A Case For Shutdown Cooling System Exemption From The Periodic Inspection Program

J. Handbury, Canadian Power Utility Services

Abstract

The Periodic Inspection Program (PIP) is conducted at CANDU stations to comply with the mandatory requirements in Canadian Standards Association (CSA) Standards N285.4, N285.5 and N287.7. A heavily-inspected system in this program is the Shutdown Cooling (SDC) System, which accounts for about 15% of the overall inspections. This paper presents a case to remove most of the SDC System from the PIP since the worst-case accident of the SDC System results in public radiological doses that are low enough to allow exemption under N285.4. This provides an opportunity for CANDU owners to inspect the SDC System on an owner-prescribed basis at their own schedule. This will reduce costs and personnel doses and allow the allocation of resources and funding to more safety-important inspections.

1. Introduction

The Shutdown Cooling (SDC) System is a CANDU safety-related system with a purpose to remove decay heat from the fuel and residual heat from the Heat Transport System (HTS) when the Reactor is shutdown. During normal operation the SDC System is isolated from the HTS and in the poised state. During Reactor shutdown, when the SDC System is in operation, it cools the HTS coolant and forms part of the HTS pressure boundary.

The SDC System is currently included in the PIP under CSA N285.4, which requires inspection of the following components:

Mechanical couplings	Nozzles
Vessel/pump supports	Valves
Pumps	Pipe supports

For a four-unit station, these inspections number in the hundreds, some in areas with high fields, and account for about 15% of the total inspections for the entire PIP.

2. SDC System Operating States

Below are the three operating states for the SDC System:

Standby State:

The SDC System is isolated from the Heat Transport System and is maintained at about 50°C.

Normal Operating State:

The SDC System is warmed up and connected to the HTS. The system circulates HTS coolant through heat exchangers to cool the HTS to below about 50°C for maintenance. After this it provides a long term heat sink for decay heat from the fuel in the Reactor.

Abnormal (Emergency) Operating State:

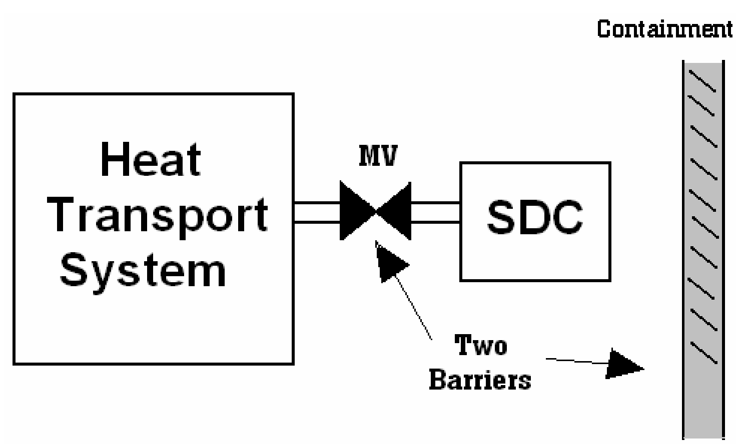
Under emergency conditions, e.g., main steam line failures, the SDC System may be credited to cool the Reactor from the zero-power-hot state where the HTS temperature can be as high as 265°C.

3. Relevant PIP Requirements

During the Standby State, the SDC System is isolated from the HTS and is exempt from periodic inspection by N285.4, Clause 3.3.2.2(a)(iii), as follows [1]:

> *For systems connected to systems containing nuclear fuel, inspection shall include any portion that does not have one barrier between the fluid boundary and the sheathing of the nuclear fuel and one barrier between the fluid boundary and the outside atmosphere.*

Allowed barriers are the isolation valves (MVs) and the containment boundary. As shown in the rough sketch below, the SDC System has the two barriers that exempt it from inspection in the standby state.

