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Docket No. 50-213
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Re: NUREG 0737
Item II.K.3.25
ISAP Topic 1.18

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Gentlemen:

Haddam Neck Plant
NUREG 0737, Item II.K.3.25, Reactor Coolant Pump
Seal Integrity Following Loss of Off-Site Power

The purpose of this letter is for Connecticut Yankee Atomic Power Company (CYAPCO) to provide the NRC Staff a summary document of information to close out TMI Action Item II.K.3.25, Reactor Coolant Pump (RCP) Seal Integrity Following Loss of Off-Site Power. Based on the information presented below, CYAPCO has concluded that it is acceptable to rely on operator action to reinstate RCP seal cooling manually following a loss of off-site power. This conclusion is based on RCP seal design, procedures in place for manually restoring seal cooling, the acceptability of the seals in the interim, and the evidence of past experience and seal performance.

RCP Design

The RCPs at the Haddam Neck Plant are four vertical constant-speed pumps, each driven by an air-cooled, 4000-hp, 3-phase, 4000-V, 60-Cycle induction motor. Rated flow of each pump is 67,200 gpm at 545°F against a 214-foot differential head. The motor is mounted directly above the pump with the inlet to the pump at the bottom of the volute and the discharge at the side. The pump has a single impeller. Design conditions are 2485 psi gauge and 650°F for the pump casing (volute) and 300°F for the seal pressure housing.

The pump shaft seals are arranged in the following order up the shaft:

- o Floating Ring Seal
- o No. 1--Controlled Leakage Seal
- o No. 2--Backup Seal
- o No. 3--Vapor Seal

(Seals 1 through 3 are 7-inch "noncartridge-type" seals)

The No. 1, or controlled leakage, seal normally controls the leakage along the driving shaft of the pump. This seal is designed to limit leakage to less than 2 gpm when operating with a differential pressure across the seal of up to 2100 psi with the pump both running and shut down. Leakage through the No. 1 seal is normally returned to the volume control tank via the seal water filter and heat exchanger.

When the No. 1 seal is operating normally, the No. 2, or backup, seal is under a differential pressure of approximately 20 to 45 psi gauge. Under this condition, the No. 2 seal is designed to limit leakage to less than 2 gallons per hour. The leakage from this seal is directed to the waste disposal system.

Should the No. 1 seal fail, the floating ring seal (also called the breakdown bushing or throttling device) would come into operation to limit leakage to less than 50 gpm. This feature is not standard on Westinghouse RCP seals and provides enhanced protection from excessive seal leakage rates. Should the seal water motor-operated return valve be manually closed due to high temperature, the No. 2, or backup, seal would come into operation. This seal is capable of withstanding a 2100-psi differential pressure. It is designed for the same service conditions as the No. 1 seal. This seal would limit the leakage along the shaft to approximately 2 gpm.

The No. 3, or vapor, seal is provided to prevent any leakage across the No. 2 seal from entering the reactor containment. It also would prevent leakage from a pressurized containment from entering the pump. A pump seal leak-off pot common to the four coolant pumps mounted above the seals ensures that the faces of the vapor seal remain set and cool by maintaining a liquid head of approximately 7 feet in the chamber between the vapor seal and the No. 2 seal.

RCP Seal Cooling Design Basis

The Haddam Neck Plant RCP seals are normally cooled by two independent systems, either of which would provide adequate seal cooling. High-pressure cooling flow is supplied to the RCP seals via the chemical and volume control system (i.e., the charging pumps). The charging pump lube oil is normally cooled by the component cooling water system which in turn is cooled by the service water system. However, an alternate means of cooling the lube oil is provided by fans which automatically start on high lube oil temperature. Therefore, RCP seal cooling can be provided independently of component cooling water (and thus independently of service water). Seal injection flow can also be provided by the positive displacement charging pump as a backup alternative. Since the seal injection water pressure is higher than the reactor coolant pressure, a small flow of approximately 5 gpm enters the reactor coolant system through the pump labyrinth seals.

The RCP seals are also protected from reactor coolant system temperatures by the thermal barriers. The thermal barriers are cooled by the component cooling water system.

Upon a loss of off-site power, the charging pumps would be manually loaded onto the emergency diesel generators (EDG) to provide seal injection flow. In addition, the component cooling water (CCW) pumps are manually loaded onto the EDGs to cool the thermal barriers and the service water pumps (which are automatically loaded onto the EDGs) provide CCW cooling. Some manual operation of valves is necessary to restore cooling in a controlled manner.

