

October 2, 2017

Mr. James Powers
Vice President, Nuclear Island & Business Development
Toshiba America Energy Systems Corporation
3545 Whitehall Park Drive
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Charlotte, NC 28273

SUBJECT: REGULATORY AUDIT REPORT FOR MAY 16-18, 2017, TOSHIBA "LICENSING TOPICAL REPORT FOR TOSHIBA NRW [NON RE-WRITABLE]-FPGA [FIELD PROGRAMMABLE GATE ARRAY]-BASED INSTRUMENTATION AND CONTROL SYSTEM FOR SAFETY-RELATED APPLICATION," UTLA 0020P, REVISION 2 (TAC NO. ME9861)

Dear Mr. Powers:

By letter dated February 23, 2015, Toshiba Corporation (Toshiba) submitted Revision 2 to "Licensing Topical Report For Toshiba NRW-FPGA-Based Instrumentation And Control System For Safety-Related Application" (Agencywide Documents Access and Management System Accession No. ML15062A183). The topical report (TR) is supported by documentation that includes plans, requirements, design specifications, programming and hardware testing, independent verification and validation, and equipment qualification testing.

From May 16, 2017, through May 18, 2017, the U.S. Nuclear Regulatory Commission (NRC) staff performed a regulatory audit at MPR Associates, Inc. in Alexandria, Virginia. The audit was a supplement to the May 16–20, 2016, audit conducted to support the NRC staff evaluation of the Toshiba TR.

The purpose of this letter is to provide Toshiba with the results of the regulatory audit. Documented in the report are the observations the NRC staff identified during the audit.

J. Powers

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If you have any questions regarding this matter, I may be reached at 301-415-7297 or by electronic mail at Joseph.Holonich@nrc.gov.

Sincerely,

/RA/

Joseph J. Holonich, Senior Project Manager
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 729

Enclosure:
Regulatory Audit Report

SUBJECT: REGULATORY AUDIT REPORT FOR MAY 16-18, 2017, TOSHIBA "LICENSING TOPICAL REPORT FOR TOSHIBA NRW [NON RE-WRITABLE]-FPGA [FIELD PROGRAMMABLE GATE ARRAY]-BASED INSTRUMENTATION AND CONTROL SYSTEM FOR SAFETY-RELATED APPLICATION," UTLA 0020P, REVISION 2 (TAC NO. ME9861) DATED: OCTOBER 2, 2017

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SUPPLEMENTAL REGULATORY AUDIT REPORT FOR MAY 16-18, 2017,
TOSHIBA “LICENSING TOPICAL REPORT FOR TOSHIBA NRW [NON RE-WRITABLE]-
FPGA [FIELD PROGRAMMABLE GATE ARRAY]-BASED
INSTRUMENTATION AND CONTROL
SYSTEM FOR SAFETY-RELATED APPLICATION,” UTLA 0020P, REVISION 2
(TAC NO. ME9861)

Background

In May 2016, U.S. Nuclear Regulatory Commission (NRC) staff performed its first audit of the Toshiba facilities in Tokyo, Japan. After this audit, NRC staff determined there was a need to conduct some additional audit activities to review equipment qualification (EQ) test procedures and results.

The supplemental regulatory audit plan (Agencywide Documents Access and Management System Accession No. ML17103A025) for the audit of the Toshiba EQ documents detailed the plans and expectations for the trip. The audit was in support of the NRC staff review of the Toshiba Power Range Monitoring (PRM) System discussed in the Licensing Topical Report (LTR), “Licensing Topical Report For Toshiba NRW [Non Re-Writable]-FPGA [Field Programmable Gate Array]-Based Instrumentation And Control System For Safety-Related Application,” UTLA 0020p, Revision 2. The NRC staff audit support the review of the PRM system and Oscillation PRM (OPRM) unit and their potential use in safety-related systems in domestic nuclear power plants.

