Rev. 0
Draft for Section 4
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4.0 PLANT RESPONSE: EQUIPMENT AND PERSONNEL

4.1 Equipment Response

Key equipment associated with the event and response to the event included:

- Main Steam and Main Condenser Air Ejector Exhaust High Radiation Monitors.
- Steam Generators (SG).
- Steam Dump Valves to the Main Condenser.
- Main Condenser Steam Jet Air Ejector (SJAE) and Mechanical Vacuum Pumps.
- Atmospheric Steam Dump Valves (ASDV).
- Safety Injection (SI)
- Isolation Valve Seal Water System (IVSWS)
- Residual Heat Removal (RHR) System
- Reactor Coolant System (RCS)

The steam generator tube rupture (SGTR) event was complicated and achieving cold shutdown delayed because a few important plant components did not function as expected (even though they functioned as designed) or did not function as designed. Each of these equipment issues is discussed in detail in the following sections.

4.1.1 Main Steam Line and Main Condenser Air Ejector High Radiation Monitors.

Each of the four main steam lines is monitored for gross activity (N-16) by individual radiation detectors. Prior to the event, the main steam line radiation monitor from the #24 SG provided indication that there was primary to secondary coolant leakage in the #24 Steam Generator (SG) steam generator of about 1 gpd. During February the leakage rate slowly increased and reached about 5 gpd on the day prior to the event, as logged by station chemists. Operations stated that they were not aware of the leak rate increase that occurred the day prior to the event.

At about 7:17 p.m. on February 15, 2000, high radiation alarms occurred on the #24 SG main steam line radiation monitor and on the condenser steam jet air ejector (SJAE) discharge radiation monitor, indicative of a SGTR. The plant equipment responded appropriately causing the SJAE exhaust to realign from discharging to the atmosphere by way of the plant vent to discharging to the primary containment structure. The leak from the steam generator tube rupture (SGTR) was estimated to be above 100 gpm (> 140,000 gpd), exceeding the capacity of one charging pump.

4.1.2 Steam Generators

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When the SGTR occurred the control room operators manually tripped the reactor, manually tripped both main feedwater pumps and shifted to auxiliary feedwater to control SG water level. The #24 SG was isolated by the operators. Pressure increased in the #24 SG approaching the atmospheric steam dump valves (ASDV) adjusted setpoint of 1030 psig (the setpoint was manually increased from 1020 to 1030 psig by the operator per procedure). The #24 SG level increased above the high level tap indicating a level greater than 100%. There was some confusion initially in the Technical Support Center regarding the actual #24 SG level since the wide range level indication only increased to 91% indicated level where it remained for over five hours.

It was later recognized that since the wide range level instrumentation is calibrated at 70^{o}F it reads low at higher SG temperatures such that at the existing SG temperature a 91% indicated level, when corrected for temperature, was equivalent to 100% level or greater (since the level indication does not go above 100%). The narrow range level trend, which covers the top 25% of the SG level range, showed level increasing to 100% and then dropping a level of 0% for about eight hours, which, by design, is indicative of level exceeding 100%. The SG level instrumentation performed properly as designed.

4.1.3 Steam Dump Valves to the Main Condenser

Due to the #24 SG pressure approaching the ADVS setpoint of 1030 psig, the control room operators manually initiated RCS cooldown using the steam dump valves to discharge steam to the main condenser. The cooldown initiated by the operators was excessive. The licensee concluded the plant exceeded the RCS cooldown technical specification limits during the SGTR transient.

The steam dump valves are designed to operate in automatic, under temperature control when the reactor is operating and in pressure control when shut down. There are four groups of three valves. Each group operates as a unit and the first group goes to full open before the next group begins to open. The control room operator has indication (a light comes on at the control panel) when each valve group begins to open but there is no indication of valve.

Based on a simulator exercise conducted by the NRC inspector subsequent to the event, the excessive cooldown rate was the result of operator action. When the NRC inspector operated the steam dump valves in fast speed on the simulator the plant cooldown rate results observed on the simulator matched plant cooldown rate that occurred during the event. The systems utilized in plant for the cooldown performed correctly as designed. It appears the operator moved the 'T' switch enough to cause the valves to go to fast speed, causing the valves to open more than needed, thereby creating the excessive cooldown rate which exceeded technical specification limits.

