UNITED STATES GOVERNMENT

Memorandum

TO : Saul Levine, Assistant Director
for Reactor Technology
Division of Reactor Licensing

DATE:

FROM : Morris Rosen, Chief
Nuclear & Systems Technology Branch
Division of Reactor Licensing

SUBJECT: REACTOR TECHNOLOGY MEMORANDUM NO. 5 (DRAFT) -- ADEQUACY OF THE CONTAINMENT DESIGN PRESSURE FOR DRY PWR CONTAINMENTS

DRL:N&STB:HS RT-458

The attached RTM sets forth for a dry PWR containment, proposed DRL evaluation techniques for determining the adequacy of the containment design pressure. It permits rapid determination of the initial peak containment pressure which could result from a loss of coolant accident and determines the containment's ability to withstand subsequent energy additions without exceeding design pressure. This RTM does not discuss in depth the need for or type of margins that could be used in assessing the acceptability of the containment design pressure.

Attachments:
1. RTM-5
2. Appendix A) To be issued shortly
3. Appendix B)

cc: Branch Chiefs, RT
Herschel Specter
Roger J. Mattson
Merrill A. Taylor
Howard J. Richings
Marvin S. Dunenfeld
J. Frederick Weinhold

REACTOR TECHNOLOGY MEMORANDUM NO. 5

ADEQUACY OF DRY PWR CONTAINMENT DESIGN PRESSURE

I. INTRODUCTION

The containment pressure transient following a loss of coolant accident can be divided into three time regions. The first time region is the blowdown phase and is about 10 to 20 seconds long for large pipe breaks. During this initial phase, the pressure transient is mainly dependent upon the volume of the primary containment, the rate of mass and energy addition during blowdown, and energy absorption by the containment structure. The second region starts at the time of the blowdown peak pressure and continues until the engineered safety features are operating on the recirculation mode. During this phase, the pressure transient is mainly dependent on the heat removal capability of the engineered safety systems, the decay heat rate and other potential energy sources such as metal-water reaction energy. The final region, or long-term heat removal phase, reduces the containment pressure to near zero values and is primarily dependent upon the capability of the long-term energy removal systems.

This RTM provides methods for rapidly assessing the adequacy of the containment design pressure for the first two time regions by allowing determination of:

(1) The peak containment pressure following the blowdown of the primary coolant system (first time region)

(2) The fraction of metal-water reaction or number of steam tube ruptures the containment can tolerate without an increase in

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containment pressure above the peak blowdown pressure (second time region).

II. PROCEDURE

A. Initial Peak Pressure (Region 1)

Method 1 - The peak blowdown pressure in the primary containment following a loss of coolant accident may be estimated by use of Figure 1a which is a plot of peak containment pressure versus V_{pc}/V at various T_{pc} values:

where V_{pc} is the volume of water in the primary coolant system, ft^3

V is the containment free volume, ft^3

T_{pc} is the average primary coolant temperature, °F

P is containment peak pressure, psig

Figure 1a is semi-empirical in derivation and is based upon results of many PWR designs previously evaluated. Unless there are heat sources or sinks significantly unique to the plant under review, such as large structural sinks, the predicted pressure will be within several psi of more accurate methods subsequently discussed.

Method 2 - A calculation showing the total energy contributions of individual components such as decay heat, core stored heat, structural sinks, etc., towards the containment peak pressure can be performed using either Appendix A or B. Appendix A is an abbreviated form of the detailed procedure presented in Appendix B and uses only a limited number of plant parameters. The effects of other plant parameters,

such as film coefficient, may be ascertained, if desired, by using the more detailed techniques in Appendix B. It is recommended that at least the procedure of Appendix A be used to allow a more thorough understanding of important energy sources and sinks.

