PSE&G

Public Service Electric and Gas Company 80 Park Plaza Newark, N.J. 07101 Phone 201/430-7000
Mailing Address: P.O. Box 570, Newark, N.J. 07101

October 27, 1981

Director of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
7920 Norfolk Avenue
Bethesda, MD 20014

Attention: Mr. Steven A. Varga, Chief
Operating Reactors Branch 1
Division of Licensing

Gentlemen:

TMI TOPIC II.F.2.3
NO. 1 AND 2 UNITS
SALEM NUCLEAR GENERATING STATION
DOCKET NO. 50-272 AND 50-311

PSE&G hereby submits, in the enclosure to this letter, its response to your request for additional information dated September 23, 1981 concerning the reactor vessel level instrument. The Salem level instruments will utilize a microprocessor for data processing.

Should you have any questions in this regard, do not hesitate to contact us.

Very truly yours,

E. A. Liden
Manager - Nuclear Licensing

FM:srd

Attachment

CC: Mr. Leif Norrholm
Senior Resident Inspector
Mr. Gary C. Meyer
Licensing Project Manager

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RESPONSES TO NRC REQUEST FOR ADDITIONAL INFORMATION ON THE WESTINGHOUSE R.V.L.I.S.

SUMMARY REPORT

(μ Processor)

0258Q:1

Item 1

Justify that the single upper head penetration meets the single failure requirement of NUREG-0737 and show that it does not negate the redundancy of the two instrument trains.

Response

1. Redundancy is not compromised by having a shared tap since it is not conceivable that the tap will fail either from plugging or breaking. Freedom from plugging is enhanced by, 1) use of stainless steel connections which preclude corrosion products and, 2) absence of mechanisms, such as, flow for concentrating boric acid. It is also inconceivable that the tap will break because it is in a protected area. It should also be pointed out that in other cases where sharing of a tap occurs in the RCS, we know of no prior experience reporting deleterious malfunctions of the shared tap. Also, even if the shared tap does fail, it should be recognized that RVLIS is not a Protection System initiating automatic action, but a monitoring system with adequate backup monitoring such as by core exit thermocouples for operator correlation.

Response to NRC Request for
Additional Information on the
Westinghouse R.V.L.I.S.

Item 2

Describe the location of the level system displays in the Control Room with respect to other plant instrument displays related to ICC monitoring in particular, the saturation meter display and the core exit thermocouple display.

Response

The primary reactor vessel level display will be located on a section of the circular console adjacent to the saturation meter display and the core exit thermocouple display. The secondary reactor vessel level display will be located on a upright panel directly behind the location of the primary reactor vessel display.

Item 3

Describe the provisions and procedures for on-line verification, calibration and maintenance.

Response

3. In general, the system electronics are verified, maintained and calibrated on-line by placing one of the redundant trains into a test and calibrate mode while leaving the other train in operation to monitor inadequate core cooling.

   A general verification is performed before shipment, but plant specific data is not used. The capability exists for the operator to verify the operation of the system. This would involve disconnecting the sensors at the RVLIS electronics, providing an artificial input, and observing the response of the system on the front panel and remote display.

   On-line calibration of the system is made possible by the controls available on the main processing unit. The calibration consists of entering constants into the non-volatile RAM along with adjusting the potentiometers on the analog to digital conversion cards. The initial calibration is done when the system is installed, but subsequent calibrations can be performed as described in the Technical Manual to maintain system accuracy.

   The RVLIS system requires the normal maintenance given to other control and protection systems within the plant. On-line maintenance is accomplished by placing only one of the two redundant trains into maintenance at a time this will allow continued monitoring of inadequate core cooling.

   In addition, software programs are provided so that the front panel controls and display can be used to perform a functional test, serial data link tests, calibration tests and deadman timer tests. These tests are considered part of the operator maintenance procedures and should be performed monthly. For additional details of procedures see "Attachment A".

ATTACHMENT A

SYSTEMS OPERATING PROCEDURES

2-1. PURPOSE

The objectives of these instructions are to establish the requirements for the use of the Reactor Vessel Level Instrumentation System (RVLIS) for various plant conditions and to specify the maintainability requirements of the system equipment.

2-2. PREREQUISITES

- The capillary lines have been vacuum filled, per the instructions of section 4.
- Ensure that the hydraulic isolators are zeroed (within plus or minus 0.1 in.^{3}).
- Calibrate the d/p cells per instructions of ITT Barton Manual for Model 752, Level B, transmitters.
- The process equipment must be scaled using the appropriate scaling document.
- Determine the height of the upper top piping above the inside top of the vessel.

2-3. INITIALIZATION

With the plant less than 200°F and less than 430 psig, obtain the following data for trains A and B:

(1) With an automatic data logger, record the following:

- o T_{hot}
- o RCS pressure
- o d/p transmitter output
- o Signal to the remote display

(2) Manually record:

- o Level indication readings
- o Hydraulic isolator dial readings
- o Reference leg RTD output

(3) Record the above data for the following reactor coolant pump operations:

NOTE

The various configurations should be obtained through the normal startup if possible.

NOTE

Upper plenum will read offscale if pump is running in the instrumented loop; narrow range will read offscale with one or more pumps running.

