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L30-84(10-10)L
1A.120

Illinois Power Company
Clinton Power Station - Unit #1

REACTOR PRESSURE VESSEL WATER LEVEL MEASUREMENT SYSTEM EVALUATION REPORT

Interim Closure Report

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I. INTRODUCTION

This interim closure report presents the preliminary results of a study performed by Illinois Power Company (IP) and Sargent & Lundy (S&L) on the Clinton Power Station (CPS) Reactor Pressure Vessel Water Level Measurement System (WLMS). This study was performed in response to Nuclear Regulatory Commission (NRC) Staff concerns regarding the ability of the BWR WLMS to respond appropriately during "off-normal" or postulated accident conditions. Based upon this study, the CPS WLMS design has been modified to provide increased reliability during such abnormal conditions. With this modification, the CPS WLMS satisfies proposed NRC requirements related to monitoring for inadequate core cooling conditions.

II. HISTORY OF ISSUE

BWR WLMS, through many years of operating experience, have demonstrated a very high degree of capability to provide reactor water level information as required during varied conditions of reactor plant operation. Almost without exception, the information presented to the operator is not ambiguous and system trips, initiations and other signals taken from the WLMS have occurred as required. However, there have been a few reported events, during which the WLMS responded to a particular set of circumstances with spurious signals and erroneous information to the operator. None of these events resulted in any serious consequences. Such events represent a very small segment of possible conditions, have occurred very rarely, and are recognizable by the operator. These events did indicate the desirability of an overall reassessment of the WLMS design with the objective of developing a full understanding of potential system vulnerabilities and assessing the need for long term improvements.

Following the accident at Three Mile Island, both the NRC and the nuclear industry focused attention on many safety-related aspects of nuclear plant design. Specific attention was given to the WLMS since ambiguous indication of level was a major contributor to the TMI accident. In April of 1979, the NRC Staff issued IE Bulletin 79-08, which requested information from each BWR licensee on their WLMS. In July of 1979, General Electric issued Service Information Letter (SIL) 299 which advised BWR Owner's of potential WLMS errors due to abnormally high drywell temperatures. In August of 1979, the NRC Staff issued IE Bulletin 79-21, which requested information concerning "Temperature Effects on Level Measurement" and issued NUREG-0626 in January, 1980. General Electric responded with NEDO-24708, which provided the NRC Staff with "Additional Information Required for NRC Staff Generic Report on Boiling Water Reactors". Several additional reports were prepared by GE and submitted to the NRC for review following issuance of NUREG-0626.

The NRC Staff requirements concerning the detection of inadequate reactor core cooling were formalized with the issuance of NUREG-0737, specifically Item II.F.2, entitled "Instrumentation for Detection of Inadequate Core Cooling". These requirements involved the addition of diverse instrumentation to the reactor for monitoring such conditions.

With the issuance of Regulatory Guide 1.97, Revision 2, the NRC required that in-core thermocouples be provided for BWRs to monitor the approach to and existence of inadequate core cooling (ICC).

The BWR Owner's Group for TMI Activities (BWROG) responded to the requirement for in-core thermocouples with a report showing that such indication would not always be reliable or accurate during postulated accident conditions within the reactor vessel. As a result of meetings with the NRC Staff, the requirement for in-core thermocouples for BWRs was placed in abeyance, and the BWROG agreed to sponsor programmatic evaluations of BWR WLMS designs and ICC detection and hardware.

In July of 1982, the BWROG submitted the results of their evaluation of BWR WLMS designs to the NRC in SLI-8211, entitled "Review of BWR Reactor Vessel Water Level Measurement Systems", prepared by Sol Levy Inc. This report identified six (6) major concerns associated with the performance of the WLMS. Recommendations were made within this report to address these concerns.

In addition to SLI-8211, Sol Levy Inc. prepared, for the BWROG, SLI-8218, entitled "Inadequate Core Cooling Detection in Boiling Water Reactors". This report provided an analysis of the relationship between reactor water level and fuel cladding temperature under accident conditions and concluded that water level is a conclusive indicator of the adequacy of core cooling. A quantitative estimate of the core damage risk associated with failures in the WLMS, using probabilistic risk assessment (PRA) techniques, showed that this risk is small. SLI-8218 therefore concluded that if the improvements to the WLMS identified in SLI-8211 were made and if adequate Emergency Procedures were provided to plant operators, then additional instrumentation to monitor for ICC is not warranted.

The NRC Staff has elevated the importance of these issues to Unresolved Safety Issue A-50 "Reactor Vessel Level Instrumentation in BWRs". The staff has prepared a memorandom for resolving Issue A-50 that encompasses their review of the BWROG work on TMI Action Plan Item II.F.2. This memorandum confirms the NRCs general agreement with the conclusions and recommendations of the BWROG work.

III. CLINTON CONFIGURATION

The CPS WLMS senses liquid level in the vessel by using a cold reference leg connected to the reactor vessel steam space via a condensing chamber and a variable leg connected at an elevation below the water level. Density compensation is not provided by this system. The water level in the reactor vessel is then determined by measuring the differential pressure between the reference leg and variable leg. In a cold reference leg system, the fluid temperature in the instrument sensing lines is not significantly affected by process conditions, but is determined by the drywell ambient temperature.

