AEOD ENGINEERING EVALUATION REPORT*

UNIT: D.C. Cook Nuclear Plant, Unit 1
DOCKET NO: 50-315
LICENSEE: Indiana and Michigan Electric Company
NSSS/AE: Westinghouse/AEP

EE REPORT NO.: AEOD/E701
DATE: January 21, 1987
EVALUATOR/CONTACT: S. Israel

SUBJECT: POTENTIAL CONTAINMENT AIRLOCK WINDOW FAILURE DUE TO RADIATION

EVENT DATE: April 16, 1986

SUMMARY

On April 16, 1986, the licensee for the D.C. Cook plant notified the NRC that vendor-supplied information on testing of windows for containment airlocks showed that the glass shattered when subjected to a beta dose of 2.5 megarads in 10 seconds. Each unit contains two airlocks and each airlock has an inner and outer window. Because of the uncertainty associated with the applicability of the test results to D.C. Cook, the licensee decided to install 3/8-inch thick cover plates over the inner windows in both units to eliminate the potential beta radiation of the windows.

The potential safety significance of the failure of the windows is the loss of containment isolation (six-inch hole) following a design basis accident. Such a loss would result in increased offsite doses which directly affect the public, or would result in an adverse impact on plant accident recovery and mitigation activities. Because the precise failure mechanism remains unknown, there is uncertainty that the windows would function adequately at the less severe beta dose rates anticipated for design basis accidents. Therefore, we suggest that the Office of Nuclear Reactor Regulation rereview the acceptability of airlock windows with respect to design basis accidents.

Our investigation also noted that there is information that may indicate potential reduction of the fracture strength of the windows at high integrated gamma doses. Although the reduction does not affect containment integrity in the vicinity of design pressures, it may have implications for severe accident scenarios which produce containment pressures significantly higher than the design pressures. Therefore, we suggest that airlock windows be reviewed as part of the Severe Accident Program.

We have not directly suggested eliminating the window because there may be other data sources available to assuage the uncertainty associated with this issue.

*This report supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

DISCUSSION

1. Event Description

On April 16, 1986, the licensee for the D.C. Cook plant notified the NRC (Ref. 1) that vendor-supplied information on testing of windows for containment airlocks showed that the glass shattered when subjected to a beta radiation dose of 2.5 megarads over a 10-second period. Each unit of D.C. Cook contains two airlocks, one in the upper containment, the other in the lower containment. Each airlock has an inner and outer door which contains a window. The test specimen was made of tempered glass, while the D.C. Cook windows are untempered glass. The licensee performed an integrated beta radiation dose calculation which showed that a dose of 2.5 megarads could be reached in less than one hour following a loss-of-coolant accident (LOCA).

In spite of the uncertainty in the applicability of the test conditions and results to the D.C. Cook plant, the licensee elected to install 3/8-inch thick steel cover plates over the inner door windows in both units. These cover plates act as beta shields and thus eliminate beta doses to the windows for all accident conditions. Subsequent reevaluation of the test report by the licensee did not resolve the uncertainties associated with the impact of beta radiation on the windows.