- o No pumps running

NOTE

An indication of 100 percent reading represents a level to the inside top of the vessel. The height of the upper top piping above the inside top of the vessel will result in a reading greater than 100 percent. This added height is plant specific and must be determined prior to adjusting the process equipment (upper plenum and narrow range) for full scale indication.

- o One noninstrumented loop pump running
- o Two noninstrumented loop pumps running
- o Two noninstrumented loop pumps and one instrumented loop pump running
- o All pumps running -- Adjust process equipment so that wide range indication reads 100 percent.

(4) With all pumps running, increase RCS pressure - temperature to T_{avg} no-load and record data refer to step (1) every 50°F increment. Data of step (2) should be recorded at 350°F and at T_{avg} no-load. Adjust process electronics for density compensation at T_{avg} no-load. Verify that wide range indication reads 100 percent.

(5) Trip all pumps and record data per steps (1) and (2). Verify that upper plenum and narrow range indication is in agreement with the reading of step (3) "No pumps running".

(6) Restart pumps in sequence and record wide range readings for both trains for each pump combination.

(7) Enter into the equipment programming the expected percent level for the various pump combinations per the microprocessor instruction manual.

2-4. NORMAL PLANT OPERATION

With the plant at power, the level readings should be as follows:

Wide range	~110 percent (wide range reading will increase from 100 percent to approximately 110 percent with all pumps running, as reactor power is increased from zero to 100 percent)

Narrow range	Off Scale - High
Upper plenum	Off Scale - Low (RCP status light on main control board is off)

Any reduction in wide range expected readings (with all pumps running) can only be caused by the presence of voids in the circulating water. Voids will not exist without reduced pressure which could trip the reactor, so all accident conditions will proceed from a condition of zero power (100 percent reading on the wide range). Check that the pressure has decreased or that subcooling meter confirms saturation conditions exist; then readings below 100 percent are an indication of voids in the coolant.

If the actual readings differ from the expected readings by 3 percent for a single train, refer to troubleshooting (paragraph 2-10).

If the indication for both trains differs from the expected readings, refer to the emergency operating instructions for immediate and subsequent action.

2-5. REFUELING

After depressurization and prior to lifting the reactor vessel head, perform the following steps to prepare the RVLIS:

(1) Close reactor vessel level head connection isolation valve.

(2) Disconnect piping between the isolation valve and the sensors.

NOTE

Contaminated water residue may be in the pipe.

(3) Provide temporary plugs for the pipe ends of the removable section and stationary sections.

Restore the RVLIS after reactor vessel head installation as follows:

(1) Remove pipe end plugs and reconnect piping section.

(2) With the isolation valve open, backfill the piping from sensors by attaching a water source to the sensor vent.

(3) Disconnect waterfill apparatus.

(4) At startup (450 psig, <200°F), visually inspect piping/ coupling of the reinstalled piping for leakage.

(5) At full system pressure, repeat inspection.

2-6. PERIODIC TESTING

2-7. Plant at Power

Perform monthly calibration checks of the process electronics in accordance with the process equipment instruction manual.

2-8. Refueling Outages

(1) For the d/p transmitters, perform zero check of each d/p transmitter by closing the respective isolation valves and opening the bypass valve. If zero reading differs from the last recorded reading by percent, then recalibrate d/p transmiter using instructions of Barton Instruction Manual (Model 752) and the instructions contained in the RVLIS system manual and the appropriate equipment instruction manuals.

(2) Record the appropriate hydraulic isolator dial readings and compare results with previous cold shutdown readings. Readings should be within plus or minus 0.1 in.^{3}.

(3) Perform the calibration check of the process electronics in accordance with the equipment technical manual.

(4) Verify the operability of the RVLIS System during the startup/heatup of plant following a refueling or major plant outage by tracking the displays of the two trains. Readings should be within percent of the previous recorded readings.

2-9. Every Other Refueling Outage

In addition to the steps of paragraph 2-8, perform the following every other refueling outage:

(1) At the process equipment cabinets, read the impulse line RTD resistances.

NOTE

Take the ambient temperature reading near the RTD and adjust the measured resistance accordingly. Compare the adjusted resistance to the original results or the previous recorded data.

(2) Employing a pneumatics calibration, per instructions of section 4 at the sensor vent ports, check the calibration of the transmitters and perform a time response check of the system. The calibration results should be within plus or minus percent of instrument span of the previous recorded data. The time response of the system should be within 10 seconds. This is the time required for the display instrument to reach the midpoint of a 50 percent step input variable change.

2-10. TROUBLESHOOTING, PLANT AT POWER

If single indication varies from the expected value, check the following:

(1) Call for the sensor status display for any abnormalities.

(2) Compare hydraulic isolator dial reading with reading taken from diverse train and those taken at T_{avg} no-load conditions. Dial readings deviating by more than plus or minus 0.1 in.^{3} may be indicative of potential capillary line leakage; however, it may not be the reason for the deviation in the display reading until the isolator reached the valve-off point.

(3) Perform a calibration check of the process equipment, per the appropriate instruction manual.

(4) Perform a zero check of the appropiate d/p transmitter.

