Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381-2000

June 9, 2011 10 CFR 2.201

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

Watts Bar Nuclear Plant, Unit 2
NRC Docket No. 50-391

Subject: **Watts Bar Nuclear Plant (WBN) Unit 2 - Reply to Notice of Violation 05000391/2010603-08 - Failure to Adequately Evaluate and Qualify Molded Case Circuit Breakers - Revised Response**

References:

1. TVA to NRC letter dated November 24, 2010, "Reply to Notice of Violation 05000391/2010603-08 - Failure to Adequately Evaluate and Qualify Molded Case Circuit Breakers"
2. NRC to TVA letter dated March 4, 2011, "Response to Corrective Actions for Notice of Violation (NOV) 05000391/2010603-08"

The purpose of this letter is to provide a revised response (Enclosure 1) for the subject violation. The corrective actions previously provided in Reference 1 have been superseded by those provided in this letter. Enclosure 2 provides a report supplied by an industry expert after having independently reviewed the issues identified by the subject violation. Enclosure 3 provides the list of commitments made in this letter.

TVA's actions to address the subject violation were discussed with NRC Region II management. In particular, TVA clarified its rationale for addressing the rigidity of the local breaker mounting as opposed to the rigidity of the overall panel. Region II requested that TVA further clarify the matter due to their prior understanding that TVA was stating that the overall panel was rigid. Further clarification is provided in Enclosure 1.

IE01
NRR

If you should have any questions, please call William Crouch at (423) 365-2004.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 9th day of June, 2011.

Respectfully,

David Stinson
Watts Bar Unit 2 Vice President

Enclosures

1. TVA's Amended Reply to Notice of Violation 391/2010603-08
2. Industry Expert's Independent Report
3. List of Commitments

cc (Enclosures):

U. S. Nuclear Regulatory Commission
Region II
Marquis One Tower
245 Peachtree Center Ave., NE Suite 1200
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NRC Resident Inspector Unit 2
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Enclosure 1

Watts Bar Nuclear Plant (WBN) Unit 2
"TVA's Amended Reply to the Notice of Violation 391/2010603-08"

Description of the Violation

"10 CFR 50, Appendix B, Criterion III, "Design Control," states that measures shall be established for the review for suitability of application of materials, parts, and equipment that are essential to the safety-related functions of the structures, systems, and components (SSCs). The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program. Where a test program is used to verify the adequacy of a specific design feature in lieu of other verifying or checking processes, it shall include suitable qualifications testing of a prototype unit under the most adverse design conditions.

Contrary to the above, measures used to review the suitability of application of materials, parts, and equipment essential to the safety-related functions of molded case circuit breakers and measures to provide for the verification of checking the adequacy of design, such as, calculational methods, performing a suitable test program, including qualifications testing of a prototype unit under the most adverse design conditions, were not adequate in that:

Example 1

On October 5, 2009, the applicant installed molded case circuit breakers into the 120VAC vital instrument power boards; however, the test program used to seismically qualify a prototype circuit breaker failed to use a suitable mounting method that reflected the most adverse mounting condition."

TVA Response:

TVA admits that the violation occurred.

Reason For The Violation - Example 1:

The reason for this violation is that Calculation WCG-ACQ-1004, "Seismic Evaluation of 120 VAC Vital Instrument Power Boards," failed to fully establish:

a. that the 1992 test mounting represented a suitable mounting method for the testing of replacement breakers and,

b. that the 1992 test bounded the configuration of the breakers installed in 2009, and

c. that the mounting of the replacement breakers installed in 2009 maintained the original rigid mounting.

The calculation should have identified that the method of support for breakers within the board was a rigid mounting system which would have justified the 1992 testing for replacement breakers.

Enclosure 1

Watts Bar Nuclear Plant (WBN) Unit 2
"TVA's Amended Reply to the Notice of Violation 391/2010603-08"

Discussion of Deficiencies and Observations, and Actions Taken (Example 1):

1. TVA has revised Calculation WCG-ACQ-1004 to address the relationship between the original Vital Instrument Power Board qualification performed by Westinghouse in 1974 and the qualification of the replacement breakers performed by Southern Testing Services in 1992. The basis for the 1992 test relied upon the fact that the breakers were considered rigidly locally mounted in the board for the 1974 test. The 1974 test did not assume, or represent, that the entire board is rigid. Since the 1992 test rigidly mounted an individual breaker, the 1992 test provides a suitable mounting method for the testing of replacement Heinemann breakers.

   In summary, the 1974 and 1992 tests confirm that, given the rigid local mount of the breakers in the Vital Instrument Power Board, the seismic qualification of the breaker and 120V AC Vital Instrument Power Board is maintained.

2. To support the fact that the local mounting of the breakers is rigid, TVA performed Calculation WCG-ACQ-1301, "Frequency Evaluation of the Heinemann Breaker Support Structure." The local mounting of the breakers is provided in the front by projection of the breaker bezel through an opening in the front supporting panel and in the rear by pressure from two structural angles. This calculation uses a GT STRUDL eigenvalue analysis to determine the frequency of the front supporting panel. Standard natural frequency equations from Roark's Formulas for Stress and Strain are used to determine the frequency of the rear supporting steel angles.

   The front supporting panel is 10 gauge (0.1345 inch) steel plate with the side edges rolled back approximately two inches at a 90 degree angle. Therefore, the panel looks like a "C" in plan view. The panel also has closure plates welded at the top and bottom so that the panel also looks like a "C" in cross section view. The panel is stiffened with 5/32 inch thick by 1 inch wide vertical stiffeners between every other breaker (5 stiffeners). The stiffeners run the full height of the panel and are welded to the front plate and top and bottom closure plates.

   The result is that by determining the natural frequency of the front supporting panel and rear angles, it is demonstrated that the breakers are mounted in a configuration which has no local amplification. Demonstrating that the local breaker mounting is rigid ensures that the use of seismic motion recorded on the boards during the 1974 testing is the appropriate motion for use in the 1992 testing of replacement breakers.

3. To reinforce the adequacy of the above evaluations, TVA obtained the independent expert opinion of James F. Gleason of the ARES Corporation. Mr. Gleason's report is provided as Enclosure 2 to this letter. Mr. Gleason's credentials are provided on page 16 of his report. According to Mr. Gleason's report:

   a. The Heinemann breakers are rigidly mounted (Questions 4.1 and 4.2)
   b. The 1974 test replicates the mounting configuration (Question 4.2)
   c. Rigid connections were replicated in the 1992 test (Question 4.4)
   d. The reconfigured breakers do not affect the seismic qualification (Question 4.6)

The discussion in Questions 4.1 and 4.2 of the report credits the support provided by the connection of each breaker to the copper buss and copper buss drops for contributing to the rigidity of the mounting arrangement. Photo 1 provided in this enclosure is the Vital Instrument Power Board with the front panel removed to reveal the breakers. It can be seen that the copper buss bar provides vertical support for the breakers (Photos 2 and 3). The report concludes in Question 4.2 that "The rigid electrical connections to the copper buss, the back angle supports, and the front panel clamping created a rigid mounting of the Heinemann Circuit Breaker to the 120 VAC Vital Instrument Power Boards."

The results achieved by the calculations and independent expert opinion are that:

a. The 1974 and 1992 tests adequately represent the installed condition.

b. The 1974 testing met the requirements of IEEE 344-1971 and the 1992 testing met the requirements of IEEE 344-1975.

c. The reconfigured breaker does not invalidate the seismic test results.

4. The 120V AC Vital Instrument Power Boards were inspected to identify and adjust any misaligned breakers so that they are correctly positioned in the front supporting panel opening for maximum support of the breaker. The inspections were accomplished under work orders which provided instructions to identify any breaker that was improperly mounted. Each work order stated that a proper mount is when the breaker bezel is protruding through the front supporting panel. The panel face plate will be against the breaker casing (behind the breaker bezel), and the back of the breaker is supported against the rear angles. Each work order stated that if rework is required to reposition the breaker properly on the front supporting panel, the breaker bezel square corners may need to be rounded to obtain proper fit through the face plate opening. Signatures were required by the performer and the verifier. Post maintenance testing and release for service was also reviewed and signed off by the Responsible Engineer.

   The result is that all breakers in the boards are properly aligned and the bezels project through the front supporting panel opening. Personnel who write work orders related to breakers and personnel who perform work on the breakers have been informed of the condition and have been coached on proper mounting of the breakers.

5. During outage work performed on the Vital Instrument Power Boards, it was discovered that an assembly aid shim, i.e., a small strip of adhesive backed dense foam material, had been applied to the surface of the upper and lower rear support angles which are in contact with the breaker back face. This material accommodates slight differences in the alignment of the rear surfaces of the breakers. This material aids the front to back alignment during assembly. Also during the outage, better visibility of the rigid electrical connections between the circuit breakers and the pair of copper buss allowed photographs of these connections to be taken (See Enclosure 2). The buss connection provides tight confinement in the vertical and

horizontal directions and aids in the confinement between the face plate and the angles. This tight confinement is the basis for considering the breakers to be rigidly mounted.

Since the dense foam material is perceived as serving a useful assembly aid purpose, it was replaced for Unit 2 with a rubber material called EPDM (ethylene propylene diene monomer). The EPDM has a durometer reading of 60 and is soft enough to compress to account for any differences in back face alignment, but hard enough to maintain pressure on the breaker. The use of the EPDM has been added to design output using plant configuration control steps. Also, the use of the EPDM is evaluated and justified in Calculation WCG-ACQ-1004, which is the breaker qualification calculation discussed in item 1 above. The EPDM was installed by removing the rear support angles, removing the dense foam material, attaching the EPDM, and reinstalling the angle.

