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U. S. Nuclear Regulatory Commission
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Dresden Nuclear Power Station, Units 2 and 3
Renewed Facility Operating License Nos. DPR-19 and DPR-25
NRC Docket Nos. 50-237 and 50-249

Subject: Request for License Amendment Regarding Shutdown Cooling System Isolation Instrumentation

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit, or early site permit," Exelon Generation Company, LLC (EGC) requests an amendment to Renewed Facility Operating License Nos. DPR-19 and DPR-25 for Dresden Nuclear Power Station (DNPS), Units 2 and 3, respectively.

Specifically, the proposed amendment revises Technical Specification (TS) 3.3.6.1, "Primary Containment Isolation Instrumentation," Table 3.3.6.1-1, "Primary Containment Isolation Instrumentation," Function 6.a, "Shutdown Cooling System Isolation, Recirculation Line Water Temperature - High," to enable implementation of a modification that replaces the temperature-based isolation instrumentation with reactor pressure-based isolation instrumentation. The proposed modification will address instrumentation reliability problems that have led to interruptions of Shutdown Cooling (SDC) system operation.

On November 2, 2009, during the shutdown of DNPS Unit 2 for a refueling outage, the SDC system experienced a spurious isolation due to an emergent failure of a temperature element, in addition to a previously failed temperature element. Failure of this second temperature element resulted in a loss of residual heat removal for a brief period until operators installed a temporary jumper, enabling restart of the SDC system.

EGC's review of the November 2009 DNPS Unit 2 spurious isolation, in conjunction with historical failures, revealed that previous corrective actions, including modifications, failed to effectively eliminate spurious SDC system isolation events on both DNPS Unit 2 and Unit 3. As a result, EGC determined that the design of the existing temperature elements would not ensure reliable performance, given the operational conditions (i.e., high temperature and radiation). EGC also concluded that the most reliable design was the installation and use of reactor pressure-based instrumentation to affect the required system isolation, consistent with other U. S. boiling water reactors (BWRs).

The proposed change to primary containment isolation system (PCIS) instrumentation function 6.a is needed to ensure reliable heat removal capability, avert plant transients and challenges to equipment, and minimize unnecessary operator actions during plant shutdowns.

This request is subdivided as follows.

- Attachment 1 provides a description and evaluation of the proposed change.
- Attachment 2 provides a markup of the affected TS pages.
- Attachment 3 provides a markup of the affected TS Bases pages. The TS Bases pages are provided for information only, and do not require NRC approval.
- Attachment 4 provides the safety-related instrument setpoint calculation supporting the proposed amendment.

The proposed change has been reviewed by the DNPS Plant Operations Review Committee and approved by the Nuclear Safety Review Board in accordance with the requirements of the EGC Quality Assurance Program.

In accordance with 10 CFR 50.91, paragraph (b), EGC is notifying the State of Illinois of this application for license amendment by transmitting a copy of this letter and its attachments to the designated State Official.

EGC requests NRC review and approval of this LAR by February 5, 2011, with implementation on DNPS Unit 2 within 30 days of issuance and on DNPS Unit 3 concurrent with, or prior to, an outage of sufficient duration following issuance.

There are no regulatory commitments contained in this submittal. Should you have any questions concerning this letter, please contact Mr. John L. Schrage at (630) 657-2821.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 4th day of February 2010.

Respectfully,

Jeffrey L. Hansen
Manager – Licensing

Attachments:

1. Evaluation of Proposed Change
2. Markup of Proposed Technical Specifications Pages
3. Markup of Proposed Technical Specifications Bases Pages
4. Setpoint Calculation No. DRE09-0041, "Shutdown Cooling Reactor High Pressure (Cut-in Permissive) Setpoint Calculation"

ATTACHMENT 1
Evaluation of Proposed Change

1.0 DESCRIPTION

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5.0 ENVIRONMENTAL CONSIDERATION

1.0 DESCRIPTION

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit, or early site permit," Exelon Generation Company, LLC (EGC) requests an amendment to Appendix A, Technical Specifications (TS) of Renewed Facility Operating License Nos. DPR-19 and DPR-25 for Dresden Nuclear Power Station (DNPS), Units 2 and 3, respectively.

Specifically, the proposed amendment revises Technical Specification (TS) 3.3.6.1, "Primary Containment Isolation Instrumentation," Table 3.3.6.1-1, "Primary Containment Isolation Instrumentation," Function 6.a, "Shutdown Cooling System Isolation, Recirculation Line Water Temperature - High," to enable implementation of a modification that replaces the temperature-based isolation instrumentation with reactor pressure-based isolation instrumentation. The proposed modification will address instrumentation reliability problems that have led to interruptions of Shutdown Cooling (SDC) system operation, leading to unplanned heat-up of reactor coolant while the reactor was in operational Modes 3 and 4.

On November 2, 2009, during the shutdown of DNPS Unit 2 for a refueling outage (D2R21), the DNPS Unit 2 SDC system experienced a spurious isolation due to failure of a temperature element (TE) (i.e., one of two thermocouples (T/Cs) or two resistance temperature detectors (RTDs) that are installed as a single TE assembly, all within a thermowell (TW)), in concert with a previously failed TE in the same TE assembly. The failure of this second TE resulted in a loss of residual heat removal until operators installed a temporary jumper, enabling restart of the SDC system.

EGC's review of the DNPS Unit 2 spurious isolation, in conjunction with previous historical failures, revealed that previous corrective actions, including modifications, failed to effectively eliminate spurious SDC system isolation events on both DNPS Unit 2 and Unit 3. Specifically, EGC determined that the design of the existing TEs would not ensure reliable performance, given the operational conditions (i.e., high temperature and radiation). EGC assessed a variety of means to address SDC system instrumentation concerns and concluded that the most reliable design to prevent recurrence was the installation and use of reactor pressure-based instrumentation and associated logic scheme to affect the required system isolation. The pressure-based instrumentation and logic scheme is consistent with the SDC system isolation function at other U. S. boiling water reactor (BWR) licensees.

The proposed change to primary containment isolation system (PCIS) instrumentation function 6.a is needed to ensure reliable heat removal capability, avert plant transients and challenges to equipment, and minimize unnecessary operator actions during plant shutdowns.

2.0 PROPOSED CHANGE

TS Table 3.3.6.1-1, function 6.a will be revised to state:

6. Shutdown Cooling System Isolation
   a. Reactor Vessel Pressure – High
   b. Reactor Vessel Water Level -Low

The applicable modes, required channels per trip system, applicable conditions and surveillance requirements that are specified in TS Table 3.3.6.1-1 for function 6.a. will remain unchanged.

The Allowable Value (AV) column of TS Table 3.3.6.1-1 will indicate two separate, instrument loop-specific AVs for function 6.a, as delineated below:

≤ 114.1 psig (Loop 1, Reactor Wide Range Pressure)

≤ 110.4 psig (Loop 2, Reactor Pressure Feedwater Control)

A markup of the proposed changes is provided in Attachment 2. These changes support implementation of a modification that replaces the function 6.a. temperature-based isolation instrumentation with four channels of pressure-based isolation instrumentation.

3.0 TECHNICAL EVALUATION

3.1 Shutdown Cooling System Design Basis

Irradiated fuel in a shutdown reactor core generates heat during the decay of fission products and increases the temperature of the reactor coolant. This decay heat must be removed to reduce the temperature of the reactor coolant to ≤ 212 degrees F in preparation for performing Refueling or Cold Shutdown maintenance operations.

The SDC system is comprised of three redundant, manually controlled subsystems (loops). Each SDC system loop consists of one motor driven pump, a heat exchanger, and associated piping and valves. Each loop can draw from either Reactor Recirculation (Recirc) system loop. Each pump discharges the reactor coolant, after circulation through the respective heat exchanger, to the reactor via either Recirc system loop. The SDC system heat exchangers transfer heat to the Service Water system via the Reactor Building Closed Cooling Water system.

The design objective of the SDC system is to cool the reactor coolant when the temperature and pressure in the reactor fall below the point at which the main condenser can no longer be used as a heat sink following reactor shutdown. To achieve this objective, the SDC system heat exchangers were designed to a pressure of 1250 psig and a temperature of 350 degrees F.

Decay heat removal by operation of the SDC system in the shutdown cooling mode is not required for mitigation of any event or accident evaluated in the safety analyses. Decay heat removal is, however, an important safety function that must be accomplished or core damage could result.

Based on the design limitations of the SDC system (i.e., 1250 psig and 350 degrees F, as described above), the system cannot be placed into operation until the reactor coolant has been cooled to below 350 degrees F. The SDC system is capable of cooling reactor water to 140 degrees F within 24 hours after reactor shutdown and maintaining it at this temperature by removing fission product decay heat from the reactor water.

The SDC system may be connected in parallel with the spent fuel pool (SFP) cooling system to assist in cooling the SFP during periods of extremely high heat loads, such as immediately after refueling or a full core discharge.

The SDC system cannot be put into service until various permissives are satisfied. A temperature interlock on ac-powered motor operated isolation valves prevents valve opening until reactor coolant system temperature, sensed on both Recirc system loops, has decreased to less than 350 degrees F. The SDC system suction valves automatically isolate the SDC system if temperature, which is sensed on the Recirc system loops, increases to 350 degrees F, or if a reactor low water level signal is present.

The existing temperature permissive consists of two trip strings, each having two trip channels. One trip string consists of an RTD and a temperature trip unit for each of the recirculation loops where the trip unit contacts are wired in series. The second trip string consists of a T/C and a temperature trip unit for each of the recirculation loops where the trip unit contacts are wired in series. These two trip strings are wired in parallel and are connected to a trip relay. The relay is used as a contact multiplier and provides coil-to-contact isolation between the non-safety related circuitry of the SDC system interlock logic and the Group 3 isolation circuitry for the SDC system. The trip unit contacts are configured to open when the temperature setpoint is exceeded or if a temperature element failure is detected. Opening of the contacts will isolate the SDC system to protect the equipment. For Unit 2, the logic is arranged in a one-out-of-two-taken-twice logic to initiate isolation. DNPS Unit 3 also uses four temperature sensors, but the logic is arranged in a one-out-of-four isolation logic, which allows for bypassing up to two failed temperature sensors.

Each pump has interlocks to prevent operation until certain conditions are met. Inlet temperature, as measured in the SDC system pump branch line, must be less than 350 degrees F, and pump suction pressure must be greater than 4 psig. If these conditions are not met, the SDC system pumps cannot be started. The pumps trip on a temperature increase to 350°F or if suction pressure decreases to less than 4 psig for a specified period of time.

3.2 Primary Containment Isolation System Instrumentation Design Basis

The SDC system, when in operation, becomes an extension of the reactor coolant pressure boundary (RCPB). As such, the suction and discharge lines are equipped with primary containment isolation valves (PCIVs). The primary containment isolation instrumentation automatically initiates closure of appropriate primary containment PCIVs. The function of the PCIVs, in combination with other accident mitigation systems, is to limit fission product release during and following postulated Design Basis Accidents (DBAs). Primary containment isolation within the time limits specified for PCIVs that are designed to automatically close ensures that the release of radioactive material to the environment will be consistent with the assumptions used in the analyses for a DBA.

The isolation instrumentation includes the sensors, relays, and switches that are necessary to cause initiation of primary containment and RCPB isolation. Most channels include electronic equipment (e.g., trip units) that compares measured input signals with pre-established setpoints. When the setpoint is exceeded, the channel output relay actuates, which then outputs a primary containment isolation signal to the isolation logic. Functional diversity is provided by monitoring a wide range of independent parameters. Redundant sensor input signals from each parameter are provided for initiation of isolation.

There are two isolation functions for the SDC system, low reactor vessel water level and high Recirc system water temperature. The SDC system isolation on low reactor water level supports actions to ensure that the reactor water level does not drop below the top of the active fuel during a vessel draindown event caused by a leak (e.g., pipe break or inadvertent valve opening) in the SDC system. The "Reactor Vessel Water Level - Low" function receives input from four reactor vessel water level channels. Each channel inputs into one of four trip strings. Two trip strings make up a trip system and both trip systems must trip to cause an isolation of the SDC system suction isolation valves. Any channel will trip the associated trip string. Only one trip string must trip to trip the associated trip system. The trip strings are arranged in a one-out-of-two taken twice logic to initiate isolation. The "Reactor Vessel Water Level - Low" isolation function is not affected by this proposed amendment.

The "Recirculation Line Water Temperature - High" SDC system isolation function is provided to prevent the SDC system heat exchangers from exceeding their design temperature of 350 degrees F. The SDC system isolation function is not credited or assumed in the accident or transient analysis.

This temperature isolation, although not unique, does not exist in later vintage BWR plants which are low pressure SDC systems and the piping is protected from high reactor pressures via a pressure interlock.

3.3 SDC System Isolation Instrumentation Failure History

The Recirc system pump suction TEs (i.e., the T/Cs and RTDs in a thermowell) and associated circuits have historically experienced numerous failures. Each thermowell has a unique four-element temperature probe that includes two T/Cs and two RTDs. The TEs and associated wiring are located in a very high gamma and neutron radiation field during power operation. Additionally due to the temperature of the Recirc system piping (i.e., approximately 525 degrees F), the TEs, and localized wiring will be exposed to a very high temperature environment during power operation. Repair of any of these components requires a containment entry, and cannot be performed during power operation.

EGC's review of the failure history indicates that the TEs have a history of spurious high spikes due to increased element or circuit resistance. Specifically, the EGC review of work history, corrective action program documents, and anecdotal information from senior instrumentation and control (I&C) personnel (i.e., I&C personnel that have been involved with maintenance on these circuits from the late-1970s to the present time) identified that the TEs, cables, cable splices, and trip units have experienced failures since the late-1970s. In these historical cases, the failed component was either repaired or replaced.

In the 1990s, there were six events that resulted in SDC system isolation. In addition to repair or replacement of the failed components for these six events, Commonwealth Edison (i.e., the predecessor to EGC) revised the SDC system operating procedure in 1999 to require installation of a jumper to bypass the temperature isolation function during operational Modes 4 and 5. While this improved the reliability of the SDC system during these modes, it did not correct the TE failure issues.

In December 2000, while in Mode 3 (i.e., hot shutdown), a TE failure resulted in a spurious SDC system isolation. As a result, EGC replaced the DNPS Unit 2 instrument drywell penetration in November 2001. In a further effort to eliminate TE failures and spurious SDC system isolation events, EGC implemented a modification in late-2000 for Unit 2 and early-2003 for Unit 3 that installed additional T/Cs and RTDs in the circuit to allow bypassing of failed elements, and changed the isolation logic scheme from one-out-of-two-taken-once to one-out-of-four-taken-once. However, the penetration replacement and modification did not eliminate the TE failures.

Between 2002 and 2008, twelve instances of SDC system isolation occurred at DNPS. Although these SDC system isolations did not result in an inadvertent Mode change, the increase in reactor coolant temperature during these events ranged from 12 degrees F to 32 degrees F before the SDC system could be restarted.

In November 2008 during shutdown to D3R20, the SDC system again isolated due to a failed TE. Following this event, EGC designed a modification for both units to change the logic scheme from one-out-of-four-taken-once to one-out-of-two-taken-twice, with the intent of eliminating a single failure vulnerability. At the time that this modification was designed, one of the four temperature sensors on Unit 2 was failed and bypassed. The installation of the modification required the removal of the bypass, thus creating a new single failure vulnerability. The Unit 2 modification was installed in October 2009 just prior to D2R21. An additional TE failure on Unit 2 in November 2009, combined with the single failure vulnerability, resulted in the November 2009 isolation. The modification was not installed on Unit 3.

EGC's review of the November 2009 DNPS Unit 2 spurious isolation, in conjunction with previous historical failures, revealed that previous corrective actions, although appropriate at the time, failed to effectively eliminate spurious SDC system isolation events on both Unit 2 and Unit 3. All previous correction actions were designed and implemented within the constraints of the TS, utilizing TEs. As a result of the November 2009 SDC system isolation event, EGC determined that the design of the existing TEs would not ensure reliable performance, given the operational conditions (i.e., high temperature and radiation).

EGC assessed a variety of means to address SDC system instrumentation concerns and concluded that the most reliable design to prevent recurrence was the installation and use of reactor pressure-based instrumentation to affect the required system isolation. The pressure-based instrumentation is consistent with the SDC system isolation function at other U. S. BWRs.

3.4 SDC System Isolation Instrumentation Modification

As stated above, EGC assessed a variety of means to address the long outstanding SDC system instrumentation concerns (i.e., equipment reliability issues associated with the temperature isolation/interlock circuit components). These options included utilizing the spare T/C and RTD within the same TE assembly, adding additional contacts within the trip string such that a failed contact could be jumpered out, and replacing the existing temperature sensor assemblies with higher quality pressure-based instrumentation.

EGC determined that the use of highly reliable pressure-based logic signals would provide the highest level of assurance that spurious SDC system isolations would be eliminated.

This determination is based on a review of similar BWRs that use highly reliable pressure channels in a one-out-of-two-taken-once logic configuration. The similar BWRs use pressure switches that monitor either the Recirc system suction line pressure or the reactor steam pressure to perform the isolation function.

The new DNPS design will utilize reactor steam pressure channels instead of temperature switches for the isolation function. The DNPS design, which utilizes reactor pressure sensors to monitor reactor pressure on both sides of the vessel for each trip string will be configured in a one-out-of-two-taken-twice logic. This logic scheme has been evaluated and accepted in licensing topical report NEDO-10139, "Compliance of Protection Systems to Industry Criteria: General Electric BWR Nuclear Steam Supply Systems," for the reactor protection and core standby cooling systems, since no signal failure can prevent or cause a spurious actuation.

Unlike the TE assemblies that had two T/Cs and two RTDs within a single assembly, the pressure channel components are independent and are separated from each other. No single failure associated with the new components can prevent or initiate the SDC system. Finally, the sensors and trip circuits will be all located outside of the containment, thus enabling on-line corrective maintenance.

In order to implement the modification, TS Table 3.3.6.1-1, function 6.a requires a revision to:

1. Change the setpoint process parameter (i.e., column 1) from temperature to pressure;
2. Revise the AV (i.e., column 6) from the single temperature value to two separate, instrument loop-specific pressure values, based on the results of new safety-related instrument setpoint calculations. The new AVs will maintain the original design margin for protection of the SDC system heat exchangers.

The TS Bases for the SDC system isolation function 6.a are also being revised to indicate that the isolation is being generated from a pressure signal instead of a temperature signal.

The purpose of the SDC system temperature permissive function is to protect the non-safety related SDC system equipment (i.e., the SDC system heat exchangers) from exceeding the design temperature limitation described in section 3.1 above. Since the new pressure signals will be obtained from both safety and non-safety related circuits, the signal from the safety related circuit requires installation of an isolator to provide electrical separation between the safety and non-safety related circuits.

The isolation of the SDC system is required prior to exceeding the design temperature of the heat exchangers (i.e., 350 degrees F). Since the SDC system isolation will now be based on steam pressure in the reactor vessel instead of temperature in the Recirc system suction lines, the pressure-based analytical limit (AL) will be based on the pressure corresponding to the design temperature of 350 degrees F under saturated conditions. ASME Steam Tables indicate that a pressure of 119.9 psig corresponds to 350 degrees F under saturated conditions.

EGC has prepared a safety related instrument setpoint calculation to determine the pressure settings (i.e., the AV and the calibration setpoint), for the two new pressure-based trip units, based on the AL of 119.9 psig. This calculation was performed utilizing EGC procedure NES-EIC-20.04, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy," and ISA-RP67.04.02-2000, "Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation." The calculation accounts for instrument uncertainties, and provides margin from the pressure-based AL that is equivalent to the existing temperature margin. The safety-related setpoint calculation is provided in Attachment 4.

The existing temperature interlock consists of two trip strings with each string having two trip channels. The existing temperature sensors, trip units, and cabling are all non-safety related and are not required to be qualified.

The new pressure interlock instrument configuration will also consist of two trip strings, with two trip channels per trip string. Each trip channel will receive a pressure signal from separated pressure channels that measure the reactor pressure from condensing chambers that are located on opposite sides of the reactor vessel. Configuring the trip strings to use a pressure signal from the two different condensing chambers will prevent a sensing line failure from initiating the isolation/interlock permissive, since only one trip channel in each trip string will be initiated.

Each trip string will receive a pressure signal from two pressure transmitters (i.e., the safety related Analog Trip System (ATS) panel and the non-safety related feedwater control system). This configuration, which is described in Section 6.0 of Attachment 4, will ensure that a complete failure of the ATS panels or the feedwater control system will not initiate the permissive, since only one trip channel in each trip string will be initiated.

The new pressure-based trip units are non-safety related. Therefore, a Category 1 safety-related isolator will be installed in the safety related pressure channels to provide isolation between the safety and non-safety related circuit components.

The two new pressure trip strings will be wired in parallel and feed the existing relays (i.e., the relays associated with the existing temperature trip strings). The relay will continue to function as a contact multiplier, and provide coil-to-contact isolation between the non-safety related circuitry of the SDC system interlock logic and the safety related inboard and outboard isolation circuitry.

EGC has evaluated the proposed instrument channel configuration and has determined that no single failure will prevent the SDC system from isolating when required and no single spurious pressure signal will cause SDC system isolation to occur.

4.0 REGULATORY ANALYSIS

4.1 No Significant Hazards Consideration

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit, or early site permit," Exelon Generation Company, LLC (EGC) requests an amendment to Appendix A, Technical Specifications (TS) of Renewed Facility Operating License Nos. DPR-19 and DPR-25 for Dresden Nuclear Power Station (DNPS), Units 2 and 3, respectively.

Specifically, the proposed amendment revises TS 3.3.6.1, "Primary Containment Isolation Instrumentation," Table 3.3.6.1-1, "Primary Containment Isolation Instrumentation," Function 6.a, "Shutdown Cooling System Isolation, Recirculation Line Water Temperature – High," to enable implementation of a modification that replaces the temperature-based isolation instrumentation with reactor pressure-based isolation instrumentation. The proposed modification will address instrumentation reliability problems that have led to interruptions of Shutdown Cooling System (SDC) system operation.

According to 10 CFR 50.92, "Issuance of amendment," paragraph (c), a proposed amendment to an operating license involves no significant hazards consideration if operation of the facility in accordance with the proposed amendment would not:

(1) Involve a significant increase in the probability or consequences of any accident previously evaluated; or

(2) Create the possibility of a new or different kind of accident from any accident previously evaluated; or

(3) Involve a significant reduction in a margin of safety.

EGC has evaluated the proposed change, using the criteria in 10 CFR 50.92, and has determined that the proposed change does not involve a significant hazards consideration. The following information is provided to support a finding of no significant hazards consideration.

(1) Does the proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?

Response: No

The proposed license amendment implements a revised process parameter and the associated Allowable Value (AV) for the DNPS Units 2 and 3 SDC system isolation function 6.a in TS Table 3.3.6.1-1.

The proposed changes to the isolation function do not affect the probability of any event initiators at the facilities. This isolation function is provided for equipment protection to prevent exceeding the system design temperature. The isolation function is not credited or assumed in the accident or transient analysis in the Updated Final Safety Analysis Report (UFSAR).

The proposed changes will not degrade the performance of, or increase the number of challenges imposed on, safety-related equipment that is assumed to function during an accident situation. The SDC system and the isolation function that is being revised are not safety related and are not credited to function during an accident situation. The proposed changes will not alter any assumptions or change any mitigation actions in the radiological consequence evaluations in the UFSAR.

Therefore, the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

(2) Does the proposed change create the possibility of a new or different kind of accident from any accident previously evaluated?

Response: No

The proposed license amendment implements a revised process parameter and AV for the DNPS Units 2 and 3 SDC system isolation function 6.a in TS Table 3.3.6.1-1.

The proposed change enables implementation of a modification that will enhance the reliability of instrumentation used to protect the functionality and integrity of the non safety-related SDC system. There is no alteration to the parameters within which the plant is normally operated or in the setpoints that initiate protective or mitigative actions. As a result, no new failure modes are being introduced.

Therefore, the proposed change does not create the possibility of a new or different kind of accident from any accident previously evaluated.

(3) Does the proposed change involve a significant reduction in a margin of safety?

Response: No

The proposed amendment revises a process parameter and AV for the DNPS Units 2 and 3 SDC system isolation function 6.a in TS Table 3.3.6.1-1.

The margin of safety is established through the design of the plant structures, systems, and components (SSCs), the parameters within which the plant is operated, and the setpoints for the actuation of equipment relied upon to respond to an accident.

The proposed change to the SDC system isolation instrumentation function for the SDC system does not change the SSCs, operational parameters, or actuation setpoints for equipment that is relied upon to respond to an accident. Both the SDC system and the isolation function that is being revised are non-safety related and are not credited to function during an accident situation.

Therefore, the proposed change does not involve a significant reduction in a margin of safety.

4.2 Applicable Regulatory Requirements/Criteria

EGC has evaluated the proposed change to Appendix A, TS of Renewed Facility Operating License Nos. DPR-19 and DPR-25 to determine whether applicable regulations and requirements have been met. EGC has determined that the proposed changes to DNPS TS Table 3.3.6.1-1, "Primary Containment Isolation Instrumentation," Function 6.a, "Shutdown Cooling System Isolation, Recirculation Line Water Temperature - High," do not require any exemptions or relief from regulatory requirements, other than a revision to the TS. The regulatory bases and guidance documents associated with the systems discussed in this license amendment request are described below:

10 CFR 50.36, "Technical Specifications"

10 CFR 50.36, paragraph (c)(2)(i) requires that the TS include limiting conditions for operation (LCOs) for equipment required to ensure safe operation of the facility. When an LCO for operation of a nuclear reactor is not met, the licensee shall shut down the reactor or follow any remedial action permitted by the technical specifications until the condition can be met.