If more than one indicator/display deviates from the diverse train or from T_{avg} no-load readings, check the following:

- o Common isolator dial readings versus previous reading
- o d/p transmitter valve lineup
- o Process equipment power supplies

If repairs are required to the capillary lines, the system must be vacuum-filled and calibrated per the instructions contained in section 4 and the appropriate equipment instruction manuals.

Item 4

Describe the diagnostic techniques and criteria to be used to identify malfunctioning components.

Response

The microprocessor based RVLIS performs internal diagnostic checks of the non-volatile RAM, non-volatile PROM and other microprocessor components. No operator interface is required for these internal checks which are performed in each cycle. A "deadman" circuit is provided to detect microprocessor failure. This circuit will indicate a processor problem on the front panel of the unit and automatically reset the CPU to restart the microprocessor. The remote display unit of the RVLIS indicates the status of the input sensors. If any sensor is out of range or disabled a symbol will follow the affected level reading on the summary display page. In addition, software programs are provided so that the front panel controls and display can be used to perform a functional test, serial data link tests, calibration tests and deadman timer test. These tests are considered part of the operator maintenance procedures and should be performed monthly.

Item 5

Estimate the in-service life under conditions of normal plant operations and describe the methods used to make the estimate, and the data and sources used.

Response

The in-service life of the RVLIS Microprocessor based electronics is dependent upon proper maintenance, including the replacement of individual component parts when necessary. The provisions for this maintenance are included in the technical manual. Based on the assumption of normal conditions and proper maintenance of the components, the only limitation to the in-service life will be the availability of replacement parts. It is estimated that in 20 years, some of the components will be technically obsolete and no longer produced. Consequently, the cards may have to be modified in the future to accommodate the current technology. Thus, any individual component failures are regarded as maintenance considerations and their replacement is necessary to prolong in-service life.

In-Service life which is different than Design Life and Qualified Life is dependent upon implementing a scheduled preventative maintenance program including periodic overhaul of the equipment. In this manner, the equipment is restored to a level that continual operatibility is ensured. In developing the maintenance program, repair costs may necessitate replacement of the equipment.

If the maintenance program is followed there is no apparent reason that operation of the equipment cannot be extended.

Some of the equipment is similar to equipment installed in present Westinghouse plants that have been operating for 10-15 years.

The following valves have been supplied by Westinghouse for the Reactor Vessel Level Instrumentation System for Beaver Valley Unit No. 1:

W Valve ID	Qty	Manufacturer	W Design Specification	Code Applicability
3/4 T 78	4	Rockwell	G-952855; Rev 0	ASME B&PV Class II
1/4 X 28I	10	Autoclave Engineers	G-955230; Rev 2	N & S
1/4 N 28I*	6	Autoclave Engineers	G-955230; Rev 2	N & S

* Shut off valve which is part of the transmitter access assembly.

The 3/4 T78 valve is a stainless steel, manually operated globe valve whose basic function is to isolate the flow of fluid. The valve is designed for a cycle life of 4000 cycles over the 40 year design life, which satisfies the normal plant operating requirements established in above referenced specification. The vave is a hermetically sealed valve, designed to be maintenance free with no consumable materials making a pressure boundary seal.

The instrumentation valves (W Valve ID's 1/4 x 28I and 1/4 N28I) stainless steel, manually operated valves, designed to meet the requirements of the above referenced specification, which calls for zero leakage (environmentally and across the seats), minimal fluid displacement during stoke and a 1000 cycle life. For normal plant operating conditions, the metallic parts are designed for a 40 year service life. The consumable items, where applicable, are identified in the appropriate drawings and instruction manuals, with recommended maintenance schedules.

Item 6

Explain how the value of the system accuracy (given as +/- 6% was derived. How were the uncertainties from the individual components of the system combined? What were the random and systematic errors assumed for each component? What were the sources of these estimates?

Response

6. The system accuracy of ± 6% water level was a target value established during the conceptual design and was related to the dimensions of the reactor vessel (12% from nozzles to top of core) and core (30%), and the usefulness of the measurement during an accident. Subsequent analyses have established a system accuracy based on the uncertainties introduced by each component in the instrument system. The individual uncertainties, resulting from random effects, were combined statistically to obtain the overall instrument system accuracy. Some of the individual uncertainties vary with conditions such as system pressure. The following table identifies the individual uncertainties for the narrow range measurement while at a system pressure of 1200 psia.

Component and Uncertainty Definition	Uncertainty % Level
a. Differential pressure transmitter calibration and drift allowance, (± 1.5% of span) multiplied by the ratio of ambient to operating water density.	± 2.1
b. Differential pressure transmitter allowance for change in calibration due to ambient temperature change (± 0.5% of span for ± 50°F) multiplied by the density ratio.	± 0.7

c.	Differential pressure transmitter allowance for change in calibration due to change in system pressure (± 0.2% of span per 1000 psi change) multiplied by the density ratio.	± 0.34
d.	Differential pressure transmitter allowance for change in calibration due to exposure to long-term overrange (± 0.5% of span) multiplied by the density ratio.	± 0.7
e.	Reference leg temperature instrument (RTD) uncertainty of ± 5°F and or allowance of ± 5°F for the difference between the measurement and the true average temperature of the reference leg, applied to each vertical section of the reference leg where a measurement is made. Stated uncertainty is based on a maximum containment temperature of 420°F, and a typical reference leg installation.	± 0.64
f.	Reactor coolant density based on auctioneering for highest water density obtained from hot leg temperature (± 6°F) or system pressure (+ 60 psi). Magnitude of uncertainty varies with system pressure and water level, with largest uncertainty occurring when the reactor vessel is full.	± 2.3

