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U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-0001

SUBJECT: Entergy Nuclear Generation Company
Pilgrim Nuclear Power Station
Docket No. 50-293

Recent Reactor Water Level Indication Issues

LETTER NUMBER: 2.02.026

Dear Sir or Madam:

Recently we have had several conversations with members of the NRC Regional Staff concerning three operating events in the year 2001 in which erroneous reactor water level indications were observed at Pilgrim Nuclear Power Station (Pilgrim). As a result of these discussions, we believed that it was appropriate to provide you a written summary, beyond that already provided in Licensee Event Reports, of the causes and corrective actions for each event as well as a current status of our future corrective actions.

As we have discussed, it is important to emphasize that although the three events shared the common attribute of erroneous reactor water level indication, the causes of the events were not the same. It is also important to note that in none of the events were required safety system actuations actually adversely impacted by erroneous water level indication. Furthermore, in each event other reactor water level indication was available. Therefore, each of these events was of minimal safety significance.

Pilgrim management fully recognizes and appreciates the importance of ensuring accurate and reliable reactor water level indication under all operating conditions. We believe that the actions we have taken to date in response to each of these events have been timely and appropriate commensurate with the safety significance of the issues.

If you desire further information, please contact Mr. Steve Bethay at 508-830-7800.

Sincerely,

Mike Bellamy

Attachment: 1. Recent Reactor Water Level Indication Issues

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Attachment 1

Recent Reactor Water Level Indication Issues

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Recent Reactor Water Level Indication Issues

A. Background

In the late 1980's and early 1990's, several Boiling Water Reactors (BWRs) experienced events in which erratic reactor water level indication was observed during periods of reactor depressurization. As a result, the Nuclear Regulatory Commission (NRC) issued Bulletin 93-03, Generic Letter 92-04, and Information Notices 92-54 and 93-27 describing reactor water level instrument operating problems resulting from non-condensable gases coming out of solution and forming "bubbles" in the instrument reference legs when the reactor depressurizes. This phenomenon came to be known as "Level Notching" due to the characteristic reactor water level recorder traces which showed sudden step changes in indicated water level at certain reactor pressures. The magnitude and duration of these step changes or "notches" could be correlated very closely to changes in static head in the instrument reference legs as bubbles moved upward through the reference leg toward the condensing chamber. In response to Bulletin 93-03, Pilgrim committed to perform hardware modifications via Reference 1 to the Emergency Core Cooling system (ECCS) and Anticipated Transient Without Scram (ATWS) initiation instruments reference legs. The NRC acknowledged the Pilgrim response via Reference 2. The Pilgrim design change, installed in 1993, is consistent with recommendations and resolutions provided by the BWR Owner's Group.

The intent of the installed system, the Instrument Reference Leg Backfill System, was to prevent migration of non-condensable gases from the two condensing chambers to the reference legs of the ECCS and ATWS initiation instruments. This system was not installed on all of the reactor water level instrumentation reference legs (e.g., the feedwater level instrumentation reference leg). The system installed was to provide a continuous flow (.008 gpm) of water to the reference leg side of the instruments. The Instrument Reference Leg Backfill System takes its water supply from the Control Rod Drive (CRD) system charging water header between the CRD header isolation valve and the Control Rod Drive Hydraulic Control Units (HCUs). The system then feeds the two reference legs through independent flow control stations and two in-series check valves (See Figure 1). Following installation of this system Pilgrim did not experience "notching" due to non-condensable gases during reactor shutdowns on the modified reference legs until the December 2001 event.

B. Recent Reactor Water Level Indication Issues

Three operating events occurred in the year 2001 in which erroneous reactor water level indications were observed at Pilgrim. Although the three events shared the common attribute of erroneous reactor water level indication, the causes of the events were not the same. It is important to note that in none of the events were required safety system actuations actually adversely impacted by erroneous water level indication. Furthermore, in each event, other level instrumentation remained fully functional. Therefore, each of these events was of minimal safety significance.

The following is a summary of the causes and corrective actions for each event as well as a current status of our future corrective actions.