10 CFR 50.36, paragraph (c)(2)(ii) Criterion 4 requires that a TS LCO for operation of a nuclear reactor must be established for a structure, system, or component which operating experience or probabilistic risk assessment has shown to be significant to public health and safety. The SDC system satisfies this criteria.

The proposed change to DNPS TS Table 3.3.6.1-1, function 6.a and the associated AV will enable EGC to implement a modification that will enhance the reliability of equipment designed to protect the integrity and functionality of a system that is used to remove residual heat from the reactor core during a normal shutdown evolution.

10 CFR 50, Appendix A, "General Design Criteria for Nuclear Power Plants"

DNPS Units 2 and 3 were originally designed and constructed prior to the issuance of 10 CFR 50, Appendix A, "General Design Criteria for Nuclear Power Plants," (GDC). Proposed GDC were issued in July 1967, during the construction of the plants. These proposed criteria were not yet adopted as regulatory requirements at the time DNPS was built and licensed. Nevertheless, the proposed GDC were used by the Atomic Energy Commission to evaluate the original design of DNPS Units 2 and 3.

This evaluation indicated that, based on the applicant's understanding of the intent of the proposed GDC, DNPS fully satisfies the intent of the criteria. The DNPS UFSAR Section 3.1.1 addresses DNPS's conformance to the proposed GDC that were issued in July 1967. DNPS UFSAR Section 3.1.2 provides the results of a later evaluation of DNPS Unit 2 against the final GDC that were published in July 1971.

DNPS UFSAR Section 3.1.1.3.2, "Criterion 12 - Instrumentation and Control Systems," states that instrumentation and controls shall be provided as required to monitor and maintain variables within prescribed operating ranges. With respect to TS Table 3.3.6.1-1, function 6.a, the proposed change will enable EGC to enhance the reliability of equipment designed to protect the integrity and functionality of a system that is used to remove residual heat from the reactor core during a normal shutdown.

DNPS UFSAR Section 3.1.1.4.4, "Criterion 22 - Separation of Protection and Control Instrumentation Systems" requires the separation of protection systems from control instrumentation systems to the extent that failure or removal from service of any control instrumentation system component or channel, or of those common to control instrumentation and protection circuitry, leaves intact a system satisfying all requirements for the protection channels. The proposed change to DNPS TS Table 3.3.6.1-1 will include a Category 1 safety-related isolator to ensure electrical separation of the non-safety related control instrumentation from safety related instrumentation.

DNPS UFSAR Section 3.1.2.4.5, "Criterion 34 - Residual Heat Removal" states that a system to remove residual heat shall be provided. The system safety function shall be to transfer fission product decay heat and other residual heat from the reactor core at a rate such that specified acceptable fuel design limits and the design conditions of the reactor coolant pressure boundary are not exceeded. In addition, UFSAR Section 3.1.2.4.5 requires suitable redundancy in components and features and suitable interconnections, leak detection, and isolation capabilities to assure that for onsite electric power system operation (i.e., assuming offsite power is not available) and for offsite electric power system operation (i.e., assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure. The proposed change to DNPS Table 3.3.6.1-1, function 6.a will not impact the design basis capability of the DNPS SDC system. The SDC system retains all isolation, leak detection, independence and interconnection features, regardless of the operating mode.

4.3 Conclusion

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or the health and safety of the public.

5.0 ENVIRONMENTAL CONSIDERATION

EGC has determined that the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, "Standards for Protection Against Radiation." However, the proposed amendment does not involve: (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22, "Criterion for categorical exclusion; identification of licensing and regulatory actions eligible for categorical exclusion or otherwise not requiring environmental review," paragraph (c)(9). Therefore, pursuant to 10 CFR 51.22, paragraph (b), no environmental impact statement or environmental assessment needs to be prepared in connection with the proposed amendment.

ATTACHMENT 2
Markup of Proposed Technical Specifications Pages

Dresden Nuclear Power Station, Units 2 and 3
Renewed Facility Operating License Nos. DPR-19 and DPR-25

<u>REVISED TECHNICAL SPECIFICATIONS PAGES</u>

3.3.6.1-7

ATTACHMENT 3
Markup of Proposed Technical Specifications Bases Pages

Dresden Nuclear Power Station, Units 2 and 3
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B 3.3.6.1-5
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ATTACHMENT 4
Safety Related Instrument Setpoint Calculations

Setpoint Calculation No. DRE09-0041

"Shutdown Cooling Reactor High Pressure (Cut-in Permissive) Setpoint Calculation"

ATTACHMENT 2
Markup of Proposed Technical Specifications Pages

Dresden Nuclear Power Station, Units 2 and 3
Renewed Facility Operating License Nos. DPR-19 and DPR-25

REVISED TECHNICAL SPECIFICATIONS PAGES

3.3.6.1-7

Table 3.3.6.1-1 (page 3 of 3)
Primary Containment Isolation Instrumentation

FUNCTION	APPLICABLE MODES OR OTHER SPECIFIED CONDITIONS	REQUIRED CHANNELS PER TRIP SYSTEM	CONDITIONS REFERENCED FROM REQUIRED ACTION C.1	SURVEILLANCE REQUIREMENTS	ALLOWABLE VALUE
5. Reactor Water Cleanup System Isolation					
a. SLC System Initiation	1,2,3				
b. Rea Lev	1,2,3			SR 3.3.6.1.7	
6. Shutdown Cooling System Isolation					
a. ~~Recirculation Line Water Temperature~~ High	1,2,3	2	F	SR 3.3.6.1.2 SR 3.3.6.1.6 SR 3.3.6.1.7	~~≤ 346°F~~
b. Reactor Vessel Water Level—Low	3,4,5	2(b)	I	SR 3.3.6.1.1 SR 3.3.6.1.2 SR 3.3.6.1.3 SR 3.3.6.1.6 SR 3.3.6.1.7	≥ 2.65 inches

Reactor Vessel Pressure -

≤ 114.1 psig
(Loop 1, Reactor Wide Range Pressure)

≤ 110.4 psig
(Loop 2, Reactor Pressure Feedwater Control)

(b) In MODES 4 and 5, provided Shutdown Cooling System integrity is maintained, only one channel per trip system with an isolation signal available to one shutdown cooling pump suction isolation valve is required.

ATTACHMENT 3
Markup of Proposed Technical Specifications Bases Pages

Dresden Nuclear Power Station, Units 2 and 3
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REVISED TECHNICAL SPECIFICATIONS BASES PAGES

B 3.3.6.1-5
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B 3.3.6.1-26

BASES

BACKGROUND

5. Reactor Water Cleanup System Isolation (continued)

The Reactor Vessel Pressure-High Function is provided to isolate the SDC system. The Reactor Vessel Pressure-high function receives input from four reactor pressure channels.

...provide 1 channel input ... two trip systems is ... ves.

... valves.

6. Shutdown Cooling (SDC) System Isolation

The Reactor Vessel Water Level—Low Function receives input from four reactor vessel water level channels. Each channel inputs into one of four trip strings. Two trip strings make up a trip system and both trip systems must trip to cause an isolation of the SDC suction isolation valves. Any channel will trip the associated trip string. Only one trip string must trip to trip the associated trip system. The trip strings are arranged in a one-out-of-two taken twice logic to initiate isolation. For Unit 3 the Recirculation Line Water Temperature—High Function receives input from four channels, each of which provides input to both logic systems. Any channel will trip both logic systems. This is a one-out-of-four logic for the trip system. ~~For Unit 2 the Recirculation Line Water Temperature-High Function receives input from four temperature channels.~~ Each channel inputs into one of the four trip strings. Two trip strings make up a trip system and both trip systems must trip to cause an isolation of the SDC suction isolation valves. Any channel will trip the associated trip string. Only one trip string must trip to trip the associated trip system. The trip strings are arranged in a one-out-of-two taken twice logic to initiate isolation function. Each of the two logic systems is connected to one of the two valves on the SDC suction penetration. ~~Only one of the logic systems isolates the SDC return penetration.~~

pressure

Each of the two logic systems is connected to one of the two valves on the SDC suction penetration. Only one of the logic systems isolates the SDC return penetration.

... ions isolate some

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY

... primary containment ... y assumed in the ... o initiate closure ... r to LCO 3.6.1.3, ... PCIVs)," Applicable ... f the safety

(continued)

The Reactor Vessel Pressure-High Function is provided to isolate the SDC system. The Reactor Vessel Pressure-High function receives input from four reactor pressure channels.

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

This Function isolates the Group 3 valves.

Shutdown Cooling (SDC) System Isolation

6.a. Recirculation Line Water Temperature—High

~~The Recirculation Line Water Temperature High Function~~ is ~~provided to isolate the Shutdown Cooling System.~~ This interlock is provided for equipment protection to prevent exceeding the system design temperature, and credit for the interlock is not assumed in the accident or transient analysis in the UFSAR.

~~For Unit 3 the Recirculation Line Water Temperature High signals are initiated from the high recirculation loop temperature alarm circuit.~~ ~~Four channels (each providing input into the trip system) of Recirculation Line Water Temperature High Function are available.~~ ~~Therefore only two channels (one channel from each loop) are required to be OPERABLE to ensure that no single instrument failure can preclude the isolation function.~~ ~~For Unit 2 the Recirculation Line Water Temperature High Isolation Function receives input from four Recirculation Line temperature channels.~~ Each **pressure** channel inputs into one of four trip strings. Two trip strings make up a trip system and both trip systems must trip to cause an isolation of the ~~shutdown cooling (~~SDC~~)~~ suction valves. Any channel will trip the associated trip string. Only one trip string must trip to trip the associated trip system. The trip strings are arranged in a one-out-of-two taken twice logic to initiate isolation. Therefore all four channels are required to be OPERABLE to ensure that no single instrument failure can preclude the isolation function. The Function is only required to be OPERABLE in MODES 1, 2, and 3, since these are the only MODES in which the reactor coolant temperature exceeds the system design temperature and equipment protection is needed. The Allowable Value was chosen to be low enough to protect the system equipment from exceeding its design temperature.

This Function isolates the Group 3 shutdown cooling valves.

(continued)

BASES

SURVEILLANCE REQUIREMENTS

<u>SR 3.3.6.1.2 and SR 3.3.6.1.5</u> (continued)

The 92 day Frequency of SR 3.3.6.1.2 is based on the reliability analyses described in References 8 and 9. The 24 month Frequency of SR 3.3.6.1.5 is based on engineering judgement and the reliability of the components.

<u>SR 3.3.6.1.3</u>

For Function 6.a only, there is a plant-specific program which verifies that the instrument channel functions as required, by verifying the as-left and as-found settings are consistent with those established by the setpoint methodology.

trip units provides a check of the actual
. The channel must be declared inoperable if
ng is discovered to be less conservative than
Value specified in Table 3.3.6.1-1. If the
s discovered to be less conservative than
in the appropriate setpoint methodology, but
the Allowable Value, the channel performance
n the requirements of the plant safety
er these conditions, the setpoint must be
be equal to or more conservative than that
in the appropriate setpoint methodology.

of 92 days is based on the reliability
analyses of References 9 and 10.

<u>SR 3.3.6.1.4 and SR 3.3.6.1.6</u>

A CHANNEL CALIBRATION is a complete check of the instrument loop and the sensor. This test verifies the channel responds to the measured parameter within the necessary range and accuracy. CHANNEL CALIBRATION leaves the channel adjusted to account for instrument drifts between successive calibrations consistent with the plant specific setpoint methodology.

The Frequency of SR 3.3.6.1.4 is based on the assumption of a 92 day calibration interval in the determination of the magnitude of equipment drift in the setpoint analysis. The Frequency of SR 3.3.6.1.6 is based on the assumption of a 24 month calibration interval in the determination of the magnitude of equipment drift in the setpoint analysis.

(continued)

ATTACHMENT 4
Safety Related Instrument Setpoint Calculations

Setpoint Calculation No. DRE09-0041

"Shutdown Cooling Reactor High Pressure (Cut-in Permissive) Setpoint Calculation"

ATTACHMENT 1
Design Analysis Major Revision Cover Sheet

Design Analysis (Major Revision)			**Last Page No.** [6] 82
Analysis No.: [1]	DRE09-0041	**Revision:** [2]	000
Title: [3]	Shut Down Cooling Reactor High Pressure (Cut-In Permissive) Setpoint Calculation		
EC/ECR No.: [4]	EC 377728 / 377766	**Revision:** [5]	002 / 000

		Component(s): [14]	
Station(s): [7]	Dresden		
Unit No.: [8]	2(3)	PT 2(3)-0263-152A(B)	PT 2(3)-0647-A(B)
Discipline: [9]	I	PIS 2(3)-0263-155A(B)	UY-2(3)-0640-2A
Descript. Code/Keyword: [10]	I04	PY 2(3)-0263-153A(B1)	FY-2(3)-0640-3A
Safety/QA Class: [11]	SR	PIS 2(3)-0263-13C(D)	UY-2(3)-0640-30A
System Code: [12]	02/06		PIS 2(3)-0640-13A(B)
Structure: [13]	N/A		

CONTROLLED DOCUMENT REFERENCES [15]

Document No.:	**From/To**	**Document No.:**	**From/To**
✓ DIS 0600-16 & DIS 0600-01 ✓	To	EC 377728 / 377766	To
DIS 0263-19 ✓	To	DRE09-0044 ✓	From

Is this Design Analysis Safeguards Information? [16] **Yes** ☐ **No** ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? [17] **Yes** ☐ **No** ☒ If yes, ATI/AR#:

This Design Analysis SUPERCEDES: [18] **N/A** **in its entirety.**

Description of Revision (list affected pages for partials): [19]

This revision is the initial issue for this setpoint calculation to calculate instrument setpoints, Allowable Values (AV), instrument tolerances, and instrument loop uncertainties for the Shut Down Cooling Reactor High Pressure Setpoint Isolation Trip.

	Print Name	Sign Name	Date
Preparer: [20]	Donald Maue	[signature]	01/14/10

Method of Review: [21] **Detailed Review** ☒ **Alternate Calculations (attached)** ☐ **Testing** ☐

	Print Name	Sign Name	Date
Reviewer: [22]	Dale Eaman	[signature]	1-14-10

Review Notes: [23] Independent review ☒ Peer review ☐

	Print Name	Sign Name	Date
(For External Analyses Only) **External Approver:** [24]	N/A		
Exelon Reviewer ITPR:	N/A		

Independent 3rd Party Review Reqd? [26] **Yes** ☐ **No** ☒

	Print Name	Sign Name	Date
Exelon Approver: [27]	Greg Howard	[signature]	01/14/10

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1.0 PURPOSE & OBJECTIVE

The purpose of calculation DRE09-0041, Revision 0, is to determine the Allowable Value (AV) and instrument setpoint for the reactor high pressure Shut Down Cooling (SDC) isolation trip. Calculation DRE09-0041 Rev. 0 also evaluates the uncertainty and instrument loop errors associated with the pressure transmitter instrument loops in a normal operating condition environment, and to ensure adequate margin between the Analytical Limit (AL) and the instrument setpoints.

This calculation also determines instrument Setting Tolerances (ST), and Expanded Tolerances (administrative as found limit) to support surveillance activities.

The control function of these loops is to provide an isolation signal on increasing pressure or temperature to protect SDC system components from temperatures in excess of 350 F. When the isolation signal is reset then a permissive is satisfied for Operations to run the Shutdown Cooling System.

This calculation applies to the following instruments:

PT-2(3)-0263-152A(B): U2(3) Reactor Wide Range Pressure
PIS 2(3)-0263-155A(B): U2(3) Wide Range Reactor Pressure
PY-2(3)-0263-153A(B1): U2(3) RX Wide Range Pressure Isolator
PIS-2(3)-0263-13C(D): U2(3) SDC Pressure Indicating Switch
PT-2(3)-0647-A(B): U2(3) Reactor Pressure Feedwater Control
PIS-2(3)-0640-13A(B): U2(3) SDC Pressure Indicating Switch
UY-2(3)-0640-2A (FY-2(3)-0640-3A): U2(3) FWLC I/O Module (A/D Channel)
UY-2(3)-0640-30A: U2(3) FWLC Output Module (D/A Channel)

2.0 METHODOLOGY & ACCEPTANCE CRITERIA

2.1 The methodology used for this calculation is that presented in NES-EIC-20.04, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy", (Ref. 3.1.2). Specific clarifications to this methodology are detailed in Sections 2.3 and 2.6 below. A description of additional methodologies utilized in this calculation is included in Section 2.4.

2.2 Classification Level

This calculation could be classified as a Level 2 setpoint as defined in Reference 3.1.2, Appendix D, "Graded Approach to Determination of Instrument Channel Uncertainty". For additional confidence and conservatism, and because this calculation will be used to support a Technical Specification Allowable Value, this calculation has been developed in compliance with a Level 1 Setpoint as defined in Reference 3.1.2, Appendix D. As a Level 1, this means that the random errors (σ) to a 2σ value are combined via Square Root Sum of Squares (SRSS), and the non-random errors (Σe) are added. The total error is the sum of the random and non-random errors.

$$TE = 2\sigma + \Sigma e$$

2.3 Clarifications per Reference 3.1.2

2.3.1 Temperature, ambient pressure, radiation, and humidity errors, when available from the manufacturer, were evaluated with respect to the conditions specified in the Dresden EQ zones. The EQ zone requirements for each instrument are obtained from Passport and the Updated EQ Zone Parameter Tables. If these errors are not provided, the EQ zone conditions are analyzed to determine if they are within the manufacturers specified operating conditions. If the environmental conditions are bounded, these error effects are considered to be included in the manufacturer's reference accuracy specification.

2.3.2 Published instrument vendor specifications are considered to be based on sufficiently large samples so that the probability and confidence level meets the 2σ criteria, unless stated otherwise by the vendor.

2.3.3 Decimal precision is limited to six decimal places. The final results are rounded to the number of decimal places appropriate for the calibration procedure. Error standard deviations or sigma (σ) values are noted in brackets [ ] following the value.

2.3.4 For normal errors, per Appendix I of Reference 3.1.2, seismic events less than or equal to an OBE are considered to produce no permanent shift in the input/output relationship of a device. For seismic events greater than an OBE, affected instrumentation will be checked per reference 3.5.10 prior to any subsequent accident, negating any permanent shift, which may have occurred.

2.3.5 Resistors tolerances are considered to be based on sufficiently large samples so that the probability and confidence level meets the 2σ criteria.

2.4 Additional Methodology Items

2.4.1 Per Reference 3.1.2, the calibration standard error may be considered negligible if the calibration standard error (STD) is more accurate than the M&TE by a ratio of at least 4:1. Per Reference 3.1.2, calibration standards are more accurate than the M&TE by a ratio of at least 4:1. Therefore, STD is considered to be negligible.

2.4.2 For instruments in the reactor building, temperature errors are evaluated in accordance with Reference 3.2.4. The errors are based on the difference between the calibration temperature and in-service ambient temperature. The instrument temperature error is evaluated from the minimum calibration temperature to the maximum "elevated" normal temperature from Reference 3.2.4, which accounts for one unit's reactor building heating up due to loss of HVAC, due to a LOCA in the opposite unit. The high temperature used is the maximum within the first 24 hours after a LOCA, because the unit will be shutting down.

2.4.3 The only temperature induced M&TE errors evaluated are those specified by the manufacturer for a specific model number, taken across the full range of non-LOCA normal temperatures. This is done because while one unit is in a LOCA no calibrations will be performed on the non-affected unit.

2.4.4 Per References 3.5.3 and 3.7.3, Expanded Tolerances (ET) are determined for each calibration component in the loop and for the loop calibration as follows:

$$ET = \pm [0.7 * (DTI_v - ST)] + ST$$

If the tolerance determined using the equation above results in an expanded tolerance (ET) value that is less than the setting tolerance (ST), then expanded tolerance is set equal to the 3 sigma setting tolerance (Reference 3.1.2).

2.4.5 Derivation of Allowable Value (AV) is in accordance with the methodology of References 3.1.2 and 3.5.3 based on the calculated setpoint, SPc.

2.4.6 The vendor drift specifications (DTI_v) are based upon reference accuracy, calibration error (CAL), setting tolerance (ST) and drift (σ_D). For these instruments, the reference accuracy consists only of the repeatability term (RPT).

Since rigorous drift analyses are not performed for the instrumentation herein, the vendor drift specifications (DTI_v) is used in the determination of Allowable Value and Expanded Tolerance per References 3.1.2 and Reference 3.5.3.

2.5 Acceptance Criteria

The acceptance criteria for this calculation are such that the field calibration setpoints associated with the subject instrument loops are bounded by the calculated setpoint. The allowable value is calculated in accordance with the methodology in reference 3.12 and the results are provided for use.

The expanded tolerances are determined in accordance with Section 2.4.4 and are acceptable if the result is greater than or equal to the applicable setting tolerance and do not result in a violation of an applicable limit.

2.6 Per Reference 3.1.2 default drift effect value is:

± 0.5 % of span per refueling cycle

This is understood to mean that the drift effect values are valid without adjustment for any refueling interval up to and including 30 months (125% of a nominal 24 month refueling cycle = 30 months).

2.7 Per reference 3.1.2, the terms Drift (D), Repeatability (RPT), Calibration (CAL), Setting Tolerance (ST), and Random Input Errors (σ_{IN}) are considered as independent, random variables.

2.8 Reference 3.1.1 and Reference 3.1.2, Appendix C provides the equation for determining an increasing protection system Setpoint and Allowable Value based on the Analytical Limit (AL).

Per References 3.1.1 and 3.1.2, increasing Setpoints are established as:

$$SP_C <= AL - (Z + MAR)$$

Where:

SP_C	=	Calculated Trip Setpoint
AL	=	Analytical Limit
Z	=	Total Loop Uncertainties
MAR	=	Margin

Per Reference 3.1.1 and 3.1.2, the Allowable Values are established as:

<u>AV (Increasing protection system):</u>

$$AV_{high} = SP_C + \text{applicable uncertainty} \quad \text{(increasing setpoint)}$$

2.9 Rosemount does not specify a separate drift term for the 710DU trip unit. However the output accuracy/trip point repeatability is stated as a 2σ value valid for up to 6 months. Therefore the drift error is included in the accuracy/repeatability value. (Reference 3.6.2)

2.10 For Rosemount transmitters, drift is defined as a "point drift specification" which is defined as an error term that is not a function of time. As such, when evaluating drift for Rosemount transmitters, the specified values will be used in its entirety and will not be reduced for lesser calibration intervals.

2.11 Setting Tolerance (ST)

Per reference 3.1.2 when Setting Tolerances are not provided per established calibration procedures, Setting Tolerances should be conservatively determined to justify a 3σ confidence level.
For Setting Tolerances (ST) not provided per established calibration procedures, ST is to be set equal to two times the vendor specifications for reference accuracy (RA). Therefore,

$$ST_{NEW} = 2*RA_{VENDOR}$$

3.0 REFERENCES

3.1.0 STANDARDS

3.1.1 ANSI/ISA-S67.04-1994, "Setpoints for Nuclear Safety Related Instrumentation"

3.1.2 NES-EIC-20.04, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy", Revision 5

3.1.3 ISA-RP67.04.02-2000, "Methodologies for the Determination of Setpoint for Nuclear Safety-Related Instrumentation, Approved January 1, 2000"

3.1.4 ANSI/ISA S51.1-1979, "Process Instrumentation Terminology" (For reference)

3.2.0 CALCULATIONS

3.2.1 DRE98-0047, Revision 3, Dresden Station Measurement and Test Equipment (M&TE) Accuracy Calculation

3.2.2 CALC. No. 0349-E-10, Rev. 6 & 0349-E-30, Rev. 3, RVLIS Modification Instrument Calibration Unit Calculation for Dresden Unit 2 & 3

3.2.3 NED-I-EIC-0250, Revision 1 & NED-I-EIC-0264, Revision 1 Determination of the Effect of the Backfill Modification on Instruments Which Provide Low, Low-Low, High, and Two-Thirds Core Height Reactor Water Level Indication/Trip Functions, Unit 2 & 3, CHRON #208960

3.2.4 DRE01-0041 Revision 2, 2A, and 2B,"Updated EQ Zone Parameter Tables following Implementation of Extended Power Uprate"

3.2.5 NED-I-EIC-0295, Revision 2, "Reactor Pressure Error Indication At Process Computer"

3.2.6 NED-I-EIC-0307, Revision 3, "Recirculation Line Water Temperature High (Cut-in Permissive) Setpoint Calculation"

3.2.7 DR-CID-06, Revision 1, "Reactor Pressure Instrument Loop Accuracy"

3.2.8 DRE99-0084, Rev. 0, "Instrument Drift Analysis for Rosemount 1151GP9 Series Pressure Transmitters"

3.2.9 DRE09-0044, Rev. 0, "Shutdown Cooling Reactor High Pressure Analytical Limit"

3.3.0 P&ID/DRAWINGS

3.3.1 M-26, Sheet 1, Revision BN & M-357, Sheet 1, Revision BS, "Diagram of Nuclear Boiler and Reactor Recirculating Piping"

3.3.2 12E-2419, Sheet 1 Revision BH & 12E-3419, Sheet 1 Revision AY, "Schematic Diagram Feedwater Control System Reactor Level"

3.3.3 12E-2493A, Revision C & 12E-3493A, Revision D, "Schematic Diagram Nuclear Boiler System Reactor Pressure"

3.3.4 12E-2508, Revision W & 12E-3508, Revision J, "Schematic Diagram Primary Containment Isolation Shutdown Cooling System Isolation Logic"

3.4.0 SPECIFICATIONS (Requirements)

3.4.1 Tech Spec Table 3.3.6.1-1, Function 6.a, Shutdown Cooling System Isolation, Recirculation Line Water Temperature – High, through Amendments 232 (Unit 2) & 225 (Unit 3)

3.4.2 Dresden UFSAR, Revision 008, Section 9.4.1, Control Room Area Ventilation System, Section 9.4.5 Reactor Building Ventilation System, and Section 9.4.8 Drywell Ventilation System.

