ANO-1 Partial Loss of Flow

Chapter 11.0
B&W Cross-Training Course
R-326C

OBJECTIVES

1. Explain the actions of the rapid feedwater reduction (RFR) circuits on the integrated control system and the feedwater system components.
2. Explain the cause of the overcooling of the reactor coolant system.
3. Explain how reverse flow occurred from the reactor coolant system into a cross connect of high pressure injection lines outside the reactor building .
4. State the concern over the reactor coolant flow into the high pressure injection system.

Appendix – Sequence of Events

Initial conditions: 100 percent power; normal operating temperature and pressure.

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20:30 (?)
(Exact time unknown) Perturbations in the form of voltage swings/spikes are observed by the operators on a control room meter that displays the output voltage from the main generator exciter voltage regulator (i.e., generator field voltage). The normal generator field voltage is 50 Vdc. The voltage spikes occur fairly regularly (at approximately four minute intervals) with peaks values of near 90 Vdc at first, and becoming more severe with time until the meter pegged high at 150 Vdc just prior to losing generator field voltage.

21:58:11
The automatic voltage regulator is placed in the off position by the control room operator. Loss of main generator field voltage occurs due to a failed electrical connection on an exciter field winding. This causes a generator lockout via the generator protection circuits (i.e., the generator field breakers and output breakers open, electrically disconnecting the generator).

The main turbine trips on generator lockout.

The reactor trips on main turbine trip via the safety related anticipatory reactor trip (ART) circuits. The plant operators proceeded to bring the unit to hot shutdown conditions.

The power source to nonsafety-related 6.9kV Bus H1 fails to automatically fast transfer from the unit auxiliary transformer (supplied from the main generator) to the startup transformer (supplied from the offsite power system). An automatic fast transfer does occur to provide power to the other nonsafety- related buses, 6.9kV Bus H2 and 4.16 kV Buses A1 and A2. All safety-related buses transfer as designed following the trip.

Appendix – Sequence of Events

21:58:15
A trouble alarm is received in the control room on 6.9 kV Bus H1 loss of voltage.

Reactor Coolant Pumps “A” and “C” trip on undervoltage. These pumps are powered from Bus H1.

Two channels of the emergency feedwater initiation and control (EFIC) system spuriously trip upon sensing once through steam generator (OTSG) low level. Actual OTSG level was well above the emergency feedwater initiation setpoint.

The main feedwater (MFW) system startup flow control valves (SUCVs CV-2623 and CV-2673) and low load flow control valves (LLCVs CV-2622 and CV-2672) fail to close as designed following the reactor trip, allowing continued MFW flow paths to each OTSG.

The “B” MFW pump (P1B) fails to runback to minimum speed as designed following the reactor trip.

The “B” MFW block valve (CV-2675) fails to close as designed following the reactor trip. The valve starts to close, but stops when the valve torque switch actuates before the valve closes.

An automatic “slow dead bus transfer” occurs to provide power to 6.9kV Bus H1 from the startup transformer, restoring power to the bus. Reactor Coolant Pumps “A” and “C” remain shutdown.

Appendix – Sequence of Events

21:59:08
The operators manually start high pressure injection (HPI) System Pump P36A to provide additional makeup flow to maintain pressurizer level above the heater cutoff point. Pressurizer level was decreasing due to reactor coolant system cooldown from excessive MFW flow to OTSG "B" and the slight overcooling (reactor coolant temperature dropped about 11F).

21:59:25
OTSG "B" high level alarm at 92 percent is received in the control room.

21:59:38
The "A" MFW isolation valve (CV-2680) and the "B" MFW isolation valve (CV-2630) are manually closed by the operators from the control room.

21:59:40
The "B" MFW main block valve (CV-2675) is manually closed by the operators from the control room

The "B" MFW pump (P1B) runs back to minimum speed on its own.

21:59:44
Level in the "B" OTSG begins decreasing from a high value of 99 percent on the operating range. Level in the "A" OTSG is less than, and paralleling, the level in the "B" OTSG.

The MFW isolation valves are reopened by the operators from the control room.

Appendix – Sequence of Events

22:00:25
“B” OTSG level begins increasing from 91 percent on the operating range.

22:01:33
HPI Pump P36A is secured.

“B” OTSG level increases to near 100 percent on the operating range (actual level may have gone slightly off scale above 100 percent).