At the same time that the dense foam material was found, other assembly aid shims, consisting of metal spacers located at the bolted connection between the structural framework of the board and the upper rear support angles, were also discovered. No spacers were found on the lower rear support angles. Although the spacers are not specifically called for on the board detail drawing (CO-33419-MKE-M2), their existence is not believed to be detrimental or to be of any significant benefit. Unlike the dense foam material discussed above which was replaced with EPDM, the spacers were not reinstalled for the Unit 2 boards because the upper rear support angles were considered to be able to perform their function without the spacers.

During the work performed for resolution of the subject violation, it was recognized that the use of the Micarta board on the reconfigured breakers can cause some of the breakers to not be tightly confined between the front panel and the rear support angles. Micrometer readings were taken on the original breakers and the reconfigured breakers with the Micarta board attached. The front-to-back dimension showed the reconfigured breaker dimension was 0.030 inches (1/32 inch) greater than that for the original breaker. Therefore, when reconfigured and original breakers are mixed within a row, the back surfaces may not align perfectly, and high and low spots may result creating slight gaps between some breaker back surfaces and the companion support angles. This type configuration could only have existed on the Unit 2 boards because the breakers in the Unit 1 boards are all of the original configuration. This configuration would not have created a condition where a breaker could become dislodged even if the lack of tightness had gone undetected because the maximum anticipated 1/32 inch (0.03125 inch) movement (gap) would have been less than the 0.1345 inch thickness of the front panel plate.

Another potential source of misalignment of the back face of the original breakers was also investigated. The retainer strip for the auxiliary contact switch is held in place by two screws. These screws are recessed approximately 1/16 inch. Some breakers have been observed to have this recess filled with a caulk-like material. The purpose of the caulk-like material appears to be to restrict access to the screws so they cannot be loosened. If the caulk overfills the hole, it could cause a bump on the back of the breaker, which creates a slight dimensional variability that must be accounted for during installation. The screw holes do not exist on the reconfigured breakers.

When the rear support angles were reinstalled after attaching the EPDM, the breakers were again checked for tightness. Additional EPDM shims were installed when necessary. By using these shims, appropriate tightness has been established on the Unit 2 breakers. The result is that measures have been taken to ensure Unit 2 breakers are tightly restrained between the front cover panel and the rear support angles to achieve local mounting rigidity. A better understanding has also been attained for achieving rigid local mounting for the use of a mixture of original and reconfigured breakers on Unit 2.

6. To ensure that future work activities involving installation of model CF2-Z51-1 Heinemann breakers in the 120V AC Vital Instrument Power Boards are performed correctly, maintenance and modification procedures will be revised or new procedures generated, as necessary, to capture installation instructions and to address lessons learned during the recent outage. Any revisions and new procedure(s) will be implemented by September 30, 2011.

7. The independent expert report prepared by James Gleason and presented in Enclosure 2 reviews conditions which could affect the operation of the breakers (See Question 4.5). The report cites EPRI research reports which determine the seismic performance of breakers subjected to various aging effects and concludes that there was no difference in the seismic performance of aged and un-aged molded case circuit breakers. The report further notes the clamping pressure created by the mounting method does not directly contribute to the safety-related function of the breakers, so there are no significant aging mechanisms that need to be addressed.

   This provides added confidence that the clamping pressure exerted on the breaker by being mounted between the front cover plate and the rear support angle does not hinder operation of the breaker.

8. During the TVA/NRC Public Meeting held on December 16, 2010, NRC staff expressed concern that existing gaps between the breaker casing and the cutout in the front panel facing would allow the breakers freedom of movement to contact each other or the panel and actuate. The NRC also questioned whether the mounting would allow localized accelerations due to the flexibility of the board/mounting. In order to address these concerns, TVA commissioned the independent investigation (see Enclosure 2), which highlights the rigidity contribution of the connection between the Heinemann Circuit Breaker poles and the copper buss. Additionally, prior to the recent outage, TVA performed actions on ten breakers representative of the mounting configuration of subject breaker population. None of the sampled breakers were under electrical load in order to avoid operational issues, but all were electrically connected, as required. After the recent outage, a 100 percent push test was performed on May 23, 2011, for the circuit breakers in the Unit 1 and Unit 2 Vital Instrument Power Boards.

The actions taken with results achieved are provided below:

a. For the ten breaker population, the breakers were inspected to determine whether a "good mount" existed. A "good mount" meant that the breaker bezel fully extended through the face of the board at the top and bottom of the bezel. The ten breakers chosen exhibited a "good mount."

b. For the ten breaker population, measurements were taken around each of the breaker bezel edges from the front panel location using feeler gauges. The greatest gap identified was found to be 0.057 (<1/16) inches. From a general observation of the Vital Instrument Power Boards, these results could be expected for all breakers.

c. For the ten breaker population, a ten-pound force was applied to each breaker using a push gauge in the east, west, north, south, up and down directions. This is the conservatively determined force that the breaker would experience in a seismic event. South was applied by opening the back door of the board and pushing on the back of the breaker. Multiple persons witnessed this activity with no breaker movement observed when the forces were applied.

d. For the 100 percent breaker population, a ten-pound force was applied to each breaker in the Unit 1 and Unit 2 boards using a push gauge and recording any movement of the breaker. There was no movement recorded on any of the 384 breakers tested (48 breakers per board times 8 boards). An NRC representative was present and verified that all breakers were tested and no movements were recorded.

The results demonstrated that the breakers are rigidly mounted from a local perspective and no movement of the breaker would occur during a seismic event. The configuration of the front supporting panel and rear support angles, as described in item 2 above, provides stiffness and does not allow the front plate or angles to deflect independently. The gap measurement also demonstrated that any movement which might unexpectedly occur would be very small.

<u>Date When Full Compliance Will Be Achieved</u>.

In summary, the discussions above provide the following information:

A. The qualification tests performed in 1974 and 1992 have been reviewed and determined to be consistent with the existing field condition.

B. The breakers have been determined to be rigidly locally mounted in the boards.

C. The breakers have been confirmed to be properly mounted with respect to the bezel properly protruding through the panel opening and with respect to the breaker being rigidly (tightly) locally mounted. Any breakers not meeting these conditions were repaired to be acceptable.

D. For Unit 2, dense foam strips which were not shown on design output were replaced with EPDM. Metal spacers, which were also found not to be on design output, were also removed.

E. Clamping pressure was shown to not hinder breaker operation.

F. Representative gaps between the bezel and front panel opening were measured and found to only allow small displacement in the unlikely event of any movement. Push tests on a 100 percent population indicated that the breakers did not displace under application of an anticipated seismic load.

With respect to the current breaker mounting configurations, TVA is in full compliance. With respect to recurrence control for this violation example, TVA will provide the procedure installation guidance as discussed previously by September 30, 2011.

Enclosure 1

Watts Bar Nuclear Plant (WBN) Unit 2
"TVA's Amended Reply to the Notice of Violation 391/2010603-08"

Photo 1

Photo 2

Photo 3

Example 2

"On September 3, 2009, the applicant failed to perform an adequate review for suitability of application parts and material used to modify dimensional critical characteristics in molded case circuit breakers; further, the applicant failed to verify the adequacy of design for the modification and the effects on essential safety related functions of the circuit breakers."

TVA Response:

TVA admits that the violation occurred.

Reason For The Violation - Example 2:

The reason for this violation is that the manufacturer made a production change to the breaker configuration but did not revise the model number or publish schematics to reflect a component change. As a result, TVA failed to identify a change in a critical characteristic (i.e., the required mounting depth between the front face and the rear angles) and the resulting impact on device seismic qualification and functionality. Rather than performing a new equivalency evaluation, TVA applied a technical evaluation for the reconfigured breakers with an added Micarta spacer board and concluded that the breakers were seismically and functionally qualified.

Corrective Steps That Have Been Taken And The Results Achieved (Example 2):

1. TVA performed an equivalency evaluation for the reconfigured Heinemann breakers that identifies the critical characteristics, addresses the role of the Micarta spacer board in restoring the needed mounting depth for contact between the rear angles and front-face panel, and addresses seismic qualification requirements. The evaluation has been issued as Attachment I to Calculation WCG-ACQ-1004. Calculation WCG-ACQ-1004 also performs an engineering evaluation of the reconfigured breaker to address the seismic qualification of the breaker.

   The change in configuration is due to an alteration in the manner in which the auxiliary contact switch is retained within the body of the molded case circuit breaker. The original breaker retained the switch with an externally mounted retainer plate attached to the backside of one pole with fasteners. The reconfigured breaker, which is the subject of the NOV, retains the switch by use of a molded insert attached with retaining tabs in the molded case body. The reconfigured breaker is installed using a Micarta board as a spacer plate.

   As a result, the reconfigured replacement breaker when fitted with the spacer board is equivalent to the original breaker in form, fit, and function and is acceptable for installation.

2. Since the breakers cannot be distinguished by the manufacturer's model number, they have to be distinguished by unique TVA inventory numbers called CATIDs. The original breakers have a CATID number of CEW199V. A note has been placed in the tracking data base for CEW199V, which says: "For future procurement use

CATID CQQ548K. CATID CEW199V breaker contains a configuration change in the auxiliary switch mounting and is now obsolete."

