WESTINGHOUSE CLASS 3

WCAP-11890

RTD BYPASS ELIMINATION LICENSING REPORT
FOR
H. B. ROBINSON UNIT 2

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1.0 INTRODUCTION

Westinghouse Electric Corporation has been contracted by Carolina Power & Light to remove the existing Resistance Temperature Detector (RTD) Bypass System and replace this hot leg and cold leg temperature measurement method with fast response thermowell mounted RTDs installed in the reactor coolant loop piping. This report is submitted for the purpose of supporting operation of H. B. Robinson Unit 2 utilizing the new thermowell mounted RTDs.

1.1 HISTORICAL BACKGROUND

Prior to 1968, PWR designs had been based on the assumption that the hot leg temperature was uniform across the pipe. Therefore, placement of the temperature instruments was not considered to be a factor affecting the accuracy of the measurement. The hot leg temperature was measured with direct immersion RTDs extending a short distance into the pipe at one location. By the late 1960s, as a result of accumulated operating experience at several plants, the following problems associated with direct immersion RTDs were identified:

- Temperature streaming conditions; the incomplete mixing of the coolant leaving regions of the reactor core at different temperatures produces significant temperature gradients within the pipe.

- The reactor coolant loops required cooling and draining before the RTDs could be replaced.

The RTD bypass system was designed to resolve these problems; however, operating plant experience has now shown that operation with the RTD bypass loops has created it's own obstacles such as:

- Plant shutdowns caused by excessive primary leakage through valves, flanges, etc., or by interruptions of bypass flow due to valve stem failure.

- o Increased radiation exposure due to maintenance on the bypass line and to crud traps which increase radiation exposure throughout the loop compartments.

The proposed temperature measurement modification has been developed in response to both sets of problems encountered in the past. Specifically:

- o Removal of the bypass lines eliminates the components which have been a major source of plant outages as well as Occupational Radiation Exposure (ORE).

- o Three thermowell mounted hot leg RTDs provide an average measurement (equivalent to the temperature measured by the bypass system) to account for temperature streaming.

- o Use of thermowells permits RTD replacement without draining the reactor coolant loops.

Following is a detailed description of the effort required to perform this modification.

1.2 MECHANICAL MODIFICATIONS

The individual loop temperature signals required for input to the Reactor Control and Protection System will be obtained using RTDs installed in each reactor coolant loop.

1.2.1 Hot Leg

a) The hot leg temperature measurement on each loop will be accomplished with three fast response, narrow range, dual element RTDs mounted in thermowells. One element of the RTD will be considered active and the other element will be held in reserve as a spare. To accomplish the sampling function of the RTD bypass manifold system and minimize the need for additional hot leg piping penetrations, the thermowells will be located within the three existing RTD bypass manifold scoops wherever possible. A hole will be drilled through the end of each scoop so that water will flow in through the existing holes in the leading edge of the scoop, past the RTD, and out through the new hole (Figure 1.2-1). Due to structural interferences on Loops A and B one thermowell on each loop cannot be installed in the existing scoop location. These thermowells will, instead, be mounted in independent bosses (Figure 1.2-3) and relocated downstream from the existing scoop. The resulting unused hot leg scoops will be capped. These three RTDs will measure the hot leg temperature which is used to calculate the reactor coolant loop differential temperature (ΔT) and average temperature (T_{avg}).

b) This modification will not affect the single wide range RTD currently installed near the entrance of each steam generator. This RTD will continue to provide the hot leg temperature used to monitor reactor coolant temperature during startup, shutdown, and post accident conditions.

1.2.2 <u>Cold Leg</u>

a) One fast response, narrow range, dual-element RTD will be located in each cold leg at the discharge of the reactor coolant pump (as replacements for the cold leg RTDs located in the bypass manifold). Temperature streaming in the cold leg is not a concern due to the mixing action of the RCP. For this reason, only one RTD is required. This RTD will measure the cold leg temperature which is used to calculate reactor coolant loop ΔT and T_{avg}. The existing cold leg RTD bypass penetration nozzle will be modified (Figure 1.2-2) to accept the RTD thermowell. One element of the RTD will be considered active and the other element will be held in reserve as a spare.

b) This modification will not affect the single wide range RTD in each cold leg currently installed at the discharge of the reactor coolant pump. This RTD will continue to provide the cold leg temperature used to monitor reactor coolant temperature during startup, shutdown, and post accident conditions.

1.2.3 Crossover Leg

The RTD bypass manifold return line will be capped at the nozzle on the crossover leg.

1.3 ELECTRICAL MODIFICATIONS

1.3.1 Control & Protection System

Figure 1.3-1 shows a block diagram of the modified protection system electronics. The hot leg RTD measurements (three per loop) will be electronically averaged in the process protection system. The averaged T_{hot} signal will then be used with the T_{cold} signal to calculate reactor coolant loop ΔT and T_{avg} which are used in the reactor control and protection system. This will be accomplished by additions to the existing process protection system equipment.