The level instruments are used by the various systems that can be actuated by the WLMS via the Analog Trip System (ATS). The outputs of the level transmitters are sent to trip units which compare the sensor output to a setpoint. When the level output from the transmitter moves

through the setpoint, the output of the trip unit changes state, causing the desired action to occur. The use of ATS allows the trip setpoints to be set at a control room panel so no access to instruments is required for adjustments.

The CPS WLMS utilizes four divisions of instrumentation covering five different instrument ranges. Briefly, the significance of the various water level ranges are as follows:

(1) Shutdown Water Level Range: This range is used to monitor the reactor water level during the shutdown condition when the reactor is flooded for maintenance and head removal. A standpipe is used to provide a reference leg. The vessel water temperature and pressure condition that is used for the calibration is 0 psig and 120° F.

(2) Upset Water Level Range: This range is continuously recorded (one pen, 0 to 180") on the same dual pen recorder as the Narrow Water Level Range (the other pen, 0 to 60"). The vessel pressure and temperature condition for accurate indication is at normal operating conditions.

(3) Narrow Water Level Range: This range has RPV taps at the elevation near the top of the dryer skirt and at the elevation near the bottom of the dryer skirt. The zero for this instrument range is the bottom of the dryer skirt, and the instruments are calibrated to be accurate at normal operating conditions. The feedwater control system uses this range for its water level control and indication inputs.

(4) Wide Water Level Range: This range has RPV taps at the elevation near the top of the dryer skirt and at an elevation near the top of the active fuel. The zero for this instrument range is the bottom of the dryer skirt, and the instruments are calibrated to be accurate at normal power operating conditions. The ECCS and Reactor Protection Systems are provided with WLMS actuation logic signals from this range.

(5) Fuel Zone Water Level Range: This range has RPV taps at the elevation near the top of the dryer skirt and at the jet pump diffuser skirt. The zero for this instrument range is the top of the active fuel, and the instruments are calibrated to be accurate at 0 psig and saturated condition. A second scale is provided on the control room indicator which references the water level to the bottom of the dryer skirt.

Attachment 1 (draft figure A-3 from the final evaluation report) shows the layout for the wide and narrow range instruments. The arrangement for the remaining ranges is similar.

IV. SIX CONCERNS FROM BWR OWNER'S GROUP SLI-8211 REPORT

SLI-8211 identified six (6) concerns related to the performance of the WLMS during and following postulated abnormal plant conditions. The 6 concerns from SLI-8211 and the CPS response for each are as follows:

Concern 1

This concern is associated with WLMSs that use Yarway temperature compensated reference legs. With the reference leg operating at an elevated drywell temperature, conflicting and erratic level indications may occur when the vessel reaches intermediate pressure (350 to 400 psia) during the course of plant cooldown. The concern arises because of the potential for Yarway reference leg flashing under these conditions. The nonconservative (i.e. "high") level indications could delay injection system actuation and cause premature termination of the high pressure injection systems.

CPS Response 1

The design of the CPS WLMS does not include Yarway temperature compensated instrumentation. Therefore, this concern is not applicable to CPS.

Concern 2

This concern is associated with the orifices that exist in the reference and variable legs of the WLMSs at most plants. Characteristically, these orifices are located as near as practical to the vessel nozzle to which the reference or variable leg is attached. During combined conditions of low vessel pressure and high drywell temperature, orifices at these locations produce a pressure gradient during liquid flashing as a result of the fluid flow out of the lines as it flashes to steam. Erratic level indications, erroneous system trips and initiations, and operator confusion can result from such flashing. Orifices located nearer the drywell penetrations are less susceptible to this concern.

CPS Response 2

This concern applies to CPS and has been resolved with the relocation of the orifices nearer the drywell penetrations. The details of this modification and its associated benefits are addressed in Sections VI & VII, respectively, of this interim report. The short-term (transient) flashing errors for the CPS WLMS have been significantly reduced as a result of this modification and are now within acceptable limits (per SLI-8211) for system accuracy and function.

Concern 3

This concern is associated with the difference in vertical drop in the drywell between the reference and variable legs of the WLMS. If a situation exists in which the reference leg vertical drop in the drywell exceeds the variable leg vertical drop and drywell temperature is high, there is a possibility that safety systems may not initiate at the prescribed levels, and there will be corresponding erroneous level indication. The larger the difference in vertical drop, the larger the corresponding potential error.

CPS Response 3

This concern applies to CPS and has been maintained in the WLMS design modification addressed in Section VI of this interim report. The difference in vertical drops for the CPS WLMS has been maintained to within approximately ±12" in the drywell. As a result, the associated drywell temperature induced WLMS indication errors remain insignificant under such postulated conditions (see Section VII for discussion of errors).

Concern 4

This concern is associated with any WLMS which has significant reference leg vertical drop in the drywell. With high drywell temperatures and low reactor vessel pressure conditions, the fluid in the vertical portion of the reference leg can flash to steam resulting in an error in level indication proportional to the vertical drop in the drywell. In this case, the WLMS will indicate higher than the actual water level and, therefore, is confusing to the operator and may cause water injection systems to terminate prematurely. This concern occurs at very low pressure while achieving cold shutdown or during the course of an accident involving vessel depressurization.