A unique identifier CATID of CQQ548K has been established for the reconfigured breaker and will be used for future purchases of the reconfigured breakers for WBN Unit 1 and Unit 2. The item description is the same as for CEW199V except the statement "with reconfigured auxiliary switch mounting" has been added. The following additional receipt inspection instruction has also been added: "Ensure the breaker(s) contain the reconfigured auxiliary switch mounting on the breaker(s) back (a small molded retaining frame around the auxiliary switch only in lieu of a 1/4" thick molded rectangular plate attached to the breaker(s) rear of one pole extending from top to bottom along the breaker(s) body). If the 1/4" molded plate for the auxiliary switch exists, the breaker(s) should be placed into CATID CEW199V."

As a result, there are two unique inventory tracking numbers (CATIDs) which will distinguish the reconfigured breakers from the original breakers, CATID CEW199V for the original breaker and CATID CQQ548K for the reconfigured breaker. Confirmation of the breaker dimensions during receipt inspection and a heightened awareness that the breakers are similar will ensure that the breakers are properly segregated.

3. TVA drawing 45N701-4, Rev. E, has been revised to provide instructions to add the Micarta spacer board, when necessary. Westinghouse drawings CO33419MKEM2 thru M6 have been revised to show the correct orientation of the rear support steel angles.

   As a result, the TVA drawing provides appropriate installation instructions and ensures that both the TVA and Westinghouse drawings are consistent and show the proper installed configuration.

<u>Date When Full Compliance Will Be Achieved</u>.

In summary, the discussions above provide the following information:

A. The change in configuration from the original breaker is due to an alteration in the manner in which the auxiliary contact switch is retained within the body of the molded case circuit breaker. A Micarta board is used as a spacer plate to account for the change in the front-to-back dimension.

B. The breakers with the new configuration are referred to as reconfigured breakers. A unique TVA inventory number called a CATID has been established for the reconfigured breaker.

C. The TVA drawing has been revised to provide appropriate installation instructions. Both the TVA and Westinghouse drawings are consistent and show the proper installed configuration.

With respect to this violation example, TVA is currently in full compliance.

Enclosure 2

Industry Expert's Independent Report

White Paper on
120 VAC Vital Instrument Power Boards
and
Heinemann Circuit Breakers
Seismic Qualification for Watts Bar

James F. Gleason, P.E. Date 5/26/2011

1. Introduction and Purpose

The Tennessee Valley Authority was issued Notice of Violation 391/2010603-08, "Failure to Adequately Evaluate and Qualify Molded Case Circuit Breakers" in a letter dated August 5, 2010 (Reference 2.1). Subsequent correspondence is contained in letters References 2.2, 2.3, 2.4 and 2.5. ARES Corporation was requested by TVA to make an independent technical review of the qualification for what is termed within these documents as the original and reconfigured Heinemann molded case circuit breakers, the TVA responses to the Notice of Violation, and subsequent actions.

Therefore, the purpose of this report is to document the independent review of the qualification for the original and reconfigured Heinemann molded case circuit breakers, the TVA responses to the Notice of Violation, and subsequent actions. This report provides information on background, the independent evaluation and conclusions.

2. References

2.1 NRC letter to TVA, "Watts Bar Nuclear Plant Unit 2 Construction - NRC Integrated Inspection Report 05000391/2010603 and Notice of Violation," dated August 5, 2010 (ML102170465)

2.2 TVA letter to NRC, "Watts Bar Nuclear Plant (WBN) Unit 2 - Denial of Notice of Violation (NOV) 05000391/2010603-08, Failure to Adequately Evaluate and Qualify Molded Case Circuit Breakers," dated September 7, 2010 (ML102520435)

2.3 TVA letter to NRC, "Watts Bar Nuclear Plant (WBN) Unit 2 - Denial of Notice of Violation (NOV) 05000391/2010603-08, Failure to Adequately Evaluate and Qualify Molded Case Circuit Breakers - Additional Information," dated October 15, 2010 (ML102880493)

2.4 NRC letter to TVA, "Response to Disputed Notice of Violation (NOV) 05000391/2010603-08," dated October 19, 2010 (ML102920665)

2.5 TVA letter to NRC, "Watts Bar Nuclear Plant Unit 2 - Reply to Notice of Violation 05000391/2010603-08 - Failure to Adequately Evaluate and Qualify Molded Case Circuit Breakers," dated November 24, 2010.

2.6 Westinghouse Drawings, Drawings 120 VAC Vital Instrument Power Bds Units 1-I & 2-I Component Location numbers CO-33419-MKE-M2, CO-33419-MKE-M3, CO-33419-MKE-M4, CO-33419-MKE-M5, and CO-33419-MKE-M6.

2.7 TVA Record B07 890914 035. Seismic Test Report on 120 VAC Vital Instrument Power Boards for Watts Bar & Sequoyah Nuclear Plant, Units 1 &2, Tennessee Valley Authority, TVA 73C2-83010 & 74C4-85126, Wesst. #CO-32699-MKE & CO-33419-MKE Shop Order 49672 & 10073, Dated 12-16-74.

2.8 Southern Testing Services, Inc Report No. S522-RP-02, " Nuclear Environmental and Seismic Qualification for Heinemann Electric company Circuit Breaker Part Number CF2-Z51-1, dated September 25, 1992.

2.9 Westinghouse Electric Corporation Bill of Material, "Tennessee Valley Authority 120 VAC Vital Instrument Power Boards Watts Bar Nuclear Plant, 7107-10073, CO-33419-MKE-BM, Rev. 0, TVA Approval October 10, 1974.

2.10 Eaton Publication CB.QG.01 / 5.98, "Heinemann® Circuit Breakers, 1998.

2.11 Electric Power Research Institute, NP-3326, "Correlation Between Aging and Seismic Qualification for Nuclear Plant Electrical Components", 1983.

2.12 Electric Power Research Institute, NP-5024, "Seismic Ruggedness of Aged Electrical Components", 1987.

2.13 MIL-STD 202, "Test Method Standard, Electronic and Electrical Component Parts"

2.14 TVA Post Issue Change 57915, Drawing 45N7014, "Replacement of Heinemann Breakers"

3. Background

The Tennessee Valley Authority procured 120 VAC Vital Instrument Power Boards for the Watts Bar Nuclear Plant per TVA Contract # 74C4-85216.

The Drawings (Reference 2.6) for the 120 VAC Vital Instrument Power Bds Units 1-I & 2-I Component Location numbers CO-33419-MKE-M2, CO-33419-MKE-M3, CO-33419-MKE-M4, CO-33419-MKE-M5, and CO-33419-MKE-M6 identify in note 1 that the boards and devices mounted there on as shown on this drawing will be used in a Class 1 System as defined in IEEE Publication 308 (See Figure 1)

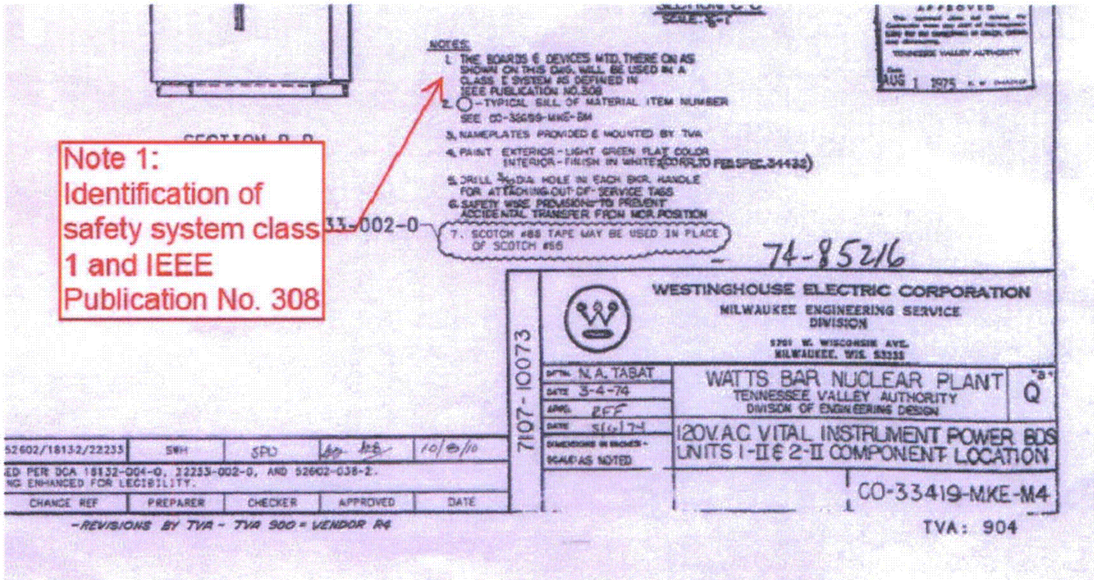


Figure 1. TVA Drawing CO-33419-MKE-M4, Note 1.

IEEE Publication 308 became IEEE Std 308-1970 and was prepared by Subcommittee 4, Auxiliary Power Systems of the Joint Committee on Nuclear Power Standards (JCNPS) of the IEEE Nuclear Science Group and the IEEE Power Engineering Society (PES). IEEE Std 308-1971 incorporated the experience of the first edition and added multiunit considerations. IEEE Std 308-1974 was completed by Working Group 4.1 of Subcommittee 4 of JCNPS, which had become the Nuclear Power Engineering Committee (NPEC) of the PES in 1973.

