Fire Hazards Assessment for Pickering Nuclear Generation Station

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ABSTRACT

This paper describes the approach used and the major finding of a recent fire hazards assessment of the Pickering Nuclear Generation Station.

1. BACKGROUND

Pickering is an 8 reactor-unit generating station located in Ontario, Canada. An aerial view of the station is shown in Figure 1. The first four units (called Pickering A Station) has been in service since 1971. They were some of the earliest commercial reactors in Canada. The original fire protection design was done in the 1960's and consisted basically

of the common practice for industrial plants at the time. There was use of redundant systems and components and provision of physical separation of redundant components and control channels, but they were not done to the same degree as later CANDU stations. Over the past years, some fire protection features such as cable fire barriers had been added.

Figure 1
Aerial View of Pickering Generating Station

When the second four units (called Pickering B Station) were built, a safety concept was incorporated to provide two groups of physically separated safety systems in the plant, thus greatly enhancing the plant's capability to cope with common cause events. A fire hazards assessment was done at the end of the design of the Pickering B Station. However, that assessment was largely a review of the fire protection concept based on drawing and design manuals and as such was unable to capture fully the fire hazards in an operating station.

Recently, a re-assessment of the fire

hazards was performed on the entire station with the objective to better define the fire hazards in the station, to identify cost-effective means of improving the existing fire protection, and to provide data for the preparation or pre-fire plants and fire fighting training programs for the on-site and off-site fire brigades.

2. STEPS OF THE ASSESSMENT

The assessment was done in several steps:

→ gathering data relevant to the occurrence, propagation and consequences of fire in

each fire zone in the station,

- postulation of potential fires and the extent of damage,
- evaluation of the adequacy of the existing protection measures, and
- recommendations for improvements in structures, equipment or operating procedures, or for further assessment.

Data on each fire zone is collected on a form as shown in the Appendix. The form is expanded as needed to record data and arguments in the assessment.

3. SCOPE AND METHODS OF THE ASSESSMENT

All buildings in the station site under control of plant operations were assessed. The scope of the assessment included nuclear safety (safety of the public), conventional health and safety of plant occupants and economic loss prevention. Due to such a wide scope, it was decided to do a broad review using expert judgment rather than sophisticated analytical tools. This process would yield the best return for the effort. More detailed assessments of individual areas, particularly those involving a concern for nuclear safety, could be undertaken later, if deemed necessary.

The assessment methodology was deterministic. One or more design basis fires were postulated for each fire zone in the station. These fires were conservatively postulated based on the nature of the combustibles found in plant operating condition. The severity of the postulated fires were determined by hand calculations using established fire protection methods or by comparison to fire incidents on record. The data was thoroughly documented so that more detailed quantification such as calculation of the fire compartment response could be undertaken in the future.

A fire risk assessment using probabilistic methods was not employed for several reasons. First, a full probabilistic risk assessment of the station was not available at the time of the fire assessment. Secondly, it was felt that there would be very large uncertainties in a probabilistic fire assessment of a station with an open layout concept and relying heavily on human intervention of fires.

The major emphasis of the assessment was on providing useful information to improve fire protection. Much less emphasis was put on accurately quantifying the overall risk of fires. With this objective the data gathering had to be fairly complete, even if the evaluation had to be broad as a first pass. The product of the assessment was to be a fire protection data bank for each area of the station. Recommendations had to be constructive and realistic. In this respect, the assessment team had to recognize the strength and limits of the station as is. The station has certain characteristics which influence fire protection. One of these is the open layout concept. The units are interconnected by open spaces and corridors. For example, an open service corridor connects up all eight units and the turbine deck is open across four units. Within each unit, many areas are not enclosed. This layout was originally devised to provide good access for equipment maintenance and removal. From a fire protection point of view, it has pros and cons: on one hand, there are fewer fire resistive barriers to contain fires and smoke; on the other hand, in a large space, heat and smoke dissipate more quickly and access for fire fighting is usually good. Other characteristics of the station include a large number of personnel on site and the close proximity to a public, full-time fire department. Thus fire protection at Pickering employs more frequently the fire influence approach than the fire containment approach.