The following Emergency Operating Procedures (EOP) provide specific guidance regarding RCP seal cooling verification and restoration:

- EOP 3.1-10, "Partial Loss of AC"
  - EDGs automatically start on loss of voltage on emergency buses.
  - Steps 6, 7, and 8 under "Subsequent Actions" call for ensuring operation of service water, CCW, and charging pumps, respectively.
  - Operation of the charging pump is qualified based on RCP lower bearing temperature.
- ES-0.1, "Reactor Trip Response"
  - Step 5 calls for verifying the availability of off-site power.
  - For the "response not obtained" (RNO), verify that the emergency buses are energized by the EDGs followed by a number of manual actions.
  - The sixth action listed is to "check RCP cooling status" and follow the appropriate guidance as provided.
- ECA-0.0, "Station Blackout"
  - Step 5 directs the operator to take steps to address RCP cooling if emergency AC power is available.
  - Step 8 directs the operator to isolate the RCP seal flows in the event that emergency AC power is not immediately available; these actions help limit RCP seal leakage in the event seal cooling is not available.
- ECA-0.1, "Station Blackout Recovery Without SI Required"
  - Step 9 directs the operator to establish normal cooling flow to the RCP seals.

o ECA-0.2, "Station Blackout Recovery With SI Required"

-- Step 7 directs the operator to establish normal cooling flow to the RCP seals.

CYAPCO has adequate procedural guidance in place to address RCP seal cooling. If off-site power is maintained during a transient or accident, normal RCP seal cooling continues. If there is a partial or total loss of AC power, procedures direct the operators on limiting RCP seal leakage and restoration of seal cooling as quickly as possible.

Loss of RCP Seal Cooling (Experience and Testing)

Experience to date with instances of loss of off-site power at the Haddam Neck Plant demonstrate that the current plant/RCP design and operating procedures ensure that seal integrity will be maintained until emergency power and RCP seal cooling can be restored.

The Haddam Neck Plant has had actual plant-specific experience with such events. On July 15, 1969, a loss of off-site power event occurred with subsequent loss of CCW, and the charging system was inadvertently shut down after the EDGs started. This resulted in a complete loss of thermal barrier cooling and seal injection flow to all four pumps. Under such conditions, one would normally have expected all four pump seals to begin to degrade. They did not. Only one of the four RCPs, namely the No. 4 RCP, experienced some seal failure, and this was because operators attempted to restart it to assist in plant cooldown from hot standby conditions after off-site power was restored. Postevent examinations revealed failure of the No. 1 and No. 2 seals in RCP No. 4. The breakdown bushing (or floating ring seal) functioned as designed, and the actual leakage rate was measured at approximately 15 gpm, which is less than the 50 gpm design basis flow. Upon observation of these leak rates during the July 15, 1969, event, operators isolated the loop and executed a routine, orderly shutdown to support subsequent replacement of the seals on the No. 4 RCP. There was no actuation of the safety injection system nor any need for high-pressure recirculation. This experience supports the CYAPCO conclusion that in reality the RCP seals will remain intact until seal cooling is reestablished by procedures.

As stated in the Updated Final Safety Analysis Report (UFSAR), the RCP seal design utilized at Haddam Neck is such that, even upon complete seal failure, the floating ring seal will limit the maximum leakage from a failed seal to 50 gpm. It is our understanding that current PWR RCP seal designs do not utilize this feature and thus have the potential for resultant large leak rates. This factor alone suggests that this issue is of lesser significance for the Haddam Neck Plant. Assuming all four RCP seals failed, total RCS leakage would be limited to a total of approximately 200 gpm.

In December 1965 Westinghouse performed a 1000-hour pump test run of the RCP seal leakage limiting assembly at their Cheswick, Pennsylvania, facility.

Measured leak rates were between 40 and 50 gpm maximum, thus confirming the UFSAR value of 50 gpm.

The RCP seal integrity issue arose originally from a comparison of the British Sizewell B design to the Standardized Nuclear Unit Power Plant System (SNUPPS) design by the NRC Staff. This comparison concluded that the addition of steam-driven emergency charging pumps in the Sizewell design to ensure cooling of the RCP seals was the only change in design having a significant effect on safety. The importance of this change followed from the assumption, in the absence of any long-term data, that RCP seal failure would result 30 minutes after the loss of all seal cooling and the resultant leakage would be large enough to cause core uncovery in 2 to 3 hours. This caused the RCP seal failure scenario to be a significant contributor to plant risk.

Westinghouse, through the sponsorship of the Westinghouse Owners Group (WOG), conducted a program of analysis and testing. Detailed thermal-stress and thermal-hydraulic analyses of the 8-inch and cartridge seal systems demonstrated that the reactor coolant system leakage rate is constrained by the entire seal package and associated leak-off system piping. The analyses' results indicated that the leakage rate, on a best-estimate basis, would remain low (approximately 21 gpm per pump) during the loss of all seal cooling.