2. Analysis and Evaluation

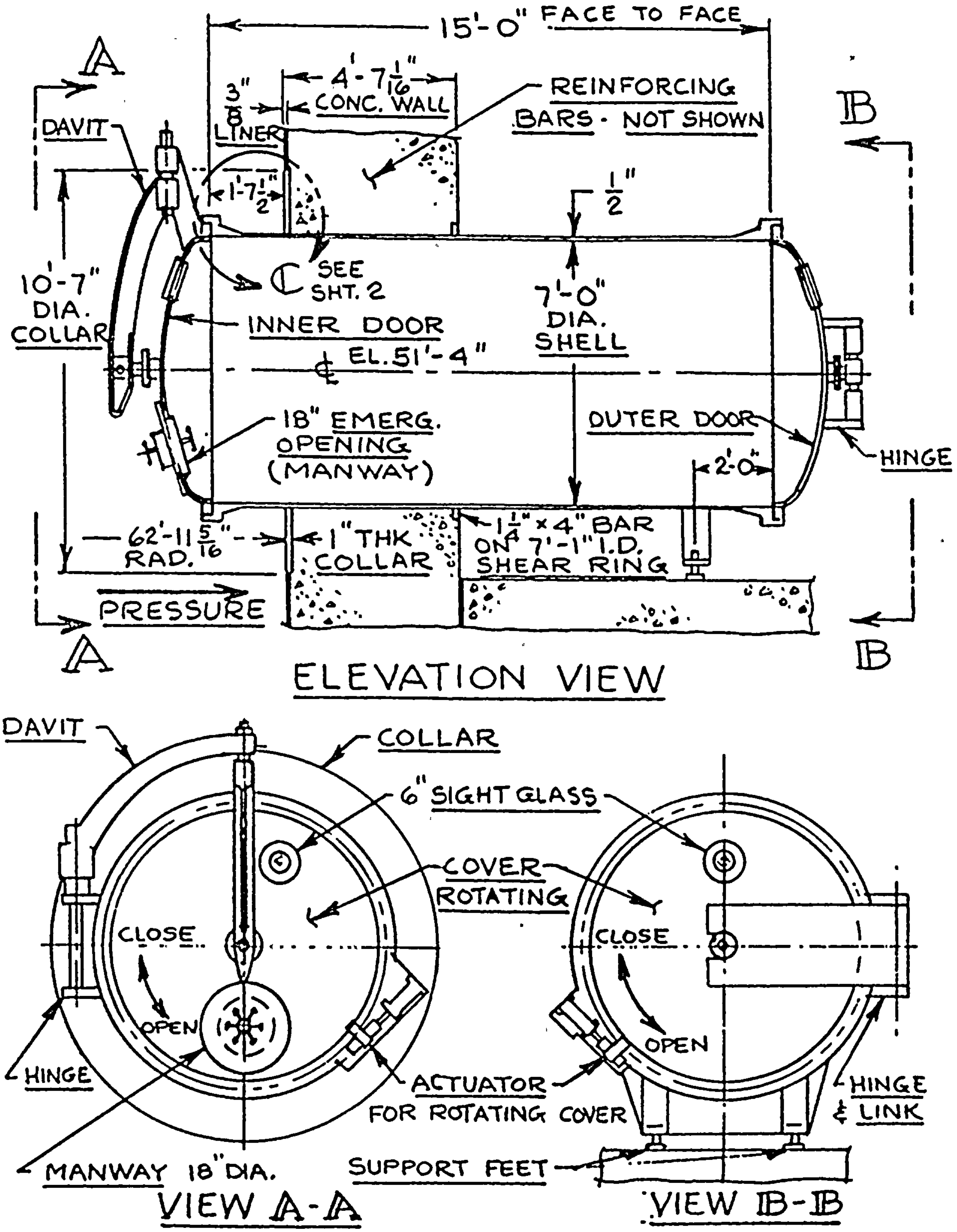
A report on containment penetrations (Ref. 2) indicates that airlock windows are used in many plants. The airlocks have inner and outer doors, as shown in Fig. 1, each of which is capable of maintaining structural integrity up to the design pressure of the containment. Both doors are normally secured during operation except when personnel are entering or leaving the containment, in which case only one door may be open at a time. The windows are typically about 6 inches in diameter by 3/4 inch thick. According to one airlock fabricator (Ref. 3), the older designs use untempered glass, while the newer designs use tempered glass.