3.5.0 PROCEDURES

3.5.1 Procedure CC-AA-309, Rev. 09 "Control of Design Analyses"

3.5.2 Procedure CC-AA-309-1001, Rev. 05 "Guidelines for Preparation and Processing Design Analyses"

3.5.3 Procedure ER-AA-520, Rev. 03, "Instrument Performance Trending"

3.5.4 Dresden Station Instrument Surveillance Procedure DIS 0600-16, Rev. 8 & DIS 0600-01, Rev. 26 "Reactor Pressure Transmitter/Indicator Channel Calibration"

3.5.5 Dresden Instrument Surveillance Procedure DIS 0263-19, Rev. 11, "Reactor Wide Range Pressure Transmitter Calibration".

3.5.6 Dresden Instrument Surveillance Procedure DIS 1000-01, Rev. 21, "Shutdown Cooling Isolation Recirculation Line Water Temperature - High (Cut-In Permissive) Channel Calibration"

3.5.7 Passport Predefined Parameters for DIS 0600-16 & DIS 0600-01, as viewed on 01-05-2010:

Unit 2 PMID 9521-01
Unit 3 PMID 10836-01
Frequency Requirements: 4-years (Frequency will be revised to 2-years per reference 3.7.1, EC 377728 / 377766. See section 4.10.)

3.5.8 Passport Predefined Parameters for DIS 0263-19, as viewed on 01-05-2010:

Unit 2 PMID 9526-01
Unit 2 PMID 10840-01
Frequency Requirements: Semi-Annual (6-months / 184 days)

3.5.9 Passport Predefined Parameters for DIS 1000-01, as viewed on 01-05-2010:

Unit 2 PMID 9591-01
Unit 3 PMID 10907-01
Frequency Requirements: 2-years

3.5.10 Dresden Operations Accident Procedure DOA 0010-03, Rev. 14, "Earthquakes"

3.6.0 VENDOR INFORMATION DOCUMENTS

3.6.1 VETIP Dresden Station Binder #D1174, Rev. 002, "Rosemount Alphaline Pressure Transmitters for Nuclear Service"

3.6.2 VETIP Dresden Station Binder #D1196, Rev. 000, "Rosemount Model 710DU Trip/Calibration Unit"

3.6.3 VETIP Dresden Station Binder #D1230, Rev. 002, "Moore Installation And Service Instructions"

3.6.4 VETIP Dresden Station Binder #D1151 Volumes I, II, & III, Rev. 001/000/000 "Bailey INFI 90 Instructions"

3.6.5 Vendor Manual for Moore model SPA^2 Programmable Current/Voltage and RTD/Thermocouple Limit Alarm Trips, Publication# 224-710-08D dated March 2008.

3.7 <u>Other Documents</u>

3.7.1 Engineering Change 377728 / 377766, rev. 002 (000), U2(3) Shutdown Cooling Logic Change

3.7.2 Passport database for the following EPNs:

PT-2(3)-0263-152A(B), Rev. 002
PIS-2(3)-0263-155A(B), Rev. 001
PY-2(3)-0263-153A, Rev. 002
PT-2(3)-0647-A(B), Rev. 002
UY-2(3)-0640-2A / FY-2(3)-0640-3A, Rev. 000
UY-2(3)-0640-30A, Rev. 001

3.7.3 Doc ID# DG99-001245, Rev. 2, Improved Technical Specifications and 24-Month Technical Specifications Project Technical Plan

3.7.4 A.S.M.E. Steam Tables Edition 5th

3.7.5 Crane Flow of Fluids, Technical Paper No. 410, 1988, Appendix B, Equivalents of Pressure and Head

4.0 DESIGN INPUTS

Design inputs are taken to be the resources used herein to evaluate the instrument setpoint. The majority of design inputs used in the preparation of this calculation are contained in references listed in Section 3 and the information contained in Section 6 Instrument Channel Configuration. Items that require further clarification are listed below.

4.1 Per Reference 3.2.9, the Analytical Limit (AL) for the SDC isolation:

AL = 134.6 psia (119.9 psig)

4.2. The pressure transmitters receive their inputs from level condensing chambers CC-2(3)-0263-13A/B. The chambers provide a constant reference leg to the transmitters. These chambers are serviced by the RVLIS backfill modification. The effect of the RVLIS backfill for normal conditions per references 3.2.2 and 3.2.3 for Unit 2 is +0.3 "wc for both condensing chambers, +0.5 "wc for Unit 3 Condensing Chamber 3-0263-13A, and +0.2 "wc for Unit 3 Condensing Chamber 3-0263-13B. The most conservative value of 0.5 "wc will be used for calculating the effect of the RVLIS backfill for normal conditions.

4.3 References 3.2.2 and 3.2.3 provide the elevations of the condensing chambers, elevations of the pressure transmitters, and head corrections for each of the pressure transmitters.

Pressure Transmitter Installation Details				
Pressure Transmitter	**Transmitter Elev.**	**Condensing Chamber**	**Condensing Chamber Elev.**	**Head Correction**
2-0263-152A	548.833 ft.	2-0263-13A	581.385 ft.	13.9 psig
2-0263-152B	549.917 ft.	2-0263-13B	581.417 ft.	13.5 psig
2-0647A	547.834 ft.	2-0263-13A	581.385 ft.	14.4 psig
2-0647B	548.000 ft.	2-0263-13B	581.417 ft.	14.3 psig
3-0263-152A	547.167 ft.	3-0263-13A	581.412 ft.	14.6 psig
3-0263-152B	550.084 ft.	3-0263-13B	581.334 ft.	13.4 psig
3-0647A	547.750 ft.	3-0263-13A	581.412 ft.	14.4 psig
3-0647B	548.750 ft.	3-0263-13B	581.334 ft.	14.3 psig

4.4 The reference accuracy and drift error for Pressure Indicating Switches (PIS) in Module 4 (section 4.11.5 and 4.12.9) of both instrument loops are determined as follows:

Per reference 3.6.5 vendor specifications for the PIS provide a 1-year stability specification of $\pm$ 0.066% of the span. This stability specification is utilized as the drift error term (σD) for the PIS (module 4). The 1-year stability specification is converted to a 30-month (section 4.10) drift value per Appendix A of reference 3.1.2 as follows:

$Drift_{Vendor}$: 0.066% (Span)
Vendor Drift Period (VDP): 12-months
Calibration Frequency (CF): 30 months (section 4.10)

Module 4 Drift (σ4D) = $\pm$ $Drift_{Vendor}$ * $(CF / VDP)^{1/2}$

$$\sigma 4D = \pm 0.066\% * (30_{months} / 12_{months})^{1/2} * (Span)$$
$$= \pm 0.104\% * (Span) \quad [2\sigma]$$

Per reference 3.7.1, the PIS has a 250Ω precision resistor (RES4) installed across its input to convert the 4-20 mA instrument signal to 1-5 Vdc. The tolerance of the resistor will be combined with the vendor reference accuracy of the PIS to determine reference accuracy for module 4 (RA4) with SRSS method as follows:

RA_{Vendor}: $\pm$ 0.001 Vdc
RES4: 250Ω $\pm$ 0.1% (2σ per section 2.3.5)
Span: 4 Vdc
RA4: Reference Accuracy Module 4

$$RA4 = \pm [(RA_{Vendor})^2 + (RES4_{TOL} * Span)^2]^{1/2}$$
$$= \pm [(0.001\ Vdc)^2 + (0.1\% * 4\ Vdc)^2]^{1/2}$$
$$= \pm 0.004123\ Vdc \quad [2\sigma]$$

4.5 The following list of calibration test instrument is added per Reference 3.2.1:

The M&TE listed in the table below can be used for measuring and calibrating the pressure transmitters. The M&TE error and evaluation parameters for each device are from Reference 3.2.1.

Pressure Calibration M&TE				
Calibration Instrument	**M&TE Error [1σ]**			**Evaluation Parameters**
Beta 320 (0 to 3000 psig)	±	2.052438	psig	1500 psig, 32 → 122°F
Fluke-700P09 0 to 1500psig Pressure Module w/ Honeywell Loveland 2020	±	0.388104	psig	any reading ≤ 1500 psig, 32 → 122°F
Fluke 700P29 0 to 3000psig Pressure Module w/ Honeywell Loveland 2020	±	1.802776	psig	any reading ≤ 3000 psig, 32 → 122°F

Review of the above pressure calibration M&TE table shows that the worst case M&TE is the Beta 320 (3000 psig), with an error of ±2.052 psig. This error is conservatively used as the MTE error for the pressure reading in calibration of the pressure transmitters.

The M&TE listed in the following table can be used for measuring and calibrating the Rosemount Master Trip Units, Isolators, and Pressure Indicating Switches, A/D converters, and D/A converters.
The MTU's are calibrated by measuring the current from the transmitter into the MTU by measuring the voltage across the input resistor in the MTU (4 - 20 mAdc = 1 - 5 Vdc). Input test jacks for the MTU are provided on the front panel of the MTU for this purpose.

The Moore Isolators are calibrated by inputting the 1-5 Vdc instrument signal into the isolator from the MTU while measuring the voltage across the input resistor on the PIS (4 - 20 mAdc = 1 - 5 Vdc).

The SDC Pressure Indicating Switches are calibrated by inputting the 4-20 mA instrument signal across a 250-ohm input resistor to produce 1 -5 Vdc. The M&TE error and evaluation parameters for each device are from Reference 3.2.1.

The A/D Converters are calibrated by inputting the 4-20 mA instrument signal into the A/D channel and observing the digital output on the Engineering Work Station (EWS) or the Operator Interface Station (OIS).

The D/A Converters are calibrated by controlling a digital signal from the EWS/OIS and measuring the 4-20 mA instrument signal from the D/A output.

Voltage & Current Calibration M&TE			
Manufacturer	**Model**	**Range**	**±Accuracy (CAL) (1σ)**
Fluke	189	5 Vdc	± 0.002365 Vdc (5 Vdc accuracy, 122°F)
Fluke	8845A	10 Vdc (Fast Rate)	± 0.001420 Vdc (5 Vdc reading, 122°F)
Fluke	8860A	20 Vdc	± 0.0011245 Vdc (10 Vdc reading, 122°F)
Fluke	8840A	20 Vdc (Medium Rate)	± 0.001763 Vdc (10Vdc reading, 122°F)
		200 mA (Slow Rate)	± 0.022422 mAdc (20 mAdc reading, 122°F)
Fluke	45	30 mA (Medium Rate)	± 0.020824 mAdc (20 mAdc reading, 122°F)
		100 mA (Slow Rate)	± 0.024021 mAdc (20 mAdc reading, 122°F)
Loveland	2020	30 mA	± 0.012091 mAdc (20 mAdc reading, 122°F)

Review of the above pressure calibration M&TE table shows that the worst case M&TE for measuring voltage is the Fluke 189, with an error of ± 0.002365 Vdc, and the worst case M&TE for measuring current is the Fluke 45, with an error of ± 0.024021 mAdc. These errors are conservatively used as the MTE error for the pressure reading in calibration of the MTU's, PIS's, Isolators, A/D Converters, and D/A Converters.

For calculation purposes, the Fluke 45 current measurement error of ± 0.024021 mAdc is converted to an equivalent voltage error measurement. Therefore:

$$M\&TE_{mAdc\ to\ Vdc} = 0.024021\ mAdc\ (5\ Vdc / 20\ mAdc)$$
$$= 0.006005\ Vdc$$

Loop 1 (Section 7)

4.6 Per section 2.9 and reference 3.6.2 the accuracy specifications for the Rosemount Master Trip Units (MTU) are a combination of reference accuracy, drift, and temperature effect. And, the vendor calibration frequency specification is for 6 months. The 6-month vendor specification is converted to a 30-month (section 4.10) value per Appendix A of reference 3.1.2 as follows:

Vendor Drift Period (VDP): 6-months
Calibration Frequency (CF): 30 months (section 4.10)
Span: 4 Vdc
ΔT_{MTU}: The difference between 120°F, the maximum temperature expected in the environment, and 90°F, the upper bound of the normal operation temperature range for the 710DU.

RA_{Vendor}: $\pm$ [0.13%*(Span) + (0.2%*(Span)/100 °F)*(ΔT_{MTU})] [2σ]
Therefore,

$$RA_{6\text{-months}} = \pm [0.13\%*(Span) + (0.2\%*(Span)/100\ °F)*(\Delta T_{MTU})]$$
$$= \pm [0.0013*(4\ Vdc) + (0.002*(4\ Vdc)/100\ °F)(120\ °F - 90\ °F)]$$
$$= \pm 0.0076\ Vdc$$

Module 2 Reference Accuracy (RA2) = $\pm$ RA_{Vendor} * $(CF / VDP)^{1/2}$
Therefore,

$$RA2 = \pm RA_{Vendor} * (CF / VDP)^{1/2}$$
$$= \pm 0.0076\ Vdc * (30_{months} / 6_{months})^{1/2}$$
$$= \pm 0.016994\ Vdc \quad [2\sigma]$$

4.7 All specifications for the Rosemount transmitters are 3σ except for drift, which is a 2σ value. (Reference 3.6.1 and Reference 3.6.2).

4.8 The Rosemount Model 1153GB9RA transmitters will be calibrated using the M&TE listed in Section 4.5.

4.9 The Rosemount Model 1153GB9RA transmitters will be calibrated for a process range of 0 to 1500 PSIG equal to a 4-20 ma output. Reference 3.7.2.

4.10 The SDC system trip criteria being added to this existing loop, and the new SDC instruments installed in the existing Reactor Wide Range Pressure instrument loops per EC 377728 / 377766 (reference 3.7.1) have a 2-year PM frequency requirement (reference 3.4.1). Therefore, this calculation applies a 2-year calibration frequency requirement with a 25% late factor (30 months) to the instruments affected by loop 1 analyses.

4.11 Loop 1 Element Data

4.11.1 Each instrument channel consists of (References 3.5.5 and 3.7.1):

Pressure transmitter (PT)	PT 2(3)-0263-152A(B)
Master Trip Unit (MTU)	PIS 2(3)-0263-155A(B)
Isolator (ISOL)	PY-2(3)-0263-153A(B1)
Pressure Indicating Switch (PIS)	PIS-2(3)-0263-13C(D)

4.11.2 Pressure Transmitter (Module 1: PT-2(3)-0263-152A(B))

The transmitter has the following uncertainty parameters (from Ref. 3.5.8 and 3.6.1):

Manufacturer:	Rosemount
Model:	1153GB9RA
Input Range:	0-500 / 0-3000 psig
Calibration Input:	0.0 to 1500.0 psig + Head Correction
URL:	3000 PSIG
Output Range:	4.00 – 20.00 mAdc
Accuracy (Includes Linearity, Hysteresis & Repeatability):	±0.25% cal. Span
Temp. Effect:	±(0.75% Upper Range Limit (URL) + 0.5% span) per 100°F ambient temp change
Drift [2σ]:	±0.2% URL (30 mo. Vendor Drift Period (VDP))
Power Supp Effect:	Less than 0.005% output span/volt
Normal Operating Temp.:	40 to 200°F
Humidity Limits:	0 to 100% RH
Radiation Limit:	Tested to $2.2x10^7$ Rads, TID Gamma
Calibration Frequency:	2-years (24 months + 25%), Section 4.10

4.11.3 Master Trip Unit (MTU) (Module 2: PIS 2(3)-0263-155A(B))

The MTU has the following uncertainty parameters (from References 3.5.8 and 3.6.2):

Manufacturer:	Rosemount
Model:	710DU
Input Range:	4.00 – 20.00 mAdc
Output Range:	1.000 – 5.000Vdc
Accuracy (Repeat + Drift):	± [0.13%*(Span) + (0.2%*(Span)/100 °F)* (ΔT_{MTU})]
Calibration Frequency:	2-years (24 months +25%), Section 4.10

4.11.4 Isolator (ISO) (Module 3: PY-2(3)-0263-153A(B1))

The Isolator has the following uncertainty parameters (from References 3.5.8 and 3.6.3):

Manufacturer:	Moore Industries
Model:	Special-FCT/1-5V/4-20mA
Input Range:	1.000 – 5.000 Vdc
Output Range:	4.00 – 20.00 mAdc
Accuracy:	± 0.1% SPAN
Calibration Frequency:	2-years (24 months +25%), Section 4.10

4.11.5 Pressure Indicating Switch (PIS) (Module 4: PIS-2(3)-0263-13C(D))

The PIS has the following uncertainty parameters (from References 3.6.5 and 3.7.1):

Manufacturer:	Moore Industries
Model:	SPA2/HLPRG/2PRG/UAC-DIN
Input Signal Range	Max Span 0 –10 Vdc (programmed for 1-5 Vdc)
Calibrated Process:	Range 0-1500 PSIG + Head Correction
Calibrated Input:	1.000 – 5.000 Vdc
Output:	Bistable
Reference Accuracy:	±1.0 mV (±0.001 Vdc)
Stability (Drift):	±0.066% of maximum span (1 year)
Calibration Frequency:	2-years (24 months +25%), Section 4.10

4.11.6 Location Data (Module 1: PT-2(3)-0263-152A(B))

Location and Operating Conditions: (References 3.3.3, 3.2.4, 3.4.2, 3.7.2)

PT-2(3)-0263-152A	Panel 2202(3)-5
PT-2-0263-152 B	Panel 2202(3)-6
Reactor Bldg Elev.	545'
Temperature Maximum	133 °F (with LOCA in opposite unit)
Temperature Maximum	104 °F (normal operation)
Temperature Minimum	65 °F
Pressure:	14.7 PSIA
Radiation	<1.0 x 10^4 Rads (TID – 40 Years)
Relative Humidity	20 - 90%
Environmental Zone:	27 (-152A) / 24 (-152B) (Reference 3.2.4)

4.11.7 Location Data (Module 2: PIS 2(3)-0263-155A(B) & Module 3: PY-2(3)-0263-153A(B1))

Location Operating Conditions: (References 3.3.3, 3.2.4, 3.4.2, 3.7.2)

PIS-2(3)-0263-155A	Panel 2202(3)-73A
PIS-2(3)-0263-155B	Panel 2202(3)-73B
PY-2(3)-0263-153A	Panel 2202(3)-73A
Turbine Bldg Elev.	538'
Temperature Maximum	120 °F
Temperature Minimum	65 °F
Pressure:	14.7 PSIA
Radiation	<1.0 x 10^4 Rads (TID – 40 Years)
Relative Humidity	20 - 90%
Environmental Zone:	31A

PY-2(3)-0263-153B1	Panel 902(3)-5
MCR Elev.	534'
Temperature Maximum	95 °F
Temperature Minimum	70 °F
Pressure:	14.7 PSIA
Radiation	<1.0 x 10^4 Rads (TID – 40 Years)
Relative Humidity	40 - 70%
Environmental Zone:	30A

4.11.8 Location Data (Module 4: PIS-2(3)-0263-13C(D))

Location Operating Conditions: (References 3.3.3, 3.2.4, 3.4.2, 3.7.2)

PIS-2(3)-0263-13C(D)	Panel 902(3)-5
MCR Elev.	534'
Temperature Maximum	95 °F
Temperature Minimum	70 °F
Pressure:	14.7 PSIA
Radiation	<1.0 x 10^4 Rads (TID – 40 Years)
Relative Humidity	40 - 70%
Environmental Zone:	30A (Reference 3.2.4)

Loop 2 (Section 8)

4.12.0 All specifications for the Rosemount transmitters are 3σ values except for drift, which is a 2σ value. (Reference 3.6.1).

4.12.1 The Rosemount Model 1151GP9E22B2 transmitters will be calibrated using the M&TE listed in Section 4.5.

4.12.2 The Rosemount Model 1151GP9E22B2 transmitters will be calibrated for a process range of 0 to 1200 PSIG equal to a 4-20 ma output. References 3.5.4 and 3.7.2

4.12.3 Per reference 3.7.2, the following process parameters are associated with Instrument Loop 2:

Process Pressure Max:	1200 psig
Process Temp Max:	550°F

4.12.4 The calibration frequency per reference 3.5.7 is 4-years. The new SDC instruments installed in the existing Feedwater Level Control instrument loops per EC 377728 / 377766 (reference 3.7.1) have a 2-year PM frequency requirement (reference 3.4.1). This calculation applies a 2-year calibration frequency requirement with a 25% late factor to the instruments affected by loop 2 analyses. This frequency will be revised to 2-years per reference 3.7.1, EC 377728 / 377766.

4.12.5 Each Loop 2 instrument channel consists of (References 3.3.2):

Pressure transmitter (PT)	PT 2(3)-0647-A(B)
A/D Converter (A/D)	UY-2(3)-0640-2A (FY-2(3)-0640-3A)
D/A Converter (D/A)	UY-2(3)-0640-30A
Pressure Indicating Switch (PIS)	PIS-2(3)-0640-13A(B)

4.12.6 Pressure Transmitters (Module 1: PT-2(3)-0647-A(B))

The pressure transmitter has the following uncertainty parameters (references 3.5.7 and 3.6.1, section 4.18):

Manufacturer:	Rosemount
Model:	1151GP9E22B2
Reference Accuracy (RA):	±0.25% SPAN
Drift [2σ]:	±0.25% URL/6 months
Output Signal:	4.00-20.00 mA
Calibration Input:	0.0 to 1200.0 psig + Head Correction
Temperature Effect:	± [0.5%URL + 0.5%SPAN]/100°F
Temperature Limits:	-20 to 200 °F
Power Supply Effect:	<0.005% SPAN per volt
Vibration Effect:	0.05% URL/g to 200 Hz
Humidity Limits:	0-100% RH
URL:	3000 psig
Calibration Frequency:	2-years (24 months +25%), Section 4.12.4

4.12.7 Analog-to-Digital (A/D) Converter (Module 2: UY-2(3)-0640-2A (FY-2(3)-0640-3A))

Per reference 3.6.4, the A/D Converter has the following uncertainty parameters:

Manufacturer:	Bailey
Model:	Infi 90 IMCIS02 (IMCIS22)
A/D Conversion:	12 bits
Input Signal:	4.00-20.00 mA
Output:	Digital signal displayed as 0 to 1200 psig at the FWLC Engineering Work Station (EWS)
Accuracy:	±0.10% of full scale range (FSR)
Linearity:	±0.03% of full scale range (FSR)
Repeatability:	±0.03% of full scale range (FSR)
Deadband:	±0.03% of full scale range (FSR)
Temperature Effect:	±0.002% of FSR/degrees C
A/D Input:	@ 25°C (77°F), Standard Conditions
Drift:	There are no drift effects because once a minute the multi-function processor corrects the measured values for drift and temperature variations.
Temperature Limits:	0 to 70°C (32 to 158°F)
Relative Humidity Limits:	0% to 95% up to 55°C (131°F) non-condensing 0% to 45% up to 70°C (158°F) non-condensing
Calibration Frequency:	2-years (24 months +25%), Section 4.12.4

4.12.8 Digital-to-Analog Converter (Module 3: UY-2(3)-0640-30A)

Per reference 3.6.4, the D/A Converter has the following uncertainty parameters:

Manufacturer:	Bailey
Model:	IMASO01 (IMASO11)
D/A Conversion:	10 bits
Input:	Digital signal from FWLC Digital Control System, 0 to 1200 psig signal controlled from the EWS
Output Signal:	4.00-20.00 mA
Accuracy:	≤0.15% (voltage mode); ≤0.25% (current mode)
Drift:	There are no drift effects because once a minute the multi-function processor corrects the measured values for drift and temperature variations.
Temperature Limits:	0 to 70°C (32 to 158°F)
Relative Humidity Limits:	0% to 95% up to 55°C (131°F) non-condensing 0% to 45% up to 70°C (158°F) non-condensing
Calibration Frequency:	2-years (24 months +25%), Section 4.12.4

4.12.9 Pressure Indicating Switch (Module 4: PIS-2(3)-0640-13A(B))

The PIS has the following uncertainty parameters (from References 3.6.5 and 3.7.1):

Manufacturer:	Moore Industries
Model:	SPA2/HLPRG/2PRG/UAC-DIN
Input Signal Range:	Max Span 0 –10Vdc (programmed for 1-5 Vdc)
Calibrated Process:	Range 0.0-1200.0 PSIG + Head Correction
Calibrated Input:	1.000 – 5.000 Vdc
Output:	Bistable
Reference Accuracy:	±1.0 mV (±0.001 Vdc)
Stability (Drift):	±0.066% of maximum span (1 year)
Calibration Frequency:	2-years (24 months +25%), Section 4.12.4

4.12.10 Location Data: Pressure Transmitter (Module 1: PT-2(3)-0647-A(B))

Location and Normal Operating Conditions: (References 3.3.3, 3.2.4, 3.4.2, 3.7.2)

PT-2(3)-0647-A	Panel 2202(3)-5
PT-2(3)-0647-B	Panel 2202(3)-6
Reactor Bldg. Elev.	545'
EQ Zone	27 (-0647A) / 24 (-0647B)
Temperature Maximum	104 °F maximum (Reference 3.4.2) 133 °F maximum (post-LOCA in opposite unit, per Reference 3.2.4)
Temperature Minimum	65 °F minimum (Reference 3.4.2)
Pressure	14.7 psia
Humidity	20-90% RH
Radiation	<1.0X10^4 RADS (TID –40 years)

4.12.11 Location Data: A/D and D/A Converter (Module 2: UY-2(3)-0640-2A (FY-2(3)-0640-3A) & Module 3:UY-2(3)-0640-30A))

Location and Normal Operating Conditions: (References 3.3.3, 3.2.4, 3.4.2, 3.7.2)

UY-2(3)-0640-2A	Panel 902(3)-18
FY-2(3)-0640-3A	Panel 902(3)-18
UY-2(3)-0640-30A	Panel 902(3)-18
MCR Elev.	534'
Temperature Maximum	95 °F
Temperature Minimum	70 °F
Pressure	14.7 PSIA
Radiation	<1.0 x 10^4 Rads (TID – 40 Years)
Relative Humidity	40 - 70%
Environmental Zone	30A (Reference 3.2.4)

4.12.12 Location Data – PIS 2(3)-0640-13A(B) (Module 4)

Location and Normal Operating Conditions: (References 3.3.3, 3.2.4, 3.4.2, 3.7.1)

PIS-2(3)-0263-13A(B)	Panel 902(3)-5
MCR Elev.	534'
Temperature Maximum	95 °F
Temperature Minimum	70 °F
Pressure	14.7 PSIA
Radiation	<1.0 x 10^4 Rads (TID – 40 Years)
Relative Humidity	40 - 70%
Environmental Zone	30A (Reference 3.2.4)

4.12.13 Reference 3.2.8 states that the bounding 30 Month drift tolerance interval (DTIc) for the Rosemount 1151GP9 transmitter (same manufacturer and model number installed in instrument loop 2 of this calculation) has been determined to be ± 0.454% of span. The rigorous drift analysis performed on the Rosemount 1151GP9 transmitters were performed on a different group of transmitters than the transmitters analyzed in this loop, PT-2(3)-0647A(B).

