AEOD ENGINEERING EVALUATION REPORT*

UNIT: St. Lucie 1
DOCKET NO.: 50-335
LICENSEE: Florida Power & Light Co.
NSSS/AE: Combustion Engineering Inc./Ebasco Services, Inc.

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SUBJECT: LOSS OF ALL THREE CHARGING PUMPS DUE TO EMPTY COMMON REFERENCE LEG IN THE LIQUID LEVEL TRANSDUCERS FOR THE VOLUME CONTROL TANK

EVENT DATE: October 23, 1982

SUMMARY

With St. Lucie Unit 1 in hot standby during recovery from a reactor trip, the three inservice positive displacement charging pumps (PDPs) stopped circulating coolant to the reactor coolant system because the volume control tank (VCT) was pumped dry. The VCT was empty although its two liquid level sensors each indicated an acceptable liquid inventory and, hence, an apparently acceptable inflow/outflow balance from the VCT. The false liquid level indication was caused by an empty reference leg that was shared by both liquid level sensors. The reference leg was found to be leaktight and the cause of the empty reference leg is not known.

We concluded that the consequences of this event were minor because the charging system is not safety-related at St. Lucie. However, it is conceivable that this event could be repeated at units with safety-related centrifugal charging pumps** which are prone to gas binding in similar circumstances and at other CE plants similar in design to St. Lucie (e.g., Millstone Unit 2) that have taken credit for charging pump injection in their LOCA analysis when they went to stretch power.

Several reports on the vulnerability of the VCT liquid level interface and of shared fluid coupling of liquid level instrumentation have been included as examples of the potential problems that can occur with this type of instrumentation.

DISCUSSION

At St. Lucie Unit 1, with the reactor in hot standby, the three inservice charging pumps stopped circulating reactor coolant when the VCT was pumped dry and the hydrogen cover-gas blanket of the VCT entered the suction of each pump. The pumps were restored to operation by repeated venting after filling the VCT to a high level. Two charging pumps were operating at a reduced flow within 15 minutes; the third pump was restored to operability in about 30 minutes. During the loss of charging flow, there was no significant decrease in pressurizer level. The VCT was pumped dry because the

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

**Some Westinghouse designs utilize the centrifugal charging pumps for the high pressure safety injection function.

two liquid level sensors (LT 2226 and LT 2227) were erroneously indicating an acceptable level of liquid within the VCT. The false level indication was caused by an empty reference leg that is shared by both liquid level sensors.

The liquid level sensors are actually differential pressure transducers with input taps connected to high and low points of the VCT. The measured VCT liquid level is proportional to the differential pressure sensed by the transducers. The reference tap of the differential pressure transducers is filled with liquid to provide a measurement that is independent of the elevation of the transducer. With a common reference leg, if some degree of reference level is lost (either by loss of actual liquid or by drift of the electrical bridge), there is no induced disagreement between sensors, and an undetectable offset exists between the indicated tank level and true tank level. In the St. Lucie event, with an empty reference leg, the offset was sufficient to indicate an acceptable VCT level when, in fact, the VCT was dry. This was the first failure of this type at St. Lucie. The cause of the empty reference leg is unknown; the system was leaktight, it was refilled without incident, and has operated satisfactorily since the event.

The event occurred on October 23, 1982 during recovery from a reactor trip. The reactor had tripped on a low steam generator water level signal after a loss of feedwater flow to the steam generator. The loss of feedwater flow began when one of the condensate pumps tripped on a differential phase current. This pump was being replaced when the loss of all charging flow occurred.

During recovery from the reactor trip, and just before the loss of charging flow, the pressurizer level had been restored to above the heater cutoff level by operating all three charging pumps. The primary system had stabilized at no-load T-average and the RCS pressure was 1960 psia. The event began when plant personnel noticed that pressurizer level was no longer continuing to increase. A loss of charging flow was confirmed by checking the flowmeter in the common discharge header of the charging pumps. It was reading zero. The PDPs casing vent valves were opened, and gas came out instead of liquid, indicating the charging system had lost its prime. The operators continued to investigate upstream of the PDPs until they discovered the VCT to be dry and the source of the gas. There was no known injection of gas downstream of the PDPs.

FINDINGS

A. Component Description and Operation

Each of the three charging pumps at St. Lucie 1 are positive displacement (piston) triplex pumps manufactured by ARMCO with a rated capacity of 44 gpm each. Their rated NPSH is 9.0 psia. The charging pumps are located on the floor level of the reactor auxiliary building and take suction from the VCT which is located on the next higher floor level to provide a positive suction head. Normally one charging pump is running to balance letdown purification flow and reactor coolant pump (RCP) leakoff flow with charging flow into the reactor coolant system. The second and third pumps automatically start and stop on demand as pressurizer level decreases or increases with load transients or varying plant conditions. It should be noted that positive displacement pumps are poor compressors and cannot pump gas very well (perhaps only a 10-100 psi pressure increase across the pump) because of their low compression ratio.

