

22.093 OPERATIONAL REACTOR SAFETY

Exam #2 is 2 days after Ses #24

Open Book

Examination # 2
Nuclear Safety Segment

1.5 Hours

Problem # 1 (70%)

(Please read the entire question and then think through the answers logically)

The Zion Nuclear Power Plant (Westinghouse) is operating at full power. The reactor primary pressure is 2,200 psi with a secondary pressure of 1,000 psi. The plant has had some fuel failures but the activity level in the coolant is about $\frac{1}{2}$ the technical specification limit. The plant has also been measuring small leaks in the steam generators but below tech spec limits and has plugged many steam generator tubes. As in all US PWRs, Doppler and moderator coefficients are negative.

At midnight, an operator notices a small leak in one of the main steam lines. As he reviews the procedures for dealing with the leakage, the pipe ruptures releasing massive amounts of steam into turbine building.

- a. Describe what happens to core temperature, primary and secondary system pressure and power level as a result of this transient. Explain your answers using basic reactor physics and heat transfer principles. Show conceptual graphs of each parameter as a function of time. (15%)
- b. Draw a simple event tree for this initiating event identifying the key functions that are important in terminating the event or preventing release of radioactivity. Please state all your assumptions and why they are valid. Work through the scenario in words. Would the plant automatically shutdown? Why or why not? Use information found in Table IV-1 of Knief (page 708) for a Westinghouse PWR if needed and the attached figure to identify interrelated systems. Assume the plant operates under the pressure control system of Figure 7-13 attached. (15%)

Consider the following systems: (NOTE: not all of these would be necessary to respond to this initial transient)

- High pressure safety injection
- Low pressure safety injection
- Emergency electrical power
- Reactor coolant system including the pressurizer
- Availability of sources of cooling water (Refueling water storage tank (RWST), Condensate Storage Tank (CST), Containment recirculation)
- Containment Spray Functions
- Reactor Protection System
- Feed and bleed using the charging pumps and pressurizer
- Main and auxiliary feedwater system.

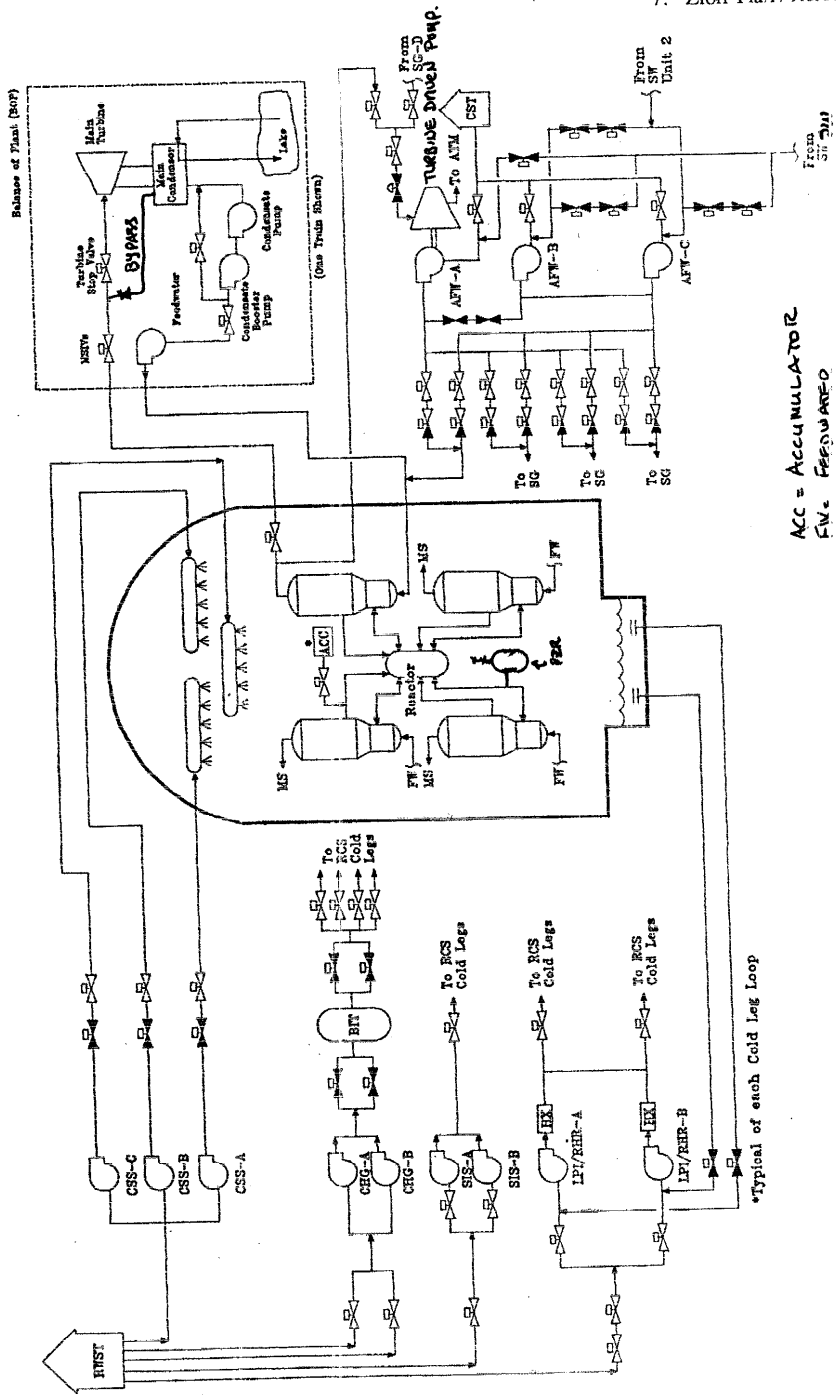
- c. Given the weakness of the steam generator tubes based on past leaks, a steam generator tube fails due to the pressure differential between the primary and secondary system. Let us assume that the primary pressure is able to be maintained above 2000 psi. Describe what happens on the

primary and secondary side using basic reactor physics and heat transfer. What should the operators be trying to do? How? (15%)

d. Suppose as a result of the tube break more tubes fail dropping pressure below 600 psi. What happens then? Will the core be uncovered? Why or why not? What systems come on line to provide cooling? Recall that we have a break in a main steam line. What should the operators be trying to do. Please prepare a chart qualitatively showing the variation of the following parameters as a **function of time**: (no calculations are necessary just draw what you think happens and briefly explain why). (15%)

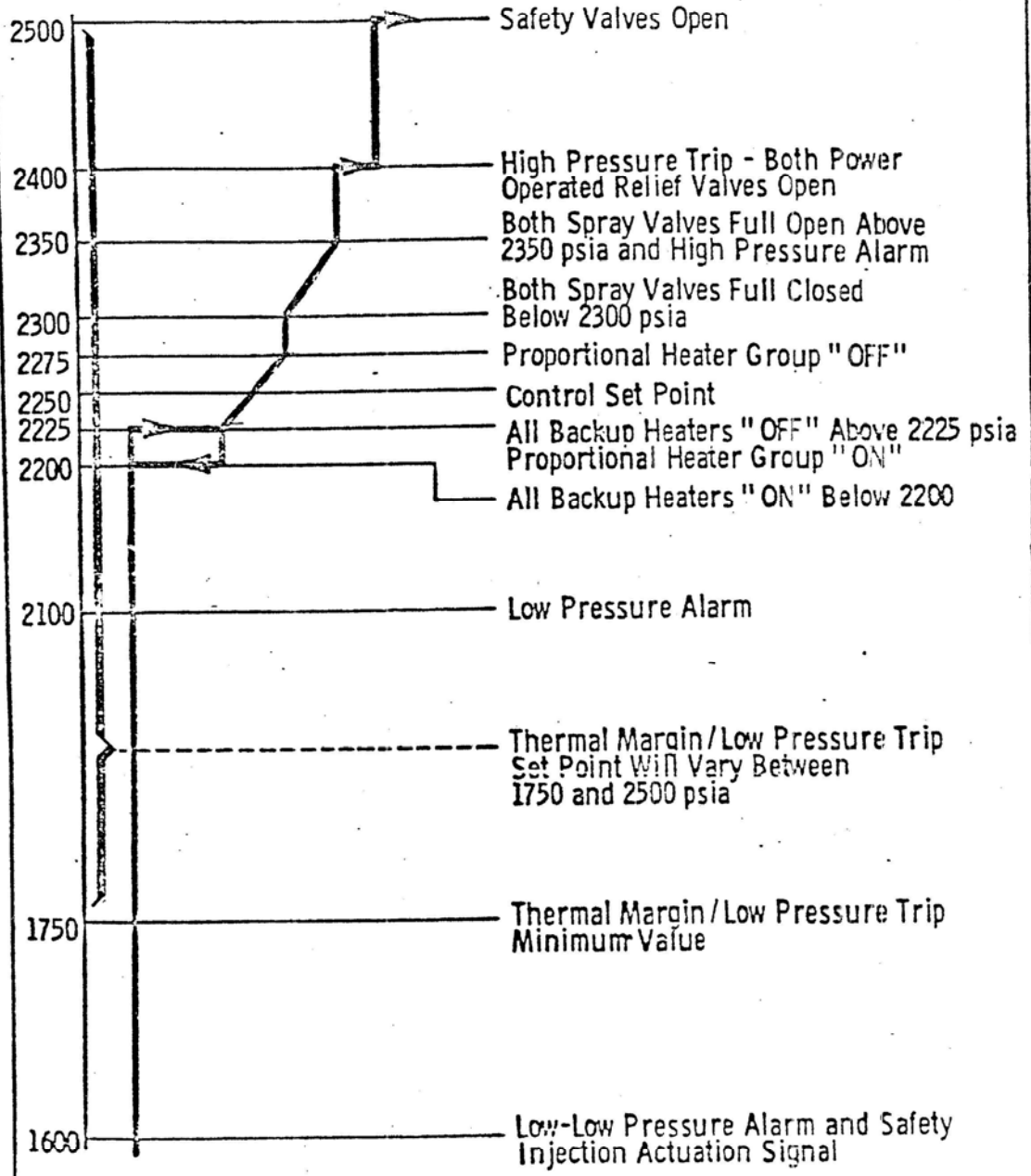
1. Power Level
2. Pressure
3. Water Level
4. Peak rod clad temperature
5. Containment Pressure

e. The containment pressure continues to rise since the containment sprays are now also out of water from the RWST. At 1 hour and 10 minutes, the operators realign the containment recirculation system to get water from the reactor cavity sump but fail to notice that the valves to the recirculation water to the reactor have not opened. What do the charts look like now? Please justify your answer for each variable above based on the physical events taking place. Does the core melt? Why or why not? (10%)



ACC = ACCUMULATOR
 FW = FEEDWATER
 MS = MAIN STEAM
 SW = SERVICE WATER
 PER = PRESSURIZER

Figure 7.1 Zion plant schematic.



BALTIMORE
GAS & ELECTRIC CO.
Calvert Cliffs
Nuclear Power Plant

Pressure Control Program

Figure
7-13

7. Zion Plant Results

Table 7.1 Summary of design features: Zion Unit 1.

1. High-Pressure Injection	<ul style="list-style-type: none"> a. Two centrifugal charging pumps. (CHG) b. Two 1500-psig safety injection pumps. (SIS) c. Charging pumps inject through boron injection tank. (BIT) d. Provides seal injection flow. e. Requires component cooling water. (CCW)
2. Low-Pressure Injection	<ul style="list-style-type: none"> a. Two RHR pumps deliver flow when RCS is below about 170 psig. (Low Pressure Injection) - (LPI) b. Heat exchangers downstream of pumps provide recirculation heat removal. c. Recirculation mode takes suction on containment sump and discharges to the RCS, HPI suction, and/or containment spray pump suction. d. Pumps and heat exchangers require component cooling water.
3. Auxiliary Feedwater (AFW)	<ul style="list-style-type: none"> a. Two 50 percent motor-driven pumps and one 100 percent turbine-driven pump. b. Pumps take suction from own unit condensate storage tank (CST) but can be manually cross-tied to the other unit's CST.
4. Emergency Power System	<ul style="list-style-type: none"> a. Each unit consists of three 4160 VAC class 1E buses, each feeding one 480 VAC class 1E bus and motor control center. b. For the two units there are 5 diesel generators, with one being a swing diesel generator shared by both units. c. Three trains of dc power are supplied from the inverters and 3 unit batteries.
5. Component Cooling Water	<ul style="list-style-type: none"> a. Shared system between both units. b. Consists of 5 pumps, 3 heat exchangers, and 2 surge tanks. c. Cools RHR heat exchangers, RCP motors and thermal barriers, RHR pumps, SI pumps, and charging pumps. d. One of 5 pumps can provide sufficient flow.
6. Service Water	<ul style="list-style-type: none"> a. Shared system between both units. b. Consists of 6 pumps and 2 supply headers. c. Cools component cooling heat exchangers, containment fan coolers, diesel generator coolers, auxiliary feedwater pumps. d. Two of 6 pumps can supply sufficient flow.
7. Containment Structure	<ul style="list-style-type: none"> a. Large, dry, prestressed concrete. b. 2.6 million cubic foot volume. c. 49 psig design pressure.
8. Containment Spray (CSS)	<ul style="list-style-type: none"> a. Two motor-driven pumps and 1 independent diesel-driven pump. b. No train cross-ties. c. Water supplied by refueling water storage tank. (RWST)
9. Containment Fan Coolers	<ul style="list-style-type: none"> a. Five fan cooler units, a minimum of 3 needed for post-accident heat removal. b. Fan units shift to low speed on SI signal. c. Coolers require service water.

Problem 2 (30%)

The 873 MWe Davis Besse Nuclear plant almost experienced one of the most serious accidents a nuclear plant can have - a loss of coolant accident that can not be isolated. As you may recall, due to management neglect, a leak on the reactor pressure vessel head control rod drive of this Babcock and Wilcox designed PWR caused boric acid corrosion of the carbon steel 6 inch thick head. This leak was unattended and the corrosion progressed to the point that the entire thickness of the vessel was corroded away leaving only the stainless steel welded on cladding, approximately 3/8 of an inch thick, that prevented a non-isolable loss of coolant accident. Fortunately the reactor was shutdown before the cladding failed.

- a. If the vessel cladding failed, what would happen? Assume the break would be approximately a 5 inch diameter hole? Describe what happens in the primary system, the containment, and what systems would be automatically actuated in what sequence. Consider all systems available to deal with light water reactor accidents. (10%)
- b. What, if anything, would the operators be capable of doing to stop the leak or limit its magnitude? (5%)
- c. Describe with a chart the pressure in the containment as a function of time. (5%)
- d. Is the core going to melt? Why or why not? Where is the water going to come from to keep the core cooled? (5%)
- e. How will this accident be terminated? What should the operators be doing to limit the consequences? (5%)

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