The present RCS loop temperature measurement system uses separate direct immersion RTDs for the control and protection systems. This was done largely to satisfy the (then proposed) IEEE Standard 279-1968 which applied single failure criteria to control and protection system interaction. The new thermowell mounted RTDs will be used for both control and protection. In order to continue to satisfy the requirements of IEEE 279, the T_{avg} and ΔT signals used in the control-grade logic will be input into a median signal selector, which will select the signal which is in between the highest and lowest values of all the three loop inputs. This will avoid any adverse plant response that could be caused by a single signal failure.

1.3.1.2 Qualification

The 7100 Process Electronics and RTD qualification will be verified to support Carolina Power & Light compliance to 10CFR50.49. The RTD qualification testing, to address the requirements of IEEE Standards 344-1975 and 323-1974, has been performed by the RTD manufacturer, WEED Instruments Inc. The WEED qualification documentation has been reviewed and verified to be in compliance with the IEEE standards.

1.3.1.3 RTD Operability Indication

Existing control board ΔT and T_{avg} indicators and alarms will provide the means of identifying RTD failures, although the now redundant indication for the T_{avg} and ΔT signals will be removed. The spare cold leg RTD element provides sufficient spare capacity to accommodate a single cold leg RTD failure per loop. Failure of a hot leg RTD can be handled two ways. In the first, manual action by the operator defeats the failed signal and rescales the electronics to average the remaining signals (see Figure 1.3-1 and Section 4.5). The second method disconnects the failed element and utilizes the second element of that same RTD, the same as for the cold leg.

a, c

Figure 1.2-1 Hot Leg RTD Scoop Modification
For Fast Respnse RTD Installation

a,c

Figure 1.2-2 Cold Leg Pipe Nozzle Modification for Fast Response RTD Installation a, c

Figure 1.2-3 Additional Boss for Hot Leg
Fast Response RTD Installation

a,c

Figure 1.3-1 RTD Averaging Block Diagram.
Typical for Each of 3 Channels

2.0 TESTING

There were two specific tests which were performed to support the installation of the thermowell mounted fast-response RTDs in the reactor coolant piping: an RTD response time test and a hot leg temperature streaming test. The response time for the H. B. Robinson Unit 2 application will be verified by testing at the RTD manufacturer. Data from thermowell/RTD performance at operating plants have provided additional support for the system.

2.1 RESPONSE TIME TEST

The RTD manufacturer, WEED Instruments Inc., will perform time response testing of each RTD and thermowell prior to installation at H. B. Robinson Unit 2. These RTD/thermowells must exhibit a response time bounded by the values shown in Table 2.1-1. The new response time has been factored into the transient analyses performed by Advanced Nuclear Fuels Corporation (Reference 2) for Carolina Power & Light and is discussed in Section 4.3.

Response time testing of similar WEED RTDs has been performed at other plants. This in-situ testing has demonstrated that the WEED RTDs can satisfy the response times requirements when installed in the plant.

2.2 STREAMING TEST

Past testing at Westinghouse PWRs has established that temperature stratification exists in the hot leg pipe with a temperature gradient from maximum to minimum of [ ]^{b,c,e}. A test program was implemented at an operating plant to confirm the temperature streaming magnitude and stability with measurements of the RTD bypass branch line temperatures on two adjacent hot leg pipes. Specifically, it was intended to determine the magnitude of the differences between branch line temperatures, confirm the short-term and long-term stability of the temperature streaming patterns and evaluate the impact on the indicated temperature if only 2 of the 3 branch line temperatures are used to determine an average temperature. This plant specific data is used in conjunction with data taken from other Westinghouse designed plants to determine an appropriate temperature error for use in the safety analysis and calorimetric flow calculations. Section 3 will discuss the specifics of these uncertainty considerations.

The test data was reduced and characterized to answer the three objectives of the test program. First, it is conservative to state that the streaming pattern [ ][b,c,e]. Steady state data taken at 100% power for a period of four months indicated that the streaming pattern [ ][b,c,e]. In other words, the temperature gradient [ ][b,c,e]. This is inferred by [ ][b,c,e] observed between branch lines. Since the [ ][b,c,e] into the RTD averaging circuit if a hot leg RTD fails and only 2 RTDs are used to obtain an average hot leg temperature. The operator can review temperatures recorded prior to the RTD failure and determine an [ ][b,c,e] into the "two RTD" average to obtain the "three RTD" expected reading. A generic procedure has been provided to Carolina Power & Light which specifies how these [ ][b,c,e] are to be determined. (Appendix A) This significantly reduces the error introduced by a failed RTD.

Both the test data and the operating data support previous calculations of streaming errors determined from tests at other Westinghouse plants. The temperature gradients defined by the recent plant operating data are well within the upper bound temperature gradients that characterize the previous data. Differences observed in the operating data compared with the previous data indicate that the temperature gradients are smaller, so the measurement uncertainties are conservative. The measurements at the operating plants, obtained from thermowell RTDs installed inside the bypass scoops, were expected to be, and were found to be, consistent with the measurements obtained previously from the bypass loop RTDs.

