlighted some of the operating situations and tasks where improved annunciation support would be desirable. Based on operational experience, the following areas represent priority areas for annunciation improvement:

4.1 Access to Reference Information

Simplification of the secondary tasks operators must perform to locate and access alarm reference information could substantially improve alarm response management. Providing direct references to the location of reference information within alarm messages or electronic links between alarms on console displays and the display of reference information are two means of providing improved support for this task.

4.2 Presentation of Unit Alarm State

An improved real-time presentation of the alarm state of the unit is required that better matches the way operators use alarm information is needed. Separating fault and status alarms into separate displays and listing fault alarms by priority is one display organization that has been shown to provide better operator support.

4.3 Suppression of Irrelevant Alarms

In upsets and outages, the majority of the alarms operators are alerted to are operationally irrelevant and complicate the task of understanding the true alarm state of the unit. Recent annunciation development work sponsored by the CANDU Owners Group has demonstrated that substantial operational benefits can be obtained with limited application of alarm conditioning [8].

4.4 Dynamic Prioritization

The importance for most alarms is a function of the plant operating state. Thus the indication of an alarm's priority should change as the plant operating conditions change. Such a dynamic prioritization approach would better assist operations staff in determining the most important problems to deal with across all operating conditions.

4.5 Operator Selectable Alarm State Views

To support the use of alarm information in specific tasks, operators and other staff should have the capability to customize the organization of console alarm displays using either current or historical alarm data. Such custom views can simplify user alarm search, identification tasks and troubleshooting occurrences or transients.

4.6 A Consistent Annunciation Strategy in all Alarm Generating Systems

Operators rely on information from several alarm generating systems in managing unit operations and there is no consistency in annunciation strategy and alarm presentation conventions from system to system. This provides an additional burden for operating staff when simultaneously interpreting information from multiple alarm generating systems. A consistent annunciation strategy and conventions should be established and worked towards as systems are routinely upgraded. (This is especially important for the Darlington annunciation systems for Shutdown system one and Shutdown system two).

5. STATION INITIATIVES FOR IMPROVEMENT

There have been several initiatives undertaken throughout the station life to improve the effectiveness of station annunciation. The initiatives discussed in this paper are in addition to the on-going operations and engineering efforts to improve annunciation message texts, response procedures and creation of new alarms to support specific operational needs. Specific initiatives are described below.

5.1 Quality Improvement Program Man-Machine Interface Review

During 1991 a small team of operations and engineering representatives performed a comprehensive review of 'problems' associated with the control room operator interface. This review organized problems with reference to specific operator tasks and prioritized recommendations for improvement. Over forty specific improvements to the annunciation systems were identified. The findings and recommendations from this study have been used to guide the development of improvements to the control room interface and annunciation over the past few years. However most of the identified areas for annunciation improvement have not been addressed as of yet.

5.2 Improvements to Historical Alarm Recall and Search

An enhancement to historical alarm recall and search was installed to simplify the operator's task in locating alarm records of interest within alarm logs. The original historical alarm recall and search capability was limited to a sequential paging method that imposed high interaction demands on users and was tedious to use. The new recall and search capability allows users to locate alarms of interest in a number of useful methods and configurations (e.g. by group or date/time period specification).

5.3 Improvements to Real-Time Annunciation Display

Several display improvements to improve the ability of operators to monitor the alarm state of the unit. A real-time chronological listing of all active alarms was created

for console display to complement the use of the four panel alarm lists. This combined alarm list display substantially helps operators understand the integrated alarm state of the unit.

To improve alarm monitoring during safety system testing, a display that mimics the console chronological listing of all active alarms was added to the right end of the safety system panels. This display allows the alarm state of the unit to be monitored while the operator is performing safety system testing tasks.

5.4 Participation in CANDU Owners Group Annunciation Improvement Program

Darlington has always been a strong supporter of and key contributor to the CANDU Owners Group (COG) annunciation improvement program. When the annunciation concepts being developed began to show operational promise, several in-station demonstrations of the concepts were arranged to solicit comments from a broad mix of station staff. These familiarization demonstrations culminated in a series of demonstrations in 1995 March where a Darlington 'Loss of Class 4 Power' upset was demonstrated to all operations staff over a period of two days.

Based on the in-station support for the concepts demonstrated, a series of 20 simulator exercises was conducted during early 1996 to compare the relative annunciation support provided by the existing annunciation system and new COG annunciation concepts. Ten operations crews participated as subjects in these exercises. The results showed the COG annunciation concepts offer substantial operational benefits over a range of plant operation phases [8].