IEEE Std 308 notes that the portions of the Class 1E power system that contribute to performing a safety function must comply with the requirements. However, the components, equipment and systems within the Class 1E power system that perform no direct safety function (e.g., overload devices, protective relaying, etc.) must meet the requirements that assure that those components, equipment, and systems do not degrade the Class 1E power system below an acceptable level.

The Heinemann Circuit Breakers Style Number CF-2-15-240-3 are two pole circuit breakers and are located in the 120 VAC Vital Instrument Power Boards. The Heinemann Circuit Breakers feed both Safety and Non-Safety related loads in the 120V AC Vital Instrument Power Boards and hence perform a safety function.

The above noted drawings show that each Heinemann Circuit Breaker is electrically connected to a pair of 1 ¼ X ¼ copper bus through 1/8 X ½ copper bus drops in Section C-C (see Figure 2) One top pole of each breaker is electrically connected to one of the pair of 1 ¼ X ¼ copper bus through 1/8 X ½ copper bus drops and the other top pole of each breaker is electrically connected to the other of the pair of 1 ¼ X ¼ copper bus through 1/8 X ½ copper bus drops.

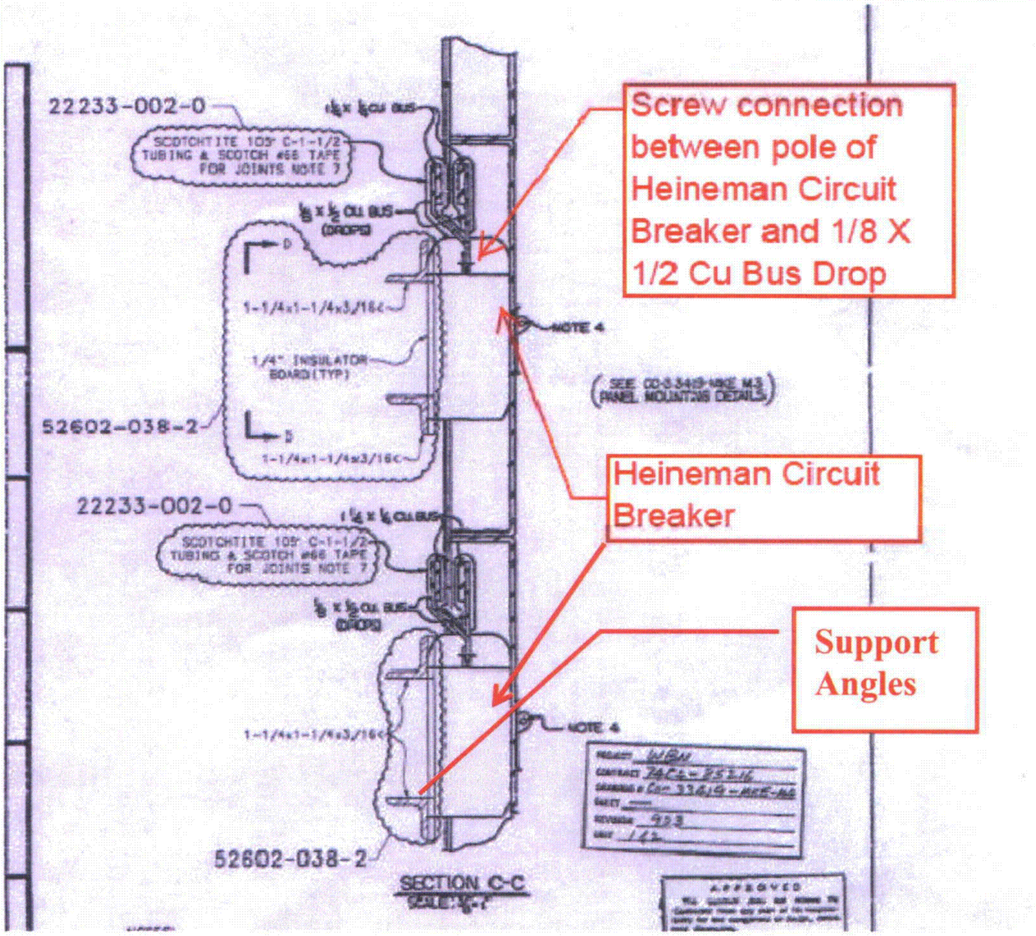
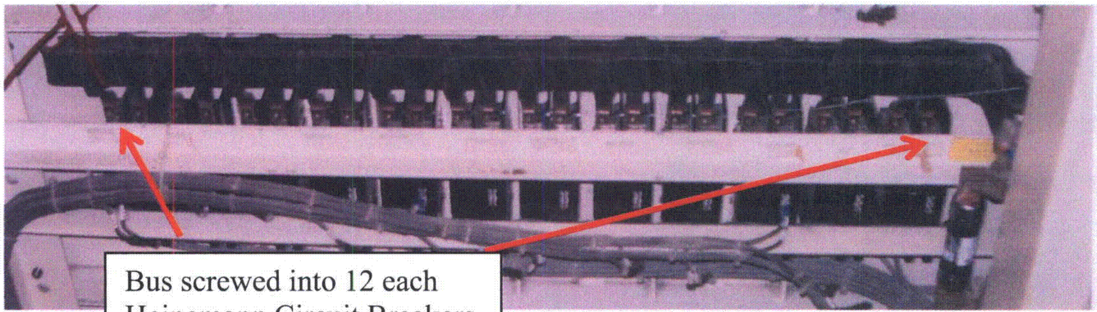


Figure 2. TVA Drawing CO-33419-MKE-M4, Section C-C.

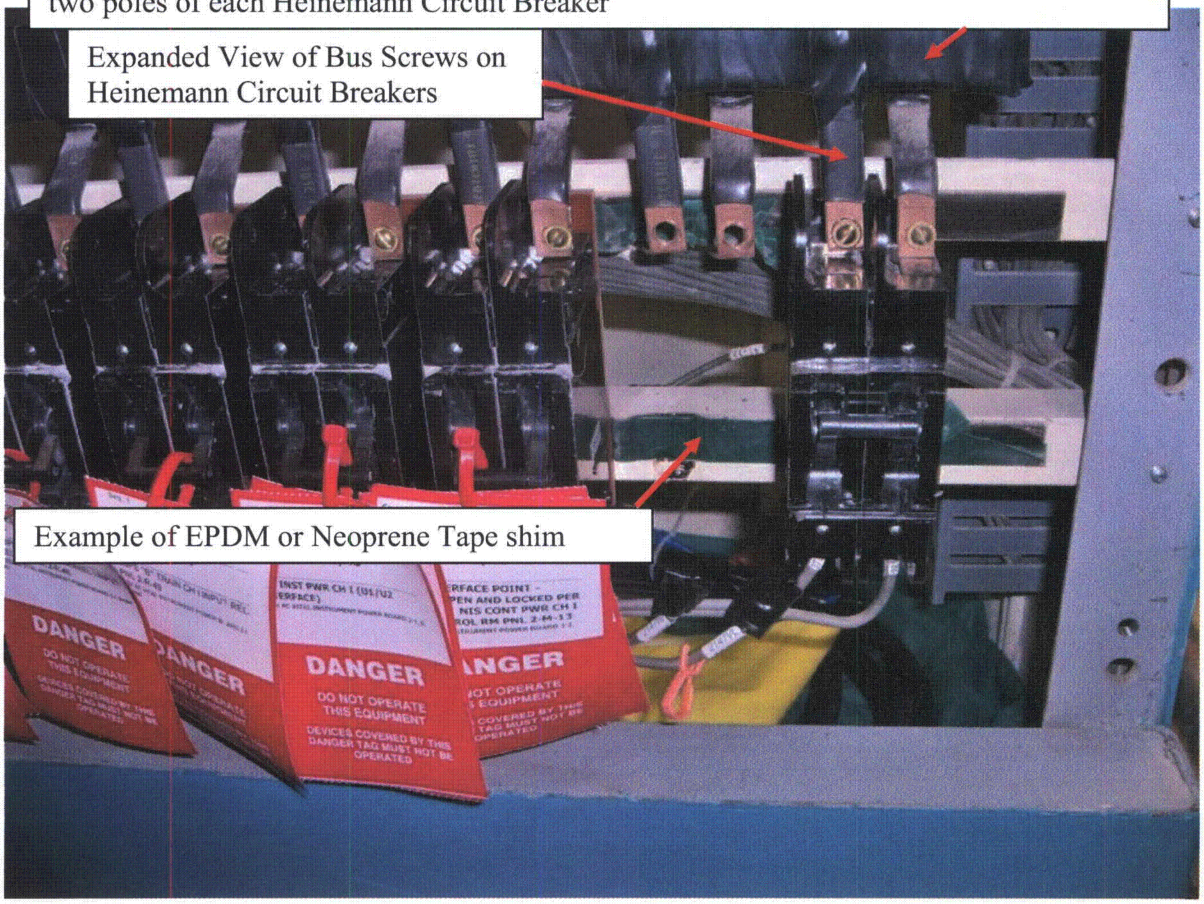
The bottom pole of each Heinemann Circuit Breaker is electrically connected to a wire for the electrical circuit to which it is connected.