The WOG also participated in a full-scale loss of all seal coolant test of a 7-inch RCP seal package. The test was conducted on a static RCP mock-up on May 29-30, 1985. The test demonstrated stable low leakage rates at conditions representative of the loss of all AC power event throughout the 24-hour test.

Probabilistic Safety Study (PSS)

The Haddam Neck Plant PSS assumes that the maximum seal flow rate per RCP, given seal failure, is 50 gpm. This value is based on the actual design documentation of the breakdown bushing, full-scale pump tests conducted by Westinghouse actual plant experience, and original Facility Description and Safety Analysis (FDSA) documentation. This assumption leads to a conclusion that even in the unlikely event that the seals of all four RCPs fail, the normal plant makeup system (i.e., one charging pump) can provide the lost coolant and sump recirculation would not be necessary. In the PSS, no credit has been taken for using the loop isolation valves to isolate one or more RCPs with a failed seal. This is somewhat conservative since Abnormal Operating Procedure AOP 3.2-17 provides for using the loop isolation valves for stopping any RCP seal leakage. The NRC has proposed in the past a highly conservative average flow rate of 100 gpm per pump should seals fail. The impact of this conservative figure would yield a dramatic distortion of the actual core-melt frequency by changing the event to a small loss-of-coolant accident requiring both high-pressure safety injection and sump recirculation cooling for successful mitigation.

Further perspective on the four-pump, 50-gpm leak flow rate per pump during RCP seal degradation scenarios assumed in the PSS has been provided by the actual plant loss of off-site power event experienced in 1969 and the Westinghouse testing performed in 1965 and 1985 (discussed above). Therefore, CYAPCO believes the 50-gpm original design basis for RCP seal leakage through the breakdown bushing is reasonable, and that assuming four RCP seals could fail (resulting in no more than a loss of 200 gpm) during a loss of seal cooling scenario is aptly conservative without distorting the event classification, success criteria, or risk significance.

With no makeup flow and 200-gpm total leakage from the seals, about 7.5 hours are required before core uncovery occurs. If the RCS remained at full pressure (which would not be the case), the RWST would provide over 12 hours of supply without need for sump recirculation. Considering the depressurization effects, it is more realistic that the RWST inventory would be sufficient for over 24 hours without the need for recirculation. By then, cold shutdown would have been attained.

Modifications Required for Automatic Initiation of Seal Cooling

Modifications to the Haddam Neck Plant would be necessary to provide for automatic restoration of RCP seal cooling. These modifications would be substantial in both design and resources and would undoubtedly require additional diesel generator capacity or new types of pumping systems. Originally the charging pumps were automatically loaded onto the EDGs. That configuration was changed in the late 1970s when questions were raised regarding EDG capacity. In the case of a loss of off-site power concurrent with a loss-of-coolant accident, the EDGs do not have sufficient capacity to support a charging pump and/or a CCW pump along with the safety injection loads. In the case of a LOCA, RCP seal leakage would only be an additional potentially small increase in existing loss of RCS inventory.

Conclusions

CYAPCO has concluded that manual restoration of RCP seal cooling at the Haddam Neck Plant is justified for the following reasons. CYAPCO has sufficient procedural guidance in place to direct the operators to restore RCP seal cooling in the event of a partial or complete loss of AC power. Plant experience has shown that given the design of the Haddam Neck RCP seals, seal integrity is maintained for at least 20 minutes with a loss of RCP seal cooling. Therefore, CYAPCO has concluded that the seals would probably remain intact until such time as the operators restored seal cooling by procedure.

In addition, CYAPCO has documented our position that in the event of a complete loss of the RCP seals, leakage would be limited to 50 gpm for each pump, based on the Haddam Neck pump design with the breakdown bushing. This conclusion is supported by pump testing and actual experience. Therefore, if all the seals on all four pumps were lost, this would yield a total leakage of no greater than 200 gpm, which is well within the capacity of a single charging pump. This scenario was evaluated in the Haddam Neck PSS to identify the time to core uncovery with no makeup flow and the adequacy of makeup supplies if no RCS depressurization takes place.

CYAPCO believes that all of the above information supports the CYAPCO conclusion that manual RCP seal cooling restoration is satisfactory and that TMI Action Item II.K.3.25 can be closed for the Haddam Neck Plant.

If you have any questions, please contact us.

Very truly yours,

CONNECTICUT YANKEE ATOMIC POWER COMPANY

E. J. Mroczka
Senior Vice President

Attachment
cc: T. T. Martin, Region I Administrator
A. B. Wang, NRC Project Manager, Haddam Neck Plant
J. T. Shedlosky, Senior Resident Inspector, Haddam Neck Plant