DEVELOPMENT OF AN OUTAGE HEAT SINK PROGRAM AT BRUCE NGS "A"

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ABSTRACT

CANDU philosophy has always included maintaining an alternate heat sink for a high power reactor, in case the primary heat transport system became ineffective. The risk of core damage due to loss of heat sink from a low power state was considered to be remote. As international and domestic experience grew, it was recognized that the risk of core damage due to loss of the low power heat sink might be as great as for the high power case. This paper describes the development of a user oriented alternate heat sink manual at Bruce NGS "A" which will minimize risk due to loss of heat sink from the low power state.

1.0 INTRODUCTION

A basic operating philosophy for CANDU stations has always been to maintain a means of transporting heat from the fuel, a means of removing the heat from the heat transport medium to a heat sink, and the maintenance of an alternative method of cooling the core. These principles have been embedded in the Operating Policy and Principles of the stations since the earliest days.

However, the generally held belief was that fuel integrity was threatened only when the reactor was at high power. Bruce NGS "A" was the first CANDU station to have an "Abnormal Incidents" Operating Manual (AIM), and the manual focused on the "big" accidents, such as the loss of heat transport coolant from the high power state, as covered in the early "Safety Report" to the Atomic Energy Control Board. The loss of heat sink from the low power state was considered only in the brief mention that:

"Cooling is required for the fuel at all times. When the reactor is at power, the cooling must be sufficient to remove fission heat and decay heat. When the reactor is shutdown, only the decay heat remains to be removed. Since the generation of decay heat cannot be stopped, continued long term cooling must be maintained."

The low power state was not further discussed in the AIM. A section on "Available Alternate Heat Sinks" did discuss the heat

removal capacity of various options, such as flow paths through the maintenance cooling circuit, driven by the main heat transport feed pumps, the purification circuit, and the emergency coolant injection header, but there were no specific instructions on how to establish this or the other alternate heat sinks. It was believed that because of the low decay powers, adequate time would be available for the operating staff to develop specific valving operations at the time needed.

A Matrix was inserted into the AIM describing the operator actions on "Loss of Heat Sink Accidents", but the matrix only discussed the catastrophic failures of "steam line break", "feedwater line break" and "loss of electrical power".

In general terms, the feeling that the need for an alternate heat sink need not be developed in advance for the low power state was not tested during the early years of operation at Bruce NGS "A", since outages were short, and affected only a single unit at a time. The interaction of an operating unit on the heat sink capability of a shutdown unit was not considered. The only significant addition made to station systems to cope with the alternate heat sink issue was the addition of four diesel driven "Emergency Boiler Cooling" Pumps, located in the power house, to cope with a total loss of station power.

2.0 OPERATING INSTRUCTION DEVELOPMENT

When outages affected the shutdown heat sink, operating instructions were added on a case by case basis, using temporary operating instructions, conveyed using "Operating Memos". In this manner, instructions were transmitted to the operating shift to be able to cope with repair of emergency cooling valves, maintenance cooling valves, and for fuel channel repair work using ice plugs.

For each outage, the practice came to be to issue an "Alternate Heat Sink" Operating Memo, which described the specific known maintenance to be carried out, and to summarize the availability of the alternative heat sinks.
Preparation of these Operating Memos became quite time consuming, in particular as outages became longer and more complex. In some cases, revision of the instructions were required several times during each outage as conditions changed. In particular, to avoid having to rewrite the instructions for each minor change in heat transport system configuration, a matrix describing the potential ways of feeding water to the heat transport was added to the instructions, so that the operating instructions would not have to be rewritten every time the feed path changed. Even still, the thirty or more pages of operating instructions needed to be reissued for each outage.

3.0 DEVELOPING ISSUES

As Bruce NGS "A" matured, outages became more and more complex.

Previously rare issues became common place, such as ice plugs for fuel channel inspection and repairs, outages of the Low Pressure Service Water System (which is required for the ultimate heat sink with many of the heat sinks) and outage work on the feedwater train and the backup feedwater paths.