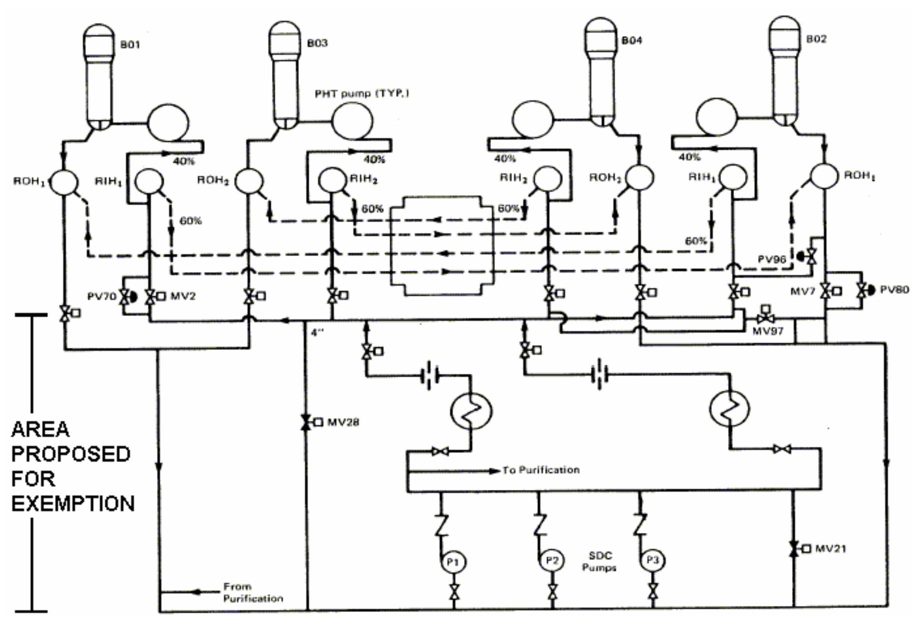


During SDC Operation, when the Reactor is shut down, we are trying to make a case for exemption by N285.4, Clause 3.3.2.2(d), as follows:

> *(d) A system ... may be exempted from periodic inspection where it has been demonstrated that, without operation of the containment system, its failure does not result in a dose exceeding the inspection determination threshold.*
>
> *Inspection determination threshold — an effective dose received by, or committed to, a typical member of the critical group in excess of 5 mSv.*

4. A case for SDC System Exemption

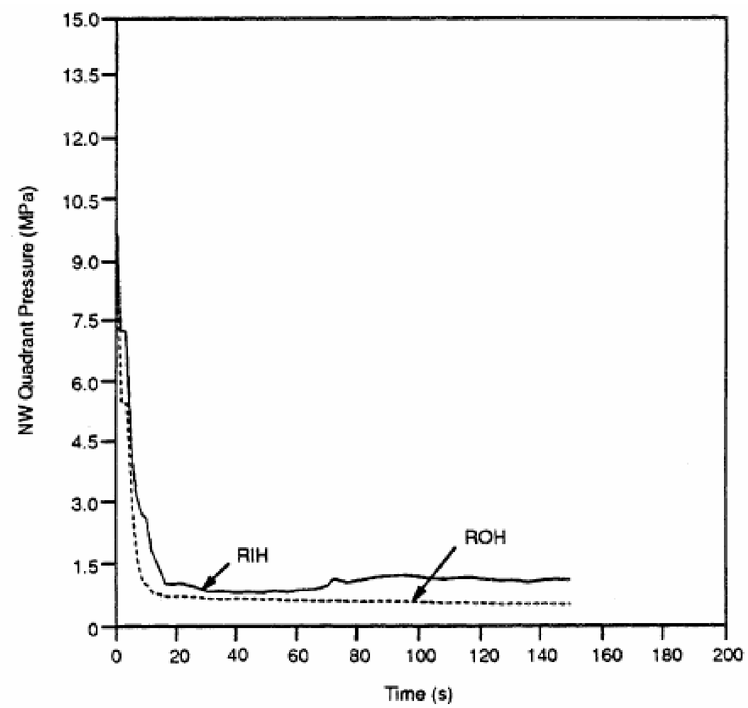
We wish to show that the worst-case accident of the SDC System, without crediting the containment system, will not result in public doses that exceed the Inspection Determination Threshold of 5 mSv. The proposed area for exemption is the SDC System components outside of the motorized valves that isolate the system from the HTS. The sketch below shows the proposed area for exemption for the Darlington SDC System design.