The charging pumps at St. Lucie are necessary to provide reactor coolant boration to reach cold shutdown. They are designed, therefore, to seismic Class 1 requirements. However, no credit is taken for charging pump operation as a component of the emergency core cooling system (ECCS) although all three pumps start automatically on a safety injection actuation signal (SIAS) to supplement the other systems during safety injection. The technical specifications require at least two charging pumps be operable in Modes 1, 2, 3 and 4.

The VCT is not required for safe shutdown, and therefore, is not seismic Class 1. However, the VCT and the level transmitters are safety Class 3. The VCT has an internal volume of about 4200 gallons and is capable of accepting a full vacuum so there is no possibility of tank collapse by the partial vacuum induced by the charging pump suction. The tank is initially purged with nitrogen and then a hydrogen overpressure is established to scavenge free oxygen during power operation.

An automatic system maintains the water level in the VCT. In conditions of decreasing VCT level, VCT level controller (LC-2227) will generate a low level signal that causes a preset solution of concentrated boric acid and makeup water to be introduced into the VCT. A low-low level signal or a SIAS automatically closes the outlet valve on the VCT. The charging pump suction switches to the concentrated boric acid storage tanks on a SIAS. There is both a low VCT level alarm and a VCT low pressure alarm. A redundant liquid level transducer (LT-2226) on the VCT was valved out at the time of the event.

The liquid level sensors are Fisher & Porter Co. Model delta-T(P) transducers. Both sensors share common high and low level penetration taps in the VCT. These two instruments also share the same instrument sensing lines with the common connecting point being in close proximity to the point of connection to the instruments. This instrument and its spare are calibrated on a monthly basis. Although there have been no previous problems, the licensee was aware that if some degree of reference leg liquid is lost, no disagreement in indication between sensors would be apparent and that the operator would not realize the indicated VCT level was incorrect.

B. Proposed Modifications at St. Lucie

The existing Fisher & Porter pressure transducers are no longer available so they will be replaced with Rosemount Model 1153 Series D transmitters. Separate instrument lines, including separate reference legs for each instrument, are being routed as close as possible to the takeoff (root) valves. In addition, the maintenance procedure will be modified to indicate that each instrument reference leg must now be filled each time prior to the monthly calibration.

C. Safety Implications of a Similar Event at a Typical Westinghouse Unit

There are some significant design and safety differences in the required operations in the charging system between St. Lucie and a typical Westinghouse Electric Corporation design. These differences are being discussed because of the apparent system and component similarity (i.e., the VCTs are similar in design and purpose; the charging pumps provide the highest possible pressure source for injection into the RCS, etc.) and hence, the event at St. Lucie can be reasonably presumed to occur at a typical Westinghouse unit if similar level instrumentation is used.

Westinghouse units usually have three charging pumps. In some Westinghouse designs, a positive displacement pump (PDP; not safety-related) is used for charging during routine operations. The other two charging pumps are centrifugal pumps. Some other Westinghouse designs use three centrifugal pumps that also function as high pressure injection pumps. In either case, the centrifugal pumps are safety-related and credit is taken in the safety analysis for their operation to lessen the effects of a loss of coolant accident by:

(1). Providing safety injection for postulated small area ruptures of the reactor coolant system (RCS) where the primary coolant pressure does not drop below the passive accumulator pressure or the shutoff head of the intermediate head safety injection pumps for an extended period of time after the accident.

(2) Providing excess negative reactivity by the injection of concentrated boric acid through the boron injection tank (BIT) for a postulated steamline break accident. In this scenario, a rapid reduction of primary coolant temperature occurs due to the removal of energy from the affected steamline and causes a positive reactivity addition with a decrease in RCS temperature due to the negative moderator coefficient. The injection of concentrated boric acid prevents a return to criticality during this presumed worst case cooldown accident.

If the centrifugal charging pumps should become gas bound, as occurred to the PDPs at St. Lucie, they would be incapable of the transferring liquid to the RCS because the pump impellers would essentially be free-wheeling in the gaseous environment. Therefore, if the event that occurred at St. Lucie immediately preceded a LOCA at a Westinghouse plant, it may be possible that all charging/HPSI pumps could become gas bound simultaneously. This highly unlikely situation could result in a loss of HPSI. However, loss of charging flow is something that would be quickly detected during plant operation and would be promptly restored. Therefore loss of charging flow, if it existed, would only exist for a very short period of time and would be more of an operational problem than a safety concern.