The Operating Shifts were also becoming more and more concerned about the lack of flexibility in dealing with the outage heat sink concerns, and the suspicion was raised that the Technical Section (who was responsible for providing the Operating Instructions) was not adequately servicing the shift. On occasions, tempers flared as outages became delayed to produce the required documentation.

4.0 SHUTDOWN HEAT SINK REF. MANUAL

For each specific outage case, analysis to confirm the provision of adequate heat sinks for maintenance activities was provided by the Head Office based "Radioactivity Management and Environmental Protection" (RMEP) analysis support group. Gradually, a set of collected letters and individual analyses were available which described a number of situations.

It was mutually agreed between the station and head office staff that it would be advisable to collect all previous analyses for specific heat sink configurations into a single reference manual. It was also recognised that if previous analysis of specific events were expanded for a range of conditions (e.g. decay heat, HT temperature, cooling water flow rate, HT inventory and equipment in service) then appropriate heat sinks and recall times could be determined by station technical staff in a more timely manner. The majority of outage work could be covered by this expanded analysis and reduce the demand on the analyst to new outage configurations.

The Shutdown Heart Sink Operations Reference Manual containing the results of the expanded analyses was prepared. This work was begun by the RMEP and completed by the Nuclear Safety Department (NSD) after the RMEP analysis group was assimilated into NSD. To ensure that the appropriate heat sinks are selected in a consistent manner, the manual contains the definitions and the philosophy that is used for the selection of heat sinks. A graphical format is used for most of the information to ease the selection of specific heat sinks. The formulas from which this information was obtained are stated, along with worked examples to assist the Station Technical Engineer / Officer in the use of the manual.

Primary heat sinks are selected on the basis of the systems capacity to dissipate the decay heat and provide the desired recall times for alternate heat sinks. Alternate heat sinks are selected on the basis of using systems that are independent of those required by the primary heat sink.

When the appropriate heat sinks are selected the information is conveyed to the Production Section staff in the form of an Operating Memo.

5.0 CURRENT SITUATION AT BRUCE NGS "A"

In recent years the length and complexity of outages at Bruce NGS "A" has increased. Many items of equipment are being repair or replaced for the first time. Of particular concern are outages for repair of components which require isolation by means of ice plugs of lines which connect to the bottom of the main reactor headers. These isolations (such as for maintenance on the pressurizer isolating valve) are of particular significance since failure of the ice plug could drain the reactor header, and result in the loss of cooling of the fuel.

These outages require significant co-ordination between the Technical, Planning and Production sections to ensure that the required primary and alternate heat sinks are identified and are available for each phase of the outage and that work protection permitry requirements are satisfied. The sequencing of work during the outage is done to ensure that an adequate recall time is always available for the alternate heat sink to be placed in service.

The recent high number of unplanned outages, because of boiler tube and HT system leaks, has imposed a considerable demand on the resources available to provide the required heat information at short notice.

This is especially true when such unplanned multi - unit outages result simultaneously.

6.0 INCREASING REACTOR SAFETY PROFILE

The profile of monitoring the "Reactor Safety" issues at operating stations was raised initially by the accident at Three Mile Island. Following that event, the Institute of Nuclear Power Operators (INPO) was established in the United States to ensure that operating experience at one plant was quickly and effectively passed from one station to another. CANDU stations became interested associates of INPO.

Then, following the Chernobyl accident, the necessity to carefully control Reactor Safety was heightened even further. In Ontario Hydro, an effectiveness survey of the Production Branch (which was responsible for Nuclear Generation at the time) recommended that each operating station should increase their expertise and resources applied to the Reactor Safety area. Some functions being carried out centrally, were considered to be issues that the stations could deal with locally. The establishment of a station Reactor Safety Unit increased station staff numbers and allowed more focus on the issues of the alternate heat sinks, in the review of outage conditions.

7.0 INCREASING CONCERNS

As more attention was put on the outage heat sink concerns, it was realized that the health of a shutdown unit could be significantly affected by an accident on another at power unit in the powerhouse. (This work was described in the Design and Development reports on the effect of harsh environment). In particular, a failure of a main steam line, or a main feedwater line was seen to have significant effects on all units on the powerhouse, and access to the diesel driven Emergency Boiler Cooling pumps in the powerhouse could not be assured.