Each of the two 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drops are wrapped in electrical tape per note 7 of the above drawings. Therefore the two 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drops are covered in black electrical tape and are not easily noted in some of the photographs taken of the 120 VAC Vital Instrument Power Boards.

Figure 3 of this paper points out the two 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drops and highlights that each of the two poles of each Heinemann Circuit Breaker is connected to one, then the other, of the two 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drops. Assembly aide shims consisting of spacers and /or EPDM or Neoprene resilient tape shims (TVA Post Issue Change 57915, Reference 2.14) may be installed on old/new breakers as necessary with dimensions determined in the field.



Two 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drops connected to each of the two poles of each Heinemann Circuit Breaker



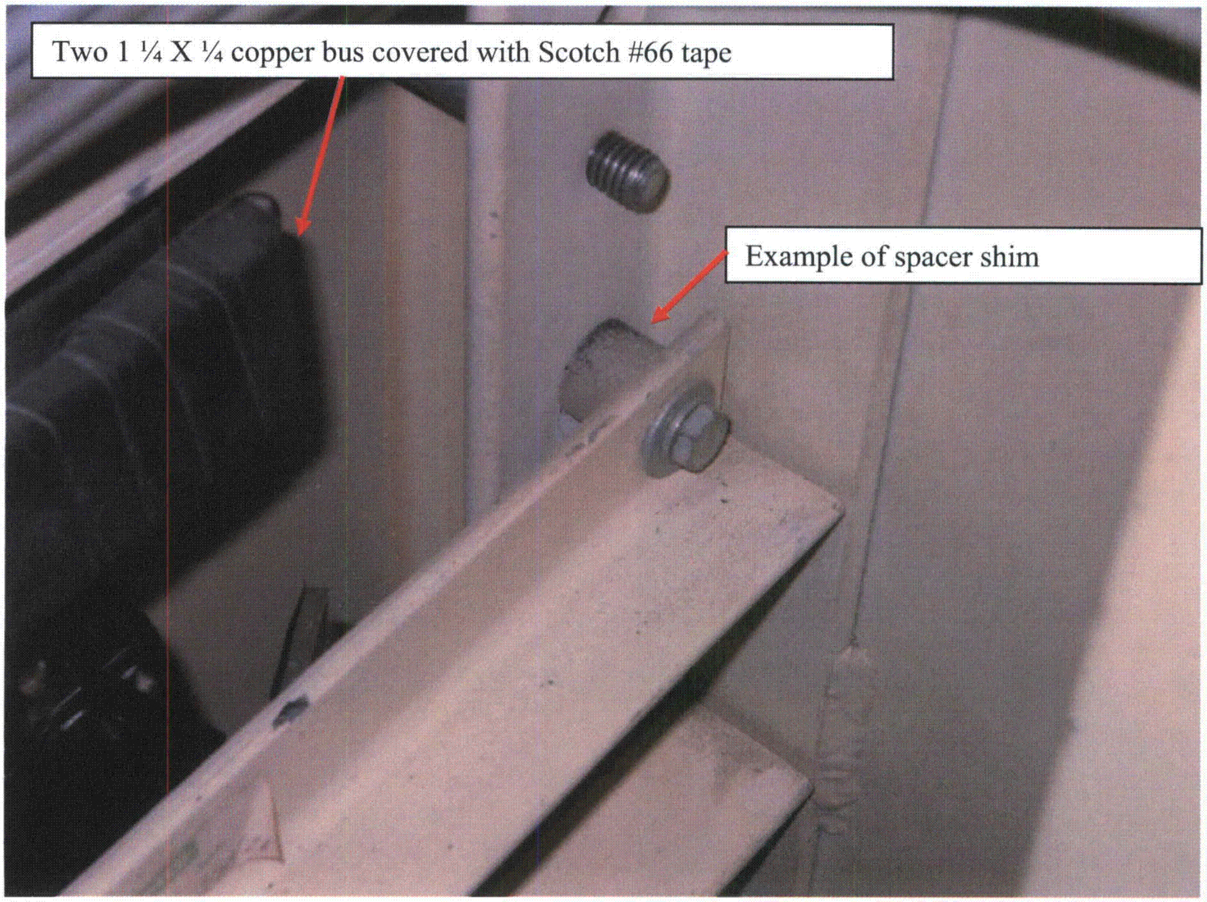


Figure 3. Photographs of Bus attachments for Heinemann Circuit Breakers

Cabinet Construction

The cabinets for the 120 VAC Vital Instrument Power Boards are engineered cabinets designed for seismic performance. The drawing (Reference 2.6) for the 120 VAC Vital Instrument Power Bds Steel Details CO-33419-MKE-M2 identify in note 3 that the fabrication and welding must withstand seismic tests. Several structural details to enhance seismic performance are identified in the drawing CO-33419-MKE-M2, some examples of these seismic details are shown in Figure 4, which show in Section A-A the seismic gusset features of 12 X 6 ¼ gussets, 6 X 6 ¼ gussets, and 4 X 4 ¼ gussets, and in Figure 5 Section B-B the seismic gusset features of eight 4 X 4 ¼ gussets. Additional structural details to enhance seismic performance are identified in Figure 2 drawing CO-33419-MKE-M4 Section C-C, which show the two 1-1/4 X 1 – ¼ X 3/16 support angle braces mounted behind each Heinemann Breaker. This allows the breaker to be rigidly mounted. Figure 4 shows that there are a total of eight of the support angle braces in the cabinets. Figure 6 is a photograph which shows the support angles and additional features, such as the horizontal stiffeners and vertical stiffeners. All of these structural features coupled with the 10 gauge steel construction are designed to ensure the seismic qualification for the circuit breakers.

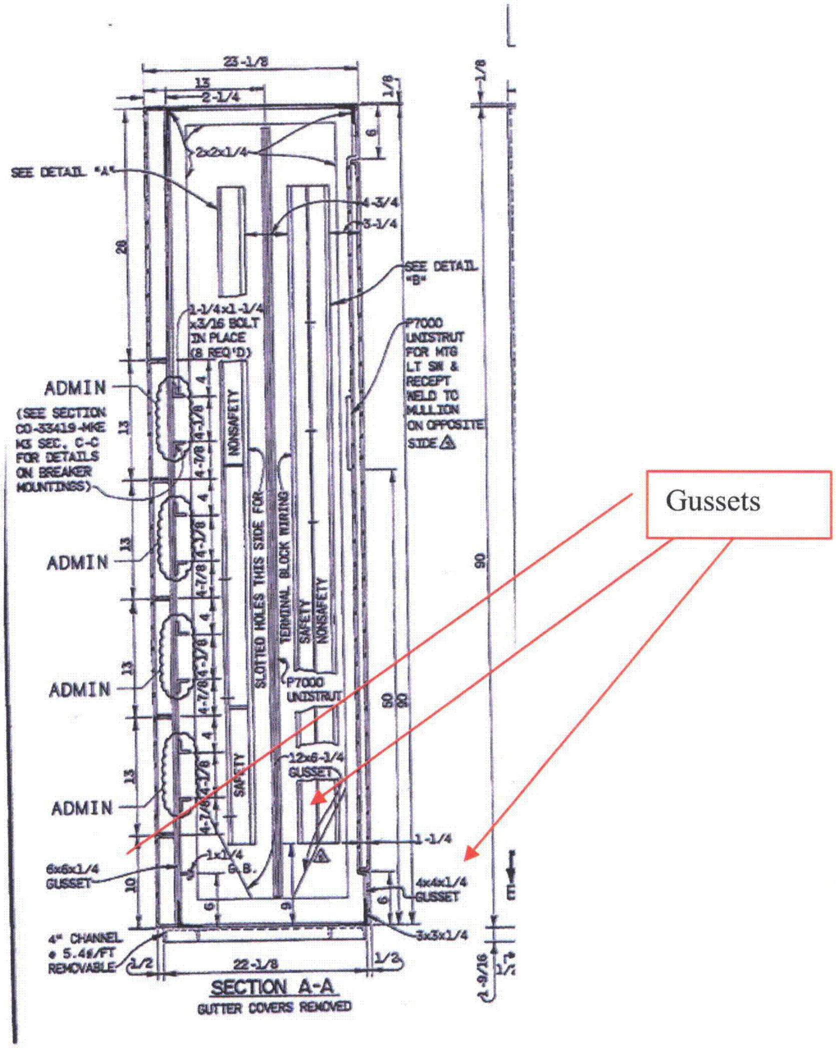


Figure 4. Section A-A of Drawing CO-33419-MKE-M2, 120 VAC Vital Instrument Power Bds, Steel Detail, Gusset Locations