g. Sensor and hydraulic isolator bellows displacements due to system pressure changes or reference leg temperature changes will introduce minor errors in the level measurement due to the small volumes and small bellows spring constants. The changes, such as pressure or temperature, tend to cancel, i.e., the bellows associated with each measurement move in the same direction. Maximum expected error due to differences in capillary line volume and local temperatures is equivalent to a level change of about 5 inches, multiplied by the density ratio. ± 1.46

h. Density function generator output mismatch with ASME Steam Tables limited to a maximum of: ± 0.50

i. Electronics system calibration, overall uncertainty limited to less than: ± 1.0

j. Control board indicator resolution; microprocessor digital readout to nearest percent of level span. ± 0.5

The statistical combination of (square root of the sum of the squares) of the individual uncertainties described above results in an overall system instrumentation uncertainty of ± 3.9% of the level span. For the narrow range indication of approximately 40 feet, or ± 1.5 feet, at a system pressure of 1200 psia. Examples of the uncertainty at other system pressures are:

Uncertainty = ± 3.6% at 400 psia
Uncertainty = ± 4.2% at 2000 psia

Item 7

Assume a range of sizes for "small break" LOCA's. What are the relative times available for each size break for the operator to initiate action to recover the plant from the accident and prevent damage to the core? What is the dividing line between a "small break" and a "large break"?

Response

7. Inadequate core coolant (ICC) was defined in WCAP-9754, "Indequate Core Cooling Studies of Scenario With Feedwater Available Using the NOTRUMP Computer Code", as a high temperature condition in the core such that the operator is required to take action to cool the core before significant damage occurs. During the design basis small loss of coolant accident, the operator is not required to take any action to recover the plant other than to verify the operable status of the safeguards equipment, trip the reactor coolant pump (RCPs) when the primary side pressure has decreased to a specific point, and initiate cold and hot leg recirculation procedures as required. In the design basis small LOCA, a period of cladding heatup may occur prior to automatic core recovery by the safeguards equipment. The heat up period is dependent upon the break size and ECCS performance.

   An ICC condition may arise if there is a failure of the safeguards equipment beyond the design basis. In that case, adequate instrumentation exists in the Beaver Valley plant to diagnose the onset of ICC and to determine the effectiveness of the mitigation actions taken. The instrumentation which may be used to determine the adequacy of core cooling consists of a subcooling meter, Core Exit Thermocouples (T/Cs), and the Reactor Vessel Level Instrumentation System (RVLIS).

   For a LOCA of an equivalent size equal to approximately six inches or less, an ICC condition can only occur if two or more failures occur in the ECCS. As indicated in WCAP-9754, an ICC condition can be calculated by hypothesizing the failure of all high head safety

injection (HPSI) for LOCAs of approximately one inch in size. For a 4 inch equivalent size LOCA one can hypothesize an ICC condition by assuming the failure of all HPSI as well as the failure of the passive accumulator system (a truly incredible sequence of events).

For LOCAs of sizes of six inches or less, the approach to ICC is unambiguous to the reactor operators. The first indication of a possible ICC situation is the indication that some of the ECCS pumps have failed to start or are not delivering flow. The second indication of a possible ICC situation is the occurrence of a saturation condition in the primary coolant system as indicated on the subcooling monitor. Shortly after the second indication, the RVLIS would start to indicate the presence of steam voids in the vessel. At some point in time the RVLIS will indicate a collapsed liquid level below the top of the core. The core exit thermocouples will begin to indicate superheated steam conditions. If appropriate the RVLIS and core exit T/C behavior will provide unambiguous indications to operator to follow the ICC mitigation procedure.

WCAP-9754 indicates that the selected core exit T/Cs will read 1200°F at approximately 11000 seconds after the initiation of a 1-inch LOCA with the loss of all HPSI. The Generic Westinghouse EOP Guideline instruct operator to pursue ICC mitigation procedures when these conditions are reached. The 4-inch LOCA will indicate 1200°F at about 1350 seconds. By following the Westinghouse recommended Emergency Operating Procedures (EOPs), the operators will have earlier indication of a possible ICC situation. Recovery procedures to depressurize the primary below the core pressure safety injection shutoff head may be followed. These procedures include correction of the HPSI failure, opening steam dump, or opening pressurizer PORVs. The RCPs may be restarted to provide additional steam cooling flow.

Large break LOCAs consist of LOCAs in which the fluid behavior is inertially dominated. Small break LOCAs, on the other hand, have

the fluid behavior dominated by gravitational effects. For LOCAs which are significantly larger than an equivalent 6-inch break, the ECCS has the maximum potential for flow delivery since the primary coolant system is at low pressure.