5. The Worst-Case SDC System Accident

The worst-case (bounding) accident for the SDC System is a guillotine break of a large pipe when the system has just been connected to the HTS. A break in any of the SDC pipes will lead to a loss of coolant from the HTS. The largest break that can occur is the guillotine break of the SDC pump suction line, the pump bypass line, or the pump discharge line.

Below is plot showing the HTS depressurization transients following a break in the 12-inch SDC Pump discharge header at Darlington.



The initial break discharge rate is about 10,800 kg/s, dropping almost instantaneously to 1800 kg/s, and then decreasing to less than 1000 kg/s in 20 s. The Emergency Coolant Injection System (ECIS), which is designed to refill the Reactor core with light water coolant, is initiated 18 s after the break occurs. The mass inventory in the HTS depletes slightly before ECIS refills the majority of the HTS within 2 minutes. The fuel is adequately cooled throughout the accident. The maximum fuel and pressure tube temperatures of 600°C and 300°C, respectively, will not cause fuel or pressure tube failures. Therefore, no activity release from the fuel is expected other than, potentially, from a few elements that have incipient sheath defects. Activity releases under such circumstances are negligibly small, and amount to much less than five percent of the reactor free inventory of volatile fission products.

6. Resulting Worst-Case Public Doses

To calculate the public doses from D_2O entering the atmosphere, we make the following conservative assumptions to present a bounding scenario:

- Assume that all D_2O vapour enters the environment with no credit for Containment volume hold-up. In actual fact the Containment volume at Darlington can hold up to 80 Mg of D_2O steam at atmospheric pressure and more at higher pressures.
- Assume no condensation takes place within the Reactor Building or Reactor Auxiliary Bay and no droplets deposit on equipment or walls.
- Assume no credit for Operator action to isolate the leak source.

- Assume maximum HTS radioactive concentrations of 2.16 mCi/kg of Iodine-131 and 2 Ci/kg of Tritium. Actual operational concentrations are less than this.

- Assume no credit for sub-cooling or condensation due to ECIS light water injection.

- Assume the HTS temperature is at a maximum at 265°C when the break occurs. This occurs only in the emergency operating state.

With the above conservative assumptions, and using the CANDU Station with the largest HTS inventory (Darlington), it is calculated that about 65 Mg of D_2O vapour would be released to the environment. The liquid inventory of D_2O and H_2O from the HTS and ECIS injection would remain inside Containment.

Based on analysed doses for other similar accidents (e.g., Feed line break outside Containment), the calculated public dose for this bounding scenario is 2.3 mSv, or 46% of the Inspection Determination Threshold. Thus the SDC System meets the requirement for exemption as given in N285.4 Clause 3.3.2.2(d).

7. Conclusions

It is concluded that the major portion of the SDC System can be exempt from the inspection requirements of the N285.4 PIP since the worst-case accident at the worst-case station (Darlington) appears to result in doses of only 46% of the Inspection Determination Threshold. The maximum fuel and pressure tube temperatures will not cause fuel or pressure tube failures. Thus we present a case for exempting the SDC portion within the isolation valves from the PIP and reduce N285.4 inspections by about 15%. This provides an opportunity for CANDU owners to inspect the SDC System on an owner-prescribed basis at their own schedule. This will reduce costs and personnel doses and allow the allocation of resources and funding to more safety-important inspections.

8. Acknowledgement

This paper is submitted with the approval of Ontario Power Generation.

9. References

[1] Canadian Standards Association, Standard N285.4, "Periodic Inspection of CANDU Nuclear Power Plant Components", June 2005.