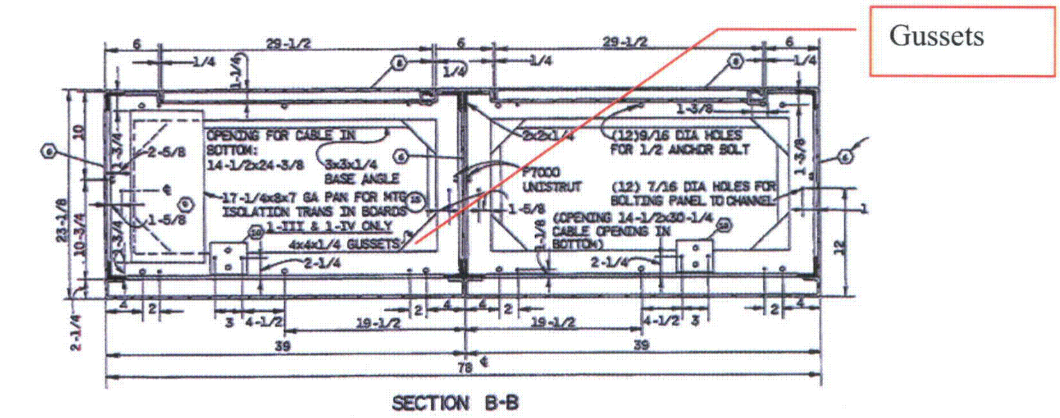


Figure 5. Section B-B of Drawing CO-33419-MKE-M2, 120 VAC Vital Instrument Power Bds, Steel Detail, Gusset Locations

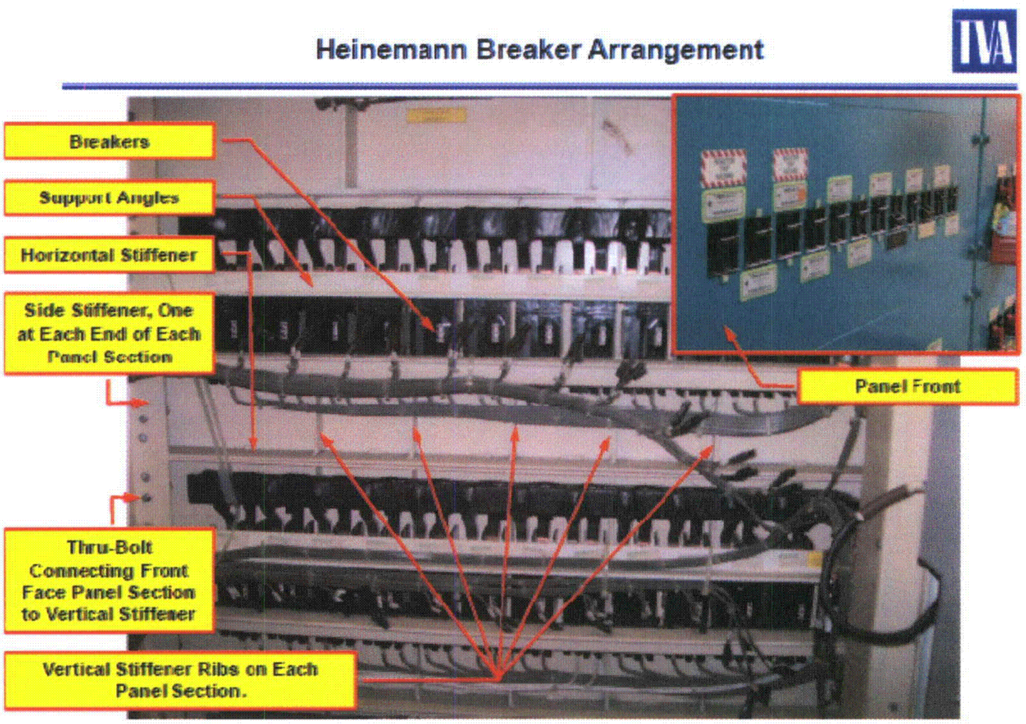


Figure 6. Photograph of inside of 120 VAC Vital Instrument Power Bds, Stiffener Detail

Circuit Breakers are Designed to Allow for Internal Movement

The Heinemann Circuit Breakers Style Number CF-2-15-240-3 are two pole circuit breakers. The poles at the top and bottom of the circuit breakers are purposely captured, but not rigidly mounted in the phenolic shell. The reason that they have some internal play is to accommodate electrical bus and electrical wire which connect at approximate right angles but need to be slightly flexible to adjust for a good electrical connection from the 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drop. The picture below, Figure 7, shows the inside of the Heinemann Circuit Breakers with the cover removed.

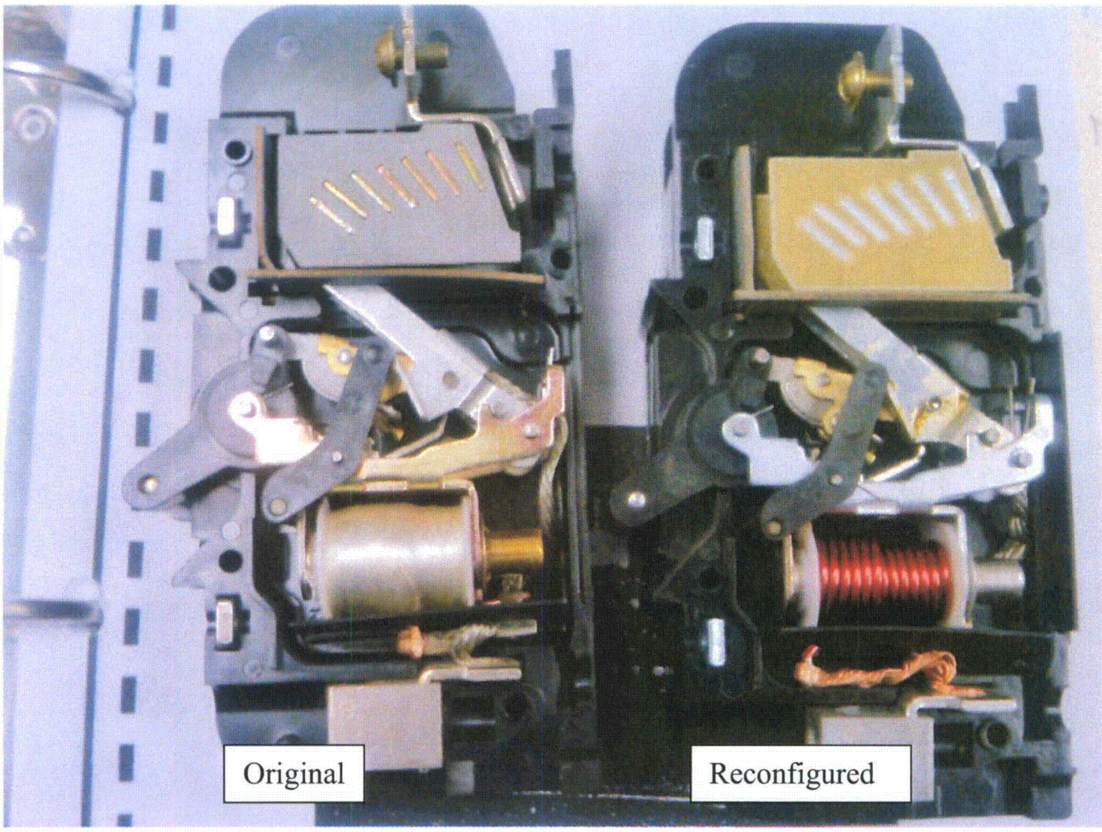


Figure 7. Inside of Original and Reconfigured Heinemann Circuit Breakers, Shown in Tripped or Open State.

The top poles and bottom poles are captured in indentations in the phenolic shell but are free to adjust to make electrical connections. Additionally, inside the Heinemann Circuit Breakers braided copper is used to accommodate flexing from the electrical connections and to allow movement when large electrical loads are present.

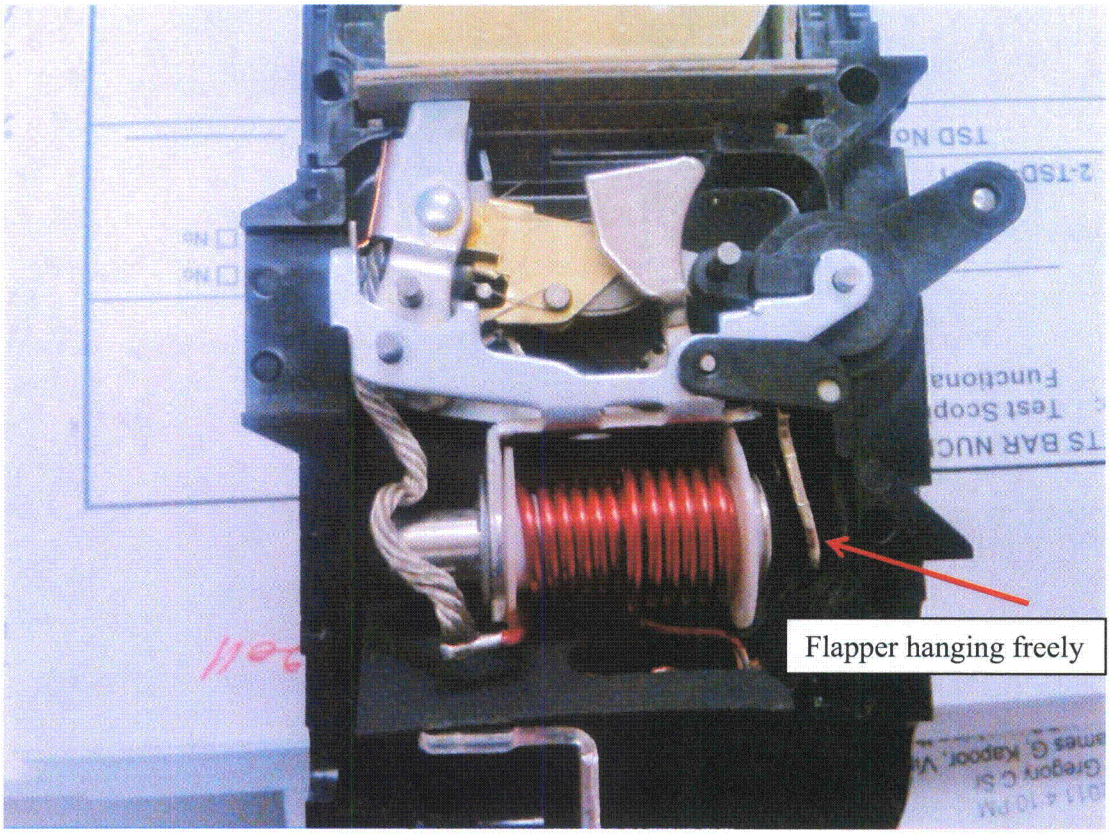


Figure 8. Inside of Heinemann Circuit Breaker shown in energized or closed state.

