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NEC-JH_54

Assessment of Proposed Program to Manage Aging of the Vermont Yankee Steam Dryer Due to Flow-Induced Vibrations

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I. Basic Concepts

NEC's Contention Three addresses Entergy's plan to manage aging of the Vermont Yankee (VY) steam dryer due to flow-induced vibration, mechanical vibration resulting from interactions between the elastic forces in the dryer and the dynamic forces of the flowing steam. Such vibrations can result when the dryer or one of its components sheds vortices due to boundary layer flow separation at the surface. These vortices create pressure oscillations near the dryer, causing the dryer to vibrate. When the natural frequency of the dryer or one of its components is close to the shedding frequency of the vortex, the resulting vibrations can cause catastrophic damage to the dryer.

The frequencies at which vortices are shed from a structure are correlated with a nondimensional number called the Strouhal number; $S = f D/V$, f is the frequency, D is a dimensional length, V is the flow velocity, S is an empirical number that depends on the Reynolds number. For high Reynolds numbers and simple geometries, such as a cylinder, S is approximately a constant, making the frequency directly proportional to the flow velocity. For a given structure, a small change in velocity may cause the vortex shedding frequency to increase and approach the natural frequency of the structure.

II. Background.

The steam dryer has no safety functions. However, the structural integrity of the dryer must be maintained such that the generation of loose parts is prevented during normal operation, transients[1] and accident events. A public safety hazard would result if the dryer was damaged and some of its parts broke loose and were transported by flow or gravity to other areas of the reactor system. Loose parts may block flow channels in the reactor core, block spray cooling nozzles, or prevent the main steam isolation valves ("MSIVs") from isolating the system during loss of coolant accidents ("LOCA"). This is a direct threat to public health and safety and in violation of General Design Criteria GDC 1 and Draft GDC -40 and -42, 10 CFR Part 50, Appendix A insofar as they require that protection must be provided against the dynamic effects of loss of coolant accidents, LOCA.

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[1] A "transient" is the plant response to a change in power level.

At the beginning of 2006, the operating power at the Vermont Yankee plant was increased by 20%. This also increased the velocities by 20%. Other plants where the velocity was increased experienced crack formation in the steam dryer as described in GE SIL No. 644[2], as discussed further below. Consequently, Entergy installed strain gauges to monitor the condition of the dryer during accession to power. The strain gauges were installed in the main steam line (MSL) to monitor pressure fluctuations within the main steam flow. The data were then used as inputs to an acoustic circuit model (ACM) to calculate pressure loads on the steam dryer and the resulting stress in steam dryer components using a finite element model (FEM).[3]

III. Dryer Failures

GE Nuclear Entergy Service Information Letter, SIL No. 644, Revision 1 (November 9, 2004) provides a summary of experience with dryer failures following power uprates.[4] Failures due to both localized high and low frequency pressure loading occurred on dryers at two different power plants. In both cases, the failures at different locations on the dryer occurred from high cycle fatigue. The small pressure fluctuations in the steam lines (3-4 psi) indicate that even small pressure fluctuations on the dryer can generate altering stresses that exceed the endurance limit at some dryer locations.[5] This is important because it indicates that in order to predict whether the dryer will crack one must first know what the loads are on the dryer at various locations.

The history of steam dryer cracking at the VY plant indicates that Entergy's program to date of visual inspection and moisture monitoring have

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[2] Exhibit NEC-JH_55.

[3] See, ML060050028, Safety Evaluation by Office of Nuclear Reactor Regulation Related to Amendment No. 229 to Facility Operating License No. DPR28, Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc., Vermont Yankee Nuclear Power Station Docket 50-271 at § 2.2.6.2.1.

[4] Exhibit NEC-JH_55 at 1-5, Appendices A, B; See also, Exhibit NEC-JH_56.

[5] Exhibit NEC-JH_55.

been ineffective in identifying cracking at the time it occurs, when it occurs in between inspections.[6] General Electric evaluated crack formation in the dryer during the last refueling outage RF026.[7] GE believes that all the cracks were caused by intergranular stress corrosion cracking ("IGSCC"). However, GE did not rule out the possibility of continued crack growth by fatigue.

IV. Entergy's Proposed Steam Dryer Aging Management Plan Program

Entergy has represented that its aging management program for the steam dryer during the period of extended operations will consist exclusively of periodic visual inspection and monitoring of plant parameters as described in GE-SIL-644, and will not involve the use of any analytical tool to estimate stress loads on the steam dryer.[8] Entergy described its proposed program as follows:

> The aging management program for the VY steam dryer during the twenty-year license renewal period will consist of well-defined monitoring and inspection activities that are defined in GE SIL-644 guidelines and are identical to those being conducted during the current post-EPU phase. Steam dryer integrity will be monitored continuously via operator monitoring of certain plant parameters. VY Off-normal Procedure ON-3178 alerts the operators that any of the following events could be indicative of reactor internals damage and/or loose parts generation: a) a sudden drop in main steam line flow > 5%; b) > 3 inch difference in reactor vessel water level instruments; c) sudden drop in steam dome pressure > 2 psig. In addition, periodic measurements of moisture carryover will be evaluated in accordance with the requirements of GE-SIL-644. This monitoring program will continue for the entire license renewal period. The inspection activities will include

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[6] Exhibit NEC-JH_57; Exhibit NEC-JH_58 at 4-5; Exhibit NEC-JH_59; Exhibit NEC-JH_60.