CPS Response 4

This concern is applicable to CPS and has been resolved with the design modification to the CPS WLMS described in Section VI of this interim report. The vertical drops of the CPS WLMS reference legs have been reduced to within approximately 30" in the drywell. As a result, the corresponding WLMS errors have been significantly reduced for the effects of long term (steady state) boiling of the reference legs of these instruments (see Section VII for discussion of errors).

Concern 5

This concern is that certain WLMS logic configurations may lead to situations or transients that have not been previously considered. If one assumes a break of one reference leg and a logic configuration whereby a single additional instrument failure can defeat a particular safety function, a sequence of events may result that requires operator action to control reactor vessel inventory.

CPS Response 5

This has been identified by the NRC Staff as the "Michelson Concern". Section V of this interim report addresses this concern as it relates to CPS. As a result of the Failure Modes and Effects Analysis performed on the CPS WLMS, the consequences of such WLMS failure combinations are not of immediate concern for any of the events evaluated. The redundancy within the CPS WLMS allows for the availability of at least one high pressure water make-up system for each event analyzed. As a result, there is never a challenge to fuel design limits or core uncovery.

Concern 6

This concern is associated with the seemingly large number of failures of mechanical trip systems/instrumentation. Mechanical instrumentation is vulnerable to drift, calibration problems, mechanical failures, and maintenance errors.

CPS Response 6

This concern does not apply to CPS since the CPS WLMS logic utilizes analog trip units connected to the WLMS transmitters.

V. MICHELSON CONCERN

The Michelson-type scenario involves a break in the reference leg of one division of the WLMS in combination with an instrument failure (i.e. loss of power supply or transmitter failure) in another division of the WLMS.

The Michelson-type scenario has been fully investigated and analyzed by the BWROG for the BWR 2-6 WLMS designs. The results of these evaluations indicate that for the BWR/6 design the probability of such postulated event scenarios occurring and leading to a failure of Emergency Core Cooling system automatic initiation is negligible ($<1 \times 10^{-7}$ per reactor year).

The final CPS WLMS Evaluation Report will present a Failure Modes and Effects Analysis (FMEA) of the CPS WLMS logic to determine WLMS vulnerabilities to such event scenarios. The preliminary results of this FMEA indicate that the worst scenario is a reference leg failure in conjunction with either an undetected transmitter failure in one of the other three reference legs or an instrument power bus failure. The significance of the reference leg failure is that it affects all attached instrumentation. When water within the reference leg is lost, the water level transmitters will immediately sense high (upscale) water level. In the FMEA it was conservatively assumed that a line break or a leak sufficient to affect the water level in a reference leg will cause high reactor vessel water level indications. In addition, the CPS FMEA addresses only system vulnerabilities in regard to WLMS input failures. Actuation of the affected systems can be initiated by many other sources such as drywell pressure transmitters, etc.

It should be noted that the following systems were not affected by the combined failures analyzed:

(1) the Reactor Protection System; and

(2) Closure of the Main Steam Isolation Valves.

It should also be noted that power bus failures are immediately recognizable to the plant operator since control room annunciators are provided which alarm on low bus voltage.

The FMEA results indicate that, for CPS, the redundancy within the WLMS allows for the availability of at least one high pressure injection system for each failure combination event. Thus, these event scenarios do not result in a challenge to fuel design limits or result in any core uncovery.
The results of the CPS WLMS FMEA are supported by evaluations performed by the Licensing Review Group II (LRG-II) for BWR/6 plants. LRG-II Position Paper 1-ICSB, "Failures in Vessel Level Sensing Lines Common to Control and Protective Systems", addresses the Michelson-type scenario for solid-state plants such as CPS.

VI. DESIGN MODIFICATION

The preliminary results of the CPS WLMS Evaluation Report demonstrates that the originally designed WLMS would have performed adequately under conditions expected for normal plant operation and during the initial stages of postulated abnormal plant events. However, under unusual plant transient conditions, the WLMS instrumentation may have been unable to provide an accurate indication of reactor vessel water level over the long term. Extreme combinations of high drywell temperature and low reactor vessel pressure may produce large positive errors in level indication (i.e. indicated level higher than actual level - nonconservative errors). The magnitude of these errors could affect safety system actuation/trip and inhibit the operator's judgement to take appropriate action to stabilize plant conditions.

The design modifications considered to be the most effective for the CPS WLMS instrument design consisted of the following:

1. Limit the reference leg vertical drop in the drywell to no greater than 30" to reduce the total fluid inventory in the vertical portion of the leg susceptible to flashing;

2. Reduce the vertical drop of the variable leg instrument lines so as to maintain the vertical drop difference in the drywell between the legs in each division no greater than ± 12" for those water level instruments responsible for the actuation of safety systems or the reactor protection system. This constraint will reduce the non-flashing drywell temperature errors to a negligible amount; and

3. Relocate the instrument line flow limiting orifices from their current location at the RPV instrument tap to as close to the drywell wall as possible to minimize the short term (transient) effects of flashing on level indication.