The airlock fabricator for the D.C. Cook plant has performed several radiation tests on glass windows to demonstrate compliance with specifications in purchase orders for different plant installations. The original qualification report applicable to the D.C. Cook plant (Ref. 4) showed that all four window samples passed the 60-psig test requirement after being irradiated with a 1.0 megarad/hr gamma source to exposures of 33.0 to 36.3 megarads. However, at elevated pressures, one window failed at 110 psig while two windows survived to 120 psig without breaking. The fabricator also performed a test on tempered glass using integrated gamma doses up to 150 megarads. These tests demonstrated that the windows could meet the 80 psig design pressure. However, beta radiation test consisting of a beta dose of 2.5 megarads over a 10-second period resulted in glass failure with no differential pressure across the window.

Regulatory Guide 1.89 (Ref. 5) on the environmental qualification of electric equipment permits use of a gamma source only if supporting analyses show that the doses and dose rates produce similar damage to that which would occur under

Figure 1

Example of Containment Airlock



accident conditions, i.e., a combination of beta and gamma sources. The airlock fabricator used conversion charts provided by the architect-engineer to specify the appropriate gamma source for the tests.

Radiation sources inside containment following a loss-of-coolant accident or a postulated severe core-melt accident may exist as aerosols, gases, deposits on the walls inside the containment, or as sediment located under water in the containment sump. Since beta particles have a short migration length (can be stopped in about 29 feet of air at standard temperature and pressure), beta dose rates would be expected to vary considerably with location in the containment. The airlocks are generally located behind the crane wall and 30 to 80 feet above the containment sump. Thus, as a first approximation, we have considered only airborne beta sources for potential radiation effects on windows in the airlocks. Two documents have estimated beta dose rates inside containment following a LOCA (Refs. 5 and 6). Both references assumed approximately a 4000-MWt reactor inside a 2.2×10^6 cubic foot containment with 100 percent noble gas release and 25 percent Iodine release. The results indicate that the beta source is dominated by the noble gases with Iodine contributing less than 16 percent. The estimated beta doses (assuming uniform distribution of the noble gases) ranged from 6 to 20 megarads in one hour. These dose rates are considerably less than that used in the window test cited above (approximately 900 megarads/hr), but the total doses expected for a LOCA are somewhat higher than those obtained in the beta radiation test.

The above calculations reflect 100 percent noble gas release which is highly conservative for LOCAs. A more realistic value may be fuel rod gap activity only. The Reactor Safety Study (WASH-1900) estimated 3 percent release for the noble gases in the fuel rod gap and 2 percent for Iodine. Thus, a more realistic beta dose rate following a LOCA would be less than one megarad in one hour, which is substantially less than the dose rate used in the test.

Our estimate of the adiabatic temperature increase for glass irradiated uniformly to 2.5 megarads is about 50°F. Since the test was not adiabatic, the temperature rise estimate is consistent with the test observation that the specimen surface temperatures never exceeded 100°F during the test (Ref. 7). Estimated thermal stress associated with a 30 to 50°F temperature differential in glass is on the order of 1000 psi which is less than the expected fracture strength of glass not in a radiation field. However, the fracture strength of glass may be degraded while it is undergoing beta irradiation.

Another hypothesized failure mechanism is excessive thermal stress associated with spontaneous discharge of the charge built up on the specimen because of the electron absorption. The arc point could generate significant temperatures depending on the discharge current. The test report did not indicate any arcing; however, grounding of glass windows in hot cells is a common practice to dissipate irradiation effects. It is not known whether the installed airlock windows are grounded. Thus, the precise combination of causal factors leading to the glass failure is not certain.

Sandia has performed beta radiation tests on glass samples (Ref. 8) that did not show any damage for exposures of about 2 megarads in 200 nanoseconds.

Although these dose rates are higher than those used in the fabricator's test, the sample thickness was only about 0.020 inch so that the energy deposition was relatively uniform compared to that in a 3/4-inch thick window. Consequently, the Sandia tests are not considered directly applicable to the airlock situation.