[7] Exhibit NEC-JH_59.

[8] Exhibit NEC-JH_61 at ¶¶ 23-24.

visual inspections of the steam dryer every two refueling outages consistent with GE and BWR Vessel Internals Program (VIP) requirements. The inspections will focus on areas that have been repaired, those where flaws exist, and areas that have been susceptible to cracking based on reactor operating experience throughout the industry.

The aging management plan for the license renewal period, consisting of the monitoring and inspection activities described above, does not depend on, or use, the CFD and ACM computer codes or the [finite element modeling] conducted using those codes.[9]

GE- SIL-644 recommends visual inservice inspections during each refueling outage, but does not require any measurements that could indicate whether existing cracks in the dryer grow in number or length. Visual inspection of the dryer is done with a camera only in accessible areas.

V. Assessment of Proposed Steam Dryer Aging Management Plan

A. Basic Considerations

The steam dryer is susceptible to two types of cracks, (a) stress corrosion cracks, ("SC") and (b) fatigue cracks. Even when one can measure with Eddy Current the density or depth of existing SC cracks, there is no way of predicting how fast such cracks would reach a critical size and then propagate through the wall very rapidly given the presence of sufficiently high loads. Fatigue cracks are usually initiated at points of high stress concentrations which were formed during the fabrication process. Fatigue cracks may be slow to initiate, but once initiated they propagate very fast when exposed to alternating stresses of sufficient magnitude and frequency. Because of the two-stage process of crack formation, when one does not find cracks during inspection, there is absolutely no reason why such cracks would not start propagating once the plant is restarted. The steam dryer problem at VY is serious because we already know that the 20%

[9] Id.; see also, License Renewal Application § 3.1.2.2.11.

increase in velocity increased the potential for the creation of fluctuating pressure loadings. Small changes in local velocity may cause pressure frequencies of local pressure fluctuations to approach the natural frequency of the dryer.

There were problems in the interpretation of the strain gauge data during the accession to 120% at VY and the ACRS questioned the validity of the analytical models.[10] Following the accession to power, Entergy removed the instrumentation that was used to monitor the pressure fluctuations within the dryer.[11]

B. Aging Management Requirements

A sufficient steam dryer aging management plan at VY must include both 1) visual inspection of the steam dryer, and 2) some means of estimating and predicting stress loads on the steam dryer, establishing dryer flow induced vibration load fatigue margins, and demonstrating that stresses on the dryer at selected locations will fall below ASME fatigue limits. The ability to accurately assess and predict stress loads that may act on the dryer during the fuel cycle is essential to ensure the dryer's structural integrity. The visual inspection program and any repairs to the dryer must be informed by knowledge of dryer loads. Plant experience (see Part III, above) demonstrates that an aging management plans that consists solely of parameter monitoring, and partial visual inspection, uninformed by knowledge of dryer loading, will not be sufficient.

Plant parameter monitoring is not effective to prevent the generation of loose parts that can damage safety-related plant components. Most parameter monitoring (moisture, steam flow, water level, dome pressure) may indicate the formation of only those steam dryer cracks that increase moisture carryover; those cracks that do not lead to significant moisture carryover may continue to grow undetected. Moisture monitoring only indicates that a failure has occurred; it does not prevent the failure from occurring. In fact, GE-SIL-644 states the limitations of parameter monitoring as follows: "monitoring steam moisture content and other reactor

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[10] See, ML060040431, Letter to Nils J. Diaz from Graham B. Wallis re. Vermont Yankee Extended Power Uprate (January 4, 2006) at 5.

[11] Exhibit NEC-JH_61 at ¶ 27.

parameters does not consistently predict imminent dryer failure nor will it preclude the generation of loose parts."[12]

VI. Conclusions

For the above-stated reasons, I believe that the operation of the steam dryer, as currently intended by Entergy, is a direct threat to public health and safety and is in violation of GDC 1 and Draft GDC -40 and -42 insofar as they require that protection must be provided against the dynamic effects of a LOCA. I also believe that it was a mistake to remove the instrumentation for the determination of the loads on the dryer. Instead of eliminating all instruments, VY should have improved the analytical tools for predicting, the loads on the dryer, perhaps by conducting additional scaling test at GE at the San Jose facility.

Entergy must formulate a new plan to manage steam dryer cracking before entering the extended period of operation. The plan should be reviewed by a competent party with no financial ties to Entergy.

[12] Exhibit NEC-JH_ at 6.