No early manual action is useful in recovering from ICC. Analyses for LOCAs in this range indicate ambiguous behavior of the core exit T/Cs and RVLIS early in the accident due to dynamic blowdown effects. This behavior is temporary and the core exit T/Cs and the RVLIS will indicate the progress being made by the ECCS in recovering the core. When the core exit T/Cs and RVLIS may be temporarily providing ambiguous indications, no manual action is needed or useful. Later in the accident when manual action may be useful, the core exit T/Cs and RVLIS will provide an unambiguous indication of ICC if it exists. This unambiguous indication may be present as early as 30 seconds after the initiation of the LOCA for a double ended guillotine rupture or a main coolant pipe.

It follows from the above discussion that, for ICC considerations, a reasonable definition of large breaks are breaks that are significantly larger than an equivalent 6 inch break. All other breaks are small breaks.

Item 8

Describe how the system response time was estimated. Explain how the response times of the various components (differential pressure transducers, connecting lines and isolators) affect the response time.

Response

8. The microprocessor reads all the inputs every five seconds and updates the digital display and analog outputs within four seconds after the inputs are read. Thus, a worst case time from analog input change to display and analog output change is 9 seconds. Any analog delays due to the front end electronics, sensor electronics, sensor mechanics, impulse lines, hydraulic isolators, etc., have five seconds to settle out. Thus, analog delays only add to the 9 second worst case response time if they are longer than 5 seconds. The front end electronics of the microprocessor system has a time constant less than 0.5 seconds, and the total analog delays due to the sensor electronics, mechanics, impulse lines and hydraulic isolators are less than 3 seconds. Therefore, the worst case response time is 9 seconds for the system.

Item 9

There are indications that the TMI-2 core may be up to 95% blocked. Estimate the effect of partial blockage in the core on the differential pressure measurements for a range of values from 0 to 95% blockage.

Response

9. Blockage in the core will increase the frictional pressure drop and increase the total differential pressure across the vessel. This will be reflected as a higher RVLIS indication. The increase in the RVLIS will be most significant under forced flow conditions when the reactor coolant pumps are operating.

   In order for blockage to be present, the core would have to have been uncovered for a prolonged period of time. A low RVLIS indication along with a high core exit thermocouple indication would have been indicated during this time. If the RCP's had been operating throughout the transient, there would have been sufficient cooling to prevent significant core damage. Therefore, for significant blockage to exist during pump operation, the operator would have restarted the pumps after an ICC condition had existed for a period of time. Based on the history of the transient, the operator would know that the RVLIS would read higher than expected. Although the RVLIS would read high, it would still follow the trend in vessel inventory. The operator would be able to monitor the recovery with the RVLIS.

   Under natural circulation conditions, the impact of core blockage is not expected to be large. Although the RVLIS indication will read slightly higher than normal, the RVLIS will still trend with the vessel inventory and provide useful information for monitoring the recovery from ICC. ICC will have been indicated at an earlier time; before a significant amount of core blockage has occurred. The operator will know that the RVLIS could read slightly high, based on the history of the transient.

Item 10

Describe the effects of reverse flows within the reactor vessel on the indicated level.

Response

10. Reverse flows in the vessel will tend to decrease the DP across the vessel which would cause the RVLIS to indicate a lower collapsed level than actually exists. The low indication would not cause the operator to take unnecessary actions, since the RVLIS would be used along with the core exit thermocouples to indicate the approach to ICC. It is important to note that large reverse flows are not expected to occur for breaks smaller than 6" in diameter during the time that the core is uncovered. Large reverse flow rates may occur early in the blowdown transient for large diameter breaks but, as is discussed in the response to Item 7, it is not necessary to use the RVLIS as a basis for operator action for breaks in this range.

Item 11

What is the experience, if any, of maintaining D/p cells at 300% overrange for long periods of time?

Response

11. Experience in overranging of D/p Instruments has been obtained in previous applications of D/p capsules similar to those used in RVLIS. In Dual Range Flow (D/p) Applications the "Low Flow" transmitter (and/or gages) are overranged to 300% or greater by normal flow rates yet provide reliable metering when required for startup.

    Also, test data exists on the basic transmitter design showing about 0.5% effect on calibration with 24 hours exposure to 3000 psig overrange. All units are similarly exposed to this overrange for 5 minutes in both directions as a part of factory testing.

    There have been instances involving accidental overrange of these instruments (including RVLIS) as the result of leakage or operator errors where full line pressure overranges have occurred for up to several weeks with minimal effect on instrument accuracy.

    Based upon this experience and test data we expect to prove statistically that reliable measurements can be made by the selected overranged instrument designs used for RVLIS. On line calibration capability is provided if needed to support gathering of statistical data.

Item 12

Five conditions were identified which could cause the DP level system to give ambiguous indications. Discuss the nature of the ambiguities for 1. accumulator injection into a highly voided downcomer, 2. when the upper head behaves like a pressurizer, 3. upper plenum injection, and 4. periods of void redistribution.

Response

12. 1. When the downcomer is highly voided and the accumlators inject, the cold accumulator water condenses some of the steam in the downcomer which causes a local depressurization. The local depressurization will lower the pressure at the bottom of the vessel which will lower the DP across the vessel, causing an apparent decrease in level indication. The lower pressure in the downcomer also causes the mixture in the core to flow to the lower plenum, causing an actual decrease in level. The period of time when the RVLIS indication is lower than the actual collapsed liquid level will be brief.