When utilized, DTIc fully encompasses the following error sources: (RA) Reference Accuracy (including Repeatability, Linearity or Conformity, Hysteresis, and Deadband), (CAL) Calibration Error (including M&TE and Cal Std Error), (ST) Setting Tolerance, and (D) Drift.

Per section 4.12.6 the vendor drift specification is ±0.25% URL/6 months.

The DTIc value provided in reference 3.2.8 will not be directly applied to the transmitter error calculations, but it does provide a high degree of confidence that the model 1151GP9 transmitters perform better than the vendor specifications. Therefore, the DTIc value of ± 0.454% Span / 30 months, rounded to ± 0.5% Span / 30 months for conservatism, will be used for the Drift term (D1) of PT 2(3)-0647A(B), Loop 2 Module 1.

The random value is time independent and is conservatively treated as normally distributed and considered to be a 2σ value.

4.13 This calculation determines the SDC Isolation setpoint, which is an increasing pressure trip. The SDC permissive setpoint (a decreasing pressure interlock) is determined per reference 3.7.1, and is based on the final results of this calculation. Reference 3.7.1 specifies the SDC permissive approximately 1 psig lower than the SDC Isolation Setpoint.

4.14 Appendix A of reference 3.1.2 states that "For new instrument channels, an additional margin of 0.5% of the instrument measurement span, in instrument units, shall be included in order to account for unanticipated or unknown loop component uncertainties. This margin may be deleted after sufficient calibration history exists to justify the instrument channel accuracy based on all other errors and uncertainties."

The instrument loops analyzed by this calculation are existing long-established instrument loops with solid historical performance per (references 3.5.7 and 3.5.8). The only physical change to the existing instrument loops is the installation of Moore Bistable trip units (reference 3.6.5) per EC 377728 / 377766 (reference 3.7.1). The addition of the Bistables will not impact the performance of the existing instrument loops.

Sufficient calibration history exists to justify the instrument channel accuracy based on all other errors and uncertainties without adding any additional uncertainty. Therefore, an additional margin of 0.5% of the instrument measurement span will not be included in the computations of this calculation.

5.0 ASSUMPTIONS

5.1 It is assumed that the Measuring and Test Equipment (M&TE) listed in Section 4.5 is calibrated to the required Manufacturer's specifications and within the Manufacturer's required environmental conditions. Use of M&TE less accurate than that listed in Section 4.5 will require evaluation of the effect upon the calculation results.

5.2 It is assumed that the calibration standard of the equipment utilized is more accurate than the M&TE equipment by a ratio of at least 4:1 such that the calibration standard errors can be considered negligible with respect to the M&TE specifications per Section 2.4.1. This is considered a reasonable assumption since M&TE equipment is typically certified to its required accuracy under lab conditions. This requires and allows for the use of more accurate calibration standard equipment.

5.3 The temperature specifications provided in Section 4.5 are assumed to be full scale. This is consistent with the other specifications, which are of full scale.

5.4 Instrument sensing lines are assumed to be cold and dead-ended. As such, process fluid temperature in contact with the instrument is assumed to be ambient temperature.

5.5 The Process error, σ_{PE} can be thought of as the error in the head correction due to elevation measurement errors and water leg density estimation errors. By engineering judgment, $\sigma_{PE} \leq \pm 6$ "wc, which equals an uncertainty of ≈ 0.2 psi [2σ]. Since the spans of the loops analyzed in this calculation are 1500 psi and 1200 psig, σ_{PE} is considered to be negligible. As this is a random variable, it is combined with other terms by square root sum of the squares. Thus, by engineering judgment, $\sigma_{PE} \approx 0$.

5.6 The instrument loops are to be calibrated as follows using the existing procedures for guidance (References 3.5.4 and 3.5.5):

1) Loop (string) calibration is to be performed by applying a pressure to the input of the Transmitter (Loops 1 & 2, Module 1) while monitoring for the trip actuation at the output of the Bistable Pressure Indicating Switch (Loops 1 & 2 Module 4). Error terms for Setting Tolerance (ST) and Calibration (CAL) in each module are computed for string calibrations and individual calibrations are also calculated. The loop (string) calibration tolerance shall be 5 psig.

2) Calibration of the individual modules in the instrument loops is to be performed by applying the calibration input values while monitoring the output.

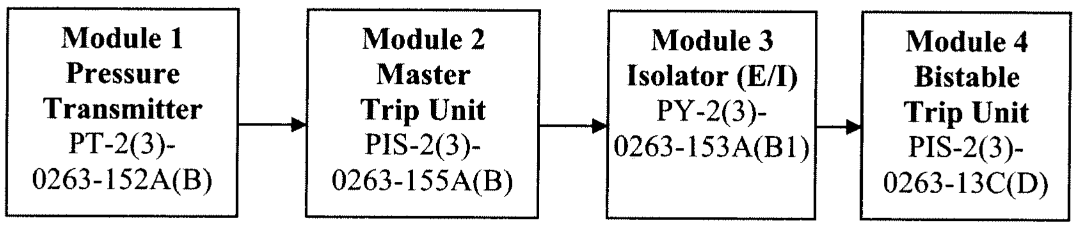
6.0 INSTRUMENT CHANNEL CONFIGURATION

The pressure instrument loops are described below.

6.1 Instrument Loop 1:
This loop evaluates the error associated with the following pressure transmitter instrument loops:

- PT-2(3)-0263-152A: U2(3) Reactor Wide Range Pressure
- PT-2(3)-0263-152B: U2(3) Reactor Wide Range Pressure

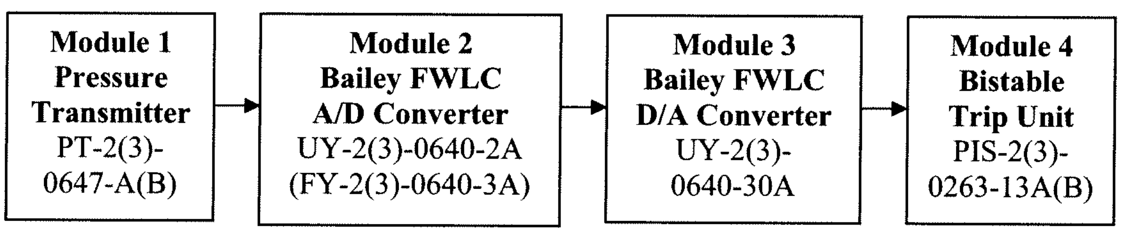
Per references 3.7.1 and 3.3.3, the following diagram shows the subject instrument loop based on the schematics:



6.2 Instrument Loop 2:
This loop evaluates the error associated with the following pressure transmitter loops:

- PT-2(3)-0647-A: U2(3) Reactor Pressure Feedwater Control
- PT-2(3)-0647-B: U2(3) Reactor Pressure Feedwater Control

Per references 3.7.1 and 3.3.2, the following diagram shows the subject instrument loop based on the schematics:



7.0 Loop 1 Calculations (Reactor Wide Range Pressure)

This Section evaluates the error associated with the following instruments associated with the Unit 2 Reactor Wide Range Pressure Loop:

2(3)-0263-152A	2(3)-0263-152B	Pressure Transmitters (PT)
2(3)-0263-155A	2(3)-0263-155B	Pressure Indicating Switches (Referred to as Master Trip Unit or MTU)
2(3)-0263-153A	2(3)-0263-153B1	Signal Isolators (ISO)
2(3)-0263-13C	2(3)-0263-13D	Bistables (Pressure Indicating Switch)

The final element in this loop (module 4) has a 1 to 5 Vdc input (4 Vdc span). All error terms will be converted to Vdc in relation to the final element span of 4 Vdc.

7.1 Module 1 Errors - Transmitter

7.1.1 Transmitter Random Errors ($\sigma 1$)

7.1.2 Reference Accuracy (σ_{RA1})

From reference 3.6.1, the reference accuracy, which represents a 3σ confidence level, is ±0.25% of calibrated span (includes reference accuracy, repeatability, linearity, and hysteresis). From reference 3.5.5, the calibrated input span is 0 to 1500 psig (14 to 1514 psig including 14 psi head correction). Therefore,

σ_{RA1} = ± 0.25% * (1500 psi / 100% span)
= ±3.75 psig [3σ]
= ±3.75 psig / 3 = 1.25 psig [1σ]

The error propagation to the transmitter output is calculated in accordance with Reference 3.1.2 (Appendix B) methodology. From reference 3.5.5, the calibrated input span is 0 to 1500 psig (14 to 1514 psig including 14 psi head correction) and the output span is 4 to 20 mA, which is converted for a 4 Vdc Span. Therefore,

$\sigma_{RA1\text{-}PROP}$ = ±3.75 psig (4 Vdc / 1500 psig)
= ±0.01 Vdc [3σ]
= ±0.01 Vdc / 3 [1σ]
= ±0.003333 Vdc [1σ]

7.1.3 Setting Tolerance (σ_{ST1})

The instrument loop is string calibrated as defined in Section 5.6.

$\sigma_{ST1\text{-}STR}$ = ± 5 psig [3σ]
= ±5 psig / 3 = 1.666667 psig [1σ]
= ±5.0 psig (16 mA / 1500 psig) [3σ]
= ±0.053333 mA [3σ]
= ±0.053333 mA (4 Vdc / 16 mA)) [3σ]
= ±0.013333 Vdc / 3 [1σ]
= ±0.004444 Vdc [1σ]

The individual instrument calibration setting tolerance is as defined in Section 5.6 and Section 4.11.2.

From reference 3.5.5, the calibration setting tolerance is ± 0.04 mA. In accordance with reference 3.1.2 (Appendix A), the calibration setting tolerance for pre-existing instrument channels that have established calibration procedures are incorporated at a 3σ confidence level. Therefore,

$\sigma_{ST1\text{-}IND} = \pm 0.04$ mA [3σ]
$= \pm 0.04$ mA (4 Vdc / 16 mA)) [3σ]
$= \pm 0.01$ Vdc / 3 [1σ]
$= \pm 0.003333$ Vdc [1σ]

7.1.4 Measurement & Test Equipment Error (CAL1)

The transmitter string calibration is performed by applying a pressure source of known accuracy to the input of the pressure transmitter while checking the trip actuation setpoint of Module 4 (Bistable) of this instrument loop. Calibration error consists of the inaccuracy of the pressure test equipment used to measure the transmitter input pressure during calibration. Per Section 2.4.1 the calibration standard error (STD) is negligible. Therefore,

From section 4.5 (conservatively using the M&TE with the largest error):

MTE_{IN} (Beta 320) $= \pm 2.052438$ psig. [1σ]

The error propagation to the transmitter output is derived as,

$MTE_{IN\text{-}PROP} = \pm 2.052438$ psig (4 Vdc / 1500 psig)
$= \pm 0.005473$ Vdc [1σ]

Therefore, the total transmitter string calibration error is given as,

$CAL1_{\text{-}STR} = [(MTE_{IN\text{-}PROP})^2 + (STD)^2]^{1/2}$
$= \pm [(0.005473\text{ Vdc})^2 + (0)^2]^{1/2}$
$= \pm 0.005473$ Vdc [1σ]

The individual instrument is calibrated as defined in Section 5.6.
From above,

$MTE_{IN} = \pm 0.005473$ Vdc [1σ]

From section 4.5 (conservatively using the M&TE with the largest error):

MTE_{OUT} (Fluke 189) $= \pm 0.002365$ Vdc [1σ]

Therefore, Calibration Error ($CAL1_{IND}$) is,

$CAL1_{IND} = \pm [MTE_{IN}^2 + MTE_{OUT}^2 + STD]^{1/2}$
$= \pm [(0.005473\text{ Vdc})^2 + (0.002365\text{ vdc})^2 + (0)^2]^{1/2}$
$= \pm 0.005962$ Vdc [1σ]

7.1.5 Drift (σ_{DI})

From section 4.11.2, transmitter drift, which represents a 2σ confidence level, is ±0.2% of Upper Range Limit (URL) for 30 months. From Section 4.11.2, the URL is 3000 psig.

For Rosemount transmitters, drift is defined as a "point drift specification" which is defined as an error term that is not a function of time. As such, when evaluating drift for Rosemount transmitters, the specified values will be used in its entirety and will not be reduced for lesser calibration intervals. Therefore,

σ_{DI} = ± 0.2% (3000 psig) = ±6.0 psig [2σ]

The error propagation to the transmitter output is calculated as derived as,

$\sigma_{DI\text{-}PROP}$ = ± 6.0 psig (4 Vdc / 1500 psig) = ±0.016 Vdc [2σ]
= ± 0.016 Vdc / 2 [1σ]
= ±0.008 Vdc [1σ]

7.1.6 Temperature Error (eT1)

From section 4.11.2 and reference 3.6.1, the transmitter temperature error, which is considered to be a random error represented by a 3σ confidence level, is ± (0.75% of Upper Range Limit + 0.5% span) per 100°F (55.6°C) ambient temperature change, and the URL of 3000 psig. From reference 3.5.5, the calibrated input span is 0 to 1500 psig (14 to 1514 psig including 14 psi head correction). From reference 3.2.4, the ambient temperature range at the transmitter varies from 65°F to 104°F (normal) and 133°F (LOCA on opposite Unit). Therefore,

eT1 = ± {[(0.75% * 3000 psig) + (0.5% * 1500 psig)]/100°F} {133°F - 65°F}
= ±20.4 psig [3σ]

The error propagation to the transmitter output is derived as,

$eT1_{PROP}$ = ± 20.4 psig. (4 Vdc / 1500 psig) = ±0.0544 Vdc [3σ]
= ± 0.0544 Vdc / 3 [1σ]
= ±0.018133 Vdc [1σ]

7.1.7 Radiation Error (eR1)

From section 4.11.2 and reference 3.6.1, the transmitter radiation error, which is considered to be a random error represented by a 2σ confidence level, is ± 8.0 of Upper Range Limit during and after exposure to 2.2 x 10^7 rads, total integrated dose. Per Section 2.3.1, radiation induced errors during normal operating conditions are considered to be included within instrument drift related errors. As such, any radiation effects associated with normal operating conditions can be accounted for in the periodic calibration process and are considered negligible with respect to other error terms. Therefore,

eR1 = 0

7.1.8 Seismic Error (eS1)

Per Section 2.3.4,

$$eS1 = 0$$

7.1.9 Static Pressure Error (eSP1)

Gauge pressure transmitters are not affected by static pressure. Therefore,

$$eSP1 = 0$$

7.1.10 Over-Pressure Error (eOP1)

From reference 3.6.1, transmitter over-pressure effects, which are considered to be a random error represented by a 3σ confidence level, is ± 0.5% of Upper Range Limit maximum shift after 4000 psi overpressure. From references 3.5.5 and 3.7.2, the maximum system operating pressure is 1500 psig. As such, the maximum system operating pressure is less than that required to produce transmitter error. Therefore,

$$eOP1 = 0$$

7.1.11 Power Supply Effect (eV1)

In accordance with Reference 3.1.2 (Appendix I), it is expected that regulated instrument power supplies have been designed to function within required voltage limits. The variations of voltage and frequency are expected to be small and, as such, these errors are considered to be negligible with respect to other error terms. Therefore,

$$eV1 = 0$$

7.1.12 Random Input Errors ($\sigma 1_{IN}$)

The transmitter is the first module in the loop. As such, there are no associated random input errors. Therefore,

$$\sigma 1_{IN} = 0$$

7.1.13 Total Random Error ($\sigma 1$)

The total random error associated with the transmitter is determined in accordance with Section 2.0 methodology, using the values calculated in Sections 7.1.2 through 7.1.12.

$$\sigma 1 = \pm[(\sigma_{RA1\text{-}PROP})^2 + (\sigma_{ST1})^2 + (CAL1)^2 + (\sigma_{D1\text{ - }PROP})^2 + (eT1_{PROP})^2 + (eR1)^2 + (eS1)^2 + (eSP1)^2 + (eOP1)^2 + (eV1)^2 + (\sigma 1_{IN})^2]^{1/2} \text{ Vdc}$$

$$= \pm[(0.003333)^2 + (\pm 0.004444)^2 + (0.005473)^2 + (0.008)^2 + (0.018133)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2]^{1/2} \text{ Vdc}$$

$$= \pm 0.021300 \text{ Vdc} \qquad [1\sigma]$$

7.1.14 Transmitter Non-Random Errors

7.1.15 Humidity Error (eH1)

There are no specific humidity effects described in the vendor's specification for the transmitter. From Section 4.11.2, the vendor's specified operating humidity range is 0 to 100% RH. From Section 4.11.6, the humidity limits at the transmitter location varies from 20 to 90% RH. As such, the humidity limits are bounded by the vendor operating limits and, in accordance with Reference 3.1.2 (Appendix I), are considered included in the reference accuracy. Therefore,

eH1 = 0

7.1.16 Process Measurement Error (e1p)

There are no known significant process errors for this device. Per Section 4.2, the effect of the RVLIS backfill modification is approximately +0.5 "wc.
Per reference 3.7.5, 1 psi = 27.7276 "wc. Therefore,

e1p = + 0.5 "wc * (1 psi / 27.7276 "wc)
= + 0.018033 psi

$e1p_{-PROP}$ = + 0.018033 psig (4 Vdc / 1500 psig)
= + 0.000048 Vdc

7.1.17 Non-Random Input ($e1_{IN}$)

The transmitter is the first module in the loop. As such, there are no associated non-random input errors. Therefore,

$e1_{IN}$ = 0

7.1.18 Total Non-Random Errors (Σe1)

The total non-random error associated with the transmitter is determined in accordance with Section 2.0 methodology, using the values calculated in Sections 7.1.15 through 7.1.17.

$\Sigma e1 = \pm [eH1 + e1p + e1_{IN}]$
$= \pm [0 + 0.000048 \text{ Vdc} + 0]$
$= + 0.000048 \text{ Vdc}$

7.2 Master Trip Unit Loop 1 (Module 2)

7.2.1 Master Trip Unit Random Errors ($\sigma 2$)

7.2.2 Reference Accuracy (RA2)

Per section 4.6, the MTU reference accuracy is:

RA2	$= \pm$ 0.016994 Vdc	[2σ]
	$= \pm$ 0.016994 Vdc / 2	[1σ]
	$= \pm$ 0.008497 Vdc	[1σ]

7.2.3 Setting Tolerance (ST2)

The instrument loop is string calibrated as defined in Section 5.6. Therefore,

$ST2_{-STR} = 0$

The individual instrument calibration setting tolerance is as defined in Section 5.6 and Section 4.11.3.
In accordance with reference 3.1.2 (Appendix A), the calibration setting tolerance for pre-existing instrument channels that have established calibration procedures are incorporated at a 3σ confidence level. Therefore,

$\sigma_{ST2\text{-}IND}$	$= \pm$ 0.02 Vdc	[3σ]
	$= \pm$ 0.02 Vdc / 3	[1σ]
	$= \pm$ 0.006667 Vdc	[1σ]

7.2.4 Calibration Error (CAL2)

The instrument loop is string calibrated as defined in Section 5.6. Therefore,

$CAL2_{-STR} = 0$

The MTU is calibrated with the Rosemount Model 710DU calibration unit. The calibration unit provides an adjustable output current to the input of the MTU for use in MTU trip setpoint verification and/or adjustment. The calibration current is displayed on the trip/calibration current indicator located on the front panel of the calibration unit Readout Assembly.

Rosemount Inc. states that errors associated with the calibration unit are included in the repeatability specification for the MTU. However, use of the calibration unit / Readout Assembly, does introduce some error into the calibration. The calibration error for the MTU calibration via the calibration unit / readout assembly is composed of the SRSS of the readout assembly digital display resolution and the ±0.01 mA [3σ] calibration unit current tolerance. Per Reference 3.6.2, the readout assembly digital resolution is ±0.01 mA [1σ]. Therefore,

$CAL2_{-IND} = \pm [(0.01\ mA / 3)^2 + (0.01\ mA)^2)]^{1/2}$

$= \pm 0.010541$ mA [1σ]

The error propagation to the MTU output is calculated in accordance with Reference 3.1.2 (Appendix B) methodology. From Section 4.11.3, the calibrated input span is 4 to 20 mA and the calibrated output span is 4 Vdc (1 to 5 Vdc). Therefore,

$CAL2_{PROP\text{-}IND}$ = ± 0.010541 mA (4 Vdc / 16 mA) [1σ]
= ±0.002635 Vdc [1σ]

7.2.5 Drift (D2)

From per section 4.6, the drift error associated with the MTU is included in the reference accuracy error determination in Section 7.2.2. So, no separate drift error term is applicable. Therefore,

D2 = 0

7.2.6 Random Input Errors ($\sigma2_{IN}$)

The random error present at the input to the MTU is due to the transmitter and was calculated in Section 7.1.13. Therefore,

$\sigma2_{IN}$ = σ1 = ± 0.021300 Vdc [1σ]

7.2.7 Total Random Error (σ2)

The total random error associated with the MTU is determined in accordance with Section 2 methodology, using the values calculated in Sections 7.2.2 through 7.2.6.

$$\sigma2 = \pm[(RA2)^2 + (ST2)^2 + (CAL2)^2 + (D2)^2 + (\sigma2_{IN})^2]^{1/2}$$
$$= \pm[(0.008497)^2 + (0)^2 + (0)^2 + (0)^2 + (0.021300)^2]^{1/2} \text{ Vdc}$$
$$= \pm 0.022932 \text{ Vdc} \quad [1\sigma]$$

7.2.8 Non-Random Errors (Σe2)

7.2.9 Temperature Error (e2T)

From section 4.6, the temperature effect of the MTU is included in the repeatability error determination. Therefore:

e2T = 0

7.2.10 Radiation Error (e2R)

From Section 4.11.7, the radiation level within the MTU environment during normal operating conditions is < 1 x 10^4 RADS TID. From Reference 3.6.2, the accuracy of the MTU will remain within its stated repeatability within radiation levels ≤ 1 x 10^5 RADS TID. Therefore, radiation has no significant effect.

e2R = 0

7.2.11 Seismic Error (e2S)

Per section 2.3.4,

e2S = 0

7.2.12 Static Pressure Error (e2SP)

The MTU is not directly in contact with the process and is therefore not susceptible to errors induced as a result of process variations, for either normal or accident conditions. Therefore:

e2SP = 0

7.2.13 Power Supply Error (e2V)

There are no power supply errors described in the vendor's specifications for this device. Per Reference 3.6.2, power supply effects associated with the MTUs are considered to be included in the instrument accuracy error determination. Therefore:

e2V = 0

7.2.14 Humidity Error (e2H)

Per and Reference 3.6.2, this device is bounded by the vendors operational limits. Therefore:

e2H = 0

7.2.15 Ambient Pressure Error (e2P)

The MTU is an electrical device and as such is not affected by ambient pressure changes. Therefore:

e2P = 0

7.2.16 Process Error (e2p)

The MTU is not directly in contact with the process and is, therefore, not susceptible to errors induced by process variations as noted below:

e2p = 0

7.2.17 Non-Random Input Error (e2in)

The non-random error present at the input to the MTU is due to the transmitter and was calculated in Section 7.1.18.

e2in = Σe1 = + 0.000048 Vdc

7.2.18 Calculation of Total Non-Random Error (Σe2)

The total non-random error associated with the MTU is determined in accordance with Section 2.0 methodology, using the values calculated in Sections 7.2.9 through 7.2.17

Σe2 = e2T + e2R + e2S + e2SP + e2V + e2H + e2P + e2p + e2in
= 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0.000048 Vdc
= + 0.000048 Vdc

7.3 Isolator Loop 1 (Module 3)

The Moore Isolator (ISO) receives a voltage input from the MTU, which it converts to a current output. For calculation consistency, all error terms will be converted to Vdc.

