AEOD TECHNICAL REVIEW REPORT

UNIT: Fort St. Vrain Nuclear Generating Station
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LICENSEE: Public Service Co. of Colorado
NSSS/AE: General Atomic/Sargent and Lundy

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SUBJECT: INOPERABILITY OF HELIUM CIRCULATOR OVERSPEED TRIP CHANNELS DUE TO IMPEDANCE VARIATIONS IN SPEED SENSING CABLES EXPOSED TO STEAM LEAK

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SUMMARY

One channel of three of the Circulator Speed-High trip function on each of the 1C and 1D steam turbine driven helium circulators was inhibited by a loss of voltage in the speed sensing cables due to temperature induced impedance variations. The affected speed sensing cables were located in the vicinity of the prestressed concrete reactor vessel (PCRV) which was experiencing above normal temperatures due to a reheat steam leak in the area. Loss of required redundancy in the speed-high trip function did not represent a significant threat to circulator availability since the challenge to the trip function to prevent damaging overspeed conditions could only arise during the unlikely event of a primary system rapid depressurization coupled with a failure of the control system to runback the circulator. Also, the loss of voltage which makes the speed-high trip signal inoperable simultaneously activates the speed-low trip function. Total loss of one circulator overspeed protection would therefore in effect require a separate failure in the speed-low protection circuitry on that circulator.

DISCUSSION

The primary coolant system is equipped with four identical helium circulators, two in each loop. Each circulator unit consists of a single-stage axial flow compressor, a single-stage steam-turbine main drive, and a single-stage water-turbine auxiliary drive. The circulator steam turbine drives normally operate on cold reheat steam from the exhaust of the high pressure element of the main turbine. Steam from the exhaust of the circulator turbines flows to the steam generator reheater sections. The steam turbine drives are designed to operate on cold reheat steam from the main turbine, saturated steam from the bypass flash tank, or steam from the auxiliary boiler or backup auxiliary boiler. The auxiliary water-turbine drives will provide power to the circulators when steam is not available. Provisions are included in the circulator auxiliary system to permit operation of the auxiliary water-turbine drives using feedwater, condensate, or firewater for motive power.

As stated in FSAR Section 7.1.2.6, "Circulator overspeed is an indication of speed control or other failure necessitating rapid shutdown of the circulator. The speed sensing system response and trip setting are chosen so that under the maximum overspeed situation possible (loss of restraining torque) the circulator will remain within design capabilities." FSAR Section A.1.13.5 identifies the maximum "credible" overspeed condition as 135% of rated, resulting from a rupture of the reheat steam pipe downstream of the circulator, combined with failures of both the control system and the overspeed trip system. However, an overspeed condition of 135% of rated will not damage the circulator.

The only event which could result in a damaging circulator speed (>170% of rated) would be a rapid depressurization of the primary loop at full load, referred to as the Design Basis Accident No. 2, simultaneous with circulator speed control and high speed trip failures (FSAR Sections 5.10.2.2 and 14.11.2.2). The Design Basis Accident (DBA) No. 2 is a non-mechanistically postulated failure of both closures in a PCRV penetration resulting in a rapid blowdown of the primary system. In the DBA No. 2 scenario, the circulator speed control and high speed trip are assumed to function as designed to prevent circulator damage from overspeed during the blowdown phase of the accident. In addition, both the circulators and other vessel internals such as the primary loop divider baffle are designed to accept the differential pressure loads and jet forces generated during the blowdown. Therefore, the DBA No. 2 by itself will not affect primary coolant flow paths or prevent continued operation of the circulators, permitting restoration of primary coolant flow following the accident. On the highly remote chance that a DBA No. 2 would occur simultaneously with a failure of a circulator's speed control and overspeed trip, means have been provided to contain any missiles generated by the failure of the circulator's compressor or turbine disc. Therefore, the overspeed failure of the compressor rotor or turbine disc would not damage the primary closure, penetration liner, or other circulators.

The fact that the overspeed trip cables were not qualified for the harsh environment raises the following question: Would a DBA No. 2 by itself cause the simultaneous failure of the speed control and overspeed trip on all the circulators? The combination of DBA No. 2 with the permanent loss of main loop cooling, which constitutes DBA No. 1 and assumes permanent loss of all four circulators on both normal and emergency drives, represents a scenario which could lead to fission product releases beyond that assumed in the FSAR. In DBA No. 1, the PCRV liner cooling system prevents major PCRV damage and limits PCRV leakage to 0.2%/day which is based on the assumption that the PCRV liner does not exist as a barrier thereby permitting permeation through the concrete (FSAR, Section 14.10.3.4).