An example of when this phenomenon may occur is when the reactor coolant pumps are running for a long period of time in a small break transient. After the RCS loops have drained and the pumps are circulating mostly steam, the level in the downcomer will be depressed. A large volume of steam will be present in the downcomer, above the low mixture level, which allows a large amount of condensation to occur. For most small break transients, the reactor coolant pumps will be tripped early in the transient and the downcomer mixture level will remain high, even in cases where ICC occurs. When the downcomer level is high the effect of accumulator injection on the RVLIS indication will be minor.

2. When the upper head begins to drain, the pressure in the upper head decreases at a slower rate than the pressure in the rest of the RCS. This is due to the upper head region behaving much like the pressurizer. The higher resistance across the upper support plate relative to the rest of the RCS prevents the upper head from draining quickly. This situation only exists until the mixture level in the upper head falls below the top of the guide tubes. At this time, steam is allowed to flow from the upper plenum to the upper head and the pressure equilibrates. While the upper head is behaving like a pressurizer, the vessel differential pressure is reduced and the RVLIS indicates a lower than actual collapsed liquid level.

This phenomenon is discussed in the summary report on the RVLIS* relative to the three inch cold leg break. Since that time, the upper head modeling has been investigated in more detail. It was found that the modeling used at that time assumed a flow resistance that was too high for the guide tubes. Subsequent analyses have shown that the pressurizer effect has less impact on the vessel dp than was originally shown. There is very little impact on the results after the level drains below the top of the guide tubes. The pressurizer effect is still believed to exist and it becomes more significant as break size increases. The interval of time when the upper head behaves like a pressurizer is brief and the RVLIS will resume trending with the vessel level after the top of the guide tubes uncover. The reduced RVLIS indication will not cause the operator to take any unnecessary action, even if a level below the top of the core is indicated since the core exit thermocouples are used as a corroborative indication of the approach to ICC.

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* Westinghouse Electric Corporation, "Westinghouse Reactor Vessel Level Instrumentation System for Monitoring Inadequate Core Cooling," December 1980.

3. The normal condition for continuous upper plenum injection (UPI) occurs only with the operation of the low head safety injection pumps, which does not occur until a pressure of under 200 psi is realized. The RVLIS may not accurately trend with vessel level during the initial start of UPI. During this short period of time, the cold water being injected will mix with the steam in the upper plenum causing condensation. This condensation will occur faster than the system response. The system will equilibrate after a short period of time. Upon equilibrating, the system will continue to accurately trend with the vessel level.

   In the range of break sizes where RVLIS is most useful in detecting the approach to ICC, the system pressure will equilibrate at a level above the pressure where UPI will normally occur. It is important to note that the flow from the low head pumps is sufficient to recover the core and no operator action based on the RVLIS indication will be necessary.

   For the vast majority of small breaks, the condition of upper plenum injection does not cause a significant impact. For the remainder, the impact is very small and within tolerable limits.

4. During the time when the distribution of voids in the vessel is changing rapidly, there can be a large change in the two-phase mixture level with very little change in collapsed mixture level. The use of the RVLIS, in conjunction with the core exit thermocouples, is still valid for this situation, however. The only event that has been identified which could cause a large void redistribuition is when the reactor coolant pumps are tripped when the vessel mixture is highly voided. After the pump performance has degraded enough that the flow pressure drop

contribution to the vessel differential pressure is small, the change in RVLIS indication will be small when the pumps are tripped. As discussed in the summary report, the approach to ICC would be indicated when the wide range indication read 33 percent. If the pumps were tripped at this time, the core would still be covered. The operator would know that the core may uncover if the pumps were tripped with a wide range indication lower than 33 percent. Prior to pump trip, the core will remain adequately cooled due to forced circulation of the mixture. When the pumps trip the two phase level may equillibrate at a level below the top of the core. The narrow range indication will provide an indication of core coolability at this time.

Item 20

Describe the behavior of the level measurement system when the upper head is full, but the lower vessel is not.

Response

20. During the course of a LOCA transient, the upper plenum will experience voiding before the upper head. The voids in the upper plenum will be indicated by a lower RVLIS reading. The RVLIS will not indicate where the voiding is occurring, but at this point in the transient, it is not necessary to know where the region of voiding is. In the early part of the transient when the mixture level is above the top of the guide tube in the upper head, it is sufficient for the operator to know that the vessel inventory is decreasing, irrespective of the region where voiding is occurring. As discussed in the response to Item 21, the fluid in the upper head does not affect the RVLIS indication after the upper head has drained to below the top of the guide tubes. As discussed in the response to Item 19, the uipper head will drain before the onset of ICC and there will not be an ambiguous indication during the period of time when RVLIS will be used.

Item 13

No recommendations are made as to the uncertainties of the pressure or temperature transducers to be used, but the choice appears to be left to the owner or AE. What is the upper limit of uncertainties that should be allowed? Describe the effect of these uncertainties on the measurement of level. What would be the effect on the level measurement should these uncertainties be exceeded?

Response

13. The reactor coolant pressure and temperature signals originate from the existing wide range pressure and hot leg RTD's already installed in the plant, and the uncertainties for these instruments are understood. As indicated in the response to question 6, the pressure uncertainty is $\pm$ 60 psi and the temperature uncertainty is $\pm$ 6°F, resulting in a maximum level uncertainty contribution of $\pm$ 2.3% when the vessel is full. This uncertainty is smaller when the level is at the elevation of the reactor core. This contribution to the total uncertainty would increase roughly in proportion to an increase in the pressure or temperature measurement uncertainty.