7.3.1 Isolator Random Errors ($\sigma3$)

7.3.2 Reference Accuracy (RA3)

The ISO RA is determined by direct application of the vendor's specifications listed in Section 4.11.4

$$
\begin{aligned}
RA3 &= \pm 0.1\% * (Span) \\
&= \pm 0.1\% * (16\ mA) \quad = 0.016mA && [2\sigma] \\
&= \pm 0.1\% * (4\ Vdc) && [2\sigma] \\
&= \pm 0.004\ Vdc && [2\sigma] \\
&= \pm 0.002\ Vdc && [1\sigma]
\end{aligned}
$$

7.3.3 Setting Tolerance (ST3)

The instrument loop is string calibrated as defined in Section 5.6. Therefore,

$$ST3_{STR} = 0$$

The individual instrument calibration setting tolerance is as defined in Section 5.6 and reference 3.5.5.

$$
\begin{aligned}
ST3_{IND} &= \pm 0.05\ mA && [3\sigma] \\
&= \pm 0.0125\ Vdc && [3\sigma] \\
&= \pm 0.0125\ Vdc / 3 && [1\sigma] \\
&= \pm 0.004167\ Vdc && [1\sigma]
\end{aligned}
$$

7.3.4 Calibration Error (CAL3)

Because of the full string calibration, there are no calibration error contributions from the signal isolator for the string calibration. Therefore,

$$CAL3_{STR} = 0$$

The individual calibration error ($CAL3_{IND}$) is determined by applying an input voltage signal of known accuracy while noting Vdc with a digital multimeter (DMM) and measuring the output current (mAdc converted to Vdc error terms per Section 4.5) with another DMM. Therefore, calibration error for the isolator consists of the MTE_{IN} and MTE_{OUT} utilizing M&TE per Section 4.5. Per Section 2.4.1 the calibration standard error (STD) is negligible. Therefore:

$$
\begin{aligned}
CAL3_{IND} &= \pm (MTE_{IN}^2 + MTE_{OUT}^2 + STD^2)^{1/2} \\
&= \pm [(0.002365\ Vdc)^2 + (0.006005\ Vdc)^2\ (0)^2]^{1/2} && [1\sigma] \\
&= \pm 0.006454\ Vdc && [1\sigma]
\end{aligned}
$$

7.3.5 Drift Error (σ3D)

There are no vendor specifications relating to drift. Therefore, per section 2.6 and reference 3.1.2,

$\sigma 3D$ = 0.5% span
= 0.5% * 4 Vdc = 0.02 Vdc [2σ]
= 0.01 Vdc [1σ]

7.3.6 Random Input Errors (σ3in)

The random error present at the input to the Isolator is the random error present at the MTU output, which was calculated in Section 7.2.7.

$\sigma 3in = \sigma 2 = 0.022932$ Vdc [1σ]

7.3.7 Calculation of Total Random Error (σ3n)

The total random error associated with the Isolator is the SRSS of the values in Sections 7.3.2 to 7.3.6.

$\sigma 3n = \pm ((RA3)^2 + (ST3)^2 + (CAL3)^2 + (\sigma 3D)^2 + (\sigma 3in)^2)^{1/2}$ [1σ]
$= \pm ((0.002 \text{ Vdc})^2 + (0)^2 + (0)^2 + (0.01)^2 + (0.022932)^2)^{1/2}$ [1σ]
$= \pm 0.025098$ Vdc [1σ]

7.3.8 Isolator Non-Random Errors (Σe3)

7.3.9 Temperature Error (e3T)

There is no vendor provided temperature affect. Therefore,

e3T = 0

7.3.10 Radiation Error (e3R)

From Section 4.11.7, the radiation level within the ISO environment during normal operating conditions is < 1 x 10^4 RADS TID. Reference 3.6.3 does not provide any radiation error effects. Therefore,

e3R = 0

7.3.11 Seismic Error (e3S)

Per section 2.3.4,

e3S = 0

7.3.12 Static Pressure Error (e3SP)

The Isolator is not directly in contact with the process and is therefore not susceptible to errors induced as a result of process variations, for either normal or accident conditions. Therefore:

e3SP = 0

7.3.13 Power Supply Error (e3V)

In accordance with Reference 3.1.2 (Appendix I), it is expected that regulated instrument power supplies have been designed to function within required voltage limits. The variations of voltage and frequency are expected to be small and, as such, these errors are considered to be negligible with respect to other error terms. Therefore,

e3V = 0

7.3.14 Humidity Error (e3H)

Per Design Input 4.11.7 and reference 3.6.3, this device is bounded by the vendor's operational limits. Therefore:

e3H = 0

7.3.15 Ambient Pressure Error (e3P)

The ISO is an electrical device and as such is not affected by ambient pressure changes. Therefore:

e3P = 0

7.3.16 Process Error (e3p)

The ISO is not directly in contact with the process and is, therefore, not susceptible to errors induced by process variations. Therefore:

e3p = 0

7.3.17 Non-Random Input Error (e3in)

The non-random error present at the input to the Isolator during normal operating conditions is due to the MTU, Σe2, and was calculated in Section 7.2.18.

e3in = Σe2 = + 0.000048 Vdc

7.3.18 Calculation of Total Non-Random Error (Σe3)

The total non-random error for the Isolator is the sum of the errors in Sections 7.3.9 through 7.3.17.

Non-Random Error

Σe3 = e3T + e3R + e3S + e3SP + e3V + e3H + e3P + e3p + e3in
= 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0.000048 Vdc
= + 0.000048 Vdc

7.4 PIS (BISTABLE) Loop 1 (Module 4)

The Moore Pressure Indicating Switch (PIS) receives its input from the Isolator.

7.4.1 PIS Random Errors ($\sigma 4$)

7.4.2 Reference Accuracy (RA4)

The PIS reference accuracy is determined per section 4.4. Therefore,

RA4	= ± 0.004123 Vdc	[2σ]
	= ± 0.004123 Vdc / 2	[1σ]
	= ± 0.002062 Vdc	[1σ]

7.4.3 Setting Tolerance (ST4)

The instrument loop is string calibrated as defined in Section 5.6. Therefore,

$ST4_{STR} = 0$

The individual instrument calibration setting tolerance is as defined in Section 5.6. Per Section 2.11 and Section 4.11.5:

$ST4_{IND}$	= 2 * RA_{VENDOR}		
	= ± 2 * 0.001 Vdc	= ± 0.002 Vdc	[3σ]
	= ± 0.002 Vdc (1500 psig / 4 Vdc)	= ± 0.75 psig	[3σ]
	= ± 0.002 Vdc / 3		[1σ]
	= ± 0.000667 Vdc		[1σ]

7.4.4 Calibration Error (CAL4)

Because of the full string calibration as described in Section 5.6, there are no string calibration error contributions from the Bistable. Therefore,

$CAL4_{STR} = 0$

The Bistable is individually calibrated by applying a voltage signal input while noting Vdc with a digital multimeter (DMM) at which the trip actuation occurs. Therefore, calibration error for the Bistable consists of only the MTE_{IN} from Section 4.5. Per Section 2.4.1 the calibration standard error (STD) is negligible. Therefore,

$$CAL4_{IND} = \pm(MTE_{IN}^2 + STD^2)^{1/2}$$
$$= \pm[(0.002365 \text{ Vdc})^2 + (0)^2]^{1/2}$$
$$= \pm 0.002365 \text{ Vdc} \quad [1\sigma]$$

7.4.5 Drift Error ($\sigma 4D$)

From section 4.4,

σ4D	= ± 0.104% * (Span)	[2σ]
	= ± 0.104% * 4 Vdc	[2σ]
	= ± 0.004160 Vdc	[2σ]
	= ± 0.002080 Vdc	[1σ]

7.4.6 Random Input Error ($\sigma 4in$)

The random error present at the input to the PIS is the random error present at the ISO output, which was calculated in Section 7.3.7. Therefore,

$\sigma 4in$ = ± 0.025098 Vdc [1σ]

7.4.7 Total Random Errors – Module 4 ($\sigma 4$)

The total random error associated with the Pressure Indicating Switch is the SRSS of the values in Sections 7.4.2 to 7.4.6.
Therefore, the Shutdown Cooling trip function total random errors:

$$\sigma 4_{TRIP} = \pm [(RA4_{1\sigma})^2 + (ST4_{STR})^2 + (CAL4_{STR})^2 + (e4D)^2 + (\sigma 4in)^2]^{1/2}$$
$$= \pm [(\pm 0.002062)^2 + (0)^2 + (0)^2 + (0.002080)^2 + (0.025098)^2]^{1/2}$$
$$= \pm 0.025268 \text{ Vdc} \quad [1\sigma]$$

7.4.8 PIS Non-Random Errors ($\Sigma e4$)

7.4.9 Temperature Error (e4T)

There is no vendor provided temperature affect. Therefore,

e4T = 0

7.4.10 Radiation Error (e4R)

From Section 4.11.8, the radiation level within the ISO environment during normal operating conditions is < 1 x 10^4 RADS TID. Reference 3.6.5 does not provide any radiation error effects. Therefore,

e4R = 0

7.4.11 Seismic Error (e4S)

Per section 2.3.4,

e4S = 0

7.4.12 Static Pressure Error (e4SP)

The Bistable is not directly in contact with the process and is therefore not susceptible to errors induced as a result of process variations, for either normal or accident conditions. Therefore:

e4SP = 0

7.4.13 Power Supply Error (e4V)

In accordance with Reference 3.1.2 (Appendix I), it is expected that regulated instrument power supplies have been designed to function within required voltage limits. The variations of voltage and frequency are expected to be small and, as such, these errors are considered to be negligible with respect to other error terms.
Therefore,

e4V = 0

7.4.14 Humidity Error (e4H)

Per Design Input 4.11.8 and reference 3.6.4, this device is bounded by the vendor's operational limits. Therefore:

e4H = 0

7.4.15 Ambient Pressure Error (e4P)

The MTU is an electrical device and as such is not affected by ambient pressure changes. Therefore,

e4P = 0

7.4.16 Process Error (e4p)

The PIS is not directly in contact with the process and is, therefore, not susceptible to errors induced by process variations. Therefore,

e4p = 0

7.4.17 Non-Random Input Error (e4in)

The non-random error present at the input to the PIS during normal operating conditions is due to the ISO, Σe3, and was calculated in Section 7.3.18.

e4in = Σe3 = +0.000048 Vdc

7.4.18 Calculation of Total Non-Random Error during Normal Operating conditions (Σe4)

The total non-random error for the PIS is the sum of the errors in Sections 7.4.9 through 7.4.17.

Non-Random Error

Σe4 = e4T + e4R + e4S + e4SP + e4V + e4H + e4P + e4p + e4in
= 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0.000048 Vdc
= +0.000048 Vdc

7.5 Total Loop 1 Uncertainty

Combining random and non-random terms:

$\sigma 4n$	$= \pm$ 0.025268 Vdc	(7.4.7)	[1σ]
$\Sigma e4$	$= +$ 0.000048 Vdc	(7.4.18)	[1σ]
TE_{Vdc}	$= \pm (2\sigma 4 + \Sigma e4)$	(Section 2.2)	
	$= \pm$ (2*0.025268 Vdc) + 0.000048 Vdc		[2σ]
	= - 0.050536 Vdc & + 0.050584 Vdc		[2σ]
TE_{PSIG}	= - (0.050536 / 4 Vdc) * 1500 psig		[2σ]
	&		
	= + (0.050584 / 4 Vdc) * 1500 psig		[2σ]
	= - 18.951000 psig & +18.969000 psig		[2σ]

Total Loop 1 uncertainty rounded to: $\pm$19.0 psig

8.0 Loop 2 Calculations (Feedwater Level Control Reactor Pressure)

This Section evaluates the error associated with the following instruments associated with the Unit 2 Feedwater Level Control Instrument Loop:

2(3)-0647-A	2(3)-0647-B	Pressure Transmitter (PT)
UY-2(3)-0640-2A	FY-2(3)-0640-3A	A/D converter (A/D)
UY-2(3)-0640-30A		D/A converter (D/A)
2(3)-0640-13A	2(3)-0640-13B	Bistable (Press. Ind. Switch- PIS)

The final element in this loop (Module 4) has a 1 to 5 Vdc input (4 Vdc span). All error terms will be converted to Vdc in relation to the final element span of 4 Vdc.

8.1 Transmitter (Module 1)

8.1.1 Transmitter Random Errors ($\sigma 1$)

8.1.2 Reference Accuracy (σ_{RA1})

From reference 3.6.1, the reference accuracy, which represents a 3σ confidence level, is ±0.25% of calibrated span (includes reference accuracy, repeatability, linearity, and hysteresis). From reference 3.5.4, the calibrated input span is 0 to 1200 psig (14 to 1214 psig including 14 psi head correction). Therefore,

σ_{RA1} = ±0.25% * (1200 psi / 100% span) = ±3.0 psig [3σ]
= ±3.0 psig / 3 = ±1.0 psig [1σ]

The error propagation to the transmitter output is calculated in accordance with Reference 3.1.2 (Appendix B) methodology. From reference 3.5.4, the calibrated input span is 0 to 1200 psig (plus head correction) and the calibrated output span is 4 to 20 mA (16 mA span), which is converted for a 4 Vdc Span as described in Section 8.0. Therefore,

$\sigma_{RA1\text{-}PROP}$ = ±3.0 psig (16 mA / 1200 psig) [3σ]
= ±0.04 mA [3σ]
= ±0.04 mA (4 Vdc / 16 mA)) [3σ]
= ±0.01 Vdc / 3 [1σ]
= ±0.003333 Vdc [1σ]

8.1.3 Setting Tolerance (σ_{ST1})

The instrument loop is string calibrated as defined in Section 5.6.

$\sigma_{ST1\text{-}STR}$ = ±5 psig [3σ]
= ±5 psig / 3 = ±1.666667 psig [1σ]
= ±5.0 psig (16 mA / 1200 psig) [3σ]
= ±0.066667 mA [3σ]
= ±0.066667 mA (4 Vdc / 16 mA)) [3σ]
= ±0.016667 Vdc / 3 [1σ]
= ±0.005556 Vdc [1σ]

The individual instrument calibration setting tolerance is as defined in Section 5.6 and Section 4.12.6.

From reference 3.5.4, the calibration setting tolerance is ±0.04 mA. In accordance with reference 3.1.2 (Appendix A), the calibration setting tolerance for pre-existing instrument channels that have established calibration procedures are incorporated at a 3σ confidence level. Therefore,

$\sigma_{ST1\text{-}IND}$ = ±0.04 mA [1σ]
= ±0.04 mA (4 Vdc / 16 mA)) [1σ]
= ±0.01 Vdc / 3 [1σ]
= ±0.003333 Vdc [1σ]

8.1.4 Measurement & Test Equipment Error (CAL1)

The transmitter string calibration is performed by applying a pressure source of known accuracy to the input of the pressure transmitter while checking the trip actuation setpoint of Module 4 (Bistable) of this instrument loop. Calibration error consists of the inaccuracy of the pressure test equipment used to measure the transmitter input pressure during calibration. Per Section 2.4.1 the calibration standard error (STD) is negligible. Therefore,

From section 4.5 (conservatively using the M&TE with the largest error):

MTE_{IN} (Beta 320) = ±2.052438 psig. [1σ]

The error propagation to the transmitter output is calculated as,

$MTE_{IN\text{-}PROP}$ = ±2.052438 psig. (4 Vdc / 1200 psig)
= ±0.006841 Vdc [1σ]

Therefore, the total transmitter string calibration error is given as,

$CAL1_{\text{-}STR}$ = $(MTE_{IN\text{-}PROP})^2 + (STD)^2$
= ± [(0.006841 Vdc)^2 + (0)^2]
= ± 0.006841 Vdc [1σ]

The individual instrument is calibrated as defined in Section 5.6.
From above,

MTE_{IN} = ±0.006841 Vdc [1σ]

From section 4.5 (conservatively using the M&TE with the largest current error, and converted to error in terms of Vdc):

MTE_{OUT} (Fluke 45) = ± 0.006005 Vdc [1σ]

Therefore, Calibration Error ($CAL1_{IND}$) is,

$CAL1_{IND}$ = ± $[MTE_{IN}^2 + MTE_{OUT}^2 + STD]^{1/2}$
= ± $[(0.006841\ Vdc)^2 + (0.006005\ vdc)^2 + (0)^2]^{1/2}$
= ± 0.009103 Vdc [1σ]
= ± 0.009103 Vdc (16 mAdc / 4 Vdc) [1σ]
= ± 0.036411 mAdc [1σ]

8.1.5 Drift (σ_{DI})

From section 4.12.6,

σ_{DI} = ± 0.5% (Span)
= ±0.5% * 1200 psig
= ± 6.0 psig [2σ]

The error propagation to the transmitter output is calculated as,

$\sigma_{DI\text{ - }PROP}$ = ± 6.0 psig. (4 Vdc / 1200 psig)
= ±0.02 Vdc [2σ]
= ±0.02 Vdc / 2 [2σ]
= ±0.01 Vdc [1σ]

8.1.6 Temperature Error (eT1)

From section 4.12.6 and reference 3.6.1, the transmitter temperature error, which is considered to be a random error represented by a 3σ confidence level, is ± (0.5% of Upper Range Limit + 0.5% span) per 100°F (55.6°C) ambient temperature change, and the URL of 3000 psig. From reference 3.5.4, the calibrated input span is 0 to 1200 psig (plus head correction). From reference 3.2.4, the ambient temperature range at the transmitter varies from 65°F to 104°F (normal) and 133°F (LOCA in other Unit). Therefore,

eT1 = ± {[(0. 5% * 3000 psig) + (0.5% * 1200 psig)]/100°F} {133°F - 65°F}
= ± 14.28 psig [3σ]

The error propagation to the transmitter output is derived as,

$eT1_{PROP}$ = ± 14.28 psig. (4 Vdc / 1200 psig)
= ± 0.0476 Vdc [3σ]
= ± 0.0476 Vdc / 3 [1σ]
= ± 0.015867 Vdc [1σ]

8.1.7 Radiation Error (eR1)

From section 4.12.10 and reference 3.6.1, the transmitter radiation error, which is considered to be a random error represented by a 2σ confidence level, is ± 8.0 of Upper Range Limit during and after exposure to 2.2 x 10^7 rads, total integrated dose. Per Section 2.3.1, radiation induced errors during normal operating conditions are considered to be included within instrument drift related errors. As such, any radiation effects associated with normal operating conditions can be accounted for in the periodic calibration process and are considered negligible with respect to other error terms. Therefore,

eR1 = 0

8.1.8 Seismic Error (eS1)

Per Section 2.3.4,

eS1 = 0

8.1.9 Static Pressure Error (eSP1)

Gauge pressure transmitters are not affected by static pressure. Therefore,

eSP1 = 0

8.1.10 Over-Pressure Error (eOP1)

From reference 3.6.1, transmitter over-pressure effects, which are considered to be a random error represented by a 3σ confidence level, is ± 0.5% of Upper Range Limit maximum shift after 4000 psi overpressure. From references 3.5.4 and 3.7.2, and section 4.12.3, the maximum system operating pressure is 1200 psig. As such, the maximum system operating pressure is less than that required to produce transmitter error. Therefore,

eOP1 = 0

8.1.11 Power Supply Effect (eV1)

In accordance with Reference 3.1.2 (Appendix I), it is expected that regulated instrument power supplies have been designed to function within required voltage limits. The variations of voltage and frequency are expected to be small and, as such, these errors are considered to be negligible with respect to other error terms. Therefore,

eV1 = 0

8.1.12 Random Input Errors ($\sigma 1_{IN}$)

The transmitter is the first module in the loop. As such, there are no associated random input errors. Therefore,

$\sigma 1_{IN} = 0$

8.1.13 Total Random Error (σ1)

The total random error associated with the transmitter is determined in accordance with Section 2 methodology, using the values calculated in Sections 8.1.1 through 8.1.12.

$$\sigma 1 = \pm [(\sigma_{RA1\text{-}PROP})^2 + (\sigma_{ST1})^2 + (CAL1)^2 + (\sigma_{D1\text{-}PROP})^2 + (eT1_{PROP})^2 + (eR1)^2 + (eS1)^2 + (eSP1)^2 + (eOP1)^2 + (eV1)^2 + (\sigma 1_{IN})^2]^{1/2}\ \text{Vdc}$$

$$= \pm [(0.003333)^2 + (\pm 0.005556)^2 + (0.006841)^2 + (0.01)^2 + (0.015867)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2]^{1/2}\ \text{Vdc}$$

$$= \pm 0.020989\ \text{Vdc} \qquad [1\sigma]$$

8.1.14 Transmitter Non-Random Errors

8.1.15 Humidity Error (eH1)

There are no specific humidity effects described in the vendor's specification for the transmitter. From Section 4.12.6, the Vendor's specified operating humidity range is 0 to 100% RH. From Section 4.12.10, the humidity limits at the transmitter location varies from 20 to 90% RH. As such, the humidity limits are bounded by the vendor operating limits and, in accordance with Reference 3.1.2 (Appendix I), are considered included in the reference accuracy. Therefore,

$eH1 = 0$

8.1.16 Process Measurement Error (e1p)

There are no known significant process errors for this device. Per Section 4.2, the effect of the RVLIS backfill modification is approximately +0.5 "wc.
Per reference 3.7.5, 1psi = 27.7276 "wc. Therefore,

e1p = + 0.5 "wc * (1 psi / 27.7276 "wc)
= + 0.018033 psi

$e1p\text{-}_{PROP}$ = + 0.018033 psig. (4 Vdc / 1200 psig)
= + 0.000060 Vdc

8.1.17 Non-Random Input ($e1_{IN}$)

The transmitter is the first module in the loop. As such, there are no associated non-random input errors. Therefore,

$e1_{IN} = 0$

8.1.18 Total Non-Random Errors ($\Sigma e1$)

The total non-random error associated with the transmitter is determined in accordance with Section 2.0 methodology, using the values calculated in Sections 8.1.15 through 8.1.17.

$\Sigma e1 = \pm[eH1 + e1p + e1_{IN}]$
$= \pm [0 + 0.000060 \text{ Vdc} + 0]$
$= + 0.000060 \text{ Vdc}$

8.2 Analog to Digital Converter Errors Loop 2 (Module 2)

The Bailey Network 90 A/D converter receives its input from the transmitter. It has an analog input, and a digital output. It is a computer input module.

8.2.1 A/D (σ2)

8.2.2 Reference Accuracy (RA2)

The A/D converter reference accuracy is determined by direct application of the vendor's specifications listed in Section 4.12.7, and references 3.5.4 and 3.6.4. The vendor specifications for accuracy, linearity, repeatability, and deadband are combined with the A/D conversion error (per reference 3.1.2) with SRSS method to determine RA2.

$$RA2 = \pm [(Ven_{RA})^2 + (Ven_{Linearity})^2 + (Ven_{Rpt})^2 + (Ven_{DBND})^2 (Ven_{A/D\text{-}RES})^2]^{1/2}$$
$$= \pm [(0.10\%FSR)^2 + (0.03\%FSR)^2 + (0.03\%FSR)^2 + (0.03\%FSR)^2 + (1 / 2^{12} * Span)^2]^{1/2}$$
$$= \pm [(0.10\% * 20\ mA)^2 + (0.03\% *20\ mA)^2 + (0.03\% * 20\ mA)^2 + (0.03\% * 20\ mA)^2 + (1 / 2^{12} * 16\ mA)^2]^{1/2}$$
$$= \pm 0.022875\ mA \quad [2\sigma]$$
$$= \pm 0.022875\ mA\ (4\ Vdc / 16\ mA)) \quad [2\sigma]$$
$$= \pm 0.005719\ Vdc \quad [2\sigma]$$
$$= \pm 0.005719\ Vdc / 2 \quad [1\sigma]$$
$$= \pm 0.002860\ Vdc \quad [1\sigma]$$

8.2.3 Setting Tolerance (ST2)

The instrument loop is string calibrated as defined in Section 5.6. As such, the string calibration error is accounted for in Section 8.1.3. Therefore,

$$ST2_{STR} = 0$$

The A/D Converter outputs its signal in digital format to the Feedwater Level Control System (FWLC) Digital Control System (DCS). The D/A output signal can be monitored at the DCS Engineering Work Station (EWS) or Operator Interface Station (OIS). The A/D output signal at the EWS is displayed in terms of psig. $ST2_{IND}$ will be derived to units of Vdc and psig.
The individual instrument calibration setting tolerance is as defined in Section 5.6. Per Section 2.11 and Section 4.12.7:

$$ST2_{IND} = 2 * RA_{VENDOR}$$
$$= \pm 2 * 0.1\%\ FSR$$
$$= \pm 2 * (0.10\% * 20\ mA)\ (5\ Vdc / 20\ mA) \quad [3\sigma]$$
$$= \pm 0.010\ Vdc / 3 \quad [1\sigma]$$
$$= \pm 0.003333\ Vdc \quad [1\sigma]$$
$$= \pm 0.003333\ Vdc * (1200\ psig / 5\ Vdc) \quad [1\sigma]$$
$$= \pm 0.8\ psig \quad [1\sigma]$$
$$= \pm 2.4\ psig \quad [3\sigma]$$

8.2.4 Calibration Error (CAL2)

The instrument loop is string calibrated as defined in Section 5.6. Therefore:

$CAL2_{-STR} = 0$

The individual instrument calibration tolerance is as defined in Section 5.6 and Section 4.12.7. The output of the A/D would be observed on the FWLC EWS or OIS. Therefore, only MTE_{IN} is considered for CAL2.