Figure 8 shows the inside of a Heinemann Circuit Breaker shown in energized or closed state. In this state the trigger is set and the flapper hangs freely, just away from the magnetic pole. When a large electrical current is applied to the circuit breaker, the coil creates an electromagnetic field and draws the flapper towards the pole. When the flapper nears the pole, the flapper initiates release of the stored energy that was created when the breaker was energized and the circuit breaker trips.

As noted in IEEE Std 308, the portions of the Class 1E power system that contribute to performing a safety function must comply with the requirements. However, the components, equipment and systems within the Class 1E power system that perform no direct safety function (e.g., overload devices, protective relaying, etc.) must meet the requirements that assure that those components, equipment, and systems do not degrade the Class 1E power system below an acceptable level.

The acceptable level to not degrade the Class 1E power system for a circuit breaker during a seismic event is to not trip, when the circuit is supposed to be closed, such as when it is energized and no electrical fault is present, and to not close a circuit when the circuit is supposed to be open.

A description of the trip characteristics of the Heinemann Circuit Breakers is in Reference 2.10, which notes that the breakers have a counterbalanced armature design that helps prevent mechanical tripping caused by shock and vibration. Heinemann notes that this feature meets MIL-STD-202 (Reference 2.13) requirements. Also noted is that the toggle and latch are strong, durable and highly efficient. The latch is stated to be shock resistant, but provides very fast operation. It states that the trip-free construction makes it impossible to hold the breaker closed against a fault, and even when the handle is held in the ON position, the contacts trip free of fault condition.

4. Evaluation

The client posed the following issues and asked for an independent evaluation. Each issue is covered by a question and evaluation.

4.1 Question: Are the Heinemann Circuit Breakers rigidly mounted in the 120 VAC Vital Instrument Power Boards?

In the TVA letter to NRC dated November 24, 2010, Reference 2.5, TVA notes that TVA performed Calculation WCG-ACQ-1301 to verify the rigidity of the breaker mounting assembly consisting of the two rear angles and front-face panel section.

Not credited in the calculation or regulatory documentation provided for review is a significant additional contribution to rigidity, i.e., that for each Heinemann Circuit Breaker in the 120 VAC Vital Instrument Power Boards one pole of the Heinemann Circuit Breaker is rigidly connected to one 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drop and the other pole of the Heinemann Circuit Breaker is rigidly connected to the other 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drop for each lineup of Heinemann Circuit Breakers.

The result of connecting one pole of the Heinemann Circuit Breaker to one 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drop, and the other pole of the Heinemann Circuit Breaker to one 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drop, is that this support arrangement creates a good electrical connection and a captured, rigidly mounted circuit breaker relative to the bus in both horizontal directions and the vertical direction.

The Heinemann Circuit Breaker housings are then additionally rigidly captured by the back angle supports and the front cover panel.

The front to back portions of the panel, the front-face cover plate, and rear support angles , along with the two connections for each circuit breaker that are connected to the two 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drop, provide the required seismic support to ensure the safety function of the breakers. These features taken together provide the necessary structural integrity, rigidity, and seismic mounting infrastructure to create a rigid mounting structure for the Heinemann circuit breakers. The TVA calculation shows the supporting arrangement of rear angles and front-face panel is rigid, and the drawings and photographs show that Heinemann Circuit Breakers are rigidly mounted in the cabinet through the copper bus connections and front panel and back angle supports.

The resultant rigidly mounted Heinemann Circuit Breakers therefore see seismic levels and motion that are limited due to the structural rigidity of the mounting arrangement and bus connections.

Therefore, the Heinemann Circuit Breakers are rigidly mounted to the 120 VAC Vital Instrument Power Boards.

4.2 Question: Did the 1974 test replicate the mounting configuration in the plant?

In Reference 2.2, TVA cited the following as bases for disputing the NRC's conclusion that a violation occurred: Westinghouse seismically tested the 120VAC Vital Instrument Power Board assembly with Heinemann Model CF2-Z51-1 circuit breakers in 1974, mounted in place solely by clamping pressure applied by the front cover pushing twelve breakers against the rear angle supports. There were no additional screws to secure the breaker to the frame. This configuration duplicated the actual configuration in the plant.

While it is a fact that no additional screws were used to secure the breaker to the frame, the two screws that rigidly connect the breaker electrical connections to the pair of 1 ¼ X ¼ copper bus through 1/8 X ½ copper bus drops were not addressed. As noted above, and discussed further below, this attachment provides an additional support mechanism for the breakers in the horizontal and vertical directions.

The 120 VAC Vital Instrument Power Boards for the Watts Bar Nuclear Plant per TVA Contract # 74C4-85216 were required to be seismically qualified. The initial seismic test utilized as the test specimen a complete 120 VAC Vital Instrument Power Board for the Watts Bar Nuclear Plant per TVA Contract # 74C4-85216. The seismic test references the appropriate TVA drawings. The Heinemann Circuit Breakers were electrically monitored and verified to operate properly in both the energized and de-energized states.

The primary mounting configuration that directly contributes to the safety related function of the Heinemann Circuit Breakers are the rigid electrical connections to the pair of 1 ¼ X ¼ copper bus through 1/8 X ½ copper bus drops in Section C-C, see Figure 2. One top pole of each breaker is rigidly electrically connected to one of the pair of 1 ¼ X ¼ copper bus through 1/8 X ½ copper bus drops and the other top pole of each breaker is electrically connected to the other of the pair of 1 ¼ X ¼ copper bus through 1/8 X ½ copper bus drops. The next important configuration is that the Heinemann Circuit Breakers are vertically mounted. Vertical mounting configuration is important since the breakers are vertically mounted in the 120 VAC Vital Instrument Power Boards, which places the Heinemann hydraulic-magnetic coil in a horizontal position and allows the flapper to hang vertically. This constitutes the seismically qualified configuration of the coil and flapper. The flapper hanging vertically avoids the added force of gravity that would have to be overcome by the magnetic field on the flapper for a tripping function, should the Heinemann Circuit Breaker be mounted other than vertically. Completing the configuration is the presence of the back angle supports and the clamping of the front panel.

The rigid electrical connections to the copper bus, the back angle supports, and the front panel clamping created a rigid mounting of the Heinemann Circuit Breaker to the 120 VAC Vital Instrument Power Boards.

Therefore, the 1974 seismic test replicated the mounting configuration in the plant.

4.3 Question: Did the original seismic test meet IEEE 344 requirements?

The 120 VAC Vital Instrument Power Boards for the Watts Bar Nuclear Plant per TVA Contract # 74C4-85216 were required to be seismically qualified. Therefore, the initial seismic test utilized as the test specimen a complete 120 VAC Vital Instrument Power Boards for the Watts Bar Nuclear Plant per TVA Contract # 74C4-85216.

By using a complete power board, all of the important safety related interconnections, such as the 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drops were properly simulated. In particular the arrangement, interconnections, and vertical orientation of the Heinemann Circuit Breakers, the 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drops, front panel, and back support angles were tested. By using the complete power board, all of the structural attributes and characteristics were also seismically tested. The clamping forces caused by the support angles and the front cover plate were present and helped contribute to a rigid mounting for the circuit breakers.

The power board and the Heinemann Circuit Breaker passed the seismic test in both the energized state and the tripped state. No degradation of the Class 1E power system was noted in the seismic test.

During the testing additional accelerometers captured the highest seismic accelerations in the panels.

The seismic levels significantly exceeded the TVA Watts Bar acceleration level requirements. A maximum acceleration of 2.72 g was recorded in Reference 2.7

The 120 VAC Vital Instrument Power Boards and Heinemann Circuit Breakers met the IEEE 344-1971 seismic requirements.

4.4 Question: Was there an incorrect application of IEEE 344-1975 and the application of the 1992 test to the plant configuration?

In 1992 replacement Heinemann Circuit Breakers were tested while attached to a rigid test fixture in the proper vertical orientation. Since the Heinemann Circuit Breakers had been rigidly connected to the 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drops, front panel, and rear angle supports in the original test, rigidly attaching the Heinemann Circuit Breakers to the seismic test fixture adequately simulated their rigid mounting from the original test.

The seismic input in the 1992 test was adjusted from the original ground motion input to the highest acceleration recorded from the accelerometers located near the Heinemann Circuit

Breakers in the original test in order to envelop the highest input from the original test at the location of the circuit breakers.