Regulatory Audit Basis

The purpose of this regulatory audit was to gain information needed to determine if the equipment qualifications have resulted in a PRM system that meets regulatory requirements for safety system applications at nuclear power plants. Specifically, this supplemental audit provided information necessary to close open items identified in the open-items list.

Audit Activities

NRC staff visited MPR Associates in Alexandria, VA, from May 16–18, 2017, to perform the supplemental regulatory audit. The following activities were performed during this audit:

1. Entrance Meeting

At the entrance meeting, NRC staff provided an overview of the audit plan and objectives for the audit. Audit logistics and a detailed audit schedule were discussed.

Toshiba provided access to all document files that are associated with EQ testing of the PRM system.

2. Closure of Open Items

In preparation for the audit, NRC staff and Toshiba discussed the open items that were the objective of this supplemental audit. These items are described below with the resolution obtained during the supplemental audit.

- Open Item #98, 98-1, and 98-2

Clarify what tests were performed during pre-qualification and post-qualification testing.

Toshiba provided document E2-2016-000749 Rev.0, E2-2017-000056 Rev.0, and E2-2017-000046 Rev.0 to describe the tests performed. In particular, Toshiba provided a table listing which tests were performed. NRC staff determined this information should be docketed, since it modifies the information provided in the LTR and docketed EQ documents. Toshiba agreed to revise Table IV-4-1 of the LTR to include this information. NRC staff will issue a request for additional (RAI) requesting this.

In these documents, Toshiba explained that even though it is common practice to perform operability and prudency tests after each EQ test, Toshiba did not perform those intermediary tests. Instead Toshiba only performed prudency and proof testing during pre-qualification and then during post-qualification testing. Toshiba did not consider this necessary, since pre-qualification and post-qualification showed the PRM system worked before and after all EQ tests were performed.

- Open Item #100

Please provide the test results for Operability and Prudency testing showing the performance of the test specimen against the acceptance criteria for Operability [Section 7.2.2 of the Equipment Requirement Specification (ERS)] and Prudency (Section 7.2.3 of the ERS) Testing and in relation to the baseline performance results. Also, clarify what tests were performed during pre-qualification and post-qualification testing, in particular to address inconsistencies between those identified in the equipment requirement specification (ERS), LTR, and qualification test summary report.

Toshiba prepared document No. E2-2016-000715, Rev. 1, which summarized tests results for the operability and prudency tests performed during pre- and post-qualifications. For example, the Operability Test – Test Record No. FPG-06-ETR-002 (included in E2-2016-000715), performed on July 5, 2006, shows the following:

- Communication operability
These tests were performed multiple times to show operation of the unit (under test) at various Low PRM (LPRM) levels. The results showed that the modules work properly, and also that data transfer communication was correct. The tests performed included: LPRM input adjustment (input level), LPRM analog output (AO) output confirmation (output level), Average PRM (APRM)/ Thermal Power Monitor (TPM) level analog output (at several projected power levels).
- Linearity check
The flow-level, analog-input signal record/calculation showed the flow calculated and the expected TPM-High setpoint.
- APRM Inoperative trip record sheet
This test showed how the system behaves when the mode in the APRM is changed.

- Discrete input operability (DIO)
DIO function record sheet – During this test, Toshiba personnel toggled the switches of the DIO simulator to verify that that alarms were indicated (e.g., APRM High-High trip).
- Low voltage power supply failure test record sheet
Test performed for LPRM unit, LPRM/APRM unit, and FLOW unit.
- Loss of power test
Tests performed to demonstrate system operation during loss of power and power interruption.
- APRM/TPM level analog output
Tests performed to demonstrate operation of the output level for the APRM and TPM in the recorder, transient monitor and computer.

Document No. E2-2016-000715, Rev. 1, also clarifies what tests were performed. As mentioned for open item #98, NRC staff determined that an updated table IV-4-1 of the LTR is necessary to close this item. NRC staff will issue an RAI requesting this.

- Open Item #100-1

Please provide the Response Time obtained during the Operability Test Results (as identified in Item B in Section 5.3 of EPRI [Electric Power Research Institute] TR-107330).