TABLE 2.1-1

RESPONSE TIME PARAMETERS FOR RCS TEMPERATURE MEASUREMENT

	Present RTD Bypass	Fast Response Thermowell RTD
RTD Bypass Transport	1.0 sec delay	NA
Thermal Lag in Bypass Piping	1.0 sec time constant*	NA
RTD Response	0.5 sec delay	4.0 sec lag* time constant
Lag Filter on Delta T and Tavg	2.0 sec time constant*	NA
Electronics Delay	0.5 sec	0.75 sec

* A first order lag is represented by the transfer function

$$\frac{\text{output}}{\text{input}} = Y(S) = \frac{1}{1 + (\text{time constant})S}$$ in Laplace Transform notation.

As such, please note that

a) all response time parameters cannot simply be added

and

b) response times will not be the same for different forcing functions as inputs (e.g., step vs. ramp changes).

3.0 UNCERTAINTY CONSIDERATIONS

This method of hot leg temperature measurement has been analyzed to determine the magnitude of the two uncertainties included in the Safety Analysis: Calorimetric Flow Measurement Uncertainty and Hot Leg Temperature Streaming Uncertainty.

3.1 CALORIMETRIC FLOW MEASUREMENT UNCERTAINTY

Reactor coolant flow is verified with a calorimetric measurement performed after the return to power operation following a refueling shutdown. The two most important instrument parameters for the calorimetric measurement of RCS flow are the narrow range hot leg and cold leg coolant temperatures. The accuracy of the RTDs has, therefore, a major impact on the accuracy of the flow measurement.

With the use of three T_{hot} RTDs (resulting from the elimination of the RTD Bypass lines) and the latest Westinghouse RTD cross-calibration procedure (resulting in low RTD calibration uncertainties at the beginning of a fuel cycle), the H. B. Robinson 2 RCS Flow Calormetric uncertainty is determined to be [.]^{a,c} This calculation is based on the standard Westinghouse methodology previously approved on earlier submittals of other plants associated with RTD Bypass Elimination or the use of the Westinghouse Improved Thermal Design Procedure. Tables 3.1-1 through 3.1-4 were generated specifically for H. B. Robinson 2 and reflect plant specific measurement uncertanties and operating conditions.

3.2 HOT LEG TEMPERATURE STREAMING UNCERTAINTY

The safety analyses incorporate an uncertainty to account for the difference between the actual hot leg temperature and the measured hot leg temperature caused by the incomplete mixing of coolant leaving regions of the reactor core at different temperatures. This temperature streaming uncertainty is based on an analysis of test data from other Westinghouse plants, and on calculations to evaluate the impact on temperature measurement accuracy of numerous possible temperature distributions within the hot leg pipe. The test data has shown that the circumferential temperature variation is no more than [ ]^{b,c,e}, and that the inferred temperature gradient within the pipe is limited to about [ ]^{b,c,e}. The calculations for numerous temperature distributions have shown that, even with margins applied to the observed temperature gradients, the three-point temperature measurement (scoops or thermowell RTDs) is very effective in determining the average hot leg temperature. The most recent calculations for the thermowell RTD system have established an overall streaming uncertainty of [ ]^{b,c,e} for a hot leg measurement. Of this total, [ ]^{b,c,e}. This overall temperature streaming uncertainty provides additional margin when applied to the 3-loop H. B. Robinson plant, since the 3-loop temperature distributions are not similar, so more of the total streaming uncertainty would be random.

The new method of measuring hot leg temperatures, with the three hot leg thermowell RTDs, is at least as effective as the existing RTD bypass system, [ ]^{a,c}. Although the new method measures temperature at one point at the RTD/thermowell tip, compared to the five sample points in a 5-inch span of the scoop measurement, the thermowell measurement point is opposite the center hole of the scoop and therefore measures the equivalent of the average scoop sample if a linear radial temperature gradient exists in the pipe. The thermowell measurement may have a small error relative to the scoop measurement if the temperature gradient over the 5-inch scoop span is nonlinear. Assuming that the maximum inferred temperature gradient of [ ]^{b,c,e} exists from the center to the end of the scoop, the difference between the thermowell and scoop measurement is limited to [ ]^{b,c,e}. Since three RTD measurements are averaged, and the nonlinearities at each scoop are random, the effect of this error on the hot leg temperature measurement is limited to [ ]^{b,c,e}. On the other hand, imbalanced scoop flows can introduce temperature measurement uncertainties of up to [ ]^{a,c}.

In all cases, the flow imbalance uncertainty will equal or exceed the [ ]^{b,c,e} sampling uncertainty for the thermowell RTDs, so the new measurement system tends to be a more accurate measurement with respect to streaming uncertainties.

Temperature streaming measurements have been obtained from tests at 2, 3 and 4-loop plants and from thermowell RTD installations at 4-loop plants. Although there have been some differences observed in the orientation of the individual loop temperature distributions from plant to plant, the magnitude of the differences have been [ ]^{b,c,e}.