Both the energized state and the tripped state were seismically tested. The acceleration levels were higher than the original test. The 1992 seismic test, Reference 2.8, used 3.0 g as the input to the seismic motion, which is higher than the 2.72 g maximum acceleration result from the 1974 test, Reference 2.7. The result of the seismic test was that the Heinemann Circuit Breaker performed properly. The higher accelerations did not change the results that circuit breakers in the energized state stay energized and in the tripped state stay tripped.

As noted previously, the Heinemann Circuit Breaker is within the Class 1E power system, and portions of the Class 1E power system that contribute to performing a safety function must comply with the applicable requirements of IEEE Std 308. However, the components, equipment and systems within the Class 1E power system that perform no direct safety function (e.g., overload devices, protective relaying, etc.) must meet the requirements that assure that those components, equipment, and systems do not degrade the Class 1E power system below an acceptable level.

By connecting the Heinemann Circuit Breaker directly and rigidly to the fixture on the seismic table, the rigid connections in the 120 VAC Vital Instrument Power Boards were replicated in the 1992 seismic test. Adjusting the seismic input to the highest enveloping condition from the 1974 tests and electrically connecting the Heinemann Circuit Breakers during the seismic test and verifying energized and deenergized safety functions properly applied IEEE 344-1975 during the 1992 seismic tests.

4.5 Question: Are there significant aging effects that affect the safety related function of the Heinemann Circuit Breakers from the pressure of the clamping arrangement that should be addressed?

The primary mounting configuration that directly contributes to the safety related function of the Heinemann Circuit Breakers are the rigid electrical connections to the pair of 1 ¼ X ¼ copper bus through 1/8 X ½ copper bus drops in Section C-C, see Figure 2. One top pole of each breaker is rigidly electrically connected to one of the pair of 1 ¼ X ¼ copper bus through 1/8 X ½ copper bus drops and the other top pole of each breaker is electrically connected to the other of the pair of 1 ¼ X ¼ copper bus through 1/8 X ½ copper bus drops. The next important configuration is that the Heinemann Circuit Breakers are vertically mounted. Completing the configuration is the presence of the back angle supports and the clamping of the front panel.

The effect of aging on the seismic performance of safety related electrical equipment was addressed in the EPRI research reports, References 2.11 and 2.12. Molded case circuit breakers similar to the Heinemann Circuit Breakers were tested in Reference 2.12. During the testing samples of molded case circuit breakers were thermally-aged, radiation-aged, and cycle-aged. The aged circuit breakers and unaged circuit breakers were then seismically tested to very high table limit seismic levels, using the IEEE 344-1975 process. The purpose of seismically testing aged and unaged molded case circuit breakers at the same time was to evaluate potential differences in seismic performance caused by aging. All of the aged and unaged molded case circuit breakers passed the seismic test. There was no difference in the seismic performance of aged and unaged molded case circuit breakers.

The seismic performance of molded case circuit breakers was not correlated to aging as noted in this research. Put another way aging did not affect the seismic performance of molded case circuit breakers.

Since (1) molded case circuit breakers are not age sensitive in mild environments in nuclear plants, (2) aging does not affect the seismic performance, and (3) the clamping pressure does not directly contribute to the safety related function of the Heinemann Circuit Breakers, there are no significant aging mechanisms that need be addressed.

4.6 Question: Do the reconfigured Heinemann Circuit Breakers affect the seismic qualification?

The safety related function of the Heinemann Circuit Breakers is related to the electrical auxiliary power function as noted above. Figures 7 and 8 show the internal components of the Heinemann Circuit Breakers that contribute to the safety function. The reconfigured breakers did not change the safety related internals of the Heinemann Circuit Breakers, the micarta insert creates an equivalent dimension to the original design, and the electrical connection to the 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drops were unaffected, and therefore the seismic qualification is not affected. Therefore, the reconfigured Heinemann Circuit Breakers does not affect the seismic qualification.

4.7 Question: Are Heinemann Circuit Breakers sensitive to impact and does this affect the seismic qualification?

Figure 8 shows the inside of a Heinemann Circuit Breaker shown in energized or closed state. In this state the trigger is set and the flapper hangs freely, just away from the magnetic pole. When a large electrical current is applied to the circuit breaker, the coil creates an electromagnetic field and draws the flapper towards the pole. When the flapper nears the pole, the flapper initiates release of the stored energy that was created when the breaker was energized and the circuit breaker trips.

The internal components of the Heinemann Circuit Breakers contribute to the electrical safety function. Some of these internal components are designed for freedom of movement, such as the flapper and the electrical braided wire. Some are designed to store energy and release it rapidly under electrical loads, such as the armature and latch.

The energization of the breaker is accomplished by forcing the trip handle up. The breakers have a counterbalanced armature design that helps prevent mechanical tripping caused by shock and vibration. Heinemann notes that this feature meets MIL-STD-202 (Reference 2.13) requirements. Also noted is that the toggle and latch are strong, durable and highly efficient. The latch is stated to be shock resistant, but provides very fast operation. It states that the trip-free construction makes it impossible to hold the breaker closed against a fault, and even when the handle is held in the ON position, the contacts trip free of fault condition.

The electrical and mechanical qualified configuration of the Heinemann Circuit Breakers in the 120 VAC Vital Instrument Power Boards helps to limit seismic motion and shocks to within the level to which the breakers are qualified and which are within the shock resistance demonstrated by the seismic tests in 1974 and 1992.

When Heinemann Circuit Breakers are outside of the qualified configuration, it is possible to exert a shock sufficiently severe as to cause an energized circuit breaker to trip. This is typical of molded case circuit breakers because in the energized state they are effectively sitting on a trigger, awaiting a small movement of the flap by an electrical field. This small, but positive flap movement releases the stored energy and irrevocably the circuit breaker trips. While the Heinemann Circuit Breakers are shock resistant, they are not shock proof, and excessive shocks, such as those in excess of the seismic qualification, can cause energized circuit breakers to trip.

5. Conclusions

The review of the Heinemann Circuit Breaker qualification results in the following conclusions:

5.1 The Heinemann Circuit Breakers are rigidly mounted to the 120 VAC Vital Instrument Power Boards. The Heinemann Circuit Breakers are rigidly connected through the pair of 1 ¼ X ¼ copper bus and each 1/8 X ½ copper bus drops, front panel, and rear angle supports.

5.2 The 1974 seismic test replicated the mounting configuration in the plant.

5.3 The 120 VAC Vital Instrument Power Boards and Heinemann Circuit Breakers met the IEEE 344-1971 seismic requirements.

5.4 By connecting the Heinemann Circuit Breaker directly and rigidly to the fixture on the seismic table, the rigid connections in the 120 VAC Vital Instrument Power Boards were replicated in the 1992 seismic test. Adjusting the seismic input to the highest enveloping condition from the 1974 tests and electrically connecting the Heinemann Circuit Breakers during the seismic test and verifying energized and deenergized safety functions properly applied IEEE 344-1975 during the 1992 seismic tests.

5.5 Since molded case circuit breakers are not age sensitive in mild environments in nuclear plants, aging does not affect the seismic performance, and the clamping pressure does not directly contribute to the safety related function of the Heinemann Circuit Breakers, there are no significant aging mechanisms that need be addressed.

5.6 The reconfigured Heinemann Circuit Breakers does not affect the seismic qualification.

5.7 The electrical and mechanical qualified configuration of the Heinemann Circuit Breakers in the 120 VAC Vital Instrument Power Boards helps to limit seismic motion and shocks to within the level to which the breakers are qualified and which are within the shock resistance demonstrated by the seismic tests in 1974 and 1992.

ADDENDA

James F. Gleason, P.E. Credentials:

Principal Investigator for NRC Nuclear Plant Aging Research investigating radiation and age related degradation, performance confirmation, testing and maintenance of Circuit Breakers and Relays.

Member of NRC's Peer Review Team on equipment qualification research at Sandia National Laboratories. Member of NRC expert panel on Equipment Qualification. Consultant to NRC and assisted in developing the Division of Operating Reactors qualification guidelines and NUREG-0588 for plants under construction.

Principal Investigator for Electric Power Research Institute on seismic and equipment qualification.

Publications:

Nuclear Regulatory Commission, NUREG/CR-5762, "Comprehensive Aging Assessment of Circuit Breakers and Relays", 1992;

Electric Power Research Institute, NP-3326, "Correlation Between Aging and Seismic Qualification for Nuclear Plant Electrical Components", 1983;

Electric Power Research Institute, NP-5024, "Seismic Ruggedness of Aged Electrical Components", 1987;

Electric Power Research Institute, NP-5000, "Handbook on Electrical Interface Sealing", 1987;

Electric Power Research Institute, NP-6731, "Guide to Optimized Replacement of Equipment Seals" 1990;

Electric Power Research Institute, NP-6408, "Guidelines for Establishing, Maintaining and Extending the Shelf Life Capability of Limited Life Items (NCIG-13)", 1992.

Chairman IEEE SC-2 Qualification Committee

Chairman IEEE SC-2.1 Equipment Qualification IEEE 323 Committee

Enclosure 3
Watts Bar Nuclear Plant, Unit 2
Regulatory Commitments

To ensure that future work activities involving installation of model CF2-Z51-1 Heinemann breakers in the 120V AC Vital Instrument Power Boards are performed correctly, maintenance and modification procedures will be revised or new procedures generated as necessary to provide installation instructions resulting from lessons learned during the recent outage. Any revisions and new procedures will be implemented by September 30, 2011.