Toshiba prepared document No. E2-2016-000934 to describe the acceptance criteria for the response time operability test performed. This document also provided the test results obtained at the end of each of the EQ tests at different TPM time constants. The TPM time constant was set using the rotary switch in the APRM module. Toshiba explained that the default value is 6 seconds, but this can be modified to any value in an established range. Document No. FPG-06-ETR002-02 describes how the TPM time constant was used. Specifically, this was done to measure the system time response at different levels. For example, the acceptance criteria of the TPM high-response time should be less than 40 milliseconds, if the TPM is selected as zero. Thus, during pre-qualification testing, which defines the baseline for the system, the TPM was set to zero. The recorded values dropped slightly from the pre-qualification and post-qualification recording.

- Open Items #100-3a, 3b, 3c, 4a, 4b, 4c

Provide the following information regarding communication operability tests:

3a) Please state your acceptance criteria.

3b) Please state if you monitored for alarms during qualification and operability testing.

3c) Please clarify if errors were detected during communication tests.

4a) For the Loss of Power Test Item, Item J in Section 5.3 of EPRI TR-107330 requires AC and any DC power sources to be shut off for at least 30 seconds and reapplied to simulate a loss of power to the test specimen. Please clarify how the testing that Toshiba performed by shutting off only one of the redundant power supplies is consistent with demonstrating a loss of power to the test specimen.

4b) Clarify the acceptance criteria for the operability test for the Loss of Power Test Operability Test Item.

4c) What are Toshiba's power off default and power on default states for the safety-related functions listed in Section 4.1.2 of the ERS?

Toshiba provided document No. E2-2016-000715 to address these items. In particular, For item 3a – This item is related to the response that was provided to open item #111 in a RAI. Specifically, Toshiba determined that the acceptance criteria for the continuous verification of communication within the PRM and the communication from the PRM to the OPRM is that an alarm is not generated. This acceptance criteria is identified in the electrostatic discharge (ESD) test procedure. Toshiba noted that during ESD testing, they observed alarms when ESD was applied to the surface of the cable connectors in the back panel. Therefore, Toshiba identified limitations due to ESD.

In particular, Toshiba stated that the back panel is locked during normal plant operation, and only unlocked and opened after that PRM division has been bypassed and is no longer performing its safety function. This is the only time personnel should be accessing the plane of the rear cabinet door opening for maintenance or surveillance activities. Since the back panel is not accessible during normal operation and since appropriate ESD protection is required when entering the rear panel, these alarms were acceptable in accordance with the acceptance criteria.

During the audit, Toshiba showed the ESD test procedure (FPG-TPRC-C51-1007), which stated that if susceptibility is registered, the ESD level is reduced until susceptibility is no longer detected. In this manner, Toshiba identified the location and level at which susceptibility was observed.

For items 3b and 3c – This item is related to the response that will be provided to open item #111 in an RAI. Toshiba monitored the alarms to determine if any communication error was occurring within the PRM and the communication from the PRM to the OPRM (see also open item #100-3a). As mentioned before, alarms only occurred when ESD was applied to the back panel.

For item 4a – Toshiba separately performed the failover operability test and the loss of power test. During the audit, Toshiba clarified that AC power to all power supplies was turned off through a single breaker, meeting the requirement for the Loss of Power Test Item, Item J in Section 5.3 of EPRI TR-107330.

For item 4b – Toshiba explained how the data collected shows that trips did not occur during testing.

For item 4c – Toshiba explained that the APRM will generate alarms if any of the conditions described in ERS, Section 4.1.2, are present.

- Open Item #104

Provide information about the data of the resonance search test for the Power Range Monitor.

Toshiba prepared document No. E2-2016-000755. This document included improved images for Figures A.1.1-A.1.15 from the Qualification Test Summary Report (FPG-TRT-C51-0101). These figures showed the spectra of the vertical or horizontal vibrations during the resonance search. The test report provided transmissibility plots of the response at each survey accelerometer versus the test control accelerometer.