The second significant difference between St. Lucie and a Westinghouse unit is the cooling and lubrication requirements of the RCP seals. In the Westinghouse unit this is accomplished by seal injection from the charging system with a total seal injection flow of about 8 gpm per pump. At St. Lucie, the pumps seals are cooled from the RCS and controlled bleedoff is returned to the chemical and volume control system (CVCS), i.e., no seal injection. Since neither the PDP or centrifugal charging pump can pump gas at RCS pressures there is no danger of RCP seal failure due to gaseous injection at a Westinghouse unit.

D. Related Operating Experience

In May 1981, Westinghouse Electric Corporation notified utility owners of three and four loop plants of their design of the potential for an adverse control and protection system interaction involving the VCT liquid level interface. In the presumed scenario postulated by Westinghouse, a failure of the VCT level control system (in this case, a presumed false high VCT level) causes letdown flow to be diverted to the letdown holdup tank, and the VCT inventory decreases due to normal charging without makeup to the VCT via letdown. Without operator intervention, the VCT could empty; if the centrifugal

charging pump is operating at the time, it could be damaged due to loss of suction fluid (no automatic switching to the RWT on a low-low level signal would occur in this scenario.)

On February 12, 1982, while the McGuire Nuclear Station, Unit 1, was operating at 50% power, the two centrifugal charging pumps became inoperable for a period of 38 minutes when hydrogen gas entered the common suction of the two pumps. At the time of the event, the PDP was out of service for modifications; therefore, a total loss of charging flow and high head safety injection capability occurred. The cause of this event was attributed to an empty reference leg in the damper level control (to smooth pulsations of the PDP) system and resulted in a continuous supply of hydrogen gas to the damper. When the PDP suction valve was opened, in preparation for returning the PDP to service, it resulted in a continuous flow of hydrogen gas into the common suction of the two centrifugal charging pumps. The cause of the empty reference leg could not be determined; no leaks were found when the reference leg was refilled. This event was classified as an Appendix C item (NUREG 0090, Vol. 5, No. 2) and also was described in IE Information Notice No. 82-19. Although this notice conveyed a concern that a single failure could lead to similar consequences, no specific preventive recommendations or guidance on lessons learned was transmitted to the licensees.

E. Survey of VCT Level Instrumentation

Because of our assumed uniform design of the VCT level instrumentation, we made a limited survey to better understand what actually is installed at some Westinghouse units.

(1) Sequoyah Units 1&2 - 3411 MWe four loop Westinghouse Reactors with Operating Licenses Issued in 1980 & 1981.

Each unit has two safety-related centrifugal charging pumps and a nonsafety-related PDP. There are four sealed bellows-type differential pressure transducers to measure the liquid level in the VCT. Each transducer has independent high and low pressure taps from a 2-inch diameter penetration in the VCT. Therefore, each sensor would have its own independent instrument legs and would not be susceptible to common mode failure.

(2) Turkey Point 3&4 - 2200 MWe three loop Westinghouse Reactors with Operating Licenses Issued in 1972 & 1973.

Each unit has three safety-related positive displacement charging pumps. The VCT has two liquid level sensors - one for level indication only, the other for controlling valve position only. Both sensors share the common reference leg.

(3) Ginna - A 1520 MWe two loop Westinghouse Reactor with Operating License Issued in 1969.

The unit has three positive displacement charging pumps. They are not safety-related and trip off on a safety injection signal (exactly opposite of the start signal generated by an SIAS at St. Lucie). There is only one liquid level sensor on the VCT.

CONCLUSIONS

The loss of all charging flow with the reactor in hot standby conditions (or at power operations) should have no significant short-term effect on safety. At St. Lucie, the charging system is not safety-related. In addition, charging flow was restored quickly and the RCPs continued to operate to insure forced circulation through the core. There was no significant decrease in RCS inventory during the loss of the charging system; pressurizer level was originally above the heater cutoff level and fluctuated around the heater cutoff level during the event.

At a typical Westinghouse unit, high head safety injection and seal injection flow would be lost by gas binding of the charging system. A loss of liquid within the VCT is not indicative of a coincident safety event, therefore, it is reasonable to assume that the coincidence of a loss of charging pump suction due to a VCT malfunction, together with an immediate need for high head safety injection, while the pumps are still gas bound, is too remote for practical consideration. Also, the RCPs at a Westinghouse unit are capable of continuous operation with a delay in restoration of seal injection flow. There is no danger of RCP seal failure due to gaseous injection as both types of charging pumps would cavitate in the absence of a liquid head.

We find the corrective actions taken by St. Lucie (separate instrument lines to each differential pressure transducer to eliminate the potential of common reference leg failure) to be the proper solution and to be all that is necessary for future satisfactory operation. We also recommend that all units with a common reference leg on the VCT level instrumentation change to a system of completely independent sensors to eliminate the potential of common mode failure as was experienced by St. Lucie. This type of change, in our opinion, would be of considerable cost benefit to the utility.