It was determined that the above modifications, if integrated into the CPS WLMS design, would greatly enhance the accuracy and reliability of the water level instrumentation under the degraded conditions of high drywell temperature and low reactor vessel pressure. The CPS WLMS design was therefore modified to bring the instrumentation into conformance with the above guidelines.

Modifications were made to 12 of the 15 WLMS instrument lines. These modifications impacted the four reference legs shared by the narrow, wide, and fuel zone range instruments and the eight variable legs used by the narrow and wide range instruments. The shutdown and upset range instrument variable legs were indirectly affected by the Division 2 narrow range variable leg instrument line modification, since they share a common variable leg. The reference leg shared by the upset and shutdown range instruments and the two fuel zone variable leg lines were not modified since these instruments are not responsible for the initiation of safety-related Emergency Core Cooling Systems.

The four divisions of reference legs were re-routed within the CPS drywell from the instrument condensing chamber to the drywell wall. New drywell penetrations were provided to accomodate the new vertical drop requirements. The 3/4" diameter stainless steel piping was sloped downward from the condensing chamber to the drywell wall such that the cumulative vertical drop did not exceed 25" for all four instrument divisions, which is well within the recommended 30" limit. Total reference leg drops were reduced by as much as 107.6 inches.

Flow limiting orifices were relocated in the reference leg and variable leg instrument lines associated with the wide and narrow range instruments to reduce the impact of transient flashing errors. Orifice plates were moved from their original location at the RPV instrument tap to within approximately 35" from the drywell wall penetration head fitting in terms of true pipe length. In most cases, the orifice plates were placed within approximately 7" of the penetration head fitting. Flow limiting orifices located in the fuel zone reference legs and the shutdown and upset range variable legs were placed near the drywell wall due to the wide and narrow range instrument line modifications. Orifice plates associated with the shutdown and upset range reference leg and the fuel zone variable leg instrument lines were left in their original position. These instruments are not used by the operator(s) during transient flashing conditions.

The relocation of the flow limiting orifices was fully evaluated for concerns related to instrument high energy line breaks (HELB) and pipe whip. With the orifices relocated near the drywell wall, steam blowdown through a ruptured instrument line at the RPV tap will significantly increase. The effects of this higher mass energy blowdown on the drywell temperature/pressure profiles used for the qualification of Class 1E components was evaluated. The design basis drywell temperature/pressure profiles presented in Table 3.11-6 of the CPS Final Safety Analysis Report (FSAR) for small break accidents were used for this evaluation. It was determined that the resulting drywell environmental conditions from an instrument high energy line break without orifice restrictions is bounded by the profiles in FSAR Table 3.11-6.

The concern of pipe whip was evaluated against the criteria of NUREG-0800, "Standard Review Plan for the Safety Analysis Reports for Nuclear Power Plants - LWR Edition", page 3.6.1-19. This criteria states that circumferential breaks in piping exceeding 1" normal pipe size must be evaluated. Because of the small diameter (3/4") of the instrument lines, pipe whip resulting from an instrument line rupture does not need to be considered in the system design.

VII. SYSTEM PERFORMANCE

This section identifies those errors affected by the sense line modifications and quantifies the impact of these design modifications on the overall WLMS performance. Attachments 2 and 3 (draft Figure 3-5 and draft Table 3-2 from the final WLMS Evaluation Report) are provided to illustrate the relationship between the system performance error magnitudes and the WLMS indication ranges and safety system actuation/trip levels.

Non-Flashing Errors

Non-flashing instrument errors can be divided into two distinct categories as follows:

(1) those errors produced by changes in plant process conditions; and

(2) those errors caused by changes in drywell and/or containment environmental conditions.

Error parameters which are a function of the process conditions within the reactor vessel will be unaffected by the modifications made to the instrument sense lines. The non-flashing errors affected by the rerouting of the sense lines include both the drywell and containment temperature errors. These non-flashing errors will be influenced since these errors are directly proportional to the instrument reference leg to variable leg vertical drop differences.

In the case of drywell temperature errors, if the drywell is above the instrument calibration temperature, and a positive vertical drop difference exists (i.e. reference leg drop is greater than variable leg drop), high level indication errors will result. High level indication errors are non-conservative from the standpoint of ECCS initiation since they may temporarily delay actuation or result in premature tripping of these systems. In addition, the high level indication presents erroneous information to the operator(s). The following provides the resultant impact of the modification on each of the WLMS instrument ranges at CPS:

1. Wide Range Instruments
   Drywell temperature errors for these instruments, as a whole, have a negligible effect upon instrument accuracy. These errors have shifted to the conservative direction for all divisions of the wide range instruments at CPS. Drywell temperature errors are negative and no greater than -0.70" at the drywell LOCA temperature of 330° F.

2. Narrow Range Instruments
   Narrow range drywell temperature errors were reduced and/or shifted to the conservative direction for all instrument divisions except Division 4. However, errors no greater than +0.40" can be expected following a drywell LOCA. The magnitude of these errors is negligible and present no problem to the operator nor to the operation of the ECCS.