1. Event During the Reactor Shutdown on 4/21/01

   a. Event

   On April 21, 2001, during reactor cool down to commence Refueling Outage #13, episodes of multiple, rapid level indication errors occurred which were characterized by positive level indication errors sometimes followed by negative level indication errors; oscillating and eventually converging at actual reactor water level.

   The actual water level was normal at the time of the event and alternate level indication was available to assess reactor conditions. Operations personnel have been trained on water level indication issues including notching. During this event, Operations personnel were aware that the signals were invalid and responded appropriately.

   b. Cause

   The investigation revealed that the level swings originated from the instrument racks where the Instrument Reference Leg Backfill System injects into the reference legs and commenced at approximately 100 psig reactor pressure. Although the level notches were similar to the notching in the early 1990's (i.e., traceable to piping geometry), no notching was observed at approximately 400 psig as is typical of non-condensable gas evolving out into the reference leg. Also, the frequency and magnitude of the notching was not consistent with prior notching events due to non-condensable gas migration in the reference legs.

   Based on this information, it was concluded that this event was not indicative of level notching caused by non-condensable gas migration in the instrument reference legs. Further investigation identified that significant CRD system maintenance had been performed in early 2001. This maintenance included opening the CRD system to repair one of the two CRD pumps. Inadequate filling and venting of the CRD system following this maintenance is believed to have allowed a volume of air to become trapped in the water source for the Instrument Reference Leg Backfill System.

   The Instrument Reference Leg Backfill System takes suction from the CRD charging water header near the CRD System high point vent. Therefore, air trapped in the charging water header during maintenance moved into the Instrument Reference Leg Backfill System as the reactor vessel (and instrument reference legs) depressurized relative to the charging water header during the reactor cool down process. As the air moved through the Instrument Reference Leg Backfill System into the instrument racks and reference legs, oscillations between train "A" level indication error episodes and train "B" level indication error episodes occurred. Apparently, air injection shifted from one parallel flow path to the other because of pressure differences created by the air injection itself. Normally, the flow paths are balanced (i.e., the same amount of flow to each train from a common header).

   Based on the above, the cause of this event was determined to be air injection through the Instrument Reference Leg Backfill System to both trains as the result of previous CRD system maintenance.

c. Corrective Actions

Corrective actions taken for this event included the following:

- Backfilled the affected reference legs.
- Inspected Instrument Reference Leg Backfill System components.
- Performed maintenance on Instrument Reference Leg Backfill System components as necessary.
- Improved procedures for venting and draining of the CRD system, backfilling of the reference legs, and the operation and maintenance of the Instrument Reference Leg Backfill System.
- Performed training on venting and draining of the CRD system and the operation and maintenance of the Instrument Reference Leg Backfill System.

2. Event During the Unplanned Automatic Reactor Scram on 8/13/01

a. Event

On August 13, 2001, Pilgrim experienced an unplanned automatic reactor scram from 100% power. Following the scram, the Operators manually closed the CRD charging water header isolation valve as a part of procedural steps to allow the control rods to settle and confirm "00" position indication. Once all control rods indicated "00" position, the Operators "reset" the scram. Per design, this action closed all 145 scram inlet valves. In the resultant configuration (i.e., CRD charging water header isolation valve closed and all scram inlet valves closed), the CRD charging water header was "floating" at essentially the CRD hydraulic control unit accumulator residual pressure.

In this configuration, both the "A" and "B" trains of reactor water level indication began to slowly increase with the "A" train eventually indicating off scale high. As the scram recovery progressed, the operators reopened the CRD charging water header isolation valve thus restoring full CRD system pressure to the charging water header and the Instrument Reference Leg Backfill System. As a result, indicated reactor water level converged to "normal" level indication. No "notching" or "entrained air" reactor water level indication anomalies occurred.