Compared with some other nuclear

power plants, Pickering has relatively few automatic fire extinguishing systems and a heavier reliance is placed on plant personnel for detection and suppression of fire. The existing in-plant fire brigade consist of volunteers drawn from operation staff. The minimum complement per shift is 5 persons in each 4 units (for a total of 10 in the station). The plant brigade is supported by a full-time public fire department with a station very close to the plant gate. Relying on human intervention carries a large uncertainty. However, such intervention rarely fails totally. In an open, accessible plant area, it would be hard to imagine a severe fire burning for a long time without some effort to extinguish it, or at least, to reduce the damage to exposed structures and equipment. Recognizing the role of operators and fire fighters in the mitigation of fires in the Pickering Station, a significant portion of the assessment was devoted to reviewing the conditions necessary for successful fire mitigation action, such as accessibility and fire area conditions.

Since the fire influence approach is used for most areas of the plant, the assessment had to determine the effectiveness of the fire detection and suppression by automatic and manual means. To facilitate such an assessment, a number of logic diagrams were prepared to assist judgment making. These diagrams show the minimum conditions necessary for the success of each mitigation measure. Evaluation is done by judgment since we have no good numerical models for quantifying operator and fire fighter response to fires. In evaluating the adequacy of the existing fire protection measures, the assessment was not done to show rigid compliance with a set of current regulations or standards. Rather, it involved making expert judgment, case by case, on the station practice to reduce the occurrence or severity of fires, the ability to detect and suppress fires if they occur, and

the consequences if the suppression measures were ineffective.

4. GENERAL FINDINGS

The findings of the assessment are still under review. For nuclear safety concern, in most cases, it was found that the spatial separation between redundant components and cables, together with the fail-safe design of many components or control logic, provided adequate protection against the loss of essential safety functions in the station. However, there were scenarios where the safety consequences depended heavily on early detection and suppression of the postulated fires and improvement to ensure the success of such action were considered necessary. In terms of protecting occupants of the plant from the hazards of fires, with very few exceptions, the ability of occupants to become aware of a fire and to leave the area of fire influence was good. This was partly due to the open concept of the building layout which often prevents rapid buildup of heat and smoke to untenable conditions and at the same time offers many paths for personnel egress. As for economic loss prevention, it was found that some fires of low frequency could cause significant equipment damage and loss of production. Recommendations for improvement have been made for each case involved.

In general most recommendations were for improvements in fire prevention and in the fire detection system. For fire prevention, there is a need to improve the storage of waste oils and to reduce the use of lumber material for temporary structures in the station. For fire detection, additional fire detectors and a few fire alarm control system were recommended. In rooms where early fire detection was considered crucial to successful fire mitigation, existing detector type and position have to be further reviewed.

The assessment team made a conscientious

tious effort in reducing the use of automatic fire suppression systems as protection against fire hazards. This approach was taken in order to reduce the cost impacts and the potential for adverse consequences of operation of fire suppression systems. In all, several small additions of sprinklers systems were recommended to extend the area of protection below the turbine generator and in some transient storage areas.

Retro-fitting massive fire barriers were also avoided but improvements to existing walls and penetration seals were recommended. Some local, light-weight fire barriers were also recommended to provide better separation between redundant components and cable routes. It was felt that detailed quantification of the necessary fire rating of barrier was less important in an existing station since the largest causes of failures of fire barriers were in opened doors, inoperable fire damper mechanisms and violated penetration seals, rather than failures by thermal destruction of the barriers. In a plant with good accessibility and a well-trained fire brigade, it is hard to imagine a serve fire going on for hours without some attempt in suppressing the fire or cooling a fire barrier by fire hose spray. The emphasis recommended for a first round of improvement is to maintain existing barriers. The assessment found that the inspection and testing of certain fire barrier features such as fire dampers and penetration seals were not carried out to the same level as was done to fire extinguishing systems. This was partly due to the lack of specific code requirements. Procedures will be established for periodic inspection and testing of these devices.

5. IMPROVEMENTS IN FIRE FIGHTING FORCES

Since the station has a heavy reliance on manual fire fighting, the preparedness of the in-plant fire brigade and outside fire

department is a key to successful fire mitigation. In the past, fire brigade training was provided largely on generic knowledge of fires and fire fighting skills. The data provided in this assessment will be useful as training material to improve their knowledge of each specific fire zone in the station. A set of pre-fire plants are currently being produced from the data of the assessment. Members of the station fire brigade were asked to participate in the data gathering process of the assessment. Although most of the fire hazard types, participation in the assessment provided them with an opportunity to look at fire hazards in the plant in a more focused manner. It also ensures that their views were reflected in the evaluation process.