22:01:40
“B” OTSG level begins decreasing from 100 percent.

22:02:33
The “B” MFW pump is secured, and Motor Operated Valve CV-2827 in the crosstie line between the discharge of the two turbine driven MFW pumps (P1A and P1B) is opened. MFW Pump “A” is now providing MFW flow to both OTSGs via the SUCVs and LLCVs.

22:03:53
The “A” and “B” MFW isolation valves are closed by the operators from the control room in response to the increasing level in the OTSGs.

Control of the SUCVs and the LLCVs for both OTSGs is transferred from automatic control to manual control, and these valves are manually closed by the operators.

Appendix – Sequence of Events

22: (?)
(Exact time unknown) A fire alarm is received in the control room. The alarm is activated from a smoke detector located in the upper north piping penetration room (UNPPR). There is no fire water system flow to the UNPPR which indicates no actual fire in the area. An operator is dispatched to the UNPPR to investigate the cause for the alarm.

22:31
The NRC Operations Center is notified of the reactor trip in accordance with 10 CFR 50.72. The call was initially misclassified by the licensee as a courtesy call instead of a required notification. The call was made by a shift administrative assistant, not an operator.

22:38 (?)
(Exact time unknown) The “A” and “B” MFW isolation valves (and SUCVs) are reopened by the operators.

22:50 (?)
(Exact time unknown) The operator dispatched to the UNPPR reports back to the control room by telephone that the temperature of the “B” and “C” HPI system injection lines, and the crossover line that connects them, is excessively high (more indicative of RCS temperature than the expected temperature of the borated water used for HPI). The smoke detector is believed to have been actuated when tape attached to the HPI piping began to melt and smolder/smoke. It was noted that this event could have gone undetected. The plant operators suspected that the high temperature in the HPI piping was caused by failure of Check Valve MU-34B to reseat after HPI Pump P36A was secured at 22:01:33. Check Valve MU-34B is located inside the reactor containment building. The leakage flow path was in the reverse direction through Check Valve MU-34B and outside the reactor containment building via the “B” HPI injection line, then through the crossover line to the “C” HPI injection line, and back inside the reactor containment building to the RCS. The upstream check valves (MU-1214 and MU-1215 in the “B’ and “C” HPI injection lines respectively) performed as designed to prevent further backflow of reactor coolant into the HPI system piping.

Appendix – Sequence of Events

22:59:41
An EFIC system initiation of emergency feedwater (EFW) occurs upon sensing low level in the "B" OTSG. The operators were aware that OTSG levels were decreasing, and were beginning to increase MFW flow at the time of the EFIC system initiation of EFW.

23:00:00
EFW is secured. Very little, if any, EFW system flow was injected into the OTSGs.

23:05 (?)
(Exact time unknown) Auxiliary Feedwater Pump P75 (motor driven) is manually started by the operators from the control room.

23:15 (?)
(Exact time unknown) The "A" MFW pump is secured.

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1:00 (?)
(Exact time unknown) The oncoming shift waste control operator is dispatched to check the piping in the UNPPR but because of confusion he missed the hot HPI crossover piping. He erroneously reported to the control room that the pipe appeared to be cooling down.

Appendix – Sequence of Events

2:02
The NRC Operations Center is notified of the EFIC system initiation of EFW in accordance with 10 CFR 50.72. This notification was made by the unit shift supervisor.
3:00 (?)
(Exact time unknown) The waste control operator is again dispatched to the UNPPR with better instructions and he correctly determines that the HPI crossover piping is still hot.

3:53
Reactor Coolant Pumps "A" and "C" are restarted. It appears that restarting the pumps causes Check Valve MU-34B to reseat and/or removed the differential pressure which was driving the backflow, stopping the RCS back leakage into the HPI system piping. The waste control operator confirms that the piping was cooling off at this time.

5:00
A routine post reactor trip walkdown of the reactor containment building identifies possible reactor coolant system leakage.

12:56
The leakage is confirmed to be from an elbow weld in a 1 1/2-inch drain line off the "B" reactor coolant pump suction line. The leakage rate is believed to be small (approximately 10 to 20 ml per minute). An Unusual Event (UE) is declared by the licensee due to unisolable RCS pressure boundary leakage. (T.S. 3.1.6.3 requires cooldown to begin within 24 hours of identifying the leakage.)
13:06
Operators begin the process of taking the reactor to a cold shutdown condition.