The actual water level was normal at the time of the event and alternate level indication was available to assess reactor conditions. Operations personnel have been trained on water level indication issues. During this event Operations personnel were aware that the signals were invalid and responded appropriately.

b. Cause

Subsequent event investigation revealed that in this unique situation (i.e., CRD charging water header isolation valve closed, scram reset, and reactor pressure very close to and slowly raising with respect to residual accumulator pressure), a portion of the reference leg water inventory drained from both independent trains into the common Instrument Reference Leg Backfill System piping and CRD charging water header. This caused the reactor water level indication to read high. Although each train of the Instrument Reference Leg Backfill System is equipped with two in-series check valves that are intended to prevent

such an event, the differential pressure between the reactor vessel and the CRD charging water header was too low to cause valve closure. The installed check valves have a design closure differential pressure of about 6 psi to preserve reference leg inventory during pipe break scenarios. In this event, the differential pressure across the check valves was less than 6 psi.

Further complicating this event was the discovery that the Instrument Reference Leg Backfill System had been operating at 10 times the normal flow rate. While this erroneous flow rate setting was beneficial from the perspective of preventing non-condensable gas migration and thus level notching, it also allowed a larger reverse flow rate under the unique differential pressure conditions experienced in the August 2001 event.

Ultimately, the event investigation determined the root cause of the erroneous level indication was an inadequate boundary isolation scheme between the common Instrument Reference Leg Backfill System and both reference legs. This inadequate boundary isolation allowed the reference leg inventory to drain from both independent reactor water level instrumentation trains into the Instrument Reference Leg Backfill System piping and CRD charging water header.

Given that there were now two operating events in which erroneous reactor water level indication had been observed, Pilgrim brought in outside experts to independently evaluate our cause determinations and corrective actions to date. Individuals from other BWR plants as well as a retired industry expert performed a detailed assessment of Pilgrim actions for both the April 2001 and August 2001 events. They concluded that the root cause evaluations were correct and that corrective actions taken were appropriate.

c. Corrective Actions

Corrective actions taken for this event included the following:

- Isolated the Instrument Reference Leg Backfill System, as a result of the discovery of this common mode failure mechanism.
- Prepared an engineering evaluation to specify the frequency at which the Instrument Reference Leg Backfill System would need to be placed in service. This evaluation was performed due to recognizing the need to minimize the possibility for level notching due to non-condensable gas migration with the system isolated. The evaluation concluded that with an assumed leakage rate of 15 ml/day, the system would need to be placed in service to purge the reference legs every 90 days.
- Filled and vented the instrument reference legs during the start-up from the August 13 scram.
- Established a weekly surveillance to monitor for external leakage from the instrument racks and verify that the assumption of the engineering evaluation was maintained valid.
- Brought in outside experts to independently evaluate the cause determinations and corrective actions to date.
- Placed the Instrument Reference Leg Backfill System in service for several hours, in late October 2001, on both the "A" and "B" instrument racks to purge non-condensable gasses from the reference legs.

3. Event During the Unplanned Automatic Reactor Scram on 12/27/01

   a. Event

   On December 27, 2001, Pilgrim experienced an unplanned automatic reactor scram due to an unanticipated equipment failure. During reactor cool down, reactor water level notching was experienced on the level instruments fed from condensing pot 12B (i.e., the "B" reference leg). The level instruments associated with the "A" reference leg were not affected.

   The actual water level was normal at the time of the event and alternate level indication was available to assess reactor conditions. Operations personnel have been trained on water level indication issues. During this event Operations personnel were aware that the signals were invalid and responded appropriately.

   b. Cause

   The event investigation determined that the reactor water level instrument notching was caused from off-gassing of dissolved gasses in the "B" train instrument reference leg fed from Condensing Pot 12B while the reactor was being slowly depressurized. The dissolved gasses in the reference leg were the result of migration of gas-laden condensate from the condensing pot into the reference leg.

   The following mechanisms for the transport of the non-condensable gases down the "B" reference leg were investigated and ruled out:

   - A thermal gradient transporting the non-condensable gas was ruled out because no heat source could be identified to provide the necessary thermal gradient.
   - Degraded equalizing valves providing an internal leakage path which drew the non-condensable gas down the reference leg was ruled out by testing the suspect valves for leakage.
   - External leakage drawing the non-condensable gas down the reference leg was ruled out by testing the method used to monitor for external leakage and the results for the leakage surveillances since the August shutdown.