Resonances in the test specimen/fixture system can be identified at the peak response

frequency when the transmissibility is greater than about two. To identify a resonance, Toshiba used the phase relationships between the sinusoidal input signal and the Equipment Under Test (EUT) response such as Figures A.1.1 through A.1.14 of the Qualification Test Summary Report. Toshiba performed resonance searches in accordance with Section 7.1.4.1 of IEEE [Institute of Electrical and Electronics Engineers] Std. 344-1987.

Toshiba also prepared document No. E2-2016-000750. This document describes the location for the accelerometers. This document referenced document No. E2-2016-000683, which shows the location of the response survey accelerometers.

- Open Items #105 and #106

The Qualification Test Summary Report shows the Random Multi-Frequency Test results in Appendix A.2. However, these figures were difficult to read. Please address the following:

- *Provide clear figures and show the strong motion portion of the seismic test*
- *Explain how Toshiba demonstrated stationarity*

Toshiba prepared document No. E2-2016-000700 to address these open items. In this document, Toshiba provided clear plots for the random multi-frequency test results in Appendix A.2 of the qualification test summary report. In addition, this document provided the time histories to show the strong motion portion of the seismic test, which was determined to be the safe, shutdown earthquake (SSE) for horizontal axis (east to west).

In document No. E2-2016-000700, Toshiba included the time histories for the SSE tests. These figures showed the time-interval power spectral density coherence and the stationarity, which was determined using the methods described in IEEE 344-2004. IEEE 344-2004, Clause 8.6.3.1 requires waveform stationarity and intends stationarity to exist over the strong motion portion of the test waveform.

- Open Item #107

Explain if the analog and digital outputs were within tolerance during the vibration application period.

Toshiba provided document No. E2-2016-000717 to address this open item. This document described how the Analog Outputs and Digital Outputs were monitored during the vibration application period, which was described in the Seismic Test Record (FPG-06-ETR-002-05). In document No. E2-2016-000717, Toshiba provided an excerpt from the seismic test report for the five OBE tests and the one SSE test. These test records showed the data recorded during seismic testing, including the type of signal, output level measured, and the acceptance criteria (range). Toshiba collected data to confirm AO and digital output (DO) were within tolerance. For the AO, Toshiba confirmed the output level for the signal met the acceptance criteria. For the DO, this is shown by generating the alarm "LPRM/APRM unit APRM_FAIL." (This meant that the fiber optic cable was disconnected to generate the alarm.)

- Open Item #108

The Master Test Plan (document No. FPG-PLN-C51-0005, Rev. 3), Table A1-1 “Listing of the Test Specimen,” includes the following note: “Spare modules for EMC [(Electromagnetic Compatibility) EMI/RFI[electromagnetic/radiofrequency interference], Surge Withstand Capability, EFT/B [Electrical Fast Transient /Burst], ESD, and Class-1E to Non-1E Isolation) Tests are added in revision 2 to confirm the enhanced noise-withstand-capabilities of these modules. These modules are installed in the Test Specimen Units instead of the modules originally installed during EMC Tests. These modules are not subject to aging effect during Environmental and Seismic Tests. So these modules are removed from and original modules are installed in the Test System in the Performance Proof Test.” Please explain if the enhanced noise withstand capability modules were evaluated in terms of a Performance Proof Test (i.e., operability and prudency testing) or if you determined they would have no difference in performance compared to the original modules.

Toshiba provided document E2-2016-000754, which described the configuration of the PRM system. This document also explained why the AO module and the LPRM module were modified. Specifically, these modules were modified because they did not pass the initial EMC test. Thus, these modifications were made to enhance the noise withstand capability of the modules by adding capacitors to the circuits of the LPRM module and by replacing several parts in the AO modules.

In document no. E2-2016-000749 Rev.0, Toshiba explained that they used these modules for the remaining EQ tests. Toshiba also evaluated that the enhanced noise withstand capability modules would have no difference in performance to baseline results for accuracy and response time, and that the added capacitors do not affect the results of the seismic test and environmental test qualification. These modules were part of the operability test and the prudency test after all the qualification tests were completed.