3. <u>Fuel Zone Instruments</u>
   The fuel zone reference leg sense line modifications produce drywell vertical drop differences which result in conservative drywell temperature-induced level indication errors (i.e. indicated level is lower than actual level). Errors range from -9.3" (Div. 3) to -6.2" (Div. 4) for the modified system. The large low level indication errors are not a concern since the fuel zone instruments are not used for initiation or trip of reactor protection systems and the operator is cautioned of the effects of elevated drywell temperature conditions on level indication accuracy in the CPS Emergency Operating Procedures.

4. <u>Upset and Shutdown Range Instruments</u>
   Drywell temperature errors for both of these instruments have increased as a result of the modifications to the WLMS. Shutdown range errors are of no concern since the operator is instructed to use this instrument for level indication only during RPV maintenance. Upset range errors increase to +36.4" (non-conservative) following a drywell LOCA. The non-conservative shift presents no threat to plant safety since the upset range instruments are not responsible for initiation of safety-related systems and are used only for information purposes during normal plant conditions.

In the case of containment temperature errors, the vertical drop difference in the containment between the reference and variable leg instrument lines affects these values. The following provides the resultant impact of the WLMS modification on the containment temperature errors for each of the WLMS instrument ranges:

1. <u>Wide & Narrow Range Instruments</u>
   These errors changed very little from those associated with the original WLMS design due to the slight changes in vertical drop differences for these instruments. For containment temperatures within the range of normal plant operation (65° F to 104° F), water level indication errors will not exceed +1.5". Containment temperature errors will approach +8.6" and +3.6", for the wide and narrow range instruments respectively, when the Containment environment reaches the design temperature of 185° F.

2. <u>Fuel Zone, Upset & Shutdown Range Instruments</u>
   These instruments were influenced to a greater extent by the WLMS modifications. During normal plant operation the containment temperature indication errors can be as large as +3.5" for the fuel zone instruments. Upset and Shutdown range errors will be negligible under normal plant conditions. Following a design basis LOCA, with the vessel fully depressurized, a maximum indication error of +16.7" can be expected for the Division 3 and 4 fuel zone instruments (non-conservative). Upset and Shutdown range errors will be no greater than +1.0" under accident conditions. Again, since these instruments do not provide input signals for the actuation of safety-related systems, these large errors will not be a problem.

Flashing Errors

Flashing errors were determined to be the dominant contributor to instrument error under extreme combinations of high drywell temperature and low RPV pressure. Instrument sense line modifications were made to reduce the magnitude of both the short-term (transient) and long-term (steady state) flashing errors. For each of these errors, the improvements are discussed below.

Transient flashing errors were significantly reduced for the narrow and wide range instruments by relocating the flow limiting orifices to near the drywell penetration. Studies performed by Sol Levy for the BWROG, and later verified by General Electric, demonstrated that the magnitude and duration of the transient flashing errors are dependent upon the event scenario and the instrument sense line configuration; specifically, the overall line length and the location of the orifice plate. The results of the analyses performed for the CPS WLMS modification indicate that the magnitude of these errors are reduced from about 72" to approximately 8" during postulated accident conditions. These errors are now considered to be acceptable for CPS per SLI-8211.

For steady-state flashing errors, the maximum error is proportional to and limited by the total reference leg vertical drop in the drywell. The steady-state flashing errors for the modified WLMS narrow and wide range instruments will not exceed +34.3". This amounted to an approximate 75% decrease in the steady-state error from the original WLMS design (it should be noted that a 12" reduction in the reference leg water column for the narrow and wide range instruments results in approximately a 15.6" reduction in the indicated level due to the density difference between the liquid in the vessel and the reference leg under conditions assumed for instrument calibration). Fuel zone range steady-state flashing errors decrease to +26.3" for both divisions. Long-term flashing errors for the upset and shutdown range instruments are +190" and +145", respectively. Although the magnitude of these errors is large for the upset and shutdown range instruments, the effects of these errors is not considered to be significant since these instruments do not provide actuation signals to the ECCS logic and are only used by the plant operator(s) under very controlled plant conditions.

VIII. The Effectiveness of the WLMS as an Indication of ICC

An evaluation of the relationship between the state of core cooling and coolant inventory under decay heat and natural circulation conditions will be included in the final CPS WLMS Evaluation Report. This evaluation is based on a review of previous work performed for the BWROG as provided in SLI-8211 and SLI-8218. This section of the Interim Report provides an overview of this evaluation and the preliminary results.

ICC relates to the status of the fuel with respect to postulated failure mechanisms. Cladding perforation commences at fuel clad temperatures between 1300° and 1500° F due to weakening of the cladding from excessive internal fuel rod pressures. Perforation-induced failure of

the fuel cladding results primarily in the release of fission product gases present in the fuel cladding gap. At fuel temperatures in excess of 1800° F, the fuel cladding begins to react chemically with water and/or steam and hydrogen is formed. The exothermic metal-water reaction accelerates fuel cladding degradation and gross cladding failure can occur. Based on these considerations, ICC is defined to exist at fuel clad temperatures in excess of 1500° F. The cladding temperature limit of 1500° F is conservative for this discussion since:

1. It limits the extent of fuel assembly damage to perforation type failures;

2. It minimizes the production of hydrogen and assures that a coolable geometry is maintained;

3. It is well within the 2200° F Post-LOCA fuel cladding temperature limit specified in 10CFR50 for light water reactor ECCS evaluations.