Item 14

Only single RTD sensors on each vertical run are indicated to determine the temperatures of the impulse lines. Where are they to be located? What are the expected temperature gradients along each line under normal operating conditions and under a design basis accident? What is the worst case error that could result from only determining the temperature at a single point on each line?

Response

14. RTD sensors are installed on every independently run vertical section of impulse line, to provide a measurement for density compensation of the reference leg. If the vertical section of impulse line runs through two compartments separated by a solid floor, an RTD sensor is installed in each compartment.

    The RTD is installed at the midpoint of each vertical section, based on the assumption that the temperature in the compartment is uniform or that the temperature distribution is linear in the vicinity of the impulse line. As stated in the response to question 6, an allowance for the true average impulse line temperature to differ from the RTD measurement by 5°F is included in the measurement uncertainty analysis. This allowance permits a significant deviation from a linear gradient, e.g., 20% of the impulse line could be up to 25°F different from a linear gradient without exceeding the allowance. During normal operation, forced circulation from cooling fans is expected to maintain compartment temperatures reasonably uniform. During the LOCA, turbulence within a compartment due to release of steam would also produce a reasonably uniform temperature. Note that the impulse lines are protected from direct jet impingement by metal instrument tubing channels.

Item 15

What is the source of the tables or relationships used to calculate density corrections for the level system?

Response

The relationships used in the microprocessor based RVLIS system to calculate density corrections are used on the ASME Steam Tables dated 1967. These relationships are implemented in the system using two fourth order polynomials, end to end, fit to approximate the tables above.

Item 16

The microprocessor system is stated to display the status of the sensor input. Describe how is this indicated and what this actually means with respect to the status of the sensor itself and the reliability of the indication.

Response

The remote display unit of RVLIS indicates the status of the input sensors. If any sensors are out of range, regardless of the reason, a symbol allows the affected level reading on the summary display page. The particular sensor that is out of range is identified at the bottom of the summary display page. Due to the redundant sensors and trains it is possible for the operator to disable some of the sensors without affecting the system reliability. The display indicates which level readings are affected. The disabled sensors are also displayed at the bottom of the summary page. A separate sensor status page can be displayed showing all sensors which are disabled or out of range and their affected level readings.

Item 17

Describe the provisions for preventing the draining of either the upper head or hot leg impulse lines during an accident. What would be the resultant errors in the level indications should such draining occur?

Response

17. The layout of the impulse lines from the upper head and hot leg are arranged to prevent or minimize the impact of drainage during an accident. In general, however, the water in the impulse lines will be cooler than the water in the reactor or hot leg, and there will be sufficient subcooling overpressure in the lines so that very little, if any, of the water would flash to steam during a depressurization or containment heatup. Heat conduction along the small diameter piping and tubing would be insufficient to result in flashing in a significant length of piping.

    The connection to the upper head from a spare control rod drive mechanism port or vessel vent line drops or slopes down from the highest point of the vessel connection to the sensor bellows mounted on the refueling canal wall, so water would be retained in this piping. Draining of the vertical section immediately above the reactor vessel has no effect on the level measurement, since this section is included in the operating range of the instrument. Draining of the horizontal portion of vessel vent piping above the vessel also has no effect on the measurement since no elevation head is involved.

    The connection from the hot leg to the sensor bellows is a horizontal run of tubing, so draining of this tubing has no effect on the measurement since no elevation head is involved.

    The majority of the impulse line length is in capillary tubing sealed at both ends with a bellows (sensor bellows at the reactor end, hydraulic isolator at the containment penetration end), so

water would be retained in this system at all times. The water will be pressurized by reactor pressure, and since the reactor temperature will be higher than containment temperature during an accident, the water in the sealed capillary lines cannot flash.

Item 18

Discuss the effect on the level measurement of the release of dissolved, noncondensible gases in the impulse lines in the event of a depressurization.

Response

18. The majority of the impulse lines are sealed capillary tubes vacuum filled with demineralized, deaerated water. The lines contain no noncondensible gases and are not in a radiation environment sufficient for the disassociation of water.

    The short runs of impulse line connected directly to the primary system will behave as described in the response to question 17. There would be no error due to gases in the hot leg line since the line is horizontal. Since there is no mechanism for concentration of gases at the top of the reactor vessel during normal operation, the connection to the top of the vessel would contain, at most, the normal quantity of dissolved gases in the coolant, and the subcooling pressure during an accident would maintain this quantity of gas in solution.

Item 19

In some tests at Semi-scale, voiding was observed in the core while the upper head was still filled with water. Discuss the possibility of cooling the core-exit thermocouples by water draining down out of the upper head during or after core voiding with a solid upper head.

Response

19. One of the indicators of an approach to an Inadequate Core Cooling (ICC) situation is the response of the core exit thermocouples (T/Cs) to the presence of super-heated steam. The core exit thermocouples will not provide an indication of the amount of core voiding. Response of the core exit T/Cs provides a direct indication of the existence of ICC, the effectiveness of ICC recovery actions, and restoration of adequate core cooling. The core is adequately cooled whenever the vessel mixture level is above the top of the core and the core may have a significant void fraction and still be adequately cooled.