The operators had experienced some oscillations in control when in automatic (identified in Condition Reports 199907799 and 200001215) and elected to operated the steam dump valves in manual which is allowed by procedure. In the manual mode, the operator can move the valve groups in either slow speed, by moving the 'T' switch a little, or in fast speed, by moving the 'T' switch all the way over.

4.1.4 Main Condenser Steam Jet Air Ejector (SJAE) and Mechanical Vacuum Pumps.

About five hours into the event vacuum was lost in the main condenser. This was caused by the operators failing to reposition a manual bypass valve that was controlling steam to the SJAE through the bypass line around the pressure control valve (PCV) and the automatic closure valve. Temperature and pressure were controlled using the ASDVs. The system is designed to control of steam pressure to the SJAE automatically using the PCV during normal plant operation, plant transients and cooldown evolutions. However, the PCV has been out of service for years and controlling steam flow manually on the bypass had become a 'normal' operator workaround. The automatic closure valve provides two protective functions: isolation for over pressure protection of the SJAE if the PCV fails; and, isolation on loss of condensate flow through the SJAE condenser to protect the SJAE condenser. Both of these protective functions are bypassed when operating in the manual mode using the bypass valve.

Approximately one hour later main condenser vacuum was reestablished using the #22 mechanical vacuum pump, even though the #22 vacuum pump had a deficiency tag indicating that the pump had a history of tripping on thermal overload. The ASDVs were closed and cooldown continued using the steam dumps to the condenser per procedure POP-3.3.

However, the exhaust of the mechanical vacuum pump from the condenser discharges to the plant vent and then to the atmosphere downstream of the condenser exhaust radiation monitor thereby creating an unmonitored release. The mechanical vacuum pumps are normally only used for prior to and during start-up.

About six hours later vacuum was again lost to the condenser due to the mechanical vacuum pump tripping off on thermal overload requiring using the ASDVs from the three intact SGs as before.

Vacuum was again restored to the main condenser about 1½ hours later using the #21 mechanical vacuum pump. The ASDVs were closed and cooldown continued by dumping steam to the main condenser.

4.1.5 Atmospheric Steam Dump Valves (ASDV).

During periods when vacuum was lost to the main condenser the operators used the ASDVs associated with the three intact SGs to continue cooldown, discharging steam to the environment.

There are four 6 inch power operated relief valves, one for each SG, which are capable of releasing steam to the atmosphere. These valves were manually controlled from the main control board to control pressure and the cooldown rate.

The pressure relief setpoint for automatic opening of the SG ASDVs is normally 1020 psig. The automatic opening of the ASDVs is determined by a proportional controller such that the rate at which the valve opens is directly related to the magnitude of the difference between the setpoint and the SG pressure. During the event the control room operators raised, per procedure AOI-1.2, the pressure relief setpoint on the #24 SG ASDV to 1030 psig to reduce the likelihood of a radiological release to atmosphere. The pressure in the #24 SG ASDV approached 1030 psig for a short period of time. High radiation levels in the #24 SG ASDV tailpipe indicate that the valve either lifted slightly or was leaking.

All ASDVs operated properly as designed.

4.1.6 Safety Injection (SI)

Due to the #24 SG pressure approaching the ADVS setpoint of 1030 psig, the control room operators manually initiated reactor coolant system (RCS) cooldown using the steam dump valves to discharge steam to the main condenser when condenser vacuum was available. The manual operating switch for controlling the steam dump valves can either initiate slow opening or fast opening of the dump valves, depending on how far the operator moves the switch. The resulting rate of RCS cooldown indicates that the operators selected fast opening of the dump valves. This scenario was verified by the NRC inspector using the Indian Point 2 plant simulator, where essentially the same rapid RCS cooldown rate was achieved when operating the steam dump valves in the fast open mode on the simulator.

When the control room operator initiated a more rapid then expected cooldown, the pressurizer level dropped below the indicating range before the cooldown rate could be reduced. Due to low pressurizer level, the operator manually initiated safety injection (SI). By design, as a result of the SI signal, the SJAE exhaust realigned from discharging to the primary reactor containment back to the plant vent, discharging contaminated SJAE exhaust to the atmosphere.

4.1.7 Isolation Valve Seal Water System (IVSWS)

The Indian Point 2 UFSAR states that the IVSWS ensures the effectiveness of those containment isolation valves that are located in lines connected to the RCS or that could be exposed to the containment atmosphere during any condition which requires containment isolation, by providing a water seal at the valves. No credit is taken for the operation of the IVSWS in the calculation of offsite accident doses. The system is not in operation during the primary containment integrated leakage rate test.