Over the testing and operating periods, there were only minor variations of less than [ ]^{b,c,e} in the temperature differentials between scoops, and smaller variations in the average value of the temperature differentials. [ ]^{b,c,e}.

Provisions were made in the RTD electronics for operation with only two hot leg RTDs in service. The two-RTD measurement will be biased to correct for the difference compared with the three-RTD average. Based on test data, the bias value would be expected to range between [ ]^{b,c,e}. Data comparisons show that the magnitude of this bias varied less than [ ]^{b,c,e} over the test period.

TABLE 3.1-1

FLOW CALORIMETRIC INSTRUMENTATION UNCERTAINTIES

(% SPAN)	FW TEMP	FW PRES	FW DP	STM PRESS	TH	TC	PRZ PRESS	
SCA =								+a,c
M&TE=								
SPE =								
STE =								
SD =								
R/E =								
RDOT=								
BIAS=								
CSA =								
# OF INST USED					3	1	1	
	DEG F	PSIA	% DP	PSIA	DEG F	DEG F	PSIA	
INST SPAN =	100.	1000.	120.	1000.	100.	100.	3000.	
INST UNC. (RANDOM) =								+a,c
INST UNC. (BIAS) =								
NOMINAL =	441.	905.		840.	604.2	546.7	2250.	

TABLE 3.1-2

FLOW CALORIMETRIC SENSITIVITIES

FEEDWATER FLOW

[ ]+a,c

FA
- TEMPERATURE =
- MATERIAL =

DENSITY
- TEMPERATURE =
- PRESSURE =

DELTA P =

FEEDWATER ENTHALPY
- TEMPERATURE =
- PRESSURE =

hS	=	1198.2 BTU/LBM
hF	=	421.0 BTU/LBM
Dh(SG)	=	777.2 BTU/LBM

STEAM ENTHALPY

[ ]+a,c

- PRESSURE =
- MOISTURE =

HOT LEG ENTHALPY
- TEMPERATURE =
- PRESSURE =

hH	=	619.2 BTU/LBM
hC	=	543.0 BTU/LBM
Dh(VESS)	=	76.2 BTU/LBM
Cp(TH)	=	1.448 BTU/LBM-DEGF

COLD LEG ENTHALPY

[ ]+a,c

- TEMPERATURE =
- PRESSURE =

Cp(TC)	=	1.235 BTU/LBM-DEGF

COLD LEG SPECIFIC VOLUME

[ ]+a,c

- TEMPERATURE =
- PRESSURE =

TABLE 3.1-3

CALORIMETRIC RCS FLOW MEASUREMENT UNCERTAINTIES

+a,c

COMPONENT	INSTRUMENT ERROR	FLOW UNCERTAINTY
FEEDWATER FLOW		
VENTURI		
THERMAL EXPANSION COEFFICIENT		
TEMPERATURE		
MATERIAL		
DENSITY		
TEMPERATURE		
PRESSURE		
DELTA P		
FEEDWATER ENTHALPY		
TEMPERATURE		
PRESSURE		
STEAM ENTHALPY		
PRESSURE		
MOISTURE		
NET PUMP HEAT ADDITION		
HOT LEG ENTHALPY		
TEMPERATURE		
STREAMING, RANDOM		
STREAMING, SYSTEMATIC		
PRESSURE		
COLD LEG ENTHALPY		
TEMPERATURE		
PRESSURE		
COLD LEG SPECIFIC VOLUME		
TEMPERATURE		
PRESSURE		

*,**,+,++ INDICATE SETS OF DEPENDENT PARAMETERS

+a,c

SINGLE LOOP UNCERTAINTY	
N LOOP UNCERTAINTY	

TABLE 3.1-4

LOW FLOW REACTOR TRIP

	% DP SPAN	% FLOW SPAN
PMA1 =		
PMA2 =		
PEA =		
SCA =		
SPE =		
STE =		
SD =		
BIASF=		
BIAS1=		
BIAS2=		
RCA =		
M&TE =		
RCSA =		
RTE =		
RD =		

+a,c

INSTRUMENT RANGE = 0 TO 120.0 % FLOW

FLOW SPAN = 120.0 % FLOW

SAFETY ANALYSIS LIMIT = 87.0 % FLOW

NOMINAL TRIP SETPOINT = 90.0 % FLOW

+a,c

TABLE 3.1-5

OVERTEMPERATURE DELTA-T REACTOR TRIP

	DELTA-T	Tavg	PRZ. PRESS.	DELTA-I
PMA				
PEA				
SCA				
SMTE				
SPE				
STE				
SD				
RCA				
RMTE				
RCSA				
RTE				
RD				

$]^{+a,c}$

INSTRUMENT RANGE = 86 ^{o}F

SAFETY ANALYSIS LIMIT = 1.26 (K_1)

NOMINAL TRIP SETPOINT = 1.1565 (K_1)

TOTAL ALLOWANCE = 6.9 % Delta-T span

CSA = [$]^{+a,c}$ based on the use of two T_H RTDs.