B. Subsequent Energy Additions (Region 2)

1. Metal-Water Reaction

The fraction of total available metal-water reaction energy that can be added to the containment during the first 10 minutes without an increase in containment pressure above the blowdown peak pressure is given by the following equation:

(2) $$F = \frac{(q_{acc} + q_{containment} + q_{esf}) - (q_{decay} + q_{loop} + q_{core})}{q_{100\%\ M\text{-}W}}$$

(2) $$= \frac{[-16.6P + 10.0NV_a - 4.1Vpc + 2.07dh]10^3 - 6.1m_c - 19.7m_f + .16Q \text{ (and/or } 14\times10^3 G)}{4600\ m_c - 250\ m_f}$$

where N = Total number of accumulators less one

V_a = Fluid volume per accumulator, ft^3

Vpc = Fluid volume of primary coolant, ft^3

d, h = Containment diameter, height, ft

P = Core thermal power, megawatts

m_c, m_f = Mass of clad, fuel - pounds

Q = Cooling capacity of minimum engineered safeguard systems, BTU/hr

G = Minimum spray flow rate - gpm

The above equation is based on (1) the assumption that the pressure is maintained constant at the initial peak value by metal-water reaction energy (including hydrogen burning) and (2) the average heat source and sinks are based upon a 10 minute average. Use of

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a ten minute interval is somewhat conservative as it somewhat overestimates some of the heat sources. Basically, the heat sources (i.e., decay heat, remaining core stored heat, and remaining loop and vessel stored heat) are subtracted from the sinks (i.e., the accumulators, containment sinks, containment sprays, and air coolers). This net difference in energy is divided by the energy released in a 100% M-W reaction to determine the fraction of the M-W reaction that can be tolerated without exceeding the containment peak blowdown pressure. A more detailed derivation of the components of the above equation and the choice of a 10 minute average is contained in Appendix A.

2. Steam Generator Tube Rupture

The energy addition due to the rupture of one steam generator tube can be estimated from the following equation, where D is the tube inside diameter in inches:

$$q_{s.g.} = 14.2\ D^2\ (10)^6$$

Similar to the calculation of the tolerable metal-water reaction energy, the net difference in energy of the sources and sinks is divided by the energy release of a single tube to determine the tolerable number of tube failures, T, without exceeding blowdown peak pressures:

$$(3)\quad T = \frac{[q_{acc} + q_{containment} + q_{esf}] - [q_{decay} + q_{loop} + q_{core}]}{q_{s.g.}}$$

[redacted]

3. Margin to Design Pressure

The allowable metal-water reaction fraction or the maximum number of tubes that may rupture without exceeding design pressure, i.e., allowing the pressure to rise from the peak blowdown pressure to the design pressure and holding it constant, during the first 10 minutes, can be determined as follows:

$$M = [\text{Design Pressure (psig)} - \text{Peak Blowdown Pressure (psig)}]\,(3.1)(10)^6$$

$$(4) \quad F' = \frac{M}{q_{100\%\ \text{Metal-Water}}}$$

$$(5) \quad T' = \frac{M}{14.2\ D^2\ (10)^6}$$

The allowable metal-water reaction for preventing the containment pressure from exceeding the design pressure is then F + F'. Similarly, the number of steam tube ruptures that would bring the containment up to design pressure (and then constant for 10 minutes) is T + T'.

III. CONCLUSIONS

The use of equation (1) will permit a rapid comparison of peak pressures and design pressures. It is recommended that the design pressure is acceptable if the calculated peak pressure does not exceed it by five percent. It is also recommended that Appendix A be used to calculate the various sources and sinks and that comparisons between the plant under review and the plants plotted in Figure 1 be made.

At this time, there are no criteria for the number of steam tube ruptures or fraction of the 100% M-W reaction energy that the containment should be

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designed to handle. Use of Table III of Appendix A will permit comparison of the plant under review with previous plant capabilities.

When criteria on handling additional energy sources are established, direct comparisons can be made. In the meanwhile it is recommended that the M-W reaction and steam tube rupture numbers be calculated. When criteria on sizing of the engineered safety features are established, they will be distributed for comment.

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