5.5 Annunciation Retrofit Feasibility Study

During 1995, AECL in conjunction with Darlington staff investigated the technical feasibility and cost/benefit of applying the CANDU Annunciation Message List System (CAMLS) annunciation improvements for retrofit to the Darlington annunciation system. The study had three main tasks:

- To propose a Darlington annunciation retrofit strategy based on CAMLS concepts,
- To specify the hardware and software options for implementation,
- To estimate the costs of implementation and the financial benefits to be realized from the annunciation improvements.

The findings from this study indicated a payback period of 3 years for a proposed retrofit implementation.

5.6 Improvements to Message Components and Formatting

A manual of standard acronyms and abbreviations has been established and applied to all plant alarms to improve alarm message consistency across plant systems. Message formatting was also standardized so that fields within alarm messages align from message to message. The improved alarm messages will be put into operational use later this fall.

5.7 Linking Alarms to the Location of Supporting Reference Information

A “system acronym” has been added to the beginning of each Darlington CRT alarm message indicating the operating manual where reference information (e.g., alarm response procedure) for the alarm is located. This improvement will remove the need for operators to memorize and rapidly recall the operating manual for each alarm. However, operators will still be required to tediously search through the manual to locate the appropriate alarm reference information. The improvement will be put into operational use later this fall.

5.8 Improvements to Shutdown System Annunciation

This project in ongoing and is currently still at the design stage. ANO input is actively being employed for the project.

6. CONCLUSIONS

This paper has outlined how the plant annunciation systems play a key role in supporting operators in supervising and controlling plant operations. While some fundamental needs for annunciated information are being met by the current Darlington annunciation systems, there is still room for much improvement in several key areas. Darlington staff are continuing to evolve the understanding of the need for annunciation and how improvements to the current annunciation systems can be incorporated to better meet safety and production needs. We are confident that, in weighing cost effectiveness, cost consciousness and current initiatives for attaining “Nuclear Excellence in operations", further improvements to Darlington annunciation will be implemented to better support operations staff in their tasks to supervise unit operations.

7. ACKNOWLEDGMENT

Many people have contributed to the understanding of the role of annunciation in supporting Darlington station operations and the initial development and continuous improvement of the station annunciation systems. First, the authors would like to acknowledge the experience and insights shared by colleagues in operations who depend on the station annunciation systems from shift-to-shift. Second, we would like to

acknowledge the contributions of Debbie Scott-Gillard, System Engineer for Annunciation, who has championed several annunciation improvements over the years and who provided helpful comments and suggestions for the preparation of this paper.

REFERENCES

[1] SMITH, J.E., "Modern Control Room Design Experience and Speculation", Proceedings of the 2nd ASME/JSME Nuclear Engineering Conference, San Francisco, California (1993).

[2] WILLIAMS, M.C., "The Role of the Control Room Operator", Proceeding of the Joint Conference on Human Factors in Control Room Design and Operation, Canadian Nuclear Association, Toronto, Ontario (1982).

[3] KORTLANDT, D. and KRAGT, H., "Ergonomics in the Struggle Against 'Alarm Inflation' in Process Control Systems - Many Questions, Few Answers", Eindhoven University of Technology, Department of Industrial Engineering report Journal A, Volume 19, No. 3, Eindhoven, Netherlands (1978).

[4] DAVEY, E.C. and GUO, K.Q., "Towards Defining the Functional Role for 0CANDU Annunciation", Proceedings of the IEEE 5th Conference on Human Factors and Power Plants, Monterrey, California (1992).

[5] DAVEY, E.C., FEHER, M.P. and GUO, K.Q., "An Improved Annunciation Strategy for CANDU Plants", Proceedings of the American Nuclear Society Conference on Computer-based Human Support Systems: Technology, Methods and Future, Philadelphia, Pennsylvania (1995).

[6] Personal experience of the authors and operating colleagues at Darlington NGS.

[7] FENTON, E.F. and DUCKITT, W., "The Darlington Control Room and Operator Interface", Proceedings of the Human Factors Society 35th Annual Meeting, San Francisco, California (1991).

[8] FEHER, M.P., DAVEY, E.C. and LUPTON, L.R., "Validation of the Computerized Annunciation Message List System", Proceedings of the IAEA Specialist Meeting on Experience and Improvements in Advanced Alarm Annunciation Systems in Nuclear Power Plants, Chalk River, Ontario (1996).