   A review of the history of "notching" at Pilgrim was performed. This review identified that the reference legs can be expected to remain free of "notching" for a period of time without a flushing or backfill. Additionally, this review determined that the time varied depending on the reference leg. The time identified from the system operating history that the reference leg can be expected to remain free of "notching" without flushing of the non-condensables is at least 30 days for the "B" reference leg and at least 100 days for the "A" reference leg. This historical data is consistent with the event in December 2001, in that flushing of the reference legs had not been performed for 71 days and the "B" reference leg experienced "notching" and the "A" reference leg did not.

   Efforts continue to determine the transport mechanism for non-condensable gas migration in the "B" reference leg prior to the December 27, 2001 scram. But based on the historical data actions can be taken to effectively preclude occurrence of "notching" without the identification of the specific mechanism.

c. Corrective Actions

Corrective actions taken for this event included the following:

- Flushing the reference legs to ensure that all non-condensibles had been removed.
- Testing the suspect equalizing valves for leakage.
- Reviewing the external leakage monitoring program including testing the leakage monitoring methods.
- Increasing the frequency of flushing the "B" reference leg to once per 14 days. The 90 day frequency on the "A" reference leg was maintained.

C. Conclusions and Current Plans concerning the Recent Reactor Water Level Indication Issues

1. Event Summary

a. Event During the Reactor Shutdown on 4/21/01

Online CRD pump maintenance and air entrapped during system restoration led to air injection through the Instrument Reference Leg Backfill System.

b. Event During the Unplanned Automatic Reactor Scram on 8/13/01

Reference leg inventory drained from 2 independent reactor water level instrumentation trains into the Instrument Reference Leg Backfill System piping and CRD charging water header.

c. Event During the Unplanned Automatic Reactor Scram on 12/27/01

Notching was seen on a single train of reactor water level indication due to non-condensable gas in the instrument reference leg fluid coming out of solution.

2. Lessons Learned from the Events

a. Event During the Reactor Shutdown on 4/21/01

A common backfill system has the potential to inject air and cause level indication errors on both trains of RWL instrumentation.

b. Event During the Unplanned Automatic Reactor Scram on 8/13/01

A common backfill system provides opportunity for internal system leakage, reference leg drain down and level indication errors on both trains of RWL instrumentation under very specific operating conditions.

c. Event During the Unplanned Automatic Reactor Scram on 12/27/01

Intermittent backfill and vigilant leakage controls are needed to prevent RWL instrumentation notching. Leakage control must include not only external paths but all internal paths as well. Continuous backfill of the reference legs provides an effective method of preventing the introduction of non-condensables into the reference legs.

3. Summary of Corrective Actions Taken

   Corrective actions taken for these events include the following:

   a Established investigation teams.
   b Revised or issued procedures for the following activities:
   - venting of the CRD System,
   - surveillance and maintenance of the instrument reference legs,
   - operation and maintenance of the Instrument Reference Backfill System,
   - testing of specific instrument equalizing valves for leakage,
   - testing of the external leak detection methods, and
   - training of Instrument Reference Leg Backfill System requirements.

   c Isolated the Instrument Reference Leg Backfill System to prevent further draining events and instituted reverence leg surveillance and periodic backfill.
   d Performed an independent review of the investigation.

4. Future Plans

   Current plans are to prepare the design and licensing documents to support placing at least the "B" side of the Instrument Reference Leg Backfill System into continuous service with the "A" side placed inservice on an intermittent basis. This approach will eliminate the potential for a common mode "drain down" event as was experienced in August 2001 while ensuring that the classical level indication notching will not occur. A permanent modification to the Instrument Reference Leg Backfill System is under development that will address all three of the 2001 events.

D. References

1. BECO letter to the NRC, NRC Bulletin 93-03: Resolution of Issues Related to Reactor Vessel Water Level Instrumentation in BWRs, Letter Number 2.93.089, dated 7/16/93

2. NRC letter to the BECO, Response to Bulletin 93-03, dated 8/11/93.

Figure 1

Simplified Instrument Reference Leg Backfill System Arrangement