In addition, Toshiba modified the design of the Printed Circuit Board for the LPRM and AO module to enhance the noise withstand capability with the added capacitors. Toshiba verified operation of the AO and LPRM modules with the modified design during system validation testing.

Based on these results, the following modules meet the requirements for EMC, environmental test and the seismic test:

- LPRM Module: HNS013
- AO Modules: HNS515, HNS516, HNS517, and HNS518

Note that the HNS011 LPRM Module and the HNS511, HNS512, HNS513, and HNS514 AO Modules are not qualified for EMC, and therefore Toshiba won't provide them.

- Open Item #110-3

Section 5.3.K of EPRI TR-107330 refers to Item F in Section 4.6.1.1. This item requires analog I/O [input/output] to not change by more than 5 percent; however, Section 7.2.2.G of the ERS (FPG-RQS-C51-0001) does not include this requirement. Please clarify if this requirement was met.

Toshiba provided document No. E2-2016-000751 to address this item. This document clarified the info provided in the open items list for item #110-3, which states that “the PRM does not have safety-related analog outputs.” In this document, Toshiba explained that the PRM unit power supply rides through a short duration power interruption described in Section 7.2.2 G of the ERS (FPG-RQS-C51-0001). Since the internal DC power never drops, the system is unaffected by short duration power outages. By confirming that the safety-related discrete output does not change through the power outage, Toshiba confirmed that safety-related system function did not change during the power interruption.

- Open Item #112-1 and 112-2

Please state your bases for excluding the Failure of Serial Port Receiver Test and the Serial Port Noise Test.

Toshiba provided document No. E2-2016-000752 to address this item. In this document, Toshiba explained that the basis for excluding the failure of the serial port receiver test and the serial port noise test is that the tests listed in the EPRI items 5.3E, 5.4B, and 5.4C are for testing connections using copper cables and electrical signals. This is not applicable to the PRM system because Toshiba is using fiber optics. Therefore, applying electrical signal to perform this test will not be appropriate. In addition, test equipment to provide controllable fiber optic signal degradation during operability testing is not available. Therefore, verification of communication protocol degradation comparable to those specified by EPRI Section 5.3.E for a copper electrical serial communication port are not included in the operability test. Failures of any of the fiber optic links will be indicated by status LEDs on alarm outputs from the test specimen. Detection of faults and failures on the fiber optic links were performed in the Unit Validation Testing of PRM and documented in Toshiba Test Record (ATC-060392).

The Failure of Serial Port Receiver Test was performed for the OPRM optical serial transmission port during the OPRM prudency test. However, this is a failure test by disconnecting the fiber optic cable and is different from the test described in EPRI-TR10730 Section 5.3B. The test was conducted in accordance with Section 7.2 of the Toshiba Prudency Test Specification (FC51-7021-1025). For the PRM, the equivalent Failure of Serial Port Receiver Test was conducted in the Unit Validation Testing of PRM.

- Open Item #116-1b

Tables B.3.2 through B.3.6 of the Qualification Test Summary Report do not make a statement regarding compliance to the CE-101 specification at a frequency of 60 Hz. The tables show a starting frequency just above 60 Hz and Figure B.3.5 appears to show emissions slightly above the corrected limit at 60 Hz.

Toshiba prepared document No. E2-2017-000088 to respond to this open item. In this document, Toshiba explained that they used the equation in MIL-STD-461E to determine the decibel (dB) relaxation limit of CE101. Toshiba found that the limit should be equal to the measured emission at 60Hz. Thus, even though Toshiba did not state its compliance to the requirement, this showed that compliance to the specification at a frequency of 60 Hz (measured emissions) meets the dB relaxation limit of CE101.

In addition, Toshiba added explanations on how to read the figures and the tables in the qualification test summary report, since they added additional labels to the lines, which are misleading. These tables show the equipment meets the emission test requirements.