MARGIN = [$]^{+a,c}$

4.0 SAFETY EVALUATION

4.1 RESPONSE TIME

The primary impact of the RTD Bypass Elimination on the FSAR Chapter 15 non-LOCA safety analyses (References 1&2) is the different response time characteristics associated with the fast response thermowell RTD system. The secondary impact is the possible change in instrument uncertainties. Currently, the response time parameters of the H. B. Robinson Unit 2 RTD bypass system assumed in the safety analysis are shown in Table 2.1-1. For the fast response thermowell RTD system, the overall response time will consist of a [

]^{a,c} (as presented in Section 2.1 and as given in Table 2.1-1).

The new RTD response time characteristics must be factored into the Overtemperature ΔT or Overpower ΔT reactor trip performance. Therefore, those transients that rely on the above mentioned trips will be evaluated for the modified response characteristics. The affected transients include Loss of External Electrical Load/Turbine Trip, Uncontrolled RCCA Bank Withdrawal at Power and Control Rod Misoperation. These events are discussed in Section 4.3.

4.2 RTD UNCERTAINTY

The proposed fast response thermowell RTD system will make use of RTDs, manufactured by Weed Instruments Inc., with a total uncertainty of [ ]^{a,c} assumed for the analyses.

The FSAR analyses make explicit allowances for instrumentation errors for some of the reactor protection system setpoints. In addition, allowances are made for the average reactor coolant system (RCS) temperature, pressure and power as described in FSAR Section 15.0. These allowances are made explicitly to the initial conditions.

The following protection and control system parameters were evaluated and determined to be unaffected (with respect to accident analysis assumptions) by the change from one hot leg RTD to three hot leg RTDs; the Overtemperature ΔT (OTDT), Overpower ΔT (OPDT), and Low RCS Flow reactor trip functions, RCS loop T_{avg} measurements used for control board indication and input to the rod control system, and the calculated value of the RCS flow uncertainty. System uncertainty calculations were performed for these parameters to determine the impact of the change in the number of hot leg RTDs. The results of these calculations indicate sufficient margin exists to account for known instrument uncertainties.

In summary, changes have been made in the Reactor Protection System response times only to account for the new thermowell mounted RTDs.

4.3 NON-LOCA TRANSIENTS REANALYZED

Reference 2 provides an evaluation of the affected transients with a detailed description of reanalysis of the limiting events. Except as otherwise noted, the general parameters presented in Section 15.0 of the UFSAR remain applicable.

4.4 LOCA Evaluation

The elimination of the RTD bypass system impacts the uncertainties associated with RCS temperature and flow measurement. The magnitude of the uncertainties are such that RCS inlet and outlet temperatures, thermal design flow rate and the steam generator performance data used in the LOCA analyses will not be affected. Past sensitivity studies have shown that the variation of the core inlet temperature (T_{in}) used in the LOCA analyses affects the predicted core flow during the blowdown period of the transient. The amount of flow into the core is influenced by the two-phase vessel-side break flow, and the core cooling is affected by the quality of the fluid. These sensitivity studies concluded that the inlet temperature effect on peak clad temperature is dependent on break size. As a result of these studies, the LOCA analyses are performed at a nominal value of T_{in} without consideration of small uncertainties. The RCS flow rate and steam generator secondary side temperature and pressure are also determined using the loop average temperature (T_{avg}) output. These nominal values used as inputs to the analyses are not affected due to the RTD bypass elimination. It is concluded that the elimination of the RTD bypass piping will not affect the LOCA analyses input and hence, the results of the analyses for H. B. Robinson Unit 2 remain unaffected. Therefore, the plant design changes due to the RTD bypass elimination are acceptable from a LOCA analysis standpoint without requiring any reanalysis.

4.5 INSTRUMENTATION AND CONTROL (I&C) SAFETY EVALUATION

The RTD Bypass Elimination modification for H. B. Robinson Unit 2 does not functionally change the $\Delta T/T_{avg}$ protection channels. The implementation of the fast response RTDs in the reactor coolant piping will change the inputs into the $\Delta T/T_{avg}$ Protection Sets I, II, and III, as follows:

1. The Narrow Range (NR) cold leg RTD in the cold leg manifold will be replaced with a fast response NR dual element RTD well mounted in the RCP pump discharge pipe. The signal from this fast response NR RTD will perform the same function as the existing RTD T_{cold} signal. One element of the RTD will be held in reserve as a spare.

2. The NR hot leg RTD in the bypass manifold will be replaced with 3 fast response NR dual element RTDs well mounted in the hot leg that are electronically averaged in the process protection system. The signal from this average T_{hot} circuit obtained from these 3 NR T_{hot} RTDs will perform the same function as the existing RTD T_{hot} signal.

3. Identification of failed signals will be by the same means as before the modifications, i.e., existing control board alarms and indications.

