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THE RESPONSE OF THE SPENT FUEL POOL TO POSTULATED ACCIDENT CONDITIONS

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MAJOR POINTS

1. Given an accident condition, such as loss of the heat removal function, the response of the pool and the fuel assemblies should be analyzed in a realistic manner.
2. With spent fuel pool water inventory available the pool is adequately cooled for days without the pool cooling function.
3. If the pool water level were to decrease sufficiently to uncover the top of the fuel bundles as a result of the accident condition, the heat removed by boiling and steam flow is important and the power distribution is not important.
4. If the pool is assumed to eventually dry out, the fuel bundle configuration is somewhat influential.
5. If the fuel pins become sufficiently hot that oxidation (chemical energy release) becomes comparable to decay power, the chemical reaction increases the heat generation which in turn increases the reaction rate. With this escalation of the heat generation, the fuel bundle response would be similar to an "at power" case. In this case the zircaloy reaction getters the oxygen resulting in core geometry changes (liquefaction, melting and relocation) comparable to the TMI-2 core response but on a somewhat longer time scale.

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APPROACH TO EVALUATIONS

- All evaluations should use a mechanistically identified failure condition.
- Evaluations should assess the results of potential recovery actions consistent with the postulated accident initiator.
- Evaluations should consider all mechanisms for cooling and for energy generation, including the results of vaporization of water in the lower regions of the pool as well as natural circulation of air.

FOCUS FOR ANALYTICAL MODELS

- Spent fuel pool is at atmospheric pressure.
- Flow within the fuel assemblies is laminar, i.e. resistances are well characterized by standard representations.
- Openings in individual fuel assemblies are influential flow paths and should be considered.
- The fuel assembly distribution within the pool does not matter for those accident conditions where the water inventory decreases below the top of fuel until the water is at about 70% of the fuel assembly height. The fuel assembly distribution would matter in the multi-dimensional flow pattern that would develop at lower water levels, i.e. if a thermal plume is developed.

EXAMPLE OF A POSTULATED ACCIDENT CONDITION AND THE RESPONSE BOILDOWN RATE

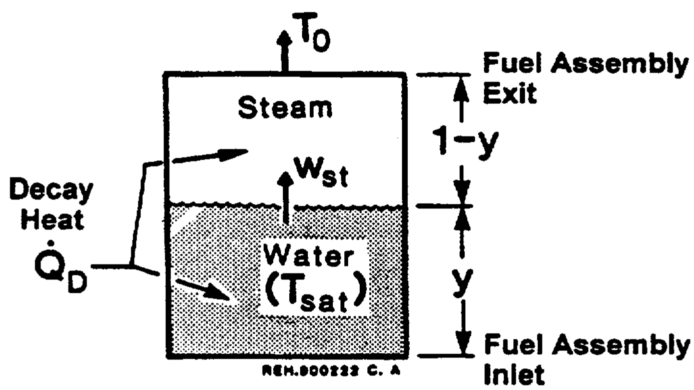
- Assume an average power of 5 kw/assy and 1000 fuel assemblies = 5 MW.
- Assume the pool is 27 ft. (8.2 m) x 23 ft. (7.0 m).
- Boildown rate when the water level is above the fuel is about 5.4 in/hr. (14 cm/hr).
- If the water level progresses into the fuel assembly, this rate is then about 9 in/hr. (23 cm/hr.).
- This boildown can be stopped with a water addition rate of about 35 gpm.

ESTIMATION OF PEAK CLADDING TEMPERATURE FOR ASSUMED ACCIDENT CONDITIONS WHERE THE TOP OF THE FUEL IS UNCOVERED – ASSUMPTIONS –

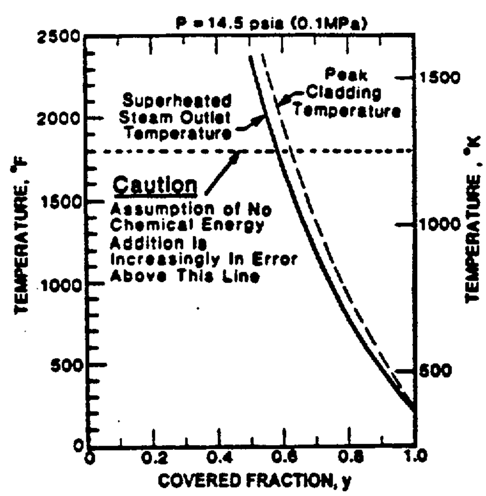
1. The process is quasi-steady.
2. Steam and water are the only fluids in the core.
3. The inlet water is at the saturation temperature T_{sat}.
4. The decay heat (Q_D) is constant along the fuel pin length.
5. The collapsed water level (y) can be used to represent the covered portion of the fuel assemblies.
6. The cladding temperatures remain low enough that the energy released by Zircaloy oxidation is an insignificant fraction of the decay heat.
7. This results in

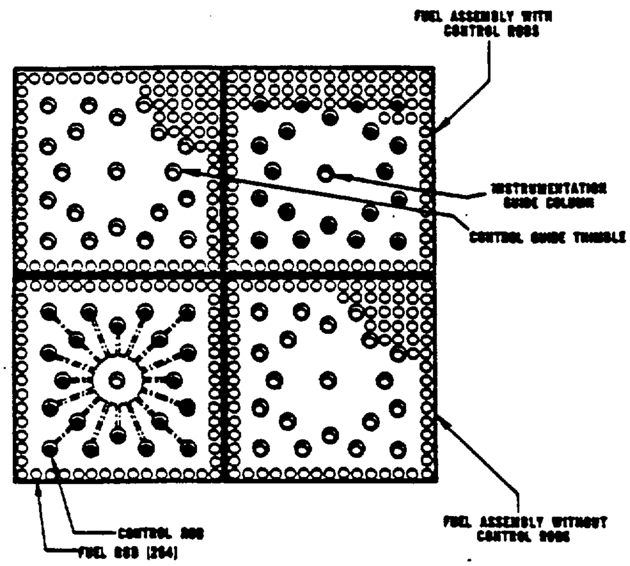
$$T_o - T_{sat} = \left[\frac{1-y}{y}\right]\frac{h_{fg}}{c_{pg}}$$

QUASI-STEADY HEAT REMOVAL



QUASI-STEADY CLADDING TEMPERATURE FOR A PARTIALLY UNCOVERED GROUP OF FUEL ASSEMBLIES





ESTIMATE OF NATURAL CIRCULATION COOLING BY AIR

$$\Delta P = f\left(\frac{L_1}{D}\right)\frac{\overline{\rho}\,U^2}{2} = \Delta\rho\, g\, L_h$$

$$f = \frac{64}{N_{Re}}; \quad \Delta\rho = \frac{\Delta\rho_{max}}{2}; \quad \dot{Q}_D = \overline{\rho}\, A_F\, U\, c_p\, \Delta T_{max}$$

$$\Delta T_{max} = \overline{T}\left[\frac{\dot{Q}_D}{A_F}\left(\frac{L_1}{L_h}\right)\right]^{1/2}\left[\frac{64\,\nu}{g\,D^2}\,\frac{R}{P\,M_w\,c_p}\right]^{1/2}$$

CONCLUSIONS

1. Each evaluation should have a well defined failure condition and recovery actions.
2. For the spent fuel pool there are long intervals available for recovery actions to be implemented.
3. For postulated accident conditions that preclude any recovery actions, the fuel assemblies would eventually increase in temperature sufficient for significant Zircaloy clad reaction. Under these conditions the chemical energy release would dominate the fuel bundle response and this would be similar to those accident conditions considered for "at power" states.