When SI was initiated, in conjunction with the event, the containment isolation valve seal water system (IVSWS) initiated to provide seal water to selected primary containment isolation valves. However, the IVSWS surge tank unexpectedly drained into the CCW system rendering the IVSWS inoperable. The Indian Point 2 Technical Specifications require that the plant not be brought above cold shutdown unless the IVSWS is operable and the IVSWS tank be maintained at a minimum pressure of 52 psig and contain a minimum of 144 gallons of water.

The IVSWS did not perform as designed. A similar event occurred in 1997 which has apparently gone uncorrected.

4.1.8 Residual Heat Removal (RHR) System

Shortly after noon on February 16, RHR was finally placed in service to continue cooldown. A delay of many hours in establishing cooldown on RHR was due to several contributors.

First, the existing Emergency Operating Procedure (EOP) ES3.1 required that the RCS be below 300 psig before going on RHR, which meant relying on natural circulation for cooldown, since the EOP also required that all RCPs be stopped before going below 350 psig. The licensee was aware of this issue for some time prior to the event, based on industry operating experience and information from their nuclear steam system supply (NSSS) vendor, but had not resolved the issue prior to the event.

The control room operators did not want to stop the RCPs before going on RHR for two reasons. They did not want to rely on natural circulation for controlling the cooldown process, which would occur without an RCP running, and they did not want to have to control RCS pressurizer using auxiliary pressurizer spray, which they would have to do with all RCPs stopped. They preferred to use normal pressurizer spray to control RCS pressure. Consequently, going on RHR was delayed to make a procedural change to the EOP.

Second, the licensee made a containment entry prior to going on RHR for two reasons. One was to open a drain valve on the containment spray (CS) header downstream of the tie in from RHR to prevent RHR system from inadvertently filling the containment and spraying containment due to a leaky RHR to CS isolation valve. Also, the licensee needed to install a jumper from the safety injection tanks' nitrogen supply to the RCS power operated relief valve (PORV) nitrogen accumulators to compensate for undersized (design deficiency) PORV accumulators to ensure the PORVs could be operated as needed to prevent over-pressurization of the RCS at low temperature. The licensee has a design modification developed to address the PORV accumulator design deficiency.

Third, the cooldown was delayed to make a procedure change to POP 3.3 to allow the cooldown to be performed without meeting the final cold shutdown boron concentrations. Also, even though boron concentration samples had been taken, the results were not provided to the TSC or the control room operators in a timely manner causing, approximately, a one hour delay.

Fourth, a SOP procedure change had to be made to isolate the idle RHR heat exchanger due to a leaking heat exchanger outlet butterfly valve.

Fifth, SOP 4.4.2 assumed that both component cooling water (CCW) valves to the RHR heat exchanger were closed and directed the operators to open one of the valves. However, since the control room operator had initiated SI both valves had opened per design, necessitating a procedure deviation to close one of the open valves to obtain the valve lineup required for that step in the procedure.

Sixth, when the RHR system was started, system warmup, per SOP 4-2.1, took longer than expected. This was due to the fact that the control room operators did not immediately realize that both RHR heat exchangers were in service, with full CCW flow, as a result of control room operators manually initiating SI. When the operators eventually isolated one of the heat exchangers they experience an unexpectedly high RHR heat up rate from 155°F to 190°F in less than 30 minutes. The inspector observed that the RHR inlet temperature indication is lower than actual RCS exit temperature. As a result, with RHR temperature at 190°F, it is possible that the RCS cold shutdown limit of 200°F was exceeded. This issue remains unresolved.

4.1.9 Reactor Coolant System (RCS)

After RHR was placed in service the operators secured the #24 reactor coolant pump (RCP) which meant that all RCPs were now secured necessitating using auxiliary pressurizer spray rather than normal pressurizer spray, to control RCS pressure. The operator had difficulty controlling RCS pressure for about one hour. This was due to a failure by the operator and the Technical Support Center (TSC) personnel to recognize in a timely manner that when using auxiliary spray it is necessary to close the normal pressurizer spray isolation valve so that auxiliary spray is directed to the pressurizer rather than directed back to the RCS via the normal spray line header. Also, Procedure ES 3.1 was deficient in that it did not instruct the operators to close the normal spray isolation valve.