In a BWR, there is a direct and consistent relationship between collapsed water level (vs. indicated level) and coolant inventory. Collapsed level is defined as the level which would result if all of the steam bubbles were removed from the water.

One condition that could lead to an ICC event is initiated by the isolation of the BWR primary system. Neither the RCIC or the ECCS are assumed to be available (only the CRD system is available for vessel water make-up). No break is postulated. Hence, the vessel remains pressurized but without emergency coolant inventory make-up. Sensible and decay heat are assumed to produce a steady boiloff of the vessel liquid inventory. In this situation, natural circulation will continue in the vessel until enough liquid inventory has been depleted so that the vessel downcomer water level drops to the level where it can no longer provide sufficient elevation head to drive liquid through the upper plenum and steam separators. Circulation will continue inside the shroud, with flow going up through the fuel assemblies and down the common bypass region between the channel walls. Unless make-up inventory is supplied, the liquid level will eventually drop below the top of the fuel bundles, breaking the coolant circulation loop, and the accident will progress towards the boiloff/core heat-up phase. During this event scenario, the water level in the fuel bundles would be controlled by the hydrostatic head available in the downcomer region.

The functional relationship between the core and downcomer-bypass region inventory levels was evaluated for this scenario. The preliminary results indicate that the lowest power fuel bundle would not begin to uncover until the downcomer water level had dropped midway between the Top of Active Fuel (TAF) and the jet pump suction level. This positive differential water level between the core and downcomer-bypass regions can be attributed to the high void fractions present within the core during the initial phase of the water level transient.

Subsequent to core uncovery, all the fuel bundles would contain nearly equal amounts of liquid water due to the downcomer hydrostatic forces. Therefore, all collapsed bundle levels would be equal. The downcomer level and the core levels would asymptomatically approach the bottom of active fuel (BAF) because only the decay heat from the submerged fuel rods would produce steam (inventory boil-off). The bypass level would decrease slightly faster during the period immediately following the downcomer level drop into the jet pumps due to the decrease in the effective downcomer cross-sectional area. However, until the water level reached BAF, the water level in the core would always be greater than the level within the downcomer-bypass region.

As the transient progresses, the location of the peak cladding temperature moves radially inward from the lower power bundles to the higher power fuel assemblies as coolant inventory is depleted. For the event analyzed, it was determined that the cladding is indeed functionally related to the core water level. ICC conditions are reached in the core at a water level approximately 4 feet above BAF. The relationship between core water level and peak cladding temperature is relatively insensitive to the rate at which core uncovery occurs.

It can be concluded that when water level is in the downcomer-bypass region (i.e. above the jet pump suction), the WLMS provides a conservative indication of core water level. For water levels above the top of the jet pumps, bypass level provides an even better indication of level in the core. In addition, water level was shown to provide an indication of the peak cladding temperature and therefore an indication of the existence of ICC. This relationship holds true irrespective of the plant transient event.

Cyclic operation of the SRVs was not modeled in the above qualitative evaluation of the CPS WLMS. Intermittent vessel depressurization would induce sudden surges in the two-phase coolant level, resulting in coolant flow past the previously uncovered portion of the fuel rods. WLMS indicated water levels would also increase due to the increased water density in the vessel downcomer region following vessel depressurization. Although the increase in indicated water level is non-conservative, this error is small as described in Section III of this report.