A detailed review of the organization, training and equipment provision of the in-plant fire brigade was undertaken in parallel to the fire hazard assessment. This review was carried out by a 20 person team drawn from many areas of operating and fire fighting background. The major areas of improvement recommended were:

- (1) Establish full-time positions to provide for an emergency response coordinator at each shift. This person will deal with day to day needs of the volunteer crews and will assume the role of incident commander.
- (2) Establish a fire and rescue coordinator for the nuclear operations branch to oversee fire and rescue across all nuclear station.
- (3) Develop a standard set of emergency crew equipment. Crews will be provided the best available equipment for personal protections.
- (4) Develop a comprehensive negotiated incentives package to reward volunteers for their contribution.
- (5) Increase the hours of training to the team members and provide more plant specific training. Dedicate 10% of each crew shift time

to training and drills. Establish a second training center closer to Pickering station.

(6) Restructure the emergency response forced in the station by combining the fire fighting crew and the search and rescue crews. Combine the two separate crews for the A and B station. This will result in a larger team available to fight a fire. The minimum complement now consist of one commander, one field captain and 10 responders that are trained in fire and rescue.

The data collected in the fire hazard assessment will be incorporated into the implementation of the above recommendations by ensuring training and equipment provision are geared to plant hazards. A number of "fire sensitive areas" will be established in the station where the consequences of fire is high, particularly in respect to nuclear safety. Some of these areas were not obvious to fire fighters and inappropriate use of fire fighting equipment or fire fighting techniques could affect the outcome of the fire. Establishment of such areas will also help operating staff in avoiding the location of transient combustibles there, even for short durations.

Inputting the data from the hazards assessment into the fire crew training programs will ensure that training is geared to actual hazards in the plant, e.g. more emphasis must be placed on strategies and techniques in fighting fires in building interiors. The addition of realistic props to fire training areas, such as transformers, large pumps and motors, hydrogen seals and turbine bearings will assist fire instructors to focus on actual plant situation rather than generic fires.

6. FEEDBACK TO FUTURE DESIGN

Besides providing input for improving fire protection in the existing station, the assessment also yielded some inputs for future

station design. Some of these are discussed in the following:

(1) Although future stations will have much stronger in passive fire protection (using barriers and spatial separation), human intervention will still play a significant role in determining the outcome of fires. Human intervention is particularly crucial when the fire incident deviates from the pre-conceived design basis. Too often in the past, fire protection design efforts were concerned with hardware. Actions by plant operators and fire fighters were assumed without much thought in the design process. During plant operation, fire brigade organization, training and provision of equipment were established to generic rules, without enough consideration to the specific fire hazards in the plant. In future station, fire fighting actions should be part of the overall fire protection design. Factors such as accessibility, visibility, personal hazards and effectiveness of manual fire equipment should be considered like all other engineering design factors. Potential errors in the course of fire fighting should be identified and reduced by design features. The findings of the present fire hazards assessment can be used by the design engineer as a reference in identifying essential factors in successful fire fighting. The design engineer may have to seek advice from those with experience in fire fighting in nuclear power plants. The design organization and the utility should devote some research into preparing a manual or data bank on factors involved in human intervention of fires, including, fire discovery, reporting, fire brigade dispatching, fire fighting and recovery. Assessments made in the design should be documented and made known to plant operations.

(2) Fire hazards assessment performed during design should consider realistically the conditions in an operating station. The analyst

should realize the limits of fire prevention control in a station occupied by a large number of staff and outside contractors. Also, theoretical figures of availability of fire detection and fire suppression systems are often not attainable.

(3) Early fire detection is one of the most crucial factors in fire intervention actions. More effort should be given to the selection, spacing and location of fire detectors. The past practice was to design to general rules, followed by functional testing of the system. This does not guarantee reliable, early fire detection. Propagation of products of combustion in many areas of the plant are complicated by air flow patterns, obstruction by structures and equipment and the specific location of the fire. These cannot be fine-tuning of the design should be part of the commissioning of the fire detection system.