Evaluation of Containment Penetration Elevated Temperature Readings (Point Beach)
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Reference- 1) PB OPR 000096 (CAP051854)
2) Paper SP 34-23 - Cure and Prism Strength of Concrete at Elevated Temperatures - A.E. Desov, K.D. Nekrasov, and A.F. Milovanov from ACI special publication SP-34 Copyright 1972.
3) Paper SP 34-24 - Effects of Temperature on the Properties of Concrete for the Containment and Shielding of Nuclear Reactors - M.F. Kaplan and F.J. P. Roux from ACI special publication SP-34 Copyright 1972.

Background: In reference 1, the licensee evaluated temperatures (up to 382 °F) identified at MS line containment penetrations and assumed high temperatures at similar penetrations for FW lines. Licensee used provision in ACI 349-75 which allowed local high temperatures if there is evidence that the increased temperatures have not caused deterioration of concrete and the design allowables are reduced. Licensee used lower bound compressive strength at 400 °F from figure 4.4 of EPRI TR-103835 (65% of f_c for containment= 3250 psi) in their evaluation. Based on anticipated loads this left a 43% margin to design allowable loads ($0.85*f_c$ @ 400 °F).

Technical Background: From reference 2, the two key mechanisms reducing concrete compressive strength in this temperature range include 1- the difference in coefficient of linear expansion between the aggregates and cement which serves to partly or completely break the bonds and, 2 - diffusion of moisture from concrete and dehydration of mineral components of the cement. Additionally, the cracking resistance of the concrete is reduced. Reference 2 also identified based upon 4 different samples of cement heated to different temperatures that the worst cement tested had a 43% reduction in strength after heating for 20 days at 212 °F. It appears the average was a 36% loss in strength reduction with a 19 % variability for tests below 400 °F. Also in reference 2, "Enlarging of the aggregate grain sizes from 10 to 40 mm provokes the supplementary decreasing of the prismatic concrete strength by 30 percent after one cycle of heating [up to 400 °F]." In reference 3, concrete heated for 6 hours to 212 °F had a 20 percent reduction in compressive strength while concrete heated to 482 °F showed no decrease in compressive strength.

Inspectors Comments, Conclusions & Recommendations:

It is clear that the test data shows large variability in concrete strength based upon the composition of the actual cement and aggregate tested. It is also likely that the two principle damage mechanisms (discussed above) could lead to progressively worse results for concrete compressive strength and the longer term affects have not been well studied (e.g. large numbers of thermal cycles and longer times at elevated temperature).

I concluded that the licensee evaluation supports operability of the penetrations. Even using worst case test data in this literature (e.g. assuming a 57% of f_c for containment = 2850 psi) I calculated that the licensee still had margin to design limit (2762 psi). However, because the elevated temperature operations appear to cause irreversible damage and may lead in the longer term to more severe degradation (e.g. continued loss of compressive strength) a design change is needed to permanently accept the concrete around these penetrations.

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Longer term (next outage) the licensee would need to implement a design change and perform a 50.59 review to accept the thermally stressed concrete for continued service (even if they insulate the concrete it may still be thermally damaged from past plant operation). If the licensee pursues a design change they would need a much more substantial elevated test documentation (using the actual aggregates and cement types in their containment) to support accepting the change in concrete material strengths. To illustrate this point, look at ACI 349-71, section 2.5 "Design" which states under design thermal limitations "Under normal operating conditions, 150F (66C), except 200 F (93C) for local areas such as at pipe penetrations, unless valid evidence of material behavior and attendant analysis is presented which establishes the acceptability of higher operating temperatures." Further, this design change may still require NRC approval due to reduction in design margins from the 5000 psi strength stated in their UFSAR.

One other issue to pursue. I did not see a licensee evaluation on the impact to the grease packed around the tendons at their estimated 250 degree local temperature.