3. Safety Significance

The failure of one window (on the inner wall of the airlock) would not compromise the containment integrity because the outer door is designed to provide redundant isolation following a design basis accident. If the inner window failed because of beta radiation effects following a LOCA, the airlock would pressurize with the same environment that caused the failure of the inner window. Thus, the conditional probability of failing the window on the outer wall of the airlock is fairly high (approaches 1) if the inner window failed from beta radiation. The loss of both windows would result in a 6-inch hole in the containment which would increase offsite doses for design basis events. Furthermore, such a 6-inch hole in containment would result in a significant leakage of radioactivity into the auxiliary building in which important equipment necessary for post-accident recovery and mitigation are located. High radiation could adversely affect plant personnel access to these areas for accident recovery and mitigation.

Potential beta dose rates following a core-melt accident are not expected to be significantly higher than those used for qualifying equipment for LOCA environments, except for scenarios that involve energetic dispersion of the corium following vessel melt-through. Such violent dispersion would probably challenge containment integrity directly. Therefore, any concern for potential degradation of the airlocks in such a scenario is diminished.

The impact of gamma doses on the strength of the window material is less certain. The fabricator has data that shows one of four windows failed at 110 psig after an exposure to about 35 megarads (gamma) and no failures at 80 psig for windows exposed to 159 megrads (gamma). These pressures are above the design pressures associated with a design basis event; however, the one failure at 110 psig is within the range of interest to severe accident scenarios and could result in early containment "failure" for such events.

FINDINGS AND CONCLUSIONS

1. Beta radiation dose rates following a LOCA or a core melt would probably be significantly less than the beta dose rate that caused the airlock window failure. However, it is not clear that the dose rate is the only or even the principal parameter causing a glass window to fail.

2. The total dose is comparable to expected short term values following a LOCA. Since the failure mechanism is unknown, we do not know if it is dose or dose rate (or both) that matters.

3. Thermal stresses within a 3/4-inch thick glass window are estimated to be small for the beta dose rate used during the test.

4. Integrated gamma doses (on the order of 35 megarads) may reduce the fracture strength of windows in the containment airlocks. Although the degradation does not reduce the glass window pressure capability to below the containment design pressure, it may adversely affect the window pressure capability during severe accident scenarios.

5. Because the precise failure mechanism of a glass window undergoing beta radiation is uncertain, there is uncertainty that the windows would function adequately during design basis accident conditions.

SUGGESTIONS

In view of the recently reviewed beta radiation test results and in the absence of a precise understanding of the window failure mechanism, we suggest that the Office of Nuclear Reactor Regulation rereview the acceptability of airlock windows with respect to design basis accidents. Additionally, because the observed failure pressure for windows having undergone gamma irradiation was in the range of interest for severe accident evaluations, it is suggested that the Division of Safety Review and Oversight, NRR, consider the implications of windows in the airlocks as part of the Severe Accident Program. We have not directly suggested eliminating the window because there may be other data sources available to assuage the uncertainty associated with this issue.

REFERENCES

1. Licensee Event Report 86-005, Docket 50-315, D.C. Cook Nuclear Plant, Unit 1, April 16, 1986.

2. M. H. Shackelford, et al., "Characterization of Nuclear Reactor Containment Penetrations Final Report," NUREG/CR-3855, January 1985.

3. R. M. Hulick, Enerfab, Inc., personal communication, December 11, 1986.

4. Letter from R. Heishman (NRC) to D. Godfrey (Enerfab, Inc.) dated October 20, 1986.

5. Regulatory Guide 1.89, Rev. 1, "Environmental Qualification of Electric Equipment Important to Safety for Light-Water-Cooled Nuclear Power Plants."

6. L. Bonzon, "Radiation Signature Following the Hypothesized LOCA," NUREG-76-6521, September 1977.

7. R. M. Hulick, Enerfab, Inc., personal communication, December 17, 1986.

8. W. Buckalew and L. Posey, "Electron Beam Diagnostics: Part I," SC-RR-69-512, October 1969.