Appendix – Sequence of Events

13:10
The NRC Operations Center is notified of the declaration of an UE in accordance with 10 CFR 50.72. This notification is made by the shift administrative assistant.

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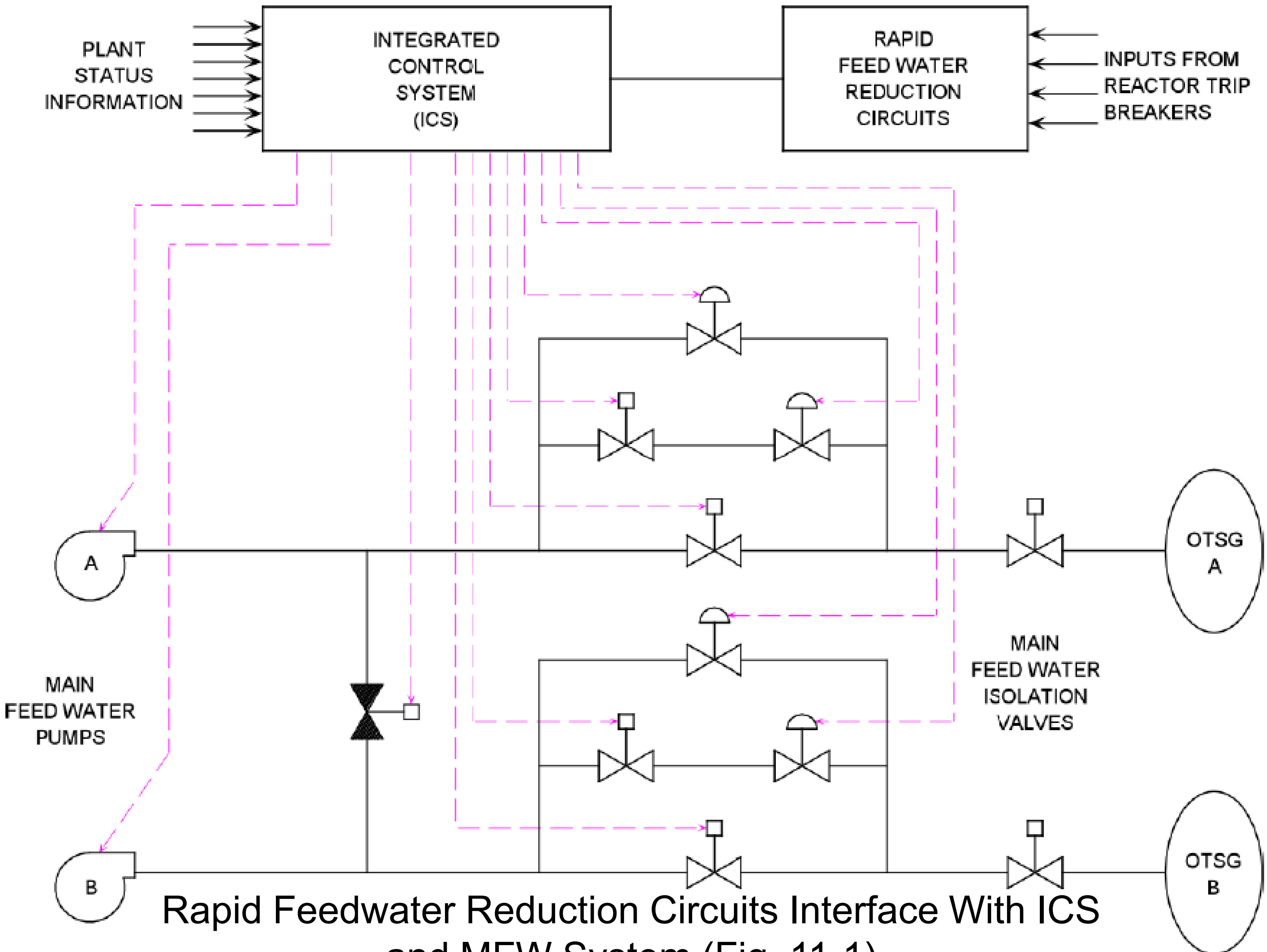
17:30
The reactor is at cold shutdown, and the UE is terminated.



Rapid Feedwater Reduction Circuits Interface With ICS and MFW System (Fig. 11-1)

High Pressure Injection System
Fig. 11-2