design basis event used to establish the process requirements for the RVs), the overpressure protection system must pass its maximum designed flow.

At the other end of the spectrum as little as 1l/s may be required to flow out from the vessel to avoid overpressurization if a number of valves (direct feed, reflux, bleed) fail closed and the PHT system inflow and outflow are governed by the orifices by-passing those valves.

2.2 RV Design

Historically a lot of attention was paid to the relief valve doing its most important and defining job; providing fast and reliable protection against overpressurization. Conservatism was always interpreted as "the faster the valve opens and the higher its capacity the better". There was not so much concern about valve resetting, tightness after it operates or, in some cases even about blowdown. In the case of Darlington, the BC relief valve were grossly oversized and equipped with a steam trim. These characteristics, combined with a 27 feet long upstream relief pipe result in a high probability of valve chattering under low flow conditions, which may lead to valve and pipe damages similar to those experienced by other stations.

3.0 PILOT OPERATED RELIEF VALVES

3.1 An Alternate Solution

The use of different types of pilot operated valves, for reactor (primary) side overpressure protection is a common in many European countries, like UK, France and Germany. This solution is also used by the French and US Navy. There are several types of such valves, some design to fail open some closed. The pilot operated valve has the advantage of being either fully open or fully closed for most of its capacity range, hence chattering is avoided. The valve is designed such as it can withstand hundreds of cycles under hot or cold conditions. It was demonstrated that, when the maximum number of cycles is exhausted and an assumed bellow failure follows, the components continue to be protected, by the SEBIM system, against both overpressure and LOCA, for a period of several hours (Ref. 2). The main disadvantages are related to slow opening, when compared to the spring loaded valves available, and to the existence of the pilot, which creates additional design problems.

3.2 The SEBIM Overpressure Protection Systems

The SEBIM Group, located near Marseilles, France is formed by a number of companies which, during the last 50 years, developed, designed, manufactured and marketed spring loaded and pilot operated relief valves in several countries around the world. Their pilot valves are used for both nuclear and conventional side applications. A three year long test program, carried out by the Electricite de France research facilities, following the TMI accident and two local incidents involving spring loaded RVs, proved the superiority of the SEBIM design (Ref. 3, 4 and 5). As a consequence all French reactors are presently equipped with these valves. The SEBIM valve has also been extensively tested for UK and German qualification.

Since, SEBIM developed new products in order to meet customer requirements and improve reliability while simplifying the product. They are presently in a position to offer an overpressure protection system called " the hot solution tandem", which consists of two valves in series, mounted inside the same body and operated by independent pilots. Two such tandems, in parallel, each having 100% relief capability and discharging into an open vessel through very short lines is the solution being implemented for Darlington bleed condenser relief valves.

3.3 Basic principles

There are several important features to the SEBIM valve design. Firstly, the valve actuation force is provided by the system pressure (the valve is medium operated). The area of the piston is about 50% larger than the area of the disc. Secondly, the valve is bistable, with a closed neutral transient.

The seating stress is maximum at the system pressure immediately prior to lift. This allows leak free operation below 95% of the valve opening pressure. The pilot is removed away from the region of transient flow and instability. Use of Pitot tubes allows even more flexibility in connecting the pilot sensing element. For very low flows the valve is able to assume an intermediate opening position, further avoiding any instability in operation.

4.0 DARLINGTON BC OVERPRESSURE PROTECTION SYSTEM

4.1 The Concept of Protection for Nuclear Vessels

It is generally accepted that preventing the pressure transients to rise above the allowable limits is not enough. The high cost of cleaning after a heavy water spill as well as the public perception are elements that require a more comprehensive approach. The solution proposed by SEBIM and adopted by Darlington NGD combines the overpressure protection for the vessel with LOCA prevention, functional reliability, 100% redundancy and minimum unit shutdown time, hence the lowest cost. It is the first time this particular device will be used on the primary side of a nuclear reactor in North America.

4.2 The Darlington Application

Darlington is a four CANDU reactor station (935 MWe).The primary circuit, (Figure 1), has two identical loops, each one including two B&W steam generators, two main circulating pumps as well as the headers and pressure tubes common to all CANDU designs. A pressurizer vessel (30 cu. m.), connected to the west ROHs on both loops, provides additional water and steam volumes to mitigate the effect of fast transients. A second large vessel (27 cu. m.), the bleed condenser, which is part of the Pressure and Inventory Control (P&IC) System. receives the vapour or liquid D2O discharged from the main circuit via various bleed and relief valves, as the controllers attempt to maintain normal pressure in the PHT or to protect it from overpressurization, during abnormal incidents. The bleed condenser temperature, pressure and level are maintained constant by reflux or spray cooling and by two level control valves.

The BC relief valves must protect the vessel when isolated but both the vessel and the PHT system when connected. This situation may occur due to valve failure or in the case of other postulated incidents, like PHT overpressurization etc.

4.3 Darlington Process Conditions

The limiting scenarios, under which the SEBIM tandem is required to perform, in Darlington, are detailed in Appendix 1. The process conditions defined in that document were intended as a design guide for the valve manufacturer. They are derived, through system analysis, from postulated accident scenarios. In the process of establishing these conditions, a conservative approach has been adopted, in order to obtain an operating envelope for the device. This allowed to easily define the minimum requirements for the SEBIM system. as follows:
"The overpressure protection system, based on two 100% hot solution tandems, having staggered opening set points and installed in parallel, shall not allow the pressure in the bleed condenser vessel as well as in the other components connected to it to rise above 110% of their design pressure, while performing inside the envelope defined by the process conditions, in compliance with the OMCCR / AECB regulations, and with absence of chattering. The system must not allow any significant spillage of heavy water and should provide indication of bellow failure, during normal and emergency operating conditions."

2) Maximum pressurization rate..2000 kPa/s
The fastest BC pressurization transient occurs for a postulated spray valve failed open, when the vessel is cold (30 deg. C) and isolated.

3) Maximum flow through the valve...108 l/s
This is the 100% relief flow required for the design basis event (loss of pressure and inventory control plus loss of heat sink and the reactor at 5% FP). For this transient, the temperature of the fluid, at the valve, is 285 deg. C.

4) Minimum flow through the valve..1 l/s
The valve must function normally at this minimum flow, under either hot (285 deg. C) or cold (60 deg. C) conditions. The pressurization rate is expected to be slow (less than 100 kPa /sec.)

5) Maximum temperature of the fluid..305 deg. C
This is the highest temperature, at the valve, for a transient that requires RV opening. It occurs for the LRV failed open transient.

OTHER CONDITIONS

It is possible that during bleed condenser normal or abnormal operation, steam, non condensable gases or a combination of the two, fill the piping, the tubing, the pilots, the relief valves, or portions of their volumes. This must not affect the functioning of the protection system, as required above. The normal functioning of the protection system must not be affected by vibration normally occurring during plant operation or due to its own operation. The system must not become impaired due to radiation occurring in the plant or to seismic events.

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