From section 4.5 (conservatively using the M&TE with the largest current error, and converted to error in terms of Vdc):

MTE_{IN} (Fluke 45) $= \pm\ 0.006005$ Vdc [1σ]

Therefore, Calibration Error ($CAL2_{IND}$) is,

$$
\begin{aligned}
CAL2_{IND} &= \pm\ [MTE_{IN}{}^2 + STD^2]^{1/2} \\
&= \pm\ [(0.006005\ \text{Vdc})^2 + (0)^2]^{1/2} \\
&= \pm 0.006005\ \text{Vdc} \quad [1\sigma] \\
&= \pm 0.006005\ \text{Vdc}\ (16\ \text{mA} / 4\ \text{Vdc}) \\
&= \pm 0.024021\ \text{mAdc} \quad [1\sigma]
\end{aligned}
$$

8.2.5 Drift (D2)

Per Section 4.12.7, the Bailey multi-function processor continuously corrects the measured value for drift, so:

$D2 = 0$

8.2.6 Random Input Errors ($\sigma 2_{IN}$)

The random error present at the input to the A/D converter is the random error on the transmitter output (σ1n) and was calculated in Section 8.1.13. Therefore,

$\sigma 2_{IN} = \pm\ 0.020989$ Vdc [1σ]

8.2.7 Total Random Error (σ2)

The total random error associated with the A/D is determined in accordance with Section 2.0 methodology, using the values calculated in Sections 8.2.2 through 8.2.6.

$$
\begin{aligned}
\sigma 2 &= \pm[(RA2)^2 + (ST2)^2 + (CAL2)^2 + (D2)^2 + (\sigma 2_{IN})^2]^{1/2} \\
&= \pm[(0.002860)^2 + (0)^2 + (0)^2 + (0)^2 + (0.020989)^2]^{1/2}\ \text{Vdc} \\
&= \pm\ 0.021183\ \text{Vdc} \quad [1\sigma]
\end{aligned}
$$

8.2.8 Non-Random Errors (Σe2)

8.2.9 Temperature Error (e2T)

The temperature effect is determined by direct application of the vendor's specifications in section 4.12.7 and the full scale range (FSR) of 20 mA. Per Section 4.12.11 the zone temperature can vary from 70°F to 95°F, which is bounded by the operating limits of 32°F to 158°F.

e2T = ± [0.002%FSR/°C] * (95°F - 70°F)*(5C°/9F°)
= ± [0.002 %*(20 mA)/°C] * (95°F - 70°F)*(5C°/9F°)
= ± 0.005556 mA [3σ]
= ± 0.005556 mA (4 Vdc / 16 mA)) [3σ]
= ± 0.001389 Vdc / 3 [1σ]
= ± 0.000463 Vdc [1σ]

8.2.10 Radiation Error (e2R)

From Section 4.12.11, the radiation level within the A/D environment during normal operating conditions is < 1 x 10^4 RADS TID. Reference 3.6.4 does not provide any radiation effects. Therefore:

e2R = 0

8.2.11 Seismic Error (e2S)

Per section 2.3.4,

e2S = 0

8.2.12 Static Pressure Error (e2SP)

The A/D is not directly in contact with the process and is therefore not susceptible to errors induced as a result of process variations, for either normal or accident conditions. Therefore:

e2SP = 0

8.2.13 Power Supply Error (e2V)

In accordance with Reference 3.1.2 (Appendix I), it is expected that regulated instrument power supplies have been designed to function within required voltage limits. The variations of voltage and frequency are expected to be small and, as such, these errors are considered to be negligible with respect to other error terms. Therefore:

e2V = 0

8.2.14 Humidity Error (e2H)

Per section 4.12.7 and Ref. 3.6.4, this device is bounded by the vendor's operational limits. Therefore:

e2H = 0

8.2.15 Ambient Pressure Error (e2P)

The A/D is an electrical device and as such is not affected by ambient pressure changes. Therefore:

e2P = 0

8.2.16 Process Error (e2p)

The A/D is not directly in contact with the process and is, therefore, not susceptible to errors induced by process variations. Therefore:

e2p = 0

8.2.17 Non-Random Input Error (e2in)

The non-random error present at the input to the A/D is due to the transmitter and was calculated in Section 8.1.18.

e2in = Σe1 = +0.000060 Vdc

8.2.18 Calculation of Total Non-Random Error (Σe2)

The total non-random error associated with the A/D is determined in accordance with Section 2.0 methodology, using the values calculated in Sections 8.2.9 through 8.2.17

Σe2 = e2T + e2R + e2S + e2SP + e2V + e2H + e2P + e2p + e2in
= ±0.000463 Vdc + 0 + 0 + 0 + 0 + 0 + 0 + 0 +0.000060 Vdc
= ±0.000463 Vdc + 0.000060 Vdc [1σ]

8.3 D/A Converter Loop 2 Errors (Module 3)

The Bailey Network 90 D/A converter receives its input from the system software. It has a digital input, and an analog output. It is a computer output module.

8.3.1 D/A Random Errors (σ3)

8.3.2 Reference Accuracy (RA3)

The D/A converter reference accuracy is determined by direct application of the vendor's specifications listed in Section 4.12.8, and references 3.5.4 and 3.6.4. The vendor specification for accuracy is combined with the D/A conversion error (per reference 3.1.2) with SRSS method to determine RA3.

$RA3 = \pm [(Ven_{RA})^2 + (Ven_{D/A\text{-}RES})^2]^{1/2}$
$= \pm [(0.25\%FSR)^2 + (1 / 2^{10} * Span)^2]^{1/2}$
$= \pm [(0.25\% * 20\ mA)^2 + (1 / 2^{10} * 16\ mA)^2]^{1/2}$
= ± 0.052385 mA [2σ]
= ± 0.052385 mA (4 Vdc / 16 mA)) [2σ]
= ± 0.013096 Vdc [2σ]
= ± 0.013096 Vdc / 2 [1σ]
= ± 0.006548 Vdc [1σ]

8.3.3 Setting Tolerance (ST3)

The instrument loop is string calibrated as defined in Section 5.6. As such, the string calibration error is accounted for in Section 8.1.3. Therefore,

$ST3_{STR} = 0$

The input to the D/A Converter is a digital signal from the FWLC DCS. The D/A input signal can be controlled from the EWS to monitor its output for calibration.
The individual instrument calibration setting tolerance is as defined in Section 5.6. Per Section 2.11 and Section 4.12.8:

$$
\begin{aligned}
ST3_{IND} &= 2 * RA_{VENDOR} \\
&= \pm 2 * 0.25\% \text{ FSR} \\
&= \pm 2 * (0.25\% * 20 \text{ mA})) && [3\sigma] \\
&= \pm 0.1 \text{ mA} * (4 \text{ Vdc} / 16 \text{ mA}) && [3\sigma] \\
&= \pm 0.025 \text{ Vdc} / 3 && [1\sigma] \\
&= \pm 0.008333 \text{ Vdc} && [1\sigma]
\end{aligned}
$$

8.3.4 Calibration Error (CAL3)

The instrument loop is string calibrated as defined in Section 5.6.

$CAL3_{-STR} = 0$

The individual instrument calibration tolerance is as defined in Section 5.6 and Section 4.12.8. The input to the D/A is observed and controlled at the FWLC EWS. Therefore, only MTE_{OUT} is considered for CAL3.

From section 4.5 (conservatively using the M&TE with the largest current error, and converted to error in terms of Vdc):

MTE_{OUT} (Fluke 45) $= \pm 0.006005$ Vdc [1σ]

Therefore, Calibration Error ($CAL3_{IND}$) is,

$$
\begin{aligned}
CAL3_{IND} &= \pm [MTE_{OUT}^2 + STD]^{1/2} \\
&= \pm [(0.006005 \text{ Vdc})^2 + (0)^2]^{1/2} \\
&= \pm 0.006005 \text{ vdc} && [1\sigma] \\
&= \pm 0.024021 \text{ mAdc} && [1\sigma]
\end{aligned}
$$

8.3.5 Drift Error (σ3D)

Per Section 4.12.8, the Bailey multi-function processor continuously corrects the measured value for drift, so:

$\sigma 3D = 0$

8.3.6 Random Input Errors ($\sigma 3in$)

The random error present at the input to the D/A is the random error present at the A/D output, which was calculated in Section 8.2.7.

$\sigma 3in \quad = \sigma 2 \quad = \pm\, 0.021183$ Vdc [1σ]

8.3.7 Calculation of Total Random Error ($\sigma 3n$)

The total random error associated with the D/A is the SRSS of the values in Sections 8.3.2 to 8.3.6.

$\sigma 3n = \pm\, ((RA3)^2 + (ST3)^2 + (CAL3)^2 + (\sigma 3D)^2 + (\sigma 3in)^2)^{1/2}$ [1σ]

$= \pm\, ((0.006548 \text{ Vdc})^2 + (0)^2 + (0)^2 + (0)^2 + (0.021183)^2)^{1/2}$ [1σ]

$= \pm\, 0.022172$ Vdc [1σ]

8.3.8 D/A Non-Random Errors ($\Sigma e3$)

8.3.9 Temperature Error (e3T)

Per Section 4.12.8, the D/A will function normally from 32°F to 158°F, which bounds the location normal temperature range per section 4.12.11. Therefore,

e3T = 0

8.3.10 Radiation Error (e3R)

From Section 4.12.11, the radiation level within the D/A environment during normal operating conditions is < 1 x 10^4 RADS TID. Reference 3.6.4 does not provide any radiation error effects. Therefore,

e3R = 0

8.3.11 Seismic Error (e3S)

Per section 2.3.4,

e3S = 0

8.3.12 Static Pressure Error (e3SP)

The D/A is not directly in contact with the process and is therefore not susceptible to errors induced as a result of process variations. Therefore:

e3SP = 0

8.3.13 Power Supply Error (e3V)

In accordance with Reference 3.1.2 (Appendix I), it is expected that regulated instrument power supplies have been designed to function within required voltage limits. The variations of voltage and frequency are expected to be small and, as such, these errors are considered to be negligible with respect to other error terms. Therefore:

e3V = 0

8.3.14 Humidity Error (e3H)

Per section 4.12.8 and reference 3.6.4, this device is bounded by the vendor's operational limits. Therefore:

e3H = 0

8.3.15 Ambient Pressure Error (e3P)

The D/A is an electrical device and as such is not affected by ambient pressure changes. Therefore:

e3P = 0

8.3.16 Process Error (e3p)

The D/A is not directly in contact with the process and is, therefore, not susceptible to errors induced by process variations. Therefore

e3p = 0

8.3.17 Non-Random Input Error (e3in)

The non-random error present at the input to the D/A during normal operating conditions is due to the A/D, Σe2, and was calculated in Section 8.2.18.

e3in = Σe2 = ±0.000463 Vdc + 0.000060 Vdc [1σ]

8.3.18 Calculation of Total Non-Random Error (Σe3)

The total non-random error for the Isolator is the sum of the errors in Sections 8.3.9 through 8.3.17.

Non-Random Error:

Σe3 = e3T + e3R + e3S + e3SP + e3V + e3H + e3P + e3p + e3in
= 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0.000463 Vdc + 0.000060 Vdc
= ±0.000463 Vdc + 0.000060 Vdc [1σ]

8.4 PIS (BISTABLE) Loop 2 (Module 4)

The Moore Pressure Indicating Switch (PIS) receives its input from the Bailey D/A Converter.

8.4.1 PIS Random Errors ($\sigma 4$)

8.4.2 Reference Accuracy (RA4)

The PIS reference accuracy is determined per section 4.4. Therefore,

RA4	= ± 0.004123 V dc	[2σ]
	= ± 0.004123 Vdc / 2	[1σ]
	= ± 0.002062 Vdc	[1σ]

8.4.3 Setting Tolerance (ST4)

The instrument loop is string calibrated as defined in Section 5.6. As such, the string calibration error is accounted for in Section 8.1.3. Therefore,

$ST4_{STR} = 0$

The individual instrument calibration setting tolerance is as defined in Section 5.6. Per Section 2.11 and Section 4.12.9:

$ST4_{IND}$	= 2 * RA_{VENDOR}		
	= ± 2 * 0.001 Vdc	= ± 0.002 Vdc	[3σ]
	= ± 0.002 Vdc (1200 psig / 4 Vdc)	= ± 0.60 psig	[3σ]
	= ± 0.002 Vdc / 3		[1σ]
	= ± 0.000667 Vdc		[1σ]

8.4.4 String Calibration Error (CAL4)

Because of the full string calibration as described in Section 5.6, there are no string calibration error contributions from the Bistable. Therefore,

$CAL4_{STR} = 0$

The Bistable is individually calibrated by applying an voltage signal input while noting Vdc with a digital multimeter (DMM) at which the trip actuation occurs. Therefore, calibration error for the Bistable consists of only the MTE_{IN} from Section 4.5. Per Section 2.4.1 the calibration standard error (STD) is negligible. Therefore,

$$CAL4_{IND} = \pm (MTE_{IN}^2 + STD^2)^{1/2}$$
$$= \pm [(0.002365 \text{ Vdc})^2 + (0)^2]^{1/2}$$
$$= \pm 0.002365 \text{ Vdc} \quad [1\sigma]$$

8.4.5 Drift Error ($\sigma 4D$)

From section 4.4,

$\sigma 4D$	$= \pm 0.104\% * (Span)$		$[2\sigma]$
	$= \pm 0.104\% * 4$ Vdc		$[2\sigma]$
	$= \pm 0.00416$ Vdc		$[2\sigma]$
	$= \pm 0.002080$ Vdc		$[1\sigma]$

8.4.6 Random Input Error ($\sigma 4in$)

The random error present at the input to the PIS is the random error present at the D/A output, which was calculated in Section 8.3.7. Therefore,

$\sigma 4in = \pm 0.022172$ Vdc $[1\sigma]$

8.4.7 Total Random Errors – Module 4 ($\sigma 4$)

The total random error associated with the Pressure Indicating Switch is the SRSS of the values in Sections 8.4.2 to 8.4.6.
Therefore, the Shutdown Cooling trip function total random errors:

$$\sigma 4 = \pm [(RA4)^2 + (ST4_{STR})^2 + (CAL4_{STR})^2 + (e4D)^2 + (\sigma 4in)^2]^{1/2}$$
$$= \pm [(\pm 0.002062)^2 + (0)^2 + (0)^2 + (0.002080)^2 + (0.022172)^2]^{1/2}$$
$$= \pm 0.022365 \text{ Vdc} \quad [1\sigma]$$

8.4.8 PIS Non-Random Errors ($\Sigma e4$)

8.4.9 Temperature Error (e4T)

There is no vendor provided temperature affect. Therefore,

$e4T = 0$

8.4.10 Radiation Error (e4R)

From Section 4.12.12, the radiation level within the PIS environment during normal operating conditions is < 1 x 10^4 RADS TID. Reference 3.6.5 does not provide any radiation error effects. Therefore,

$e4R = 0$

8.4.11 Seismic Error (e4S)

Per section 2.3.4,

$e4S = 0$

8.4.12 Static Pressure Error (e4SP)

The Bistable is not directly in contact with the process and is therefore not susceptible to errors induced as a result of process variations, for either normal or accident conditions. Therefore:

$e4SP = 0$

8.4.13 Power Supply Error (e4V)

In accordance with Reference 3.1.2 (Appendix I), it is expected that regulated instrument power supplies have been designed to function within required voltage limits. The variations of voltage and frequency are expected to be small and, as such, these errors are considered to be negligible with respect to other error terms. Therefore,

e4V = 0

8.4.14 Humidity Error (e4H)

Per section 4.12.9 and reference 3.6.5, this device is bounded by the vendor's operational limits. Therefore:

e4H = 0

8.4.15 Ambient Pressure Error (e4P)

The PIS is an electrical device and as such is not affected by ambient pressure changes. Therefore,

e4P = 0

8.4.16 Process Error (e4p)

The PIS is not directly in contact with the process and is, therefore, not susceptible to errors induced by process variations. Therefore,

e4p = 0

8.4.17 Non-Random Input Error (e4in)

The non-random error present at the input to the PIS during normal operating conditions is due to the D/A, Σe4, and was calculated in Section 8.3.18.

e4in = Σe3 = ±0.000463 Vdc + 0.000060 Vdc

8.4.18 Calculation of Total Non-Random Error during Normal Operating conditions (Σe4)

The total non-random error for the PIS is the sum of the errors in Sections 8.4.9 through 8.4.17.

Non-Random Error

Σe4 = e4T + e4R + e4S + e4P + e4V + e4H + e4P + e4p + e4in
= 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0.000463 Vdc + 0.000060 Vdc
= ±0.000463 Vdc + 0.000060 Vdc [1σ]

8.5 Total Loop 2 Uncertainty

Combining random and non-random terms:

$\sigma 4n$	$= \pm$ 0.022365 Vdc	(8.4.7)	[1σ]
$\Sigma e4$	$= \pm$ 0.000463 Vdc +0.000060 Vdc	(8.4.18)	[1σ]

TE_{Vdc} $= \pm (2\sigma + \Sigma e)$ (Section 2.2)
$= [\pm (2 * 0.022365 \text{ Vdc} + 0.000463 \text{ Vdc})] + 0.000060 \text{ Vdc}$ [2σ]
$= -\ 0.045193 \text{ Vdc} \ \& + 0.045253 \text{ Vdc}$ [2σ]

TE_{PSIG} $= [-\ (0.045193 \text{ Vdc} / 4 \text{ Vdc}) * 1200 \text{ psig}]$
&
$= [+\ (0.045253 \text{ Vdc} / 4 \text{ Vdc}) * 1200 \text{ psig}]$
$= -13.5579 \text{ psig} \ \& + 13.5759 \text{ psig}$ [2σ]

Total Loop 2 uncertainty rounded to ± 13.6 psig [2σ]

9.0 Determination of Setpoint, Allowable Value, and Expanded Tolerance

Loop 1

9.1 Drift Tolerance Interval Derivation

Per Appendix C of Reference 3.1.2, only those errors that effect the as-found measurement are used in the determination of Allowable Value. Per Reference 3.1.2, the Drift Tolerance Interval (DTI), fully encompasses the following error sources: Reference Accuracy, Calibration Error (including M&TE and Cal Std Error), Setting Tolerance, and Drift. These are the only terms anticipated during the as-found measurement, and as such, DTIv will be used as the "applicable uncertainties" for computing the Allowable Value. Therefore,

$$DTI_V = [(RA)^2 + (CAL)^2 + (ST)^2 + (\sigma_D)^2]^{1/2} \quad [1\sigma]$$

Drift Tolerance interval String (DTI_{VSTR}) is computed with the string calibration terms for the above error sources with the Input Error term (σin) also combined using the SRRS method. Therefore,

$$DTI_{V\text{-}STR} = [(RA)^2 + (CAL_{STR})^2 + (ST_{STR})^2 + (\sigma_D)^2 + (\sigma 2in^2)]^{1/2} \quad [1\sigma]$$

9.1.1 Drift Tolerance Interval for Pressure Transmitter

Determination of DTI for PT:

$$DTI_{VPT} = 2 * [(\sigma_{RA1\text{-}PROP})^2 + (CAL1_{\text{-}IND})^2 + (\sigma_{ST1\text{-}IND})^2 + (\sigma_{D1\text{-}PROP})^2]^{1/2} \quad [2\sigma]$$

Determination of DTI-String for PT:

$$DTI1_{VPT\text{-}STR} = 2 * [(\sigma_{RA1\text{-}PROP})^2 + (CAL1_{STR})^2 + (\sigma_{ST1\text{-}STR})^2 + (\sigma_{D1\text{-}PROP})^2 + (\sigma 1in^2)]^{1/2} \quad [2\sigma]$$

Where:

$\sigma_{RA1\text{-}PROP}$	= ±0.003333 Vdc	(7.1.2)	[1σ]
$CAL1_{\text{-}IND}$	= ± 0.005962 Vdc	(7.1.4)	[1σ]
$\sigma_{ST1\text{-}IND}$	= ± 0.003333 Vdc	(7.1.3)	[1σ]
$\sigma_{D1\text{-}PROP}$	= ±0.008 Vdc	(7.1.5)	[1σ]
$CAL1_{STR}$	= ± 0.005473 Vdc	(7.1.4)	[1σ]
$\sigma_{ST1\text{-}STR}$	= ± 0.004444 Vdc	(7.1.3)	[1σ]
$\sigma 1in$	= ± 0 Vdc	(7.1.12)	[1σ]

Substituting:

$$DTI_{VPT} = 2*[(0.003333)^2 + (0.005962)^2 + (0.003333)^2 + (0.008^2)]^{1/2} \text{ Vdc} \quad [2\sigma]$$

$$DTI_{VPT} = \pm 2 * 0.011035 \text{ Vdc} \quad [2\sigma]$$

$$DTI_{VPT} = \pm 0.022070 \text{ Vdc} \quad [2\sigma]$$

$DTI1_{VPT-STR} = 2*[(0.003333)^2 + (0.005473)^2 + (0.004444)^2 + (0.008)^2 + (0)^2]^{1/2}$ Vdc [2σ]
$DTI1_{VPT-STR} = \pm 2 * 0.011172$ Vdc [2σ]
$DTI1_{VPT-STR} = \pm 0.022344$ Vdc [2σ]

9.1.2 Drift Tolerance Interval for Master Trip Unit ($DTI1_{MTU}$)

Determination of DTI for MTU:

$$DTI_{MTU} = 2 * [(RA2)^2 + (CAL2_{PROP-IND})^2 + (\sigma_{ST2-IND})^2 + (D2)^2]^{1/2} [2\sigma]$$

Determination of DTI – String for MTU:

$$DTI1_{MTU-STR} = 2 * [(\sigma_{RA2-PROP})^2 + (CAL2_{STR})^2 + (\sigma_{ST2-STR})^2 + (\sigma_{D2-PROP})^2 + (\sigma 2in)^2]^{1/2} \quad [2\sigma]$$

Where:

RA2	= ± 0.008497 Vdc	(1σ)	[7.2.2]
$CAL2_{PROP-IND}$	= ± 0.002635 Vdc	(1σ)	[7.2.4]
$\sigma_{ST2-IND}$	= ± 0.006667 Vdc	(1σ)	[7.2.3]
D2	= ± 0Vdc	(1σ)	[7.2.5]
$CAL2_{STR}$	= ± 0 Vdc	(1σ)	[7.2.4]
$ST2_{STR}$	= ± 0 Vdc	(1σ)	[7.2.3]
σ2in	= $DTI1_{VPT-STR}$ = ± 0.011172 Vdc	(1σ)	[9.1.1]

Substituting:

$DTI_{MTU} = 2*[(0.008497)^2 + (0.002635)^2 + (0.006667)^2 + (0)^2]^{1/2}$ Vdc [2σ]
$DTI_{TMU} = \pm 2 * 0.011117$ Vdc [2σ]
$DTI_{TMU} = \pm 0.022234$ Vdc [2σ]

$DTI1_{MTU-STR} = 2*[(0.008497)^2 + (0)^2 + (0)^2 + (0)^2 + (0.011172)^2]^{1/2}$ Vdc [2σ]
$DTI1_{MTU-STR} = \pm 2* 0.014036$ Vdc [2σ]
$DTI1_{MTU-STR} = \pm 0.028072$ Vdc [2σ]

9.1.3 Drift Tolerance Interval for Isolator ($DTI1_{Isolator}$)

Determination of DTI for Isolator:

$$DTI_{Isolator} = 2 * [(RA3)^2 + (CAL3)^2 + (ST3_{IND})^2 + (\sigma 3D)^2]^{1/2} \quad [2\sigma]$$

Determination of DTI – String for Isolator:

$$DTI1_{Isolator-STR} = 2 * [(\sigma_{RA3-PROP})^2 + (CAL3_{STR})^2 + (\sigma_{ST3-STR})^2 + (\sigma_{D3-PROP})^2 + (\sigma 3in)^2]^{1/2} \quad [2\sigma]$$

Where:

$RA3$	$= \pm 0.002$ Vdc	(1σ)	[7.3.2]
$CAL3_{IND}$	$= \pm 0.006454$Vdc	(1σ)	[7.3.4]
$ST3_{IND}$	$= \pm 0.004167$ Vdc	(1σ)	[7.3.3]
$\sigma3D$	$= \pm 0.01$Vdc	(1σ)	[7.3.5]
$CAL3_{STR}$	$= \pm 0$Vdc	(1σ)	[7.3.4]
$ST3_{STR}$	$= \pm 0$Vdc	(1σ)	[7.3.3]
$\sigma3in$	$= DTI1_{MTU-STR} = \pm 0.014036$ Vdc	(1σ)	[9.1.2]

Substituting:

$DTI_{Isolator} = \pm 2*[(0.002)^2 + (0.006454)^2 + (0.004167)^2 + (0.01)^2]^{1/2}$ Vdc [2σ]
$DTI_{Isolator} = \pm 2* 0.012768$ Vdc [2σ]
$DTI_{Isolator} = \pm 0.025536$ Vdc [2σ]

$DTI1_{Isolator\ STR} = \pm 2*[(0.002)^2 + (0)^2 + (0)^2 + (0.01)^2 + (0.014036)^2]^{1/2}$ Vdc [2σ]
$DTI1_{Isolato\ STR} = \pm 2 * 0.017351$ Vdc [2σ]
$DTI1_{Isolator\ STR} = \pm 0.034702$ Vdc [2σ]

9.1.4 <u>Drift Tolerance Interval for Pressure Indicating Switch ($DTI1_{PIS}$)</u>

<u>Determination of DTI for PIS</u>

$$DTI_{PIS} = 2 * [(RA4)^2 + (CAL4)^2 + (ST4_{IND})^2 + (\sigma4D)^2]^{1/2} \quad [2\sigma]$$

<u>Determination of DTI – String for PIS</u>

$$DTI1_{PIS-STR} = 2 * [(\sigma_{RA4-PROP})^2 + (CAL4_{STR})^2 + (\sigma_{ST4-STR})^2 + (\sigma_{D4-PROP})^2 + (\sigma4in)^2]^{1/2} \quad [2\sigma]$$

Where:

$RA4$	$= \pm 0.002062$ Vdc	(1σ)	[7.4.2]
$CAL4_{IND}$	$= \pm 0.002365$ Vdc	(1σ)	[7.4.4]
$ST4_{IND}$	$= \pm 0.000667$ Vdc	(1σ)	[7.4.3]
$\sigma4D$	$= \pm 0.002080$ Vdc	(1σ)	[7.4.5]
$CAL4_{STR}$	$= \pm 0$ Vdc	(1σ)	[7.4.4]
$ST4_{STR}$	$= \pm 0$ Vdc	(1σ)	[7.4.3]
$\sigma4in$	$= DTI1_{Isolator\ STR} = \pm 0.017351$ Vdc	(1σ)	[9.1.3]

Substituting:

$DTI_{PIS} = 2*[(0.002062)^2 + (0.002365)^2 + (0.000667)^2 + (0.002080)^2]^{1/2}$ Vdc [2σ]
$DTI_{PIS} = \pm 2 * 0.003823$ Vdc [2σ]
$DTI_{PIS} = \pm 0.007646$ Vdc [2σ]

$DTI1_{PIS-STR} = 2*[(0.002062)^2 + (0)^2 + (0)^2 + (0.002080)^2 + (0.017351)^2]^{1/2}$ Vdc [2σ]
$DTI1_{PIS-STR} = \pm 2* 0.017596$ Vdc [2σ]
$DTI1_{PIS-STR} = \pm 0.035192$ Vdc [2σ]

9.1.5 Drift Tolerance Interval for String calibration ($DTI1_{STR}$)

The string calibration will be performed by applying an input pressure to the pressure transmitters and will be observed at the output of the bistable. Therefore, from section 9.1.4:

$DTI1_{STR} = DTI1_{PIS\text{-}STR} = \pm\ 0.017596$ Vdc [1σ]

$DTI1_{STR} = DTI1_{PIS\text{-}STR} = \pm\ 0.035192$ Vdc [2σ]

9.2 Trip Setpoint (SPc) determination

The setpoint is calculated in accordance with section 2.8. Therefore,

$SP_C \leq AL - (Z + MAR)$ (for an increasing setpoint)

Where,

SP_C = Calculated Setpoint
AL = Analytical Limit
Z = Total Uncertainty
MAR = Margin

The values for the parameters associated with the calculated setpoint are as follows:

Analytical Limit (AL)	= 119.9 psig	(section 4.1)
Total Loop Uncertainty $(Z)_{Loop1}$	= ± 19.0 psig	(section 7.5)

*Note: As presented in section 6.0, both the loops, i.e. Loop 1 and Loop 2, were analyzed for the total loop uncertainty in section 7 and section 8 respectively. The calculated total loop uncertainty error for section 7, Loop1 (19.0 psig), is larger than the calculated total loop uncertainty error for section 8, Loop2 (13.6 psig). Therefore, the total loop uncertainty from section 7 (19.0 psig) is selected as the uncertainty value used to calculate the SDC Isolation Trip Setpoint, SPc, that will be used for all of the Bistable trip units in both instrument loops.