    Realistically, an indication of an ICC condition would not occur until the primary coolant system has drained sufficiently for the reactor vessel mixture level to fall below the top of the core. Westinghouse has performed analyses which indicate that the upper head will drain below the top of the guide tubes before ICC conditions exist. The guide tubes are the only flow path from the upper head to the upper plenum. In WCAP-9754, "Inadequate Core Cooling Studies of Scenarios With Feedwater Available, Using the NOTRUMP Computer Code", it was found that inadequate core cooling situations woul not result for LOCAs of an equivalent size or equal to approximately 6 inches or less without two or more failures in the ECCS. In both specific scenarios examined in WCAP-9759, a 1-inch and 4-inch small LOCA, the upper head and upper plenum had completely drained before the onset of an ICC condition.

In the Beaver Valley plant, the core exit T/Cs protrude slightly from the bottom of the support columns . In this location, they measure the temperature of the fluid leaving the core region through the flow passages in the upper core plate. Flow from the upper head must enter the upper plenum via the guide tube before being able to enter the upper core plate flow passages. In addition, the LOCA blowdown depressurization behavior must be such that there is a flow reversal for the core exit T/Cs to detect the upper head fluid temperature. The upper head fluid is expected to mix with the upper plenum fluid as it drains from the upper head.

The potential for core exit T/C cooling from colder upper head fluid, while the core has an appreciable void fraction is not viewed as a potential problem for the detection of an inadequate core cooling situation. Although some Semi-scale tests indicated core voiding while the upper head was liquid solid that does not imply that the core exit T/Cs would give an ambigious indication of ICC. Calculations for a Westinghouse PWR and consideration of the core exit T/C design would not result in ambigious ICC indications.

Item 21

One discussion of the microprocesor system states that water in the upper head is not reflected in the plot. Does this mean that there is no water in the upper head or that the system is indifferent to water in the upper head under these conditions?

Response

21. The discussion in the system description is contained in the section describing the analysis of the system performance. The statement in question is referring to the WFLASH code calculation of mixture level, rather than how the RVLIS will respond to water in the upper head. The computer code includes calculation of water mass and pressure in the upper head, but this water mass is not included in the calculation of mixture level; hence, the mixture level is indicated only below the elevation of the upper support plate.

    The RVLIS measurement from top to bottom of the vessel will measure the level in the following regions: top of vessel to top of guide tube; inside guide tube from top to upper support plate; upper plenum; reactor core; lower plenum. During a LOCA, the RVLIS will measure the water level in the upper head only until the level drops to the top of the guide tubes; RVLIS would then measure level reduction in the guide tubes and upper plenum. The water remaining in the upper head below the top of the guide tubes would not be measured by RVLIS. This water would eventually drain through small holes into the guide tubes and downcomer, and this draining would be accomplished within a few minutes, depending on the accident. In any case, the water temporarily retained in the upper head would have no effect on the RVLIS indication.

Item 22

Describe the details of the pump flow/Dp calculation. Discuss the possible errors.

Response

22. Calculations are performed to obtain an estimate of the differential pressure that the wide range instrument will measure with all pumps operating, from ambient temperature to operating temperature. The calculations employ the same methods used to estimate reactor coolant flow for plant design and safety analysis. These calculations are used primarily to define the instrument span and to provide an estimate for the function that compensates the differential pressure signal over the full temperature range, i.e., that results in the wide range display indicating 100% over the full temperature range with all pumps operating, pumping subcooled coolant. During the initial plant startup following installation of the instrumentation, wide range differential pressure data would be obtained and used to confirm or revise the compensation function so that a 100% output is obtained at all temperatures. Since the calculated compensation function is verified by plant operating data, any uncertainties in the flow and differential pressure estimates are eliminated.

Item 23

Have tests been run with voids in the vessel? Describe the results of these tests.

Response

23. At present a Westinghouse RVLIS is installed at the Semiscale Test Facility in Idaho. Small break loss-of-coolant experiments are being conducted at this facility by EG&G for the NRC. The results of these tests are used to compare the RVLIS measurements with Semiscale differential pressure measurements, gamma densitometer data and core cladding surface thermocouple indications. To date, after correcting for differences between PWR reactor vessel internals and Semiscale modeling, good correlation between Semiscale level indications and RVLIS measurements has been observed. In cooperation with the NRC, EG&G and ORNL, Westinghouse is preparing a report summarizing the RVLIS performance during selected Semiscale tests.

Item 24

Estimate the expected accuracy of the system after an ICC event.

Response

24. The accuracy of the system as described in the response to question 6 would be the same for any LOCA-type incident, including an ICC event, causing a temperature increase within the reactor containment. Uncertainties due to reference leg temperature measurements and sensor and hydraulic isolator displacements are included in the accuracy analysis.

Item 25

Describe how the conversion of RTD resistance to temperature made in the analog level system.

Response

The RTD is connected such that an analog voltage which is proportional to RTD temperature, is input to the microprocessor system. This analog voltage is converted to temperature by using a curve stored in memory which relates voltage to RTD temperature.