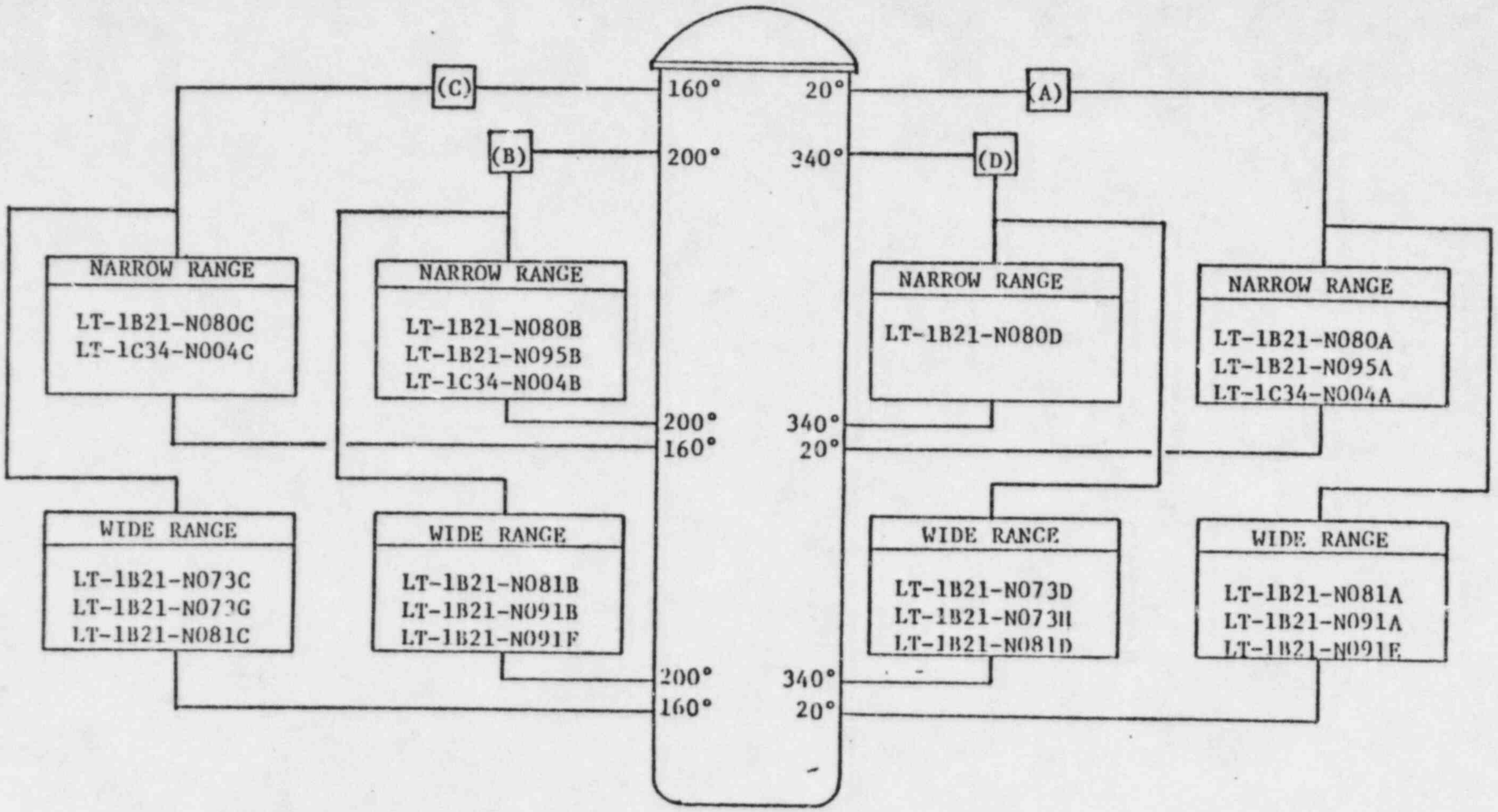
Automatic or operator initiated vessel depressurization would result in an accelerated loss of vessel inventory. This will produce increased steam flowrates within the core region. Fuel rod-to-steam convection is the most crucial heat transfer mechanism in the cladding heat-up process. This convective cooling, in the early stages of vessel boil-off, would be greater at the lower vessel pressure as a result of the lower fluid temperature even with the reduced steam flowrate through the core. Therefore, the conclusions presented above are conservative and apply to transient events occuring at lower system pressures.

IX. CONCLUSIONS

As a result of the modifications made to the CPS WLMS inside the drywell (i.e. line re-routing and orifice relocation), plant-specific analyses indicate that, regardless of the initiating plant transient, the WLMS will always provide automatic initiation of ECCS without uncovering the Top of Active Fuel core region. In addition, the modified WLMS errors are significantly reduced from the original WLMS design, resulting in reliable and accurate reactor vessel water level indications for use by the plant operator(s) during both normal plant operation and during design basis accidents. As such, the design of the CPS WLMS is now considered adequate to meet the NRC Staff requirements related to NUREG-0737, Item II.F.2. Therefore, it is believed that no additional instrumentation will be necessary for CPS to detect conditions that may lead to inadequate core cooling.