SPc_{Loop1} = 119.9 psig – (19.0 psig + 0)
= 100.9 psig

Therefore, the new calculated setpoint is:

$SPc = SPc_{Loop1}$ = 100.9 psig

9.3 Allowable Value (AV) determination

The Allowable Value is calculated in accordance with section 2.8. Therefore,

$AV \leq SP_C + au(2\sigma)$ (for an increasing setpoint)

Where,

SP_C = Calculated Setpoint
AV = Allowable Value
au = Applicable Uncertainty

Per reference 3.1.2, the Allowable Value is determined by offsetting from the setpoint by the amount of the errors and uncertainties present during calibration.

Per Section 9.2, the calculated setpoint is:

SPc = 100.9 psig

Per reference 3.1.2, the applicable uncertainty is referred to as the uncertainties that have been determined to affect the trip setpoint at the time of the As-Found measurement.
Per Section 9.1.5, the Drift Tolerance Interval (DTIv) fully encompasses the errors due to Accuracy, Calibration Error (including M&TE, and Cal Std Error), Drift Value, and Setting Tolerance. Therefore, the term DTI_V is the Allowable Uncertainty for this calculation.
The term DTI_{VPT}, Drift Tolerance Interval for string calibration with test pressure applied to input of the Pressure Transmitter, calibrates the Pressure Indicating Switch (PIS). Therefore the term DTI_{VPT} is the Allowable Uncertainty for the loop. Therefore,

$au\ (1\sigma) = DTI1_{STR}\ (1\sigma)$

Per Section 9.1.5,

$DTI1_{STR}\ (1\sigma) = \pm\ 0.017596$ Vdc [1σ]

$DTI1_{STR}\ (2\sigma) = \pm\ 0.035192$Vdc [2σ]

Converting the Drift Tolerance Interval to psig:

$DTI1_{STR}$ = ± 0.035192 Vdc * 1500 psig / 4 Vdc [2σ]
= ± 13.197 psig [2σ]

Therefore,

$au\ (2\sigma)$ = $DTI1_{STR}\ (2\sigma)$
= ± 13.197 psig
= ± 13.2 psig (Rounded)

The Allowable Value is computed as follows:

AV_{Loop1} ≤ SPc + au (2σ)
≤ 100.9 psig + 13.2 psig
≤ 114.1 psig

The terms included in the AV determination were treated in the same way as they were in the setpoint determination. Therefore, adequate margin exists between the Analytical Limit and the Allowable Value, and no check calculation is required.

9.4 Expanded Tolerance (ET) determination

9.4.1 Expanded Tolerance for Pressure Transmitter PT 2(3)-0263-152A(B)

Expanded Tolerances (ET) for the Transmitters are derived based on the methodology in Section 2.4.4.

Expanded Tolerances are computed as follows:

$ET1_{PT} = \pm [0.7 * (DTIv_{PT} - ST1) + ST1]$ (ST and DTIv are 2σ values)

Where,

$ST1 = \pm 0.013333$ Vdc (Section 7.1.3) [3σ]
$= \pm 0.006667$ Vdc [2σ]

$DTI1v_{PT} = \pm 0.022070$ Vdc (Section 9.1.1) [2σ]

Substituting:

$ET1_{PT} = \pm [0.7 * (DTI1v_{PT} - ST1) + ST1]$
$= \pm [0.7*(0.022070 \text{ Vdc} - 0.006667 \text{ Vdc}) + 0.006667 \text{ Vdc}]$
$= \pm 0.017449$ Vdc [2σ]
$= \pm 0.020$ Vdc (Rounded) [2σ]
$= \pm 0.020$ Vdc (16 mA / 4 Vdc) [2σ]
$= \pm 0.08$ mAdc [2σ]

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance (±0.003333 Vdc per Section 7.1.3).

$ET1_{PT}$ (Vdc) > ST1 (Vdc)
$ET1_{PT}$ (0.020 Vdc) > 0.013333 Vdc [pass]

Therefore, the Expanded Tolerance is acceptable with respect to the Setting Tolerance. Secondly, the Setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. In this case, the string tolerance is all that is used in comparison to the Allowable Value, and that is the only applicable limit to this instrument string. Therefore, the second ET comparison is not necessary, and the ET is acceptable as computed.

Converting to psig:

$ET1_{PT} = \pm (ET1_{PT})) * (\text{Conversion Factor})$
$= \pm [(0.02 \text{ Vdc}) * (1500 \text{ psig} / 4 \text{ Vdc})]$
$= \pm 7.5$ psig [2σ]

9.4.2 Expanded Tolerance for Master Trip Unit (MTU)

Expanded Tolerances (ET) for the MTU, PIS 2(3)-0263-155A(B), is derived based on the methodology in Section 2.4.4.

Expanded Tolerances are computed as follows:

$$ET_{MTU} = \pm [0.7 * (DTI1v_{MTU} - ST2) + ST2]$$

Where,

ST2	$= \pm 0.02$ Vdc	(Section 7.2.3)	[3σ]
	$= \pm 0.013333$ Vdc		[2σ]
$DTI1v_{MTU}$	$= \pm 0.022234$ Vdc	(Section 9.1.2)	[2σ]

Substituting:

$ET_{MTU} = \pm [0.7 * (DTI1_{MTU} - ST2) + ST2]$
$= \pm [0.7 * (0.022234 \text{ Vdc} - 0.013333 \text{ Vdc}) + 0.013333 \text{ Vdc}]$
$= \pm 0.019564$ Vdc [2σ]
$= \pm 0.0196$ Vdc (Rounded) [2σ]

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance.

ET_{MTU} (Vdc) > ST2 (Vdc)
ET_{MTU} (± 0.0196 Vdc) < ST2 (0.02 Vdc) [Fail]

Since the calculated ET value is less than the 3σ value of the ST (0.02 Vdc), per section 2.4.4,

ET_{MTU} = ST2
= ± 0.02 Vdc

Secondly, the Setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. In this case, the string tolerance is all that is used in comparison to the Allowable Value, and that is the only applicable limit to this instrument string. Therefore, the second ET comparison is not necessary, and the ET is acceptable as computed.

9.4.3 Expanded Tolerance for Isolator

Expanded Tolerances (ET) for the Isolator, PY 2(3)-0263-153A(B1), are derived based on the methodology in Section 2.4.4.

Expanded Tolerances are computed as follows:

$$ET_{ISO} = \pm [0.7 * (DTI_{Isolator} - ST3) + ST3]$$

Where,

ST3	$= \pm$ 0.0125 Vdc	(Section 7.3.3)	[3σ]
	$= \pm$ 0.008334 Vdc		[2σ]
$DTIv_{ISO}$	$= \pm$ 0.025536 Vdc	(Section 9.1.3)	[2σ]

Substituting:

ET_{ISO}	$= \pm$ [0.7 * (DTIvISO – ST3) + ST3]		
	$= \pm$ [0.7*(0.025536 Vdc – 0. 008334 Vdc) + 0. 008334 Vdc]		
	$= \pm$ 0.020375 Vdc		[2σ]
	$= \pm$ 0.020Vdc	(Rounded)	[2σ]
	$= \pm$ 0.020 Vdc (16 mA / 4 Vdc)		[2σ]
	$= \pm$ 0.08 mAdc		[2σ]

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance.

ET_{ISO} (V dc) > ST3 (Vdc)
ET_{ISO} (0.020 Vdc) > ST3 (0.0125 Vdc) [pass]

Therefore, the Expanded Tolerance is acceptable with respect to the Setting Tolerance. Secondly, the Setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. In this case, the string tolerance is all that is used in comparison to the Allowable Value, and that is the only applicable limit to this instrument string. Therefore, the second ET comparison is not necessary, and the ET is acceptable as computed.

9.4.4 Expanded Tolerance for Pressure Indicating Switch (PIS)

Expanded Tolerances (ET) for the PIS, PIS 2(3)-0263-13C(D) are derived based on the methodology in Section 2. The ET will be converted in terms of psig.

Expanded Tolerances are computed as follows:

$$ET_{PIS} = \pm [0.7 * (DTI1v_{PT} - ST4) + ST4]$$

Where,

ST4	$= \pm$ 0.002 Vdc	(Section 7.4.3)	[3σ]
	$= \pm$ 0.001333 Vdc		[2σ]
$DTIv_{PIS}$	$= \pm$ 0.007646 Vdc	(Section 9.1.4)	[2σ]

Substituting:

ET_{PIS} = ± [0.7 * (DTI1vPIS – ST4) + ST4]
= ± [0.7 * (0.007646 Vdc – 0.001333Vdc) + 0.001333Vdc]
= ± 0.005752Vdc [2σ]
= ± 0.006 Vdc (Rounded) [2σ]

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance.

ET_{PIS} (Vdc) > ST4 (Vdc)
ET_{PIS} (0.006 Vdc) > ST4 (0.002Vdc) [pass]

Secondly, the Setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. The only limit of concern here is the Allowable Value. Therefore,

SPc + ET_{PIS} < AV

Per section 9.1, SPc = 100.9 psig.

Therefore, converting ET from Vdc to psig:

ET_{PIS} = ± ($ET_{PIS)}$) * (Conversion Factor)
= ± [(0.006 Vdc) * (1500 psig / 4Vdc)]
= ± 2.25 psig [2σ]

SPc (100.9 psig) + ET_{PIS} (2.25 psig) = 103.15 psig < AV (114.1 psig) [pass]

Therefore, SPc + ET does not exceed the Allowable Value, and the ET_{PIS} is acceptable as defined at a value of ± 2.25 psig

9.4.5 Expanded Tolerance for String Calibration

Expanded Tolerances (ET) for the String Calibration is derived based on the methodology in Section 2. The ET will be converted in terms of psig.

Expanded Tolerances are computed as follows:

ET_{STR} = ± [0.7 * (DTI1$_{STR}$ – ST1$_{STR)}$ + ST1 $_{STR}$]

Where,

ST1$_{STR}$	= ± 0.013333 Vdc	(Section 7.1.3)	[3σ]
	= ± 0.008889 Vdc		[2σ]
DTI1$_{STR}$	= ± 0.035192 Vdc	(Section 9.1.5)	[2σ]

Substituting:

$ET_{STR} = \pm [0.7 * (DTI1v_{PIS} - ST1) + ST1]$
$= \pm [0.7 * (0.035192 \text{ Vdc} - 0.008889 \text{ Vdc}) + 0.008889 \text{ Vdc}]$
$= \pm 0.027301$ Vdc [2σ]
$= \pm 0.027$ Vdc (Rounded) [2σ]

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance.

ET_{STR} (Vdc) > ST1 (Vdc)
ET_{STR} (0.027 Vdc) > ST1 (0.013333 Vdc) [pass]

Secondly, the Setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. The limit of concern here is the Allowable Value. Therefore,

$SPc + ET_{STR} < AV$

Per section 9.1, SPc = 100.9 psig.

Therefore, converting ET from Vdc to psig:

$ET_{STR} = \pm (ET_{STR})) * (\text{Conversion Factor})$
$= \pm [(0.027 \text{ Vdc}) * (1500 \text{ psig} / 4\text{Vdc})]$
$= \pm 10.125$ psig [2σ]
$= \pm 10.1$ psig (Rounded) [2σ]

SPc (100.9 psig) + ET_{STR} (10.1 psig) = 111.0 psig < AV (114.1 psig) [pass]

Therefore, SPc + ET_{STR} does not exceed the Allowable Value, and the ET_{STR} is acceptable as defined at a value of ± 10.1 psig.

9.5 Instrument Calibration and Setpoint Determination

9.5.1 Calibration Criteria for transmitter

Calibration Criteria for PT- 2(3)-0263-152A ($CAL1_{PT1}$)

Per section 4.11.2, the input span for the transmitter is 0-1500 psig. Per section 4.3, the Head Correction (hc) is 13.9 psig for 2-0263-152A and 14.6 psig for 3-0263-152A. Therefore, Calibration Input Span Range is:

$CAL1_{PT1\text{-}IN}$ = Span + hc

$CAL1_{PT1\text{-}IN\ 2\text{-}0263\text{-}152A}$ = (0.0 – 1500.0) + 13.9 psig
= 13.9 – 1513.9 psig

$CAL1_{PT1\text{-}IN\ 3\text{-}0263\text{-}152A}$ = (0.0 – 1500.0) + 14.6 psig
= 14.6 – 1514.6 psig

Calibration Criteria for PT- 2(3)-0263-152A ($CAL1_{PT1}$)

Per section 4.11.2, the output span for the transmitter is 4.00 – 20.00 mAdc. Therefore, Calibration Output Span Range is:

$CAL1_{PT1\text{-}OUT}$ = Output Span
= 4.00 – 20.00 mAdc

Calibration Criteria for PT- 2(3)-0263-152B ($CAL1_{PT2\text{-}IN}$)

Per section 4.11.2, the input span for the transmitter is 0-1500 psig. Per section 4.3, the Head Correction (hc) is 13.5 psig for 2-0263-152B and 13.4 psig for 3-0263-152B. Therefore, Calibration Input Span Range is:

$CAL1_{PT2\text{-}IN}$ = Span + hc

$CAL1_{PT2\text{-}IN\ 2\text{-}0263\text{-}152B}$ = (0.0 – 1500.0) + 13.5 psig
= 13.5 – 1513.5 psig

$CAL1_{PT2\text{-}IN\ 3\text{-}0263\text{-}152B}$ = (0.0 – 1500.0) + 13.4 psig
= 13.4 – 1513.4 psig

Calibration Criteria for PT- 2(3)-0263-152B ($CAL1_{PT2\text{-}OUT}$)

Per section 4.11.2, the output span for the transmitter is 4.00 – 20.00 mAdc. Therefore, Calibration Output Span Range is:

$CAL1_{PT2\text{-}OUT}$ = Output Span
= 4.00 – 20.00 mAdc

9.5.2 Calibration Criteria for MTU

Calibration Criteria for PIS 2(3)-0263-155A(B) ($CAL1_{MTU\text{-}IN}$)

Per section 4.11.3, the input span for the MTU is 4.00 – 20.00 mAdc. Therefore, Calibration Input Span Range is:

$CAL1_{MTU\text{-}IN}$ = Input Span
= 4.00 – 20.00 mAdc

Calibration Criteria for PIS 2(3)-0263-155A(B) ($CAL1_{MTU\text{-}OUT}$)

Per section 4.11.3, the output span for the MTU is 1.00 – 5.00 Vdc. Therefore, Calibration Output Span Range is:

$CAL1_{MTU\text{-}OUT}$ = Output Span
= 1.000 – 5.000 Vdc

9.5.3 Calibration Criteria for Isolator

Calibration Criteria for PY-2(3)-0263-153A(B1) ($CAL1_{ISO\text{-}IN}$)

Per section 4.11.4, the Input span for the Isolator is 1.00 – 5.00 Vdc. Therefore, Calibration Input Span Range is:

$CAL1_{ISO\text{-}IN}$ = Input Span
= 1.00 – 5.00 Vdc

Calibration Criteria for PY-2(3)-0263-153A(B1) ($CAL1_{ISO\text{-}OUT}$)

Per section 4.11.4, the Output span for the Isolator is 4.00 – 20.00 mAdc. Therefore, the Calibration Output Span Range is:

$CAL1_{ISO\text{-}OUT}$ = Output Span
= 4.00 – 20.00 mAdc

9.5.4 Calibration Criteria for PIS (Bistable)

Calibration Criteria for PIS-2(3)-0263-13C(D) ($SP1_{BISTABLE}$)

Per calibration data from section 4.11.5, the instrument setpoint for the Bistable is determined as follows:

$SP1_{BISTABLE1}$ = [(SPc) / $CAL1_{PT1\text{-}IN}$ (100%FSR) * Bistable span Vdc]
+ 1 Vdc (Bistable Min. Range)
= [(100.9 psig) / 1500 psig * 4 Vdc] + 1Vdc
= 1.269067 Vdc
= 1.269 Vdc (Rounded)

Instrument Loop 2

9.6 Drift Tolerance Interval Derivation

Per Appendix C of Reference 3.1.2, only those errors that effect the as-found measurement are used in the determination of Allowable Value. Per Reference 3.1.2, the Drift Tolerance Interval (DTI), fully encompasses the following error sources: Reference Accuracy, Calibration Error (including M&TE and Cal Std Error), Setting Tolerance, and Drift. These are the only terms anticipated during the as-found measurement, and as such, DTIv will be used as the "applicable uncertainties" for computing the Allowable Value. Therefore,

$$DTI_V = [(RA)^2 + (CAL)^2 + (ST)^2 + (\sigma_D)^2]^{1/2} \quad [1\sigma]$$

9.6.1 Drift Tolerance Interval for Pressure Transmitters

Determination of DTI for PT:

$$DTI_{VPT2} = 2 * [(\sigma_{RA1\text{-}PROP})^2 + (CAL1_{IND})^2 + (\sigma_{ST1\text{-}IND})^2 + (\sigma_{D1\text{ - }PROP})^2]^{1/2} \quad [2\sigma]$$

Determination of DTI-String for PT:

$$DTI2_{VPT2\text{-}STR} = 2 * [(\sigma_{RA1\text{-}PROP})^2 + (CAL1_{STR})^2 + (\sigma_{ST1\text{-}STR})^2 + (\sigma_{D1\text{ - }PROP})^2 + (\sigma lin_2)^2]^{1/2} \quad [2\sigma]$$

Where:

$\sigma_{RA1\text{-}PROP}$	$= \pm$ 0.003333 Vdc	(1σ)	[8.1.2]
$CAL1_{IND}$	$= \pm$ 0.009103Vdc	(1σ)	[8.1.4]
$\sigma_{ST1\text{-}IND}$	$= \pm$ 0.003333 Vdc	(1σ)	[8.1.3]
$\sigma_{D1\text{ - }PROP}$	$= \pm$ 0.01 Vdc	(1σ)	[8.1.5]
$CAL1_{\text{-}STR}$	$= \pm$ 0.006841 Vdc	(1σ)	[8.1.4]
$\sigma_{ST1\text{-}STR}$	$= \pm$ 0.005556 Vdc	(1σ)	[8.1.3]
σlin_2	$= \pm$ 0 Vdc	(1σ)	[8.1.12]

Substituting:

$DTI_{VPT2} = 2*[(0.003333)^2 + (0.\ 009103)^2 + (0.\ 003333)^2 + (0.01)^2]^{1/2}$ Vdc [2σ]
$DTI_{VPT2} = \pm 2*$ 0.014321Vdc [2σ]
$DTI_{VPT2} = \pm$ 0.028642 Vdc [2σ]

$DTI2_{VPT2\text{-}STR} = 2*[(0.003333)^2 + (0.\ 006841)^2 + (0.005556)^2 + (0.01)^2 + (0)^2]^{1/2}$ Vdc [2σ]
$DTI2_{VPT2\text{-}STR} = \pm 2 *$ 0.013740 Vdc [2σ]
$DTI2_{VPT2\text{-}STR} = \pm$ 0.027480 Vdc [2σ]

9.6.2 Drift Tolerance Interval for A/D Converter

Determination of DTI for A/D:

$DTI_{A/D} = 2 * [(RA2)^2 + (CAL2_{-IND})^2 + (ST2_{IND})^2 + (D2)^2]^{1/2}$ [2σ]

Determination of DTI – String for A/D:

$DTI2_{A/D-STR} = 2 * [(RA2)^2 + (CAL2_{STR})^2 + (ST2_{STR})^2 + (D2)^2 + \sigma 2in_2]^{1/2}$ [2σ]

Where:

RA2	= ± 0. 002860 Vdc	(1σ)	[8.2.2]
$CAL2_{-IND}$	= ± 0. 006005 Vdc	(1σ)	[8.2.4]
$ST2_{IND}$	= ± 0.003333 Vdc	(1σ)	[8.2.3]
D2	= ± 0 Vdc	(1σ)	[8.2.5]
$CAL2_{STR}$	= ± 0 Vdc	(1σ)	[8.2.4]
$ST2_{STR}$	= ± 0 Vdc	(1σ)	[8.2.3]
$\sigma 2in_2$	= $DTI2_{VPT2-STR}$ = ± 0.013740 Vdc	(1σ)	[9.6.1]

Substituting:

$DTI_{A/D} = 2 * [(0.\ 002860)^2 + (0.\ 006005)^2 + (0.003333)^2 + (0)^2]^{1/2}$ Vdc [2σ]
$DTI_{A/D} = \pm 2 * 0.007440$ Vdc [2σ]
$DTI_{A/D} = \pm 0.014880$ Vdc [2σ]

$DTI2_{A/D-STR} = 2*[(0.002860)^2 + (0)^2 + (0)^2 + (0)^2 + (0.013740)^2]^{1/2}$ Vdc [2σ]
$DTI2_{A/D-STR} = \pm 2 * 0.014035$ Vdc [2σ]
$DTI2_{A/D-STR} = \pm 0.028070$ Vdc [2σ]

9.6.3 Drift Tolerance Interval for D/A Converter

Determination of DTI for D/A Converter:
$DTI_{D/A} = 2 * [(RA3)^2 + (CAL3)^2 + (ST3_{IND})^2 + (\sigma 3D)^2]^{1/2}$ [2σ]

Determination of DTI – String for D/A Converter:
$DTI2_{D/A-STR} = 2 * [(RA3)^2 + (CAL3_{STR})^2 + (ST3_{STR})^2 + (\sigma 3D)^2 + \sigma 3in_2]^{1/2}$ [2σ]

Where:

RA3	= ± 0.006548 Vdc	(1σ)	[8.3.2]
$CAL3_{IND}$	= ± 0.006005Vdc	(1σ)	[8.3.4]
$ST3_{IND}$	= ± 0.008333 Vdc	(1σ)	[8.3.3]
σ3D	= ± 0 Vdc	(1σ)	[8.3.5]
$CAL3_{STR}$	= ± 0 Vdc	(1σ)	[8.3.4]
$ST3_{STR}$	= ± 0 Vdc	(1σ)	[8.3.3]
$\sigma 3in_2$ = $DTI2_{A/D-STR}$ = ± 0.014035 Vdc		(1σ)	[9.6.2]

Substituting:

$DTI_{D/A} = \pm 2*[(0.006548)^2 + (0.006005)^2 + (0.008333)^2 + (0)^2]^{1/2}$ Vdc [2σ]
$DTI_{D/A} = \pm 2 * 0.012181$ Vdc [2σ]
$DTI_{D/A} = \pm 0.024362$ Vdc [2σ]

$DTI2_{D/A\text{-}STR} = \pm 2*[(0.006548)^2 + (0)^2 + (0)^2 + (0)^2 + (0.014035)^2]^{1/2}$ Vdc [2σ]
$DTI2_{D/A\text{-}STR} = \pm 2 * 0.015488$ Vdc [2σ]
$DTI2_{D/A\text{-}STR} = \pm 0.030976$ Vdc [2σ]

9.6.4 Drift Tolerance Interval for Pressure Indicating Switch ($DTI1_{PIS}$)

Determination of DTI for PIS

$DTI_{PIS2} = 2 * [(RA4)^2 + (CAL4_{IND})^2 + (ST4_{IND})^2 + (\sigma 4D)^2]^{1/2}$ [2σ]

Determination of DTI – String for PIS

$DTI2_{PIS2\text{-}STR} = 2 * [(RA4)^2 + (CAL4_{STR})^2 + (ST4_{STR})^2 + (\sigma 4D)^2 + \sigma 4in_2]^{1/2}$ [2σ]

Where:

RA4	= ± 0.002062 Vdc	(1σ)	[8.4.2]
$CAL4_{IND}$	= ± 0.002365 Vdc	(1σ)	[8.4.4]
$ST4_{IND}$	= ± 0.000667 Vdc	(1σ)	[8.4.3]
σ4D	= ± 0.002080 Vdc	(1σ)	[8.4.5]
$CAL4_{STR}$	= ± 0 Vdc	(1σ)	[8.4.4]
$ST4_{STR}$	= ± 0 Vdc	(1σ)	[8.4.3]
$\sigma 4in_2 = DTI2_{D/A\text{-}STR}$	= ±0.015488 Vdc	(1σ)	[9.6.3]

Substituting:

$DTI_{PIS2} = \pm 2*[(0.002062)^2 + (0.002365)^2 + (0.000667)^2 + (0.002080)^2]^{1/2}$ Vdc [2σ]
$DTI_{PIS2} = \pm 2 * 0.003823$ Vdc [2σ]
$DTI_{PIS2} = \pm 0.007646$ Vdc [2σ]

$DTI2_{PIS2\text{-}STR} = \pm 2*[(0.002062)^2 + (0)^2 + (0)^2 + (0.002080)^2 + (0.015488)^2]^{1/2}$ Vdc [2σ]
$DTI2_{PIS2\text{-}STR} = \pm 2 * 0.015763$ Vdc [2σ]
$DTI2_{PIS2\text{-}STR} = \pm 0.031526$ Vdc [2σ]

9.6.5 Drift Tolerance Interval for String calibration ($DTI2_{STR}$)

The string calibration will be performed by applying an input pressure to the pressure transmitter and will be observed at the output of the bistable. Therefore, from section 9.6.4,

$DTI2_{STR} = DTI2_{PIS2\text{-}STR} = \pm 0.015763$ Vdc [1σ]
$DTI2_{PIS2\text{-}STR} = \pm 0.031526$ Vdc [2σ]

9.7 <u>Trip Setpoint (SPc) determination</u>

The setpoint is calculated in accordance with section 2.8. Therefore,

$SP_C \leq AL - (Z + MAR)$ (for an increasing setpoint)

Where,

SP_C = Calculated Setpoint
AL = Analytical Limit
Z = Total Uncertainty
MAR = Margin

The values for the parameters associated with the calculated setpoint are as follows:

Analytical Limit (AL)	= 119.9 psig	(section 4.1)
Total Loop Uncertainty $(Z)_{Loop2}$	= ±13.6 psig	(section 8.5)

Instrument Loop 1 has a larger uncertainty (±19.0 psig) than Loop 2 (±13.6 psig). In order to keep the setpoints of all four of the SDC Bistables the same, a margin (MAR2) will be applied to the setpoint computation for Loop 2 so that:

$SPc_{Loop2} = SPc_{Loop1} = SPc = 100.9$ psig

Therefore,

$MAR2_{Loop2} = 5.4$

Therefore,

$SPc_{Loop2} = AL - (Z_{Loop2} + MAR1 + MAR2) = SPc$

$= 119.9 \text{ psig} - (13.6 \text{ psig} + 0 \text{ psig} + 5.4 \text{ psig}) = 100.9 \text{ psig}$

Therefore, the calculated setpoint for the SDC Isolation trip is:

SPc = 100.9 psig

9.8 Allowable Value (AV) determination

The Allowable Value is calculated in accordance with section 2.8. Therefore,

$AV \leq SP_C + au(2\sigma)$ (for an increasing setpoint)

Where,

SP_C = Calculated Setpoint
AV = Allowable Value
au = Applicable Uncertainty

Per reference 3.1.2, the Allowable Value is determined by offsetting from the setpoint by the amount of the errors and uncertainties present during calibration.

