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Here is an idea to kick around. Please let me have your reactions.

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DRAFT

Pressure-Suppression Containments

1. Conclusions and Recommendations

Recent events have highlighted the safety disadvantages of pressure-suppression containments. While they also have some safety advantages, on balance I believe the disadvantages are preponderant. I recommend that the AEC adopt a policy of discouraging further use of pressure-suppression containments, and that such designs not be accepted for construction permits filed after a date to be decided (say two years after the policy is adopted).

2. Discussion

A pressure-suppression containment system has some means of absorbing the heat of vaporization of the steam in the fluid released to the containment volume. In all three GE models, the steam is forced to bubble through a pool of water and is condensed. In the Westinghouse design, the steam is condensed by flowing it over ice cubes. The objective is to reduce the pressure in the containment through "suppressing" the partial pressure of the steam by condensing it. To be effective, pressure suppression must take place concurrent with the flow of steam into the containment, and its effectiveness is therefore dependent on the rate at which steam is generated or released. If some unexpected event should result in steam generation or flow greater than the suppression capability, then the steam that is not condensed would add an increment of containment pressure. Since the objective of pressure suppression is to permit use of a smaller containment, rated at lower pressure than would be required without suppression, then incomplete suppression would lead to overpressurizing a pressure-suppression containment so designed.

It may be noted that the Stone and Webster "subatmospheric" design has little effect on the initial containment pressure rise due to an accident, and is therefore not a "pressure-suppression containment" for the present discussion. In this design, chilled water sprays are used to reduce the containment pressure, and therefore the containment leakage, quickly after a postulated LOCA. The pressure capability and volume are designed to take the full accident, without credit for condensation.

Like all containments, the pressure-suppression designs are required to include margins in capability. Experiments have been conducted by GE and Westinghouse to establish the rate of steam generation that can be accommodated. The pressure-suppression pools, ice condenser, etc., are then sized for the double-ended break steam flow, with margins for unequal distribution of steam to the many modular units of which the condenser is composed. The rate and distribution margins are probably adequate.

More difficult to assess is the margin needed when applying the experimental data to the reactor design. Recently we have reevaluated the 10-year-old GE test results, and decided on a more conservative interpretation than has been used all these years by GE (and accepted by us). We now believe that the former interpretation was incorrect, using data from tests not applicable to accident conditions.

We are requiring an independent evaluation of the ice condenser design and its bases to make less probable any comparable misinterpretation of this design.

Since the pressure-suppression containments are smaller than conventional "dry" containments, the same amount of hydrogen, formed in a postulated accident, would constitute a higher volume or weight percentage of the containment atmosphere. Therefore, such hydrogen generation tends to be a more serious problem in pressure-suppression containments. The small GE designs (both the light-bulb-and-doughnut and the over-under configurations) have to be inerted because the hydrogen assumed (per Safety Guide 7) would immediately form an explosive mixture. The GE Mod 3 and the Westinghouse ice condenser designs (they have equal volumes) require high-flow circulation and mixing systems to ensure even dilution of the hydrogen to avoid flammable mixtures in one or more compartments (see following for an additional serious disadvantage of this needed recirculation and its valves). By contrast, the dry containments only require recombination or purging starting weeks after the accident.

All pressure-suppression containments are divided into two (or more) major volumes, the steam flowing from one to the other through the condensing water or ice. Any steam that flows from one of these volumes to the other without being condensed is a potential source of unsuppressed pressure. Neither the strength nor the leakage rate of the divider (between the volumes) is tested in the currently approved programs for initial or periodic inservice testing. Some effort is now underway to devise a leakage test, but none has so far been accomplished.

Because of limited strength against collapse, the "receiving" volume has to be provided with vacuum relief. In all designs except GE Mod 111, this function is performed by a group of valves. Such a valve stuck open is a large bypass of the condensation scheme; the amount of steam that thus escapes condensation can overpressurize the containment.

Valves do not have a very good reliability record. Recently, five of the vacuum relief valves for the pressure-suppression containment of Quad Cities 2 were found stuck partly open. Moreover, these valves had been modified to include redundant "valve-closed" position indicators and testing devices, because of recent Reg concerns. The redundant position indicators were found not to indicate correctly the particular partly open situation that obtained on the five failed valves. We have only recently begun to pay serious attention to these valves, so previous surveillance programs have not generally included them. The GE Mod 111 design has an elegant water-leg seal that obviates the need for vacuum relief valves.

The high-capacity atmosphere recirculation systems provided for hydrogen mixing involve additional valves which, if open at the wrong time, would constitute a serious steam bypass and thus a potential source of containment over-pressurization. These valves are large, and must open quickly and reliably when recirculation is needed. In other engineered safety features, no single valve is relied on for such service, yet redundancy has not been provided even for single failures, open and closed, of these valves. This is a serious mission, since opening at the wrong time leads to over-pressurization, while failure to open when needed inhibits recirculation.

The smaller size of the pressure-suppression containment, plus the requirement for the primary system to be contained in one of the two volumes, has led to overcrowding and limitation of access to reactor and primary system components for surveillance and in-service testing. Separate shielding of components has tended to subdivide into compartments the volume occupied by the primary system. (Some compartmentation of dry containments also occurs.) A pipe break in one of these compartments creates a pressure differential; each compartment must be designed to withstand this pressure. A method of testing such designs has not been developed.

What are the safety advantages of pressure suppression, apart from the cost saving. GE people talk about a decontamination factor of 30,000 from scrubbing of iodine out of the steam by the water. This is hard to swallow, but some decontamination undoubtedly occurs. One wonders why GE doesn't do an experiment to measure it, and get credit for it. The ice condenser decontamination is measurable but not significant.

Recirculation of the containment atmosphere through the ice has the potential for rapidly reducing the containment pressure by cooling its atmosphere. But in the present design there's not enough ice for that, so containment sprays are furnished (in both volumes), just as in dry containments. Recirculation through the water in the GE designs seems not to have been tried, but may be necessary in Mod 111 for hydrogen control. We have no analysis whether any significant cooling will result.

It is by no means clear that the pressure-suppression containments are, overall, significantly cheaper than dry containments when all costs are included. Information on this point would be useful in evaluating costs and benefits, and should be obtained.