4. Signal process and the added circuitry to the Protection Set racks will be accomplished by additions to the process control (Westinghouse Model 7100) racks using 7100 technology. When one T_{hot} signal is removed from the averaging process, the electronics will allow a bias to be manually added

to a 2-RTD average T_{hot} (as opposed to a 3-RTD average T_{hot}) in order to obtain a value comparable with the 3-RTD average T_{hot} prior to the failed RTD. In addition the spare hot leg element of each dual element could, instead be manually connected to the 7100 circuitry in place of the failed element. In the event of a cold leg RTD failure, the spare cold leg RTD element will be manually connected to the 7100 circuitry in place of the failed RTD.

Existing control board ΔT and Tavg indicators and alarms will provide the means of identifying RTD failures. Upon identification of a failed RTD, the operator would place that protection channel in trip (consistent with the time requirements specified in the Technical Specifications), identify and disconnect the failed RTD, and rescale the summing amplifier averaging card for a two RTD input condition. The channel would then be returned to service. During this process the plant will be in a partial trip mode and will therefore be in a safe condition.

There are functional inputs on the T_{avg} and ΔT signals used in the control grade hot and cold leg RTDs, separate from the protection-grade RTDs, that are used to develop the T_{avg} and ΔT signals input into the control system. The conversion to thermowell mounted RTDs will result in elimination of the control grade RTDs and their associated control board indicators. The protection grade channels will now be used to provide inputs to the control system, through optical isolators to avoid failures in one rack from propagating to another.

In order to satisfy the control and protection interaction requirements of IEEE 279-1971, a Median Signal Selector (MSS) will be used in the control channels present'y relying on a high auctioneered T_{avg} or ΔT signal (there will be a separate MSS for each signal). This Median Signal Selector will use as inputs the protection grade T_{avg} or ΔT signals from all three loops, and will supply as an output the channel signal which is the median of the three signals. The effect will be that the various control grade systems will still use a valid RCS temperature in the case of a single signal failure.

To ensure proper action by the Median Signal Selector, the present manual switches that allow for defeating of a T_{avg} or ΔT signal from a single loop will be eliminated. The MSS will automatically select valid signal in the case of a signal failure. Warnings that a failure has occurred will be provided by the existing loop-to-loop T_{avg} and ΔT deviation alarms.

Other than the above changes, the Reactor Protection System will remain the same, and unchanged from what has previously been utilized. For example, two out of three voting logic continues to be utilized for the thermal overpower protection functions, with the model 7100 process control bistables continuing to operate on a "de-energize to actuate" principle. Non-safety related control signals will now to be derived from protection channels via a Median Signal Selector.

The above principles of the modification have been reviewed to evaluate conformance to the requirements of IEEE-279-1971 criteria and associated 10CFR 50 General Design Criteria (GDC), Regulatory Guides, and other applicable industry standards. IEEE 279-1971 requires documentation of a design basis. Following is a discussion of design basis requirements in conformance to pertinent I&C criteria:

a. The single failure criterion continues to be satisfied by this change because the independence of redundant protection sets is maintained.

b. The quality of the components and modules being added is consistent with use in a Nuclear Generating Station Protection System. For the Westinghouse Quality Assurance program, refer to Chapter 17 of the FSAR.

c. The changes will continue to maintain the capability of the protection system to initiate a reactor trip during and following natural phenomena credible to the plant site to the same extent as the existing system.

d. Channel independence and electrical separation is maintained because the Protection Set circuit assignments continue to be Loop 1 circuits input to Protection Set I; Loop 2, to Protection Set II; and Loop 3 to Protection Set III, with appropriate observance of field wiring interface criteria to assure the independence.

e. Due to the elimination of the dedicated control system RTD elements effected by the RTD bypass elimination modification, temperature signals for use in the plant control systems must now be derived from the remaining protection system RTDs. As a result of this configuration change, new complexities regarding control and protection system interaction, as described in IEEE-279, are introduced into the H. B. Robinson instrumentation and control system design. To eliminate any degrading control and protection system interaction mechanisms introduced as a consequence of the RTD Bypass Elimination modification, a Median Signal Selector has been introduced into the control system. The Median Signal Selector preserves the functional isolation of interfacing control and protection systems that share common instrument channels (such as the present case). The details of the signal selector implementation are contained in Section 1.3.1.

On the basis of the foregoing evaluation, it is concluded that the compliance of H. B. Robinson Unit 2 to IEEE 279-1971, applicable GDCs, and industry standards and regulatory guides has not been changed with the I&C modifications required for RTD bypass removal.

4.6 MECHANICAL SAFETY EVALUATION

The presently installed RTD bypass system is to be replaced with fast acting narrow range RTD thermowells. This change requires modifications to the hot leg scoops, the hot leg piping, the crossover leg bypass return nozzle, and the cold leg bypass manifold connection. All welding and NDE will be performed per ASME Code Section XI requirements. Each of these modifications is evaluated below.