Electrical Emergency Boiler Cooling pumps were added, remotely located from the accident location. These pumps were supplied by a "Qualified Power Supply" (QPS) supplied by remote standby generators, to ensure that operation would be possible even following a powerhouse "harsh environment" type of accident.

Further, concerns about the habitability of the power house immediately following a "harsh environment" type of accident led to concerns about the ability of the operating staff to maintain ice plugs for a number of hours after the accident. Since an outage unit might well have its heat transport system opened for maintenance, and have the emergency coolant injection system and normal and backup feedwater systems isolated for work protection of individuals working inside vessels such as the boiler manways or the steam drums, it was clear that the effect of a "harsh environment" type accident might even be greater in the long term on a shutdown unit than on an operating unit. The operating unit could be cooled by means of thermosyphoning, so long as water was delivered to the steam drums by the QPS supplied EBC system, but the shutdown unit integrity after a few hours was questionable.

Bruce NGS "A" has no QPS supplied remotely controlled means of adding water to the heat transport if the ECI system is blocked. Although manual field valving could be done to connect from the EBC system to the heat transport, those actions could only be carried out after power house access was again possible, and that flow path would be unmonitored. Adding water in an unmonitored fashion to the heat transport might even starve the EBC feed needed for the other units.

In addition to the concerns being discovered at Bruce NGS "A", international experience was also indicating that outages might constitute a significant contributor to the overall risk of core damage. NJ Holloway and IK Gibson write in Nuclear Engineering International (January 1992) that "The most interesting finding of (the French) studies was the importance of some of the shutdown states, which had been analyzed in depth in the French PSAs ..." The incident at Vogtle 2 Generating Station, when a total loss of power occurred during an outage, confirmed that the low power case needed to be considered as well as the high power case when considering the need for alternate heat sinks.

8.0 TEAM APPROACH

Given the complexity of recent outages, accidents that affect all units in the station and increased concern for reactor safety during outages, it was recognised that a team approach was essential to achieve safe and successful outages. The foundation is laid during the pre-outage activities, which culminate in the pre-outage task analysis meeting. All members of Technical, Planning and Production involved in the outages attend this meeting which reviews the identified outages activities, the importance of each activity and the sequence of all activities with the associated constraints throughout the outage.

Before and during the outage, heat sinks are reviewed with the control room staff, outage supervisors and planners to ensure that the requirements are met. When unforeseen conditions arise each of these groups contribute to the development of the appropriate heat sink strategy.

Using this team approach, the collection of previously issued Operating Memos and information from the Shutdown Heat Sinks Reference Manual was converted into an Operating Manual which could be more immediately accessible to the operating staff. This would ensure that if a unit was shutdown at any time, the operating staff would immediately have available Operating Instructions covering most of the foreseen outage heat sink cases, and Technical support would only be required for unusual conditions, which normally would not arise for several days into the outage.

9.0 OPERATING MANUAL ISSUANCE

The Bruce NGS "A" Outage Heat Sink Operating Manual (USI 03674) was issued in early 1992. This manual presents material from the previous analyses and Shutdown Heat Sink Reference Manual in a convenient manner, designed for user convenience. Specific addendums for any particular outage will continue to be added by means of an Operating Memo, but the Manual is expected to cover over 80% of the cases to be experienced. This manual will be more convenient to the Operating staff, but will also significantly reduce the load on the Technical Section to produce Operating Memos for each outage.