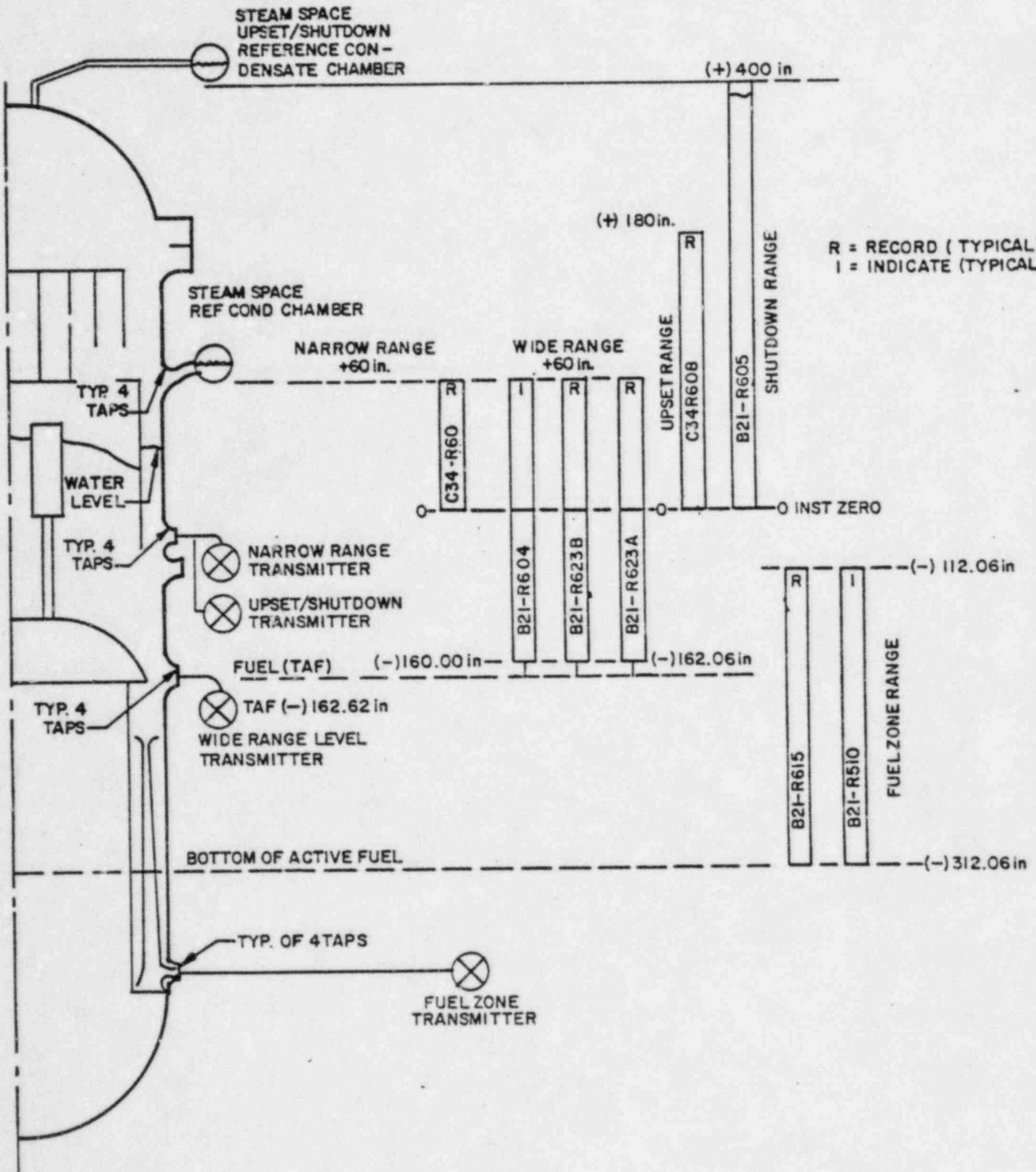
DWW/F

(A) - Condensing Chamber 1B21-D004A, Division 1 Reference Leg
(B) - Condensing Chamber 1B21-D004B, Division 2 Reference Leg
(C) - Condensing Chamber 1B21-D004C, Division 3 Reference Leg
(D) - Condensing Chamber 1B21-D004D, Division 4 Reference Leg



NOTE: (1) See Figures 3-3 and 3-4 in Section 3 for orientation of all RPV water level transmitters. See Table A-1 for tap elevations.

Figure A-3: Orientation of Safety-Related RPV Water Level Transmitters Which Initiate Plant Systems (1)



LEVEL INSTRUMENT RANGES

FIGURE 3.5

ATTACHMENT 3

TABLE 3-2

CPS VESSEL LEVEL TRIP EVALUATION CORRELATION

REFERENCE	DESCRIPTION	INCHES ABOVE* TOP OF ACTIVE FUEL	LEVEL INSTRUMENT ZERO	VESSEL ZERO
Tap "a" nozzle	Steam tap for condensing chambers narrow and wide range upscale	227.69 222.10	65.63 60.0	586.25 580.62
Level 8	Trip RCIC turbine and HPCS injection valve closure signal. Close main turbine stop valves, trip feed pumps and condensate booster pumps, SCRAM	214.06	52.00	572.62
Level 7	Feedwater control high level alarm	200.86	38.80	559.42
Level 4	Feedwater control low level alarm	192.86	30.80	551.42
Level 3	SCRAM and contribute to ADS. Run recirculation flow back and close RHR shutdown isolation valves.	170.96	8.90	529.52
Instrument Zero	For wide, narrow, shutdown/upset range instrumentation. Narrow range and shutdown range downscale.	162.06	0.00	520.62
Tap "b" nozzle	Narrow range tap (variable leg)	150.44	-11.62	509.00
	Feedwater sparger	124.94	-37.12	483.50
Level 2	Intiate RCIC and HPCS. Close primary system isolation valves except RHR shutdown isolation valves, start Division 3 standby diesel, initiate ATWS (non-safety related ARI and trip recirculation pumps).	116.56	-45.50	475.12
Level 1	Initiate RHR and LPCS. Contribute to ADS. Start Division 1 and Division 2 standby diesels. Close MSIV's.	16.56	-145.50	375.12
TAF	Top of Active Fuel, Fuel Zone Instrument Zero	0	-162.06	358.56
Tap "c" nozzle	Wide range tap (variable leg)	-0.56	-162.62	358.00
BAF	Bottom of Active Fuel Fuel Zone Downscale	-150.00	-312.06	208.56
Tap "d"	Fuel Zone variable leg	-209.56	-371.62	149.00

*Elevations based on cold vessel conditions