The original three scoops in the loop A, B and C hot legs, which feed the bypass manifold, and the bypass manifold connection must be removed and all but two scoops modified to accept three fast response RTD thermowells. [ ]^{a,c} to provide the proper flow path. A thermowell design will be used such that the thermowell will be positioned to provide an average temperature reading. The thermowell will be fabricated in accordance with Section III (Class 1) of the ASME Code. The installation of the thermowell into the scoop will be performed using GTAW for the root pass and finished out with either Gas Tungsten Arc Weld (GTAW) or Shielded Metal Arc Weld (SMAW). The welding will be examined by penetrant test (PT) per the ASME Code Section XI. Prior to welding, the surface of the scoop onto which welding will be performed will be examined as required by Section XI.

One of the three hot leg fast response RTDs will be installed into a new penetration on both loops A and B. To accomplish this, a new boss will be installed approximately one foot downstream from the existing hot leg scoops. The remaining two hot leg scoops on each loop will be utilized for thermowell mounting as was done for all the scoops in loop C. The installation boss for the new penetrations and the thermowells will be root welded by GTAW. Finish welding can be either GTAW or SMAW. Weld inspection by PT will be performed per Section XI. The installation bosses and thermowells are fabricated in accordance with Section III (Class 1) of the ASME Code.

The cold leg RTD bypass line must also be removed. The nozzle must then be modified to accept the fast response RTD thermowell. The installation of the thermowell into the nozzle will be performed using GTAW for the root pass and finished with either GTAW or SMAW. Weld inspection by PT will be performed as required by Section XI. The thermowells will extend approximately [ ]^{a,c} inches into the flow stream. This depth has been justified based on [ ]^{a,c} analysis. The root weld joining the thermowells to the modified nozzles will be deposited with GTAW and the remainder of the weld may be deposited with GTAW or SMAW. Penetrant testing will be performed in accordance with the ASME Code Section XI. The thermowells will be fabricated in accordance with the ASME Section III (Class 1).

Upon removal of the RTD bypass piping, the two hot leg scoops not utilized in Loops A and B will be capped. The caps will be fabricated in accordance with Section III (Class 1) of the ASME Code. The root weld joining the caps to the scoops will be done by GTAW. Finish welding will be done by either GTAW or SMAW. The welds will be inspected by PT per the ASME Code Section XI.

The cross-over leg bypass return , ping connection must be removed and the nozzles capped. The cap design, including materials, will meet the pressure boundary criteria of ASME Section III (Class 1). The cap will be root welded to the nozzles by GTAW and fill welded by either GTAW or SMAW. Non-destructive examinations (PT and radiographs) will be performed per ASME Section XI. Machining of the bypass return nozzle, as well as any machining performed during modification of the penetrations in the hot and cold legs, shall be performed such as to minimize debris escaping into the reactor coolant system.

The present Reactor Vessel Level Instrumentation System (RVLIS) has pressure taps located on the RTD bypass piping hot leg branch lines on loops B and C. In order to retain the hot leg connection for the RVLIS a new boss will be mounted on these two hot legs. The installation boss for the new RVLIS connections will be root welded by GTAM. Finish welding can be either GTAW or SMAW. Weld inspection by PT will be performed per Section XI. The RVLIS bosses are fabricated in accordance with Section III (Class 1) of the ASME Code.

In accordance with Article IWA-4000 of Section XI of the ASME Code, a hydrostatic test of new pressure boundary welds is required when the connection to the pressure boundary is larger than one inch in diameter. Since the cap for the crossover leg bypass return pipe is [ ]^{a,c} inches and the cold leg RTD connections are [ ]^{a,c} inches, a system hydrostatic test is required after the bypass elimination modification is complete. Paragraph IWB-5222 of Section XI defines this test pressure to be 1.02 times the normal operating pressure at a temperature of 500°F or greater.

In summary, the integrity of the reactor coolant piping as a pressure boundary component, is maintained by adhering to the applicable ASME Code sections and Nuclear Regulatory Commission General Design Criteria. Further, the pressure retaining capability and fracture prevention characteristics of the piping is not compromised by these modifications.

4.7 TECHNICAL SPECIFICATION EVALUATION

As a result of the calculations summarized in Section 3.0, the impact of the fast response RTDs on flow measurement uncertainty, no Technical Specification setpoint modifications are necessary. Technical Specification modifications as a result of the Non LOCA evaluation are contained in Reference 2.

5.0 CONTROL SYSTEM EVALUATION

A prime input signal to the various NSSS control systems is the RCS average temperature (T_{avg}). This is calculated electronically as the average of the measured hot leg and cold leg temperatures in each loop.

The effect of the new RTD temperature measurement system is to potentially change the time response of the T_{avg} channels in the various loops. This in turn could impact the response of [.]^{a,c} However, as previously noted, the new RTD system will have a time response essentially equal to that of the present system; the additional time delay associated with the Median Signal Selector (MSS) would be small in comparison with the RTD time response [ ]^{a,c}. Therefore, there should be no significant effect in the T_{avg} channel response, and no apparent need to revise any of the control system setpoints. The need to modify control system setpoints will be determined during the plant startup following the installation of the new RTD system by observing the response of the control systems. If necessary, signal compensators and function generators in the control systems could be adjusted to obtain a more optimum system response. Also, control systems do not perform any protective function in the FSAR accident analyses. Instead, control systems are only assumed operative (1) in cases in which their action aggravates the consequences of an event and/or (2) with respect to maintaining the initial plant conditions in the analysis. Their modeling in accident analysis is based on nominal system parameters presented in the plant "Precautions, Limitations, and Setpoints" document.

