Neutron embrittled reactors worry NRC

The toughest part of a pressurized water reactor (PWR) is the pressure vessel that houses its core. It has to be tough, because, as one Nuclear Regulatory Commission official characterized it last week, it's the "last line of defense": Any breach and it could spew its radioactive guts, setting off a nuclear meltdown and the venting of potentially lethal clouds of radioactive gases into the atmosphere. And NRC officials now worry that several older nuclear plants are becoming potentially vulnerable to just such breaching. The cause is a faster than anticipated embrittling of reactor pressure vessels from the routine bombardment by neutrons radiated from the reactor's fissioning core.

At low temperatures metal becomes brittle and if stressed can crack or shatter, almost like glass. Pressure vessels are huge, metal containers six or more inches thick, welded together from several pieces. While they should be able to handle temperatures down to from 0°F to 40°F when new without becoming brittle, under steady neutron irradiation the metal changes, taking on brittle characteristics at higher and higher temperatures. Under a reactor's normal operating temperatures, this escalating embrittlement phase presents no problem.

The problem occurs when the pressure vessel, warmed by the core to about 560°F, is suddenly cooled. As the temperature on the inside of the vessel wall starts to fall, the wall tries to contract. The wall's still-warm outer side prevents that. If the core remains highly pressurized, the vessel experiences tensile stresses superimposed upon thermal stresses that result from the thermal gradient across the vessel wall. Cracks may form or hairline fractures enlarge and then radiate out through the wall in pulsing sequences, particularly if the pressure inside the vessel oscillates.

Last week NRC's commissioners met with staff safety analysts to discuss the threat to older, embrittled PWR's posed by pressurized thermal shock — a type of "transient" (unusual operating event) — that can lead to the accidental overcooling of a reactor. Overcooling may occur whenever emergency core-cooling systems flush water (perhaps 40°F to 80°F) through the vessel to prevent the core from overheating or building up excess pressure — either could be disastrous. But for reactor vessels whose walls become brittle at 200°F or higher (see list), 40°F cooling water could also prove disastrous — literally a shattering experience. And a March 20, 1978, accident involving the Rancho Seco nuclear plant involved pressure vessel cooling of 300°F per hour.

A fracture-mechanics study reported by Oak Ridge National Laboratory this February indicated that had the Rancho Seco overcooling transient occurred after the plant had operated the equivalent of 10 years at full power, the probability of its pressure vessel rupturing "would have been very high." NRC now realizes the plant was lucky; it had operated only about four full-power years.

EMBRITTLEMENT RANGE

PLANT	NEAR	TEMP °F
Fort Calhoun	Ft. Calhoun, Neb.	250-280
Robinson 2	Hartsville, S.C.	250-280
San Onofre	San Clemente, Calif.	250-280
Maine Yankee	Wiscasset, Maine	200-230
Palisades	South Haven, Mich.	190-220
Yankee Rowe	Rowe, Mass.	180-210
Oconee 1*	Seneca, S.C.	160-190
Zion 1	Zion, Ill.	150-180
Arkansas ANO-1*	Russellville, Ark.	150-180
Indian Point 2	Buchanan, N.Y.	150-180
TMI-1*	Middletown, Pa.	140-170
Rancho Seco*	Clay Sta., Calif.	130-160
Surry 1	Gravel Neck, Va.	120-150
Crystal River 3*	Red Level, Fla.	110-140

*Nuclear steam-supply system manufactured by Babcock & Wilcox

NRC data

Plants whose pressure vessels (PVs) run the highest risk of developing rupturing cracks during pressurized thermal-shock accidents. Although the PVs were designed to reach temperatures in the range of 0°F to 40°F before embrittling when new, they are now expected to become brittle at temperatures as high as those shown because of routine neutron irradiation. The upper cutoff for the brittle range will continue to climb slowly each year of continued operation.

Rancho Seco experienced the most severe overcooling event thus far, but not the only one. Fourteen others have occurred since May 1973 in Babcock & Wilcox nuclear steam-supply systems. Each transient exceeded the 100°F per hour cooling limit set forth in NRC technical design specifications. B&W designs are considered most prone to transients that could precipitate overcooling, although no PWR systems are totally immune.

For the time being NRC is studying the oldest, most vulnerable plants to assess their vulnerability and to work out contingency plans for their dealing with transients that could precipitate overcooling events.

"I think we've got a year, most of the staff would probably say five," before any of the most vulnerable reactors would crack in a Rancho Seco type transient, said an NRC safety official last week. But he added, "We know [these plants] are not going to last their full design lifetimes." Among corrective actions contemplated is a costly in-place annealing of the vessel to temporarily reverse its embrittlement. □

Sealing the fate of encapsulation

Anthony McMahon did not expect to walk away from the recent conference in Washington on asbestos encapsulants (sealants) with a lowered opinion of that type of asbestos control. While he and his colleagues at the New Jersey Department of Environmental Protection have been advising against the use of encapsulants to seal asbestos-containing material in nearly all cases, McMahon attended the conference "expecting to hear that encapsulation is advisable in some cases." But, "The opposite happened: More problems associated with encapsulation that we did not know about were raised," he says.

Encapsulation involves covering asbestos-containing material with either a sealant that penetrates and hardens the material or a bridging sealant that protectively coats the material to prevent fiber release. Like removal of asbestos-containing material or the construction of barriers such as drop ceilings, the purpose of encapsulation is to minimize human exposure to asbestos — a naturally occurring mineral that readily separates into fibers that can cause asbestosis (a noncancerous lung disease) and cancers of the lung and other organs (SN: 7/15/78, p. 41). Although EPA officials have no precise figures, they know that encapsulants "have been used rather extensively" in schools and other buildings to control friable, or easily pulverized, asbestos-containing materials. So after receiving reports that called into question the ability of this method to "provide a long-term solution to asbestos problems," EPA officials organized the recent conference to discuss certain issues regarding encapsulation.

One such issue concerns the validity of the tests that were run on encapsulants. Battelle Columbus Laboratories — awarded an EPA contract to research encapsulation — conducted encapsulant tests on a mineral-wool-containing, rather than an asbestos-containing material. "Although Battelle did learn quite a bit about how different encapsulants compare to one another, it is difficult to tell what the relationship of these test results is to any kind of performance in the field," says EPA's Forest Reinhardt. In fact, "There have been cases in which an encapsulant that looked good on the mineral wool...did not perform well on amosite [as opposed to chrysotile] asbestos when applied in the field," he says.

As a result of such uncertainty, EPA now is working with the American Society for Testing and Materials to formulate a set of standards for testing encapsulant performance. Reinhardt says, "It will be 18 months before the thing hits the street." Meanwhile, EPA officials continue to believe that encapsulation is an appropriate means of asbestos control in certain situations. Says Reinhardt: "We don't see sufficient evidence to take as strong a position as New Jersey's." □