Per Section 9.7, the calculated setpoint is:

SPc = 100.9 psig

Per reference 3.1.2, the applicable uncertainty is referred to as the uncertainties that have been determined to affect the trip setpoint at the time as the As-Found measurement.

Per Section 9.6.5, the Drift Tolerance Interval (DTIv) fully encompasses the errors due to Accuracy, Calibration Error (including M&TE, and Cal Std Error), Drift Value, and Setting Tolerance. Therefore, the term DTI_V is the Allowable Uncertainty for this calculation.
The term DTI_{VPT}, Drift Tolerance Interval for string calibration with test pressure applied to the input of the Pressure Transmitter, calibrates the Pressure Indicating Switch (PIS). Therefore the term DTI_{VPT} is the Allowable Uncertainty for the loop. Therefore,

$au(1\sigma) = DTI2_{STR}(1\sigma)$

Per Section 9.6.5,

$DTI2_{STR}(1\sigma) = \pm 0.015763$ Vdc [1σ]

$DTI2_{STR}(2\sigma) = \pm 0.031526$ Vdc [2σ]

Converting the Drift Tolerance Interval to psig:

$DTI2_{STR} = \pm 0.031526 \text{ Vdc} * 1200 \text{ psig} / 4 \text{ Vdc}$ [2σ]
$= \pm 9.4578$ psig [2σ]

Therefore,

$au(2\sigma) = DTI2_{STR}(2\sigma)$
$= \pm 9.4578$ psig
$= \pm 9.5$ psig (Rounded)

Therefore The Allowable Value is computed as follows:

$$AV_{Loop2} \leq SPc + au\ (2\sigma)$$
$$\leq 100.9\ psig + 9.5$$
$$\leq 110.4\ psig$$

The terms included in the AV determination were treated in the same way as they were in the setpoint determination. Therefore adequate margin exists between the Analytical Limit and the Allowable Value, and no check calculation is required.

9.9 Expanded Tolerance (ET) determination

9.9.1 Expanded Tolerance for Transmitter

Expanded Tolerances (ET) for the Transmitters are derived based on the methodology in Section 2.4.4.

Expanded Tolerances are computed as follows:

$$ET_{PT2} = \pm [0.7 * (DTIv_{PT2} - ST_{PT2}) + ST_{PT2}] \text{ (ST and DTIv are } 2\sigma \text{ values)}$$

Where,

$ST_{PT2} = \pm 0.01Vdc$ (Section 8.1.3) [3σ]
$= \pm 0.006667$ Vdc [2σ]

$DTIv_{PT2} = \pm 0.028642$ Vdc (Section 9.6.1) [2σ]

Substituting:

$ET_{PT2} = \pm [0.7 * (DTI1v_{PT} - ST1) + ST1]$
$= \pm [0.7 * (0.028642\ Vdc - 0.006667Vdc) + 0.006667Vdc]$
$= \pm 0.022050$ Vdc [2σ]
$= \pm 0.022$ Vdc (Rounded) [2σ]
$= \pm 0.022$ Vdc (16 mA / 4 Vdc) [2σ]
$= \pm 0.088$ mAdc [2σ]

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance.

ET_{PT2} (V dc) > ST_{PT2} (Vdc)
ET_{PT2} (0.022 Vdc) > ST_{PT2} (0.01Vdc) [pass]

Therefore, the Expanded Tolerance is acceptable with respect to the Setting Tolerance. Secondly, the Setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. In this case, the string tolerance is all that is used in comparison to the Allowable Value, and that is the only applicable limit to this instrument string. Therefore, the second ET comparison is not necessary, and the ET is acceptable as computed.

Converting to psig:

ET_{PT2} = ± ($ET_{PT2)}$) * (Conversion Factor)
= ± [(0.022 Vdc) * (1200 psig / 4Vdc)]
= ± 6.6 psig [2σ]

9.9.2 Expanded Tolerance for A/D Converter

Expanded Tolerances (ET) for the A/D Converter is derived based on the methodology in Section 2.4.4.

Expanded Tolerances are computed as follows:

$ET_{A/D}$ = ± [0.7 * ($DTIv_{A/D}$ – ST2 $_{A/D}$) + ST2 $_{A/D}$]

Where,

$ST2_{A/D}$ = ± 0.01 Vdc (Section 8.2.3) [3σ]
= ± 0.006667 Vdc [2σ]

$DTI_{A/D}$ = ± 0.01488 Vdc (Section 9.6.2) [2σ]

Substituting:

$ET_{A/D}$ = ± [0.7 * ($DTI_{A/D}$ – $ST2_{A/D}$) + $ST_{A/D}$]
= ± [0.7 * (0.01488 Vdc – 0.006667 Vdc) + 0.006667 Vdc]
= ± 0.012416 Vdc [2σ]
= ± 0.012 Vdc (Rounded) [2σ]
= ± 0.012 Vdc (1200 psig / 4 Vdc) [2σ]
= ± 3.6 psig (Rounded) [2σ]

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance.

$ET_{A/D}$ (V dc) > ST2 $_{A/D}$ (Vdc)
$ET_{A/D}$ (± 0.012Vdc) > ST2 $_{A/D}$ (0.01 Vdc) [Pass]

Therefore, the Expanded Tolerance is acceptable with respect to the Setting Tolerance. Secondly, the Setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. In this case, the string tolerance is all that is used in comparison to the Allowable Value, and that is the only applicable limit to this instrument string. Therefore, the second ET comparison is not necessary, and the ET is acceptable as computed.

9.9.3 Expanded Tolerance for D/A Converter

Expanded Tolerances (ET) for the D/A Converter is derived based on the methodology in Section 2.4.4.

Expanded Tolerances are computed as follows:

$$ET_{D/A} = \pm [0.7 * (DTI_{D/A} - ST3_{D/A}) + ST3_{D/A}]$$

Where,

$ST3_{D/A}$	$= \pm 0.025$ Vdc	(Section 8.3.3)	[3σ]
	$= \pm 0.016667$ Vdc		[2σ]
$DTI_{D/A}$	$= \pm 0.024362$ Vdc	(Section 9.6.3)	[2σ]

Substituting:

$ET_{D/A}$	$= \pm [0.7 * (DTI_{D/A} - ST3_{D/A}) + ST3_{D/A}]$	
	$= \pm [0.7 * (0.024362 \text{ Vdc} - 0.016667 \text{ Vdc}) + 0.016667 \text{ Vdc}]$	
	$= \pm 0.022054$ Vdc	[2σ]
	$= \pm 0.022$ Vdc (Rounded)	[2σ]
	$= \pm 0.022$ Vdc (16 mA / 4 Vdc)	[2σ]
	$= \pm 0.088$ mAdc	[2σ]

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance.

$ET_{D/A}$ (V dc) > $ST3_{D/A}$ (Vdc)
$ET_{D/A}$ (0.022 Vdc) < $ST3_{D/A}$ (0.025 Vdc) [Fail]

Since the calculated ET value is less than the 3σ value of the ST (0.025 Vdc), per section 2.4.4,

$ET_{D/A}$ = ST3
= 0.025 Vdc
= ± 0.025 Vdc (16 mA / 4 Vdc)
= 0.1 mAdc

Secondly, the Setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. In this case, the string tolerance is all that is used in comparison to the Allowable Value, and that is the only applicable limit to this instrument string. Therefore, the second ET comparison is not necessary, and the ET is acceptable as computed.

9.9.4 Expanded Tolerance for Pressure Indicating Switch (PIS)

Expanded Tolerances (ET) for the PIS are derived based on the methodology in Section 2. The ET will be converted in terms of psig.

Expanded Tolerances are computed as follows:

$$ET_{PIS} = \pm [0.7 * (DTI1v_{PIS} - ST4_{IND}) + ST4_{IND}]$$

Where,

$ST4_{PIS}$ = ± 0.002 Vdc (Section 8.4.3) [3σ]
= ± 0.001333 Vdc [2σ]

$DTIv_{PIS}$= ± 0.007646 Vdc (Section 9.6.4) [2σ]

Substituting:

ET_{PIS} = ± [0.7 * ($DTIv_{PIS}$ – $ST4_{PIS}$) + $ST4_{PIS}$]
= ± [0.7*(0.007646 Vdc – 0.001333 Vdc) + 0.001333 Vdc]
= ± 0.005752 Vdc [2σ]
= ± 0.006 Vdc (Rounded) [2σ]

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance.

ET_{PIS} (Vdc) > $ST4_{PIS}$ (Vdc)
ET_{PIS} (0.006 Vdc) > $ST4_{PIS}$ (0.002 Vdc) [pass]

Secondly, the Setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. The only limit of concern here is the Allowable Value. Therefore,

SPc + ET_{PIS} < AV

Per section 9.7, SPc = 100.9 psig.

Therefore, converting ET from Vdc to psig:

ET_{PIS} = ± (ET_{PIS})) * (Conversion Factor)
= ± [(0.006 Vdc) * (1200 psig / 4Vdc)]
= ± 1.8 psig [2σ]

SPc (100.9 psig) + ET_{PIS} (1.8 psig) = 102.7 psig < AV (110.4 psig) [pass]

Therefore, SPc + ET does not exceed the Allowable Value, and the ET_{PIS} is acceptable as defined at a value of ±1.8 psig

9.9.5 Expanded Tolerance for String Calibration

Expanded Tolerances for loop 2 (ET2) for the String Calibration is derived based on the methodology in Section 2. The ET will be converted in terms of psig.

Expanded Tolerances are computed as follows:

$ET2_{STR}$ = ± [0.7 * ($DTI2_{STR}$ – $ST1_{STR}$) + $ST1_{STR}$]

Where,

$ST1_{STR}$	$= \pm 0.016667$ Vdc	(Section 8.1.3)	[3σ]
	$= \pm 0.011111$ Vdc		[2σ]
$DTI2_{PIS2-STR}$	$= \pm 0.031526$ Vdc	(Section 9.6.5)	[2σ]

Substituting:

$$ET2_{STR} = \pm [0.7 * (DTI2_{PIS2-STR} - ST1_{STR}) + ST1_{STR}]$$
$$= \pm [0.7 * (0.031526 \text{ Vdc} - 0.011111 \text{ Vdc}) + 0.011111 \text{ Vdc}]$$
$$= \pm 0.025402\text{Vdc} \quad [2\sigma]$$
$$= \pm 0.025 \text{ Vdc} \quad \text{(Rounded)} \quad [2\sigma]$$

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance.

$ET2_{STR}$ (Vdc) > ST1 (Vdc)
$ET2_{STR}$ (0.025 Vdc) > ST1 (0.016667 Vdc) [pass]

Secondly, the Setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. The only limit of concern here is the Allowable Value. Therefore,

$SPc + ET2_{STR} < AV$

Per section 9.7, SPc = 100.9 psig.

Therefore, converting ET from Vdc to psig:

$$ET2_{STR} = \pm (ET2_{STR)}) * \text{(Conversion Factor)}$$
$$= \pm [(0.025 \text{ Vdc}) * (1200 \text{ psig} / 4\text{Vdc})]$$
$$= \pm 7.5 \text{ psig} \quad [2\sigma]$$

SPc (100.9 psig) + $ET2_{STR}$ (7.5 psig) = 108.4 psig < AV (110.4 psig) [pass]

Therefore, SPc + ET does not exceed the Allowable Value, and the $ET2_{STR}$ is acceptable as defined at a value of ±7.5 psig

9.10 Instrument Calibration and Setpoint Determination

9.10.1 Calibration Criteria for transmitter

Calibration Criteria for PT-2(3)-0647-A ($CAL2_{PT1-IN}$)

Per section 4.12.2, the input span for the transmitter is 0-1200 psig. Per section 4.3, the Head Correction (hc) is 14.4 psig for both PT 2-0647A and PT 3-0647A. Therefore, Calibration Input Span Range is:

$CAL2_{PT1-IN}$ = Span + hc
$CAL2_{PT1-IN}$ = (0 - 1200) + 14.4 psig
$CAL2_{PT1-IN}$ = 14.4 – 1214.4 psig

Calibration Criteria for PT-2(3)-0647-A ($CAL2_{PT2-OUT}$)

Per section 4.12.2, the output span for the transmitter is 4.00 – 20.00 mAdc. Therefore, Calibration Output Span Range is:

$CAL2_{PT2-OUT}$ = Output Span
$CAL2_{PT2-OUT}$ = 4.00 – 20.00 mAdc

Calibration Criteria for PT-2(3)-0647-B ($CAL2_{PT2-IN}$)

Per section 4.12.2, the input span for the transmitter is 0-1200 psig. Per section 4.3, the Head Correction (hc) is 14.3psig for both PT 2-0647B and PT 3-0647B. Therefore, Calibration Input Span Range is:

$CAL1_{PT2-IN}$ = Span + hc
$CAL1_{PT2-IN}$ = (0 - 1200) + 14.3 psig
$CAL1_{PT2-IN}$ = 14.3 – 1214.3 psig

Calibration Criteria for PT-2(3)-0647-B ($CAL2_{PT2-OUT}$)

Per section 4.12.2, the output span for the transmitter is 4.00 – 20.00 mAdc. Therefore, Calibration Output Span Range is:

$CAL1_{PT2-OUT}$ = Output Span
$CAL1_{PT2-OUT}$ = 4.00 – 20.00 mAdc

9.10.2 Calibration Criteria for A/D Converter

Calibration Criteria for UY-2(3)-0640-2A / FY-2(3)-0640-3A ($CAL2_{A/D}$)

Per section 4.12.7, the input span for the A/D Converter is 4.00 – 20.00 mAdc. Therefore, Calibration Input Span Range is:

$CAL2_{A/D}$ = Input Span
$CAL2_{A/D}$ = 4.00 – 20.00 mAdc

Calibration Criteria for UY-2(3)-0640-2A / FY-2(3)-0640-3A ($CAL2_{A/D-OUT}$)

Per section 4.12.7, the output span for the A/D Converter is a digital signal to the FWLC DCS displayed at the EWS, for a span of 0 to 1200 psig. Therefore, Calibration Output Span Range is:

$CAL2_{A/D-OUT}$ = Output Span
$CAL2_{A/D-OUT}$ = 0 to 1200 psig (at the EWS/OIS screen)

9.10.3 Calibration Criteria for D/A Converter

Calibration Criteria for UY-2(3)-0640-30A ($CAL3_{D/A}$)

Per section 4.12.8, the Input span for the D/A is a digital signal from the FWLC DCS displayed and controlled at the EWS, for a span of 0 to 1200 psig. Therefore, Calibration Input Span Range is:

$CAL3_{D/A}$ = Input Span
$CAL3_{D/A}$ = 0 to 1200 psig (at the EWS screen)

Calibration Criteria for UY-2(3)-0640-30A ($CAL3_{D/A-OUT}$)

Per section 4.12.8, the output span for the D/A Converter is 4.00 – 20.00 mAdc. Therefore, Calibration Output Span Range is:

$CAL3_{A/D-OUT}$ = Output Span
$CAL3_{A/D-OUT}$ = 4.00 – 20.00 mAdc

9.10.4 Calibration Criteria for PIS (Bistable)

Calibration Criteria for PIS-2(3)-0640-13A(B) ($SP2_{BISTABLE}$)

Per section 4.12.9, the instrument setpoint for the Bistable is determined as follows:

$SP2_{BISTABLE2}$ = [(SPc) / $CAL1_{PT1-IN}$ (100%FSR) * Bistable span Vdc] + 1Vdc (Bistable Min. Range)

= [(100.9 psig) / 1200 psig * 4 Vdc] + 1 Vdc

= 1.336 Vdc

10.0 SUMMARY AND CONCLUSIONS

This calculation has determined the Calibrated Setpoints and Allowable Values for the instrumentation that initiates Shutdown Cooling Isolation. These values, along with the associated Analytical Limits are listed in the tables below. In addition, the calibration values and expanded tolerances are identified.

10.1 Calibration Setpoints, Instrument Scaling, and Allowable Values:

INSTRUMENT SETPOINTS, SCALING, AND ALLOWABLE VALUES			
EPN	**PARAMETER**	**INSTRUMENT SIGNAL**	**REACTOR PRESSURE**
PIS 2(3)-0263-13C(D) (BISTABLE)	Analytical Limit (AL)	N/A	119.9 psig
	Allowable Value (AV_1)	N/A	≤ 114.1 psig
	Calibration Setpoint (SP1)	1.269 Vdc (increasing)	100.9 psig
PIS 2(3)-0640-13A(B) (BISTABLE)	Analytical Limit (AL)	N/A	119.9 psig
	Allowable Value (AV_2)	N/A	≤ 110.4 psig
	Calibration Setpoint (SP2)	1.336 Vdc (increasing)	100.9 psig
PT 2(3)-0263-152A	PT 2-0263-152A Calibration Input	13.9 to 1513.9 psig	0 to 1500.0 psig
	PT 3-0263-152A Calibration Input	14.6 to 1514.6 psig	
	Calibration Output	4.00 to 20.00 mAdc	
PT 2(3)-0263-152B	PT 2-0263-152B Calibration Input	13.5 to 1513.5 psig	
	PT 3-0263-152B Calibration Input	13.4 to 1513.4 psig	
	Calibration Output	4.00 to 20.00 mAdc	
PT 2(3)-0647-A	Calibration Input	14.4 to 1214.4 psig	0 to 1200.0 psig
	Calibration Output	4.00 to 20.00 mAdc	
PT 2(3)-0647-B	Calibration Input	14.3 to 1214.3 psig	
	Calibration Output	4.00 to 20.00 mAdc	
PIS 2(3)-0263-155A(B) (MTU)	Calibration Input	4.00 to 20.00 mAdc	0 to 1500.0 psig
	Calibration Output	1.000 to 5.000 Vdc	
PY 2(3)-0263-153A(B1)	Calibration Input	1.000 to 5.000 Vdc	0 to 1500.0 psig
	Calibration Output	4.00 to 20.00 mAdc	
UY-2(3)-0640-2A FY-2(3)-0640-3A (A/D)	Calibration Input	4.00 to 20.00 mAdc	0 to 1200.0 psig
	Calibration Output	Digital Signal for 0 to 1200.0 psig to FWLC DCS	
UY 2(3)-0640-30A (D/A)	Calibration Input	Digital Signal for 0 to 1200.0 psig from FWLC DCS	0 to 1200.0 psig
	Calibration Output	4.00 to 20.00 mAdc	

10.2 Instrument Functions, Setting Tolerance, and Expanded Tolerance:

INSTRUMENT FUNCTION & TOLERANCES			
EPN	**Function**	**Setting Tolerance (3σ)**	**Expanded Tolerance (2σ)**
PT-2(3)-0263-152A(B)	Pressure Transmitter	± 0.040 mAdc	± 0.080 mAdc
PT-2(3)-0647-A(B)	Pressure Transmitter	± 0.040 mAdc	± 0.088 mAdc
UY-2(3)-0640-2A FY-2(3)-0640-3A	A/D Signal Converter	± 2.4 psig (Displayed on FWLC EWS/OIS)	± 3.6 psig (Displayed on FWLC EWS/OIS)
UY-2(3)-0640-30A	D/A Signal Converter	± 0.10 mAdc (Displayed on FWLC EWS)	± 0.10 mAdc (Displayed on FWLC EWS)
PIS-2(3)-0263-13C(D)	Bistable	± 0.002 Vdc / ± 0.75 psig	± 0.006 Vdc / ± 2.25 psig
PIS-2(3)-0640-13A(B)	Bistable	± 0.002 Vdc / ± 0.6 psig	± 0.006 Vdc / ± 1.8 psig
PIS 2(3)-0263-155A(B)	I/E Signal Converter (MTU)	± 0.02 Vdc	± 0.02 Vdc
PY-2(3)-0263-153A(B1)	E/I Isolator	± 0.05 mAdc	± 0.08 mAdc
DIS 0263-19 (Rx Wide Range) String Calibration for Pressure Transmitters and Pressure Indicating Switches	Instrument Loop 1 Calibration	± 5.0 psig / ± 0.0133 Vdc	± 10.1 psig / ± 0.027 Vdc
DIS 0600-16 & DIS 0600-01 (FWLC) String Calibration for Pressure Transmitters and Pressure Indicating Switches	Instrument Loop 2 Calibration	± 5.0 psig / ± 0.017 Vdc	± 7.5 psig / ± 0.025 Vdc

10.3 Calibration frequency is 24 months (+ 25% late factor) for all instruments listed in the tables in this conclusion section.

10.4 Calculation Implementation Items:

a. DIS 0263-19 (Reference 3.5.5), and DIS 0600-16 & DIS 0600-01 (Reference 3.5.4) shall be revised to incorporate the results of this calculation.

b. DIS 0263-19 (Reference 3.5.5), and DIS 0600-16 & DIS 0600-01 (Reference 3.5.4) shall be revised to incorporate the M&TE requirements of this calculation per section 4.5.

c. DIS 0263-19 (Reference 3.5.5), and DIS 0600-16 & DIS 0600-01 (Reference 3.5.4) shall be revised to perform a string calibration as described in section 5.6 by inputting a known calibrated pressure signal into the pressure transmitter while observing the Pressure Indicating Switch (Bistable Output).

d. Acceptance criteria for AV, setpoints, and expanded tolerance (ET) are satisfied.

e. The above results are valid for Unit 2 only after Dresden EC 377728 (Reference 3.7.1) has been installed.

f. The above results are valid for Unit 3 only after Dresden EC 377766 (Reference 3.7.1) has been installed.

10.5 Additional Conclusions:

Per section 10.3, the calculated Setpoint for SDC Isolation is 100.9 psig with a normal instrument calibration tolerance of ± 10.1 psig (Expanded Tolerance) for Loop 1. Per section 7.5 the worst case Total Loop Uncertainty is ± 19.0 psig (Loop 1). Per Section 4.13 the SDC permissive setpoint will be set at approximately 99.9 psig by reference 3.7.1 (EC 377728 / 377766).
Therefore, the normal expected operating range to initiate SDC is 99.9 psig ± 10.1 psig, 89.8 psig to 110.0 psig.
The calculated worst case to initiate SDC is 99.9 psig -19.1 psig = 80.8 psig (Using total error).