6.0 CONCLUSIONS

The method of utilizing fast-response RTDs installed in the reactor coolant loop piping as a means for RCS temperature indication has undergone extensive analyses, evaluation and testing as described in this report. The incorporation of this system into the H. B. Robinson Unit 2 design meets all safety, licensing and control requirements necessary for safe operation of this unit. The analytical evaluation has been supplemented with in-plant and laboratory testing to further verify system performance. The fast response RTDs installed in the reactor coolant loop piping adequately replace the present hot and cold leg temperature measurement system and enhances ALARA efforts as well as improve plant reliability.

7.0 REFERENCES

1. H. B. Robinson Unit 2 Final Safety Analysis Report, Amendment 5.

2. ANF-88-094, H. B. Robinson Unit 2 Chapter 15 Over Temperature Delta-T Trip Event Analysis for Elimination of RTD Bypass Piping.

APPENDIX A

RTD BYPASS ELIMINATION

FOR

H. B. ROBINSON 2

DEFINITION OF AN OPERABLE CHANNEL AND
HOT LEG RTD FAILURE COMPENSATION PROCEDURE

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DEFINITION OF AN OPERABLE CHANNEL

The RTD Bypass Elimination modification uses the average of 3 RTDs in each hot leg to provide a representative temperature measurement. In the event one or more of the RTDs fails steps must be taken to compensate for the loss of that RTD's input to the averaging function. H. B. Robinson 2 will have dual element RTDs installed in each hot leg thermowell location. The second element may be used when the first element fails and the three RTD average maintained. In the event of the second element failing in the same RTD, then this procedure could be envoked.

Single RTD Failure

Hot Leg: All three hot leg RTDs must be operable during the period following refueling from cold to hot zero power and from hot zero power to full power. During the heat up period the plant operators will be [

]a,c Typically this data is recorded at initial 100% power and thereafter during the normal protection channel surveillance interval.

Once [ ]a,c any hot leg can then tolerate a single total dual element RTD failure and still remain operable. If the situation arises where a single hot leg RTD failure occurs a bias value must be applied to the average of the remaining two valid RTDs. [

.]a,c

The plant may operate with a failed hot leg RTD at any power level during that same fuel cycle. It is permissible to shutdown and startup during the cycle without requiring that the failed RTD be replaced. [

.][a,c]

The Median Signal Selector will eliminate any control system concerns, the Tavg and ΔT signal associated with the loop containing the failed hot leg RTD will most likely not be the Median Signal chosen as the input to the control systems. If another hot leg RTD fails in a different loop the utility should operate using manual control. Manual control is recommended so that the operator can control the plant based on the best measurement available. If automatic operation is continued the control system may choose the biased channel due to the positive (or zero) bias application. This means the control system will perceive a higher Tavg than is real at reduced power and the plant will operate at depressed temperatures. While this is not necessarily undesirable it does reduce the total plant megawatt output. The use of automatic control can be considered based on utility power requirements.

Cold Leg: If the active cold leg RTD fails, then that RTD should be disconnected from the 7100 cabinets. The installed spare RTD should then be connected in the failed RTD's place.

Double RTD Failure: Inoperable Channel

Hot Leg or Cold Leg: If two or more of the three hot leg dual element RTDs or both cold leg RTD elements fail in the same protection channel then that channel is considered inoperable and should be placed in trip. Operation with only one valid hot leg RTD is not presently analyzed as part of the licensing basis.

PROCEDURE FOR OPERATION WITH A HOT LEG RTD OUT OF SERVICE

The hot leg temperature measurement is obtained by averaging the measurements from the three thermowell RTDs installed on the hot leg of each loop. [of the RTD measurements will

.]^{a,c}

In the event that one of the three RTDs fails, the failed RTD will be disconnected and the hot leg temperature measurement will be obtained by averaging the remaining two RTD measurements. [

]^{a,c}

The bias adjustment corrects for [

.]^{a,c} To assure that the measured hot leg temperature is maintained at or above the true hot leg temperature, and thereby avoid a reduction in safety margin at reduced power, [

]^{a,c}

An RTD failure will most likely result in an offscale high or low indication and will be detected through the normal means in use today (i.e., T_{AVG} and ΔT deviation alarms). Although unlikely, the RTD (or its electronics channel) can fail gradually, causing a gradual change in the loop temperature measurements. [

.]^{a,c}

The detailed procedure for correcting for a failed hot leg RTD is presented below:

a,c

a,c

(Detailéd Procedure For Correcting Failed Hot
Leg RTD Continued)

a,c

(Detailed Procedure For Correcting Failed Hot Leg RTD continued)

APPENDIX

CALCULATION OF HOT LEG TEMPERATURE BIAS

a,c