The Outage Heat Sink Operating Manual includes the following features:

- an index by section
- a list of relevant OP&Ps related to heat sinks
- definitions of terms related to heat sinks, such as
  - recall time
  - primary and back-up heat sinks
  - heat sink independence , and so on
- responsibilities for outage heat sinks of
  - Reactor Safety Section
  - Authorized Nuclear Operators

- Shift Superintendents
- graphs showing back-up heat sink recall time after outage begins
  - with heat transport full, or partly drained
- saturated steam tables (for immediate reference)
- graph of sub-cooling margin
- descriptions of normal outage heat sinks
- description of the effect of steam line breaks on an operating unit on an outage unit heat sinks
- description of analyzed heat sink cases, including:
  - boiler tube leak repair
  - fuel channel work
  - service water outages
  - flow defuelling (and so on)
- description of systems credited for alternate heat sink cases, such as:
  - capability
  - restrictions on use
  - availability verification requirements
- flow charts of operating actions in the event of loss of the outage heat sink to establish a backup
- a copy of the heat sinks check list
- an alphabetic reference index

10.0 HEAT SINK CHECK LIST

It was recognized that for alternate heat sinks to be available within the recall time, it was essential that the reactor unit Authorised Nuclear Operator (ANO) was always aware of the status of the unit heat sinks and actions required to place the alternate heat sink in service. A uniform method of turning this information over from one shift to the next was also required. Field activities are often an essential part of placing an alternate heat sink in service. Equipment and personnel for these activities must be identified and confirmed to be available each shift.

The methods used at other stations were reviewed by control room staff and they decided to use a check list that recorded the status of all systems that were required for the primary and alternate heat sinks. The actions manpower and equipment required to place each system in service is also recorded on the check sheet.

The check sheet is prepared each week on the Friday day shift by the unit ANO. It is also reviewed each shift by the unit ANO and the Shift Supervisor. The sheet is revised when any changes occur to the listed systems during the week. A copy of the check list is included in the Outage Heat Sink Operating Manual for reference.

11.0 DECISION ASSIST PROGRAM

Since the Operating Manual cannot cover all the possible

situations that can occur during a reactor unit outage special cases require the technical section to assess the specific system availability and restrictions. These assessments can become very time consuming, particularly as the availability of individual back up systems can vary on a day to day basis during the outage. In much the same manner as a "living PSA", it is also desirable for the technical and operating staff to be able to predict the effect on the heat sink availability of removing a specific set of equipment in advance, to be able to ensure that an adequate heat sink is maintained.

To be able to carry out these technical assessments in a timely manner, and to eventually give the operating staff a tool to be able to independently assess the adequacy of the outage heat sinks, Bruce NGS "A" is working with Atomic Energy of Canada Limited - Chalk River Nuclear Laboratories to develop a decision assist program for outage heat sinks.

The "engine" of this program will be capable of calculating the capacity of each of the available heat sinks, and to be able to calculate the "recall time" for each situation. In the "planning mode" for system, it will be able to determine in advance the effect of removing a heat sink contributing system from service.

The system "user interface" is designed to be able to operate on a Local Area Network based 386-20 MHz microcomputer, to be accessible by the technical staff, by planning staff, and by operating staff. It is expected that this system will be applicable with relatively little conversion to other CANDU stations.

12.0 CONCLUSIONS

This paper has shown that from fairly basic considerations of outage heat sinks in the early days of operation, due to a recognition of the concern of potential risk during outages, a comprehensive set of operating instructions has been developed for use today, to give the operating staff the tool needed to make decisions on outage heat sinks.

The development of a computer decision assist tool will extend this user oriented approach to permit advanced planning of outage situations and the required heat sinks.

The ultimate goal of the outage heat sink program is to ensure the risk to the public from outages will be maintained in a controlled manner below acceptable levels, while simultaneously making the most effective use of personnel. The outage heat sink program now in place at Bruce NGS "A" has made significant progress towards this goal.

REFERENCES

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3) "Bruce NGS "A" Abnormal Incidents Operating Manual 09034", Revision 30, dated December 1991.

4) "Bruce NGS "A" Shutdown Heat Sinks Reference Manual", prepared by Nuclear Safety Department, Revision 0, dated 1989.

5) "Bruce NGS "A" Outage Heat Sinks Operating Manual 03674", Revision A, dated February 1992.

6) HOLLOWAY, N.J. AND GIBSON, I.K., "PSA: everybody's doing it", Nuclear Engineering International, London, England, January 1992, Page 44.