The licensee has stated that the design of the lower PCRV structure and the cable separation is such that the occurrence of a DBA No. 2 in one loop would not affect the sensing cables for the circulator speed trip in the other loop. Even, if two cables associated with the speed-high trip function on a given circulator were severely damaged by direct impingement of a jet of steam or hot helium, the loss of the circulator speed-high trip would be accompanied by the simultaneous actuation of the speed-low trip resulting from the loss of voltage in both cables. Therefore, the occurrence of a DBA No. 2 through a PCRV penetration in one cooling loop would not provide the basis for circulator overspeed failure in the other loop. As a result, the occurrence of a DBA No. 2 could not cause by itself a concurrent DBA No. 1 (permanent loss of forced circulation).

In Section 14.11.2.2 of the FSAR, the implication is made that in the event of a DBA No. 2 all or some of circulators may not be subject to conditions which could cause an overspeed even if the circulator control system, overspeed and underspeed trips were to fail. This implication is drawn from statements indicating that "for cases of a refueling penetration rupture, top head access penetration rupture, or bottom head access penetration rupture....the pressure differential....(across the circulators) would be the same for both loops and is less than design." Further, statements are made to the effect that "for the cases of a rupture of a circulator or steam generator penetration, the circulators in the two loops will have different pressure differentials across them" such that the circulators in the loop without the rupture "will have the normal differential." However, the licensee has been unable either to define the meaning of the term "design pressure differential" as used in the FSAR or to clarify or interpret the meaning of the quoted statements from Section 14.11.2.2. Therefore, the possibility of an inherent resistance to circulator overspeed during DBA No. 2 without benefit of control or trip functions cannot be confirmed at this time although the FSAR implies such a possibility. As now written, the statements in the FSAR tend to confuse and obscure the situation regarding circulator performance during the DBA No. 2.

The current high speed trip setting is 11,000 rpm (115% of rated) based on 2/3 logic (Technical Specification, LCO 4.4.1, Table 4.4-3). There is a proposed change to the technical specifications to raise this trip setting to 11,700 rpm (123% of rated) in order to increase the system's resistance to unwarranted trips while providing adequate protection to the maximum credible overspeed (135% of rated) which could result from a downstream reheat steam pipe break. This trip setting is still conservative with respect to the overspeed (≥170% of rated) required to induce circulator damage.

In order to restore required level of redundancy (LCO 4.4.1) in the trip function at the time of the event, the licensee provided additional ventilation in the area of the reheat steam leak in order to prevent further cable damage and replaced inoperable cables with available spares. During the recent long maintenance and refueling shut down, the licensee investigated the extent of cable damage. The licensee found that on the installed Belden cables, which had been subjected to steam impingement by the leak, the insulation had melted and run. The Belden cables had been installed originally during plant construction and were deemed qualified for the application at that time. The licensee has now replaced the damaged cables and about half of the other speed cables with new Rockbestos insulated cables which are qualified for higher temperature environments. The licensee states that both the undamaged Belden cables and the new cables meet requirements for 30 minutes of operability under the worst case temperature environment which is imposed by a steam line break (FSAR, Section 1.4.5.4). The licensee also acknowledges that the direct impingement of a steam jet on a cable could cause earlier failure of that cable. However, as discussed above, although the loss of one cable causes the inoperability of one of three high speed trip channels associated with a given circulator, the loss of two cables will cause a low speed trip of that circulator. The licensee intends to replace all Belden cables with new Rockbestos as part of future normal maintenance. The reheat steam leak has been repaired so that the cable environment has been returned to normal temperature conditions.

FINDINGS

The loss of redundancy of the high speed circulator trip on the 1C and 1D circulators did not affect plant safety for the maximum credible accident of a downstream reheat steam pipe break. The action taken by the licensee to improve the qualification of the cables for normal and abnormal high temperature environments is considered to be appropriate and adequate. Since the extremely remote combination of a DBA No. 2 and simultaneous failure of the circulator speed control system and overspeed and underspeed trips is required to cause a design overspeed on the circulators and since the PCRV design should prohibit the blow down gases from affecting speed cables to the other loop, there appears to be adequate separation and redundancy to assure one operable loop with at least one operable circulator under unlikely worst case conditions. This is sufficient to prevent core damage. The licensee is unable, however, to clarify vaguely worded statements in the FSAR which imply that there is an inherent resistance to circulator overspeed during the DBA No. 2.

CONCLUSIONS

The event is of minimal safety significance. There appears to be no situation in which loss of the high speed trip channels on the 1C and 1D circulators could lead to the loss of more than one cooling loop under worse case conditions.