- Open Item #116-3

Table B6 in Appendix B.6 of the Qualification Test Summary report shows test points that include Cable #9 and Cable #10 simultaneously, Cable #10 only, and the line lead of Cable #10 only. However, it is not clear what Cable #9 is or why it was included in the test, and it is not clear from the information in Table B6 how Toshiba complies with Section 5.12.3.4c of MIL-STD-461E. Please state how the information in Table B6 of the Qualification Test Summary Report shows that you comply with the requirements in Section 5.12.3.4c of MIL-STD-461E.

Toshiba provided document No. E2-2016-000935. This document included a table showing the EUT cable characteristics. In particular, Cable #9 is the Chassis ground. Cable #10 is the Chassis Power Line (Hot), Neutral, and Ground Lines. Cable #9 provides the single ground for all units, and cable #10 provides the 120VAC for the unit's power supplies. The document also includes a figure with the equipment setup and describes the procedure followed to perform CS114 power leads test required in Section 5.12.3.4c of MIL-STD-461E. Toshiba did not observe any susceptibility during this test.

- Open Item #116-4

Section 5.12.3.4c of MIL-STD-461E is performed on each cable bundle interfacing with each electrical connector. Please explain how Table B7 (B8 and B9) in the Qualification Test Summary Report shows this requirement is met.

Table B7 (B8 and B9) in the Qualification Test Summary Report shows a list of test points which include cable bundles for LPRM and FLOW units. Toshiba provided document No. E2-2017-000021 to address this open item. In this document Toshiba explained that they performed the tests using cables with connectors to the test specimen. The document includes figures illustrating these connections and the test points for all signals transmitted (e.g., Bundle of LPRM cables (#101 through #110), LPRM signals (from test equipment) to connector and then to modules in the LPRM/APRM Unit).

- Open Item #116-5

Please clarify the distance at which the test specimen was installed in relationship with the sources of large magnetic fields (> 600 A/m).

Toshiba provided document No. E2-2016-000935 to address this item. This document includes the system setup for the RS101 test, which shows the radiation loop positioned 5 cm away from the EUT face.

- Open Item #117-2

For IEC [International Electrotechnical Commission] 61000-4-5, RG [Regulatory Guide] 1.180 specifies the pulse shape in terms of rise time and duration. Please clarify if the width that Toshiba specifies in Section 5.5.4 of the ERS is consistent with the duration specified in RG 1.180.

Toshiba provided document No. E2-2016-000936 to address this item. In this document Toshiba explained and justified why the width (for IEC 61000-4-5) that Toshiba specifies in Section 5.5.4 of the ERS is the same as the duration specified in RG 1.180. Thus, the waveform Toshiba used for testing is consistent with the IEEE C62.41 and IEC 61000-4-5 waveform requirements.

- Open Item #117-4

Section 6.1.1 and 7.1 of IEC 61000-4-12 specify two values for impedance: 12 Ω and 30 Ω . Please specify the impedance used in the test.

Toshiba provided document No. E2-2017-000088 to address this item. In this document, Toshiba explained why they believe they used a 12 Ω impedance for IEC 61000 4-12, even though Toshiba and the test lab cannot find the record of the impedance value used for the EMC susceptibility 100 kHz Ring Wave tests.

Further, Toshiba notes that R.G. 1.180 Revision 1 does not specify the impedance, and references IEEE Std. C62.41-1991. Specifically, for Category B Locations, IEEE Std. C62.41 specifies a 12 Ω impedance. For Category A locations IEEE Std. C62.41 specifies 30 Ω .

Toshiba conducted the IEC 61000-4-12 test at Low Exposure (2 kV) for a Category B Location, which Toshiba required of the test lab. Based on this information, Toshiba assumed that 30 Ω was applied for the test to take conservative position for the appropriate evaluation in a situation where the impedance value cannot be confirmed. Toshiba considers this assumption appropriate because the PRM is designed to be connected to the end of the power supply system in nuclear power plants.

- Open Item #119-1a

Need clarification on how Toshiba confirmed that the system worked after destruction of AO module.

Toshiba provided a copy of the 1E to non-1E test record FPG-06-ETR-002-10, 1E to non-1E test procedure FPG-TPRC-C51-1008, and test system setup procedure FPG-TPRC-C51-1001. This information showed the data input into the LPRM with the expected output in the AO modules.

Specifically, Toshiba confirmed operation by receiving the TPM signal (alarm). For the 1E to non-1E test, Toshiba applied 600VAC and then 250VDC to each AO module. However, because this test is destructive, Toshiba did not connect the AO module under test to the recorder, but connected the other AO modules and the DO modules to confirm operation and communication of the system. After an AO module was tested, it would be replaced with an operating module. For these tests Toshiba recorded the temperature and humidity in the lab.

- Open Item #119-2

Please clarify why Tables B13.1 and B13.2 of the Qualification Test Summary Report are not consistent with the description of AO modules tested in Section III-2.2.3.6 of the LTR.

Toshiba provided document No. E2-2017-000022 to address this item. In this document Toshiba explained that data for the FLOW analog outputs was mislabeled in Tables B13.1 and B13.2, as well as other mistakes noted during the audit. Toshiba agreed to revise the Qualification Test Summary Report to fix all errors discussed during the audit.

- Open Item #120-1

Section 5.16.3.5 of MIL-STD-461E under data presentation specifies plots for both the measurement and system check portions of the procedure. Plots for the system check were not provided in Appendix B.2 of the Qualification Test Summary Report.

Toshiba prepared document No. E2-2017-000138, which included the data and figures for MIL-STD-461E tests RE102, CE101, and CE102. In particular, this document describes:

- For RE102, the document describes the test equipment setup, test frequency bandwidths and measurement time. This document also describes the procedure followed by the lab to perform these tests. Toshiba provided a figure showing the RE102 signal verification results and a table summarizing the highest emanations observed during signal verification. The lab results show compliance with specifications and requirements.
- For CE101, the document describes the test equipment setup and method used. Specifically, Toshiba applied a signal at least 6dB below the limit, at approximately 1kHz, 3kHz, and 10kHz. Toshiba provided a figure showing the CE101 signal verification results and a table summarizing the signal verification results. The lab results show compliance with specifications and requirements.
- For CE102, the document describes the test equipment setup and method used. In particular sine wave signals at 10kHz and 100kHz (with an input impedance of 1M Ω) were injected into the line impedance stabilization network. The document includes the EMI receiver output. Then the test was repeated for 2MHz injected sine wave (impedance of 50 Ω). Figures were provided for signal verification for Lines L1, L2, L3. The lab results show compliance with specifications and requirements.

- Open Item #120-2

Section 5.7.3.5 (Data Presentation) of MIL-STD-461E requires graphical or tabular data showing the frequencies and amplitudes at which the test was conducted for each lead. This information could not be found. In addition, Appendix B of the Qualification Test Summary Report does not include detailed test results for CS101.

Toshiba provided document No. E2-2016-000937 to address this open item. This document includes the figure showing the frequencies and amplitudes for CS101 (120Hz-150kHz) recorded in the test lab report.

- Open Item #120-3

Section 5.18.3.5 (Data Presentation) of MIL-STD-461E requires tabular data showing verification of the calibration of the radiating loop in 5.18.3.4b. Please provide this information.

Toshiba provided document No. E2-2016-000937 Rev. 3 to address this item. This document included the calibration data plot for RS101.

- Open Item #120-4

Section 5.19.3.5 (Data Presentation) of MIL-STD-461E requires diagrams and photographs showing actual equipment setup and the associated dimensions, graphical or tabular data showing frequency ranges and field strength levels tested, and graphical or tabular listing of calibration data collected. Please provide this information.

Toshiba provided document No. E2-2016-000937 Rev. 3 to address this item. This document included a diagram of the test setup, photos of the test equipment in the chamber, and data (frequency and amplitude) obtained during the RS103 test.

- