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THE BABCOCK & WILCOX COMPANY
POWER GENERATION DIVISION

NUCLEAR POWER GENERATION DEPARTMENT

ENGINEERING CALCULATIONS

DESIGN AND PERFORMANCE ANALYSIS
PRESSURIZER

SIZING OF PRESSURIZER

I. PURPOSE

To provide the method for sizing the pressurizer for B&W Nuclear Steam Systems.

II. GENERAL

A. The pressurizer is an integral component of the primary system. Its function is to maintain system pressure within system design values and to absorb system fluid volume changes during all normal and abnormal transients.

B. This procedure is used to obtain the following values:

1. Pressurizer total volume
2. Pressurizer water volume and steam volume
3. Pressurizer spray rate
4. Pilot actuated relief valve capacity
5. Safety valve capacity
6. Pressurizer surge line size.
7. Pressurizer electrical heater capacity.

C. The following information is required to size the pressurizer:

1. Reactor Coolant System design temperature and pressure.
2. Reactor Coolant expected temperature and pressure over the entire load range.
3. Steam generator secondary design temperature and pressure.
4. Steam generator expected secondary temperature and pressure over the entire load range.
5. Reactor Coolant System component water volumes.
6. Steam system relief and safety valve setpoints, and the expected blowdown for these valves.
7. The High Pressure Injection set point.
8. The pressurizer internal diameter.

III. PROCEDURE

A. The pressurizer is sized in the following manner:

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1. Prepare a graph in the format of Figure 1, referred to in this procedure ... the following information:

a. Curve (a) - Reactor Coolant System temperature as a function of load.

b. Curve (b) - The band of temperatures corresponding to the saturation temperatures at the steam system design pressure and 105% of design pressure. (This is the setpoint range for the steam safety valves.)

c. Curve (c) - The saturation temperature corresponding to the turbine bypass system set point for reactor trip. This pressure is normally 2% below the secondary system design pressure or 50 psi below design pressure, whichever criterion results in the ~~higher~~ lower pressure setting.

d. Curve (d) - The saturation temperature corresponding to the steam generator secondary outlet pressure as a function of load for normal operation.

2. Prepare a graph in the format of Figure 2, referred to in this procedure as graph 2, displaying the following information:

   a. Curve (a) - Pressurizer outsurge in cubic feet as a function of Reactor Coolant System average temperature decrease from the normal average temperature at 100% power. This curve is prepared for a constant pressure equal to high pressure injection set point plus 200 psi. The curve should extend to the ΔT value corresponding to the change in average temperature from zero power to 15% power. Average temperatures may be used at isothermal conditions for the system.

   b. Curve (b) - Pressurizer insurge in cubic feet as a function of Reactor Coolant System average temperature increase from the normal temperature at 100% power. This curve is prepared for a constant pressure equal to the high pressure reactor trip. Average temperatures should be evaluated on a volume weighted basis, system section by system section. 100% power ΔT's should be used.

3. Set the pressurizer minimum level at the higher of:

   a. 150 cubic feet, or

   b. the volume in the pressurizer lower head up to the tangent line.

The level should not drop below this point during or after a reactor trip.

4. Obtain the maximum outsurge. The outsurge is associated with a reactor trip from full power. The reactor coolant system temperature will drop from the reactor coolant system temperature at full power to the temperature corresponding to the turbine bypass set point. This is the difference between curve (a) and curve (c) on graph 1, labeled ΔT_{RT} on the graph.

Go to graph 2 and obtain the maximum normal outsurge associated with ΔT_{RT} from curve (a).

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6. Add the level associated with this outsurge volume to the level established in step 3 of this procedure. This level is the minimum normal pressurizer level. A low level alarm is actuated at this level.

7. Determine, from graph 2, the maximum surge, in or out, associated with a 5 F change in reactor system temperature.

8. Add the volume determined in step 7 to that established in step 6. This is the normal pressurizer water level or volume.

9. Add the volume from step 7 to the volume determined in step 8. This is the maximum normal pressurizer level. A high level alarm is actuated at this level.

10. Obtain the maximum insurge. The insurge is associated with a turbine trip or closure of the turbine control valves at full power. The temperature of the secondary system heat sink increases from the normal temperature, curve (d), graph 1, into the region of curve (b), graph 1. The maximum insurge is that of raising the reactor coolant system temperature by an amount equal to the difference between curves (b) and (d) on graph 1. This value is labeled ΔT_{TT} on graph 1.

11. From graph 2, determine the insurge associated with ΔT_{TT} from curve (b) in cubic feet.

12. Add the insurge volume established in step 11 to the volume established in step 9. This is the maximum pressurizer level.

13. Divide the total water volume established in step 12 by 0.9 to determine the required pressurizer total volume and multiply the resultant value by 1.03 to allow for shop tolerances.

14. Set the location of pressurizer level indication taps by the following criteria:

    a. The lower level taps must be below the minimum pressurizer level to avoid loss of indication during the design outsurge.

    b. The upper level taps must be above the maximum pressurizer level to avoid loss of indication during the design insurge.

15. Set up the KAPP and Power Train computer programs (see Standard 2A3-N-2A39-2A231) for the NSS using the pressurizer volume established in step 13 and check and determine the following:

    a. Pressure and pressurizer level following a reactor trip from full power and minimum normal pressurizer level (KAPP or Power Train). Check these values against the criteria used in step 3 and the following:

1) The lower level indication tap must not be uncovered.

2) The resulting pressure must not be less than the high pressure injection set point plus 100 psi.

3) If the pressurizer heaters are uncovered, the addition of makeup water to cover the pressurizer heaters should not cause the reactor coolant system pressure to decrease to less than the high pressure injection set point plus 50 psi.

b. Pressure, surge rate and pressurizer level for a turbine trip or throttle valve closure from full power at maximum normal pressurizer level (Power Train). Check the values against the criteria used in steps 13 and 14, i.e., the maximum level must be no more than that associated with 90% of the total pressurizer volume, and the upper pressurizer level indication taps must not be covered.

c. Pressure, surge rate and pressurizer level for the rod withdrawal accident from zero power (KAPP). Check the results against the criteria used in 15.b.

16. Using the maximum surge rate obtained in step 15, size the surge line such that a pressure drop of 2% of system design pressure is not exceeded. This criterion includes pressure drop attributable to the surge diffuser.

17. Estimate the safety valve capacity by assuming it equal to the steam flow required to remove the steam at the maximum insurge rate from step 15.

18. Input the data obtained to this point into the DYSID computer program. Use a pressure drop of 50 psi from the pressurizer steam space to the safety valve throat to allow for water seals and/or manifolding and use the pressure drop in the surge line found in step 16. The resulting safety valve characteristics should meet the following criteria:

a. Peak pressure at the reactor coolant pump discharge should be less than 110% of design pressure. (Add the pressure drop from the surge line tee to the reactor coolant pump discharge to the pressure at the tee from DYSID output.)

b. The safety valve should exhibit a clean lift and reseat. If the valves cycle open a number of times, the capacity is too large and can be reduced.

c. The requirements of Article 9, Protection against Overpressure, of the ASME Code, Section III. The safety valves must be adequate for: 1) the rod withdrawal accident from low power with no credit for pressurizer spray or pilot actuated relief valves, and 2) turbine trip or control valve closure from full power without credit for turbine bypass operation or Integrated Control System runback and 3) the ability to remove decay ...

19. Use the Power Train computer code to determine the following:

   a. The maximum insurge rate during 10% of full power per minute ramp load changes between 15% and 100% of full power.

   b. The maximum insurge rate for a 10% of full power step load change in the range of 15% to 100% of full power.

   c. The maximum insurge rates during the guaranteed amount of load rejection. Use selected turbine bypass flow rates and set points.

20. Input the surge rate from step 19.a. into DYSID and determine the pressurizer spray flow rate required to maintain reactor coolant pressure below the set point of the pilot actuated relief valves during ramp load changes.

21. Input the surge rates from steps 19.b and 19.c. into DYSID and determine the required capacity of the pilot actuated relief valves to hold pressure below the reactor high pressure trip set point.

22. To size the pressurizer heaters, perform the following steps:

   a. From step 13, estimate the pressurizer metal mass and obtain specific heat from the 2A3-N Manual.

   b. Determine the guaranteed heating rate from the Proposal or Contract Information Sheets.

   c. Input pressurizer metal mass and specific heat, normal pressurizer water volume (from step 8) and estimated pressurizer heater capacity into DYSID and run a heatup transient. Repeat this run several times using different estimated heater capacities. Select that heater capacity that gives a heating rate which averages the guaranteed value over the heatup range.

23. For those contracts with Reactor Coolant System loop isolation valves it will be necessary to analyze single loop operation to the method and criteria of this procedure to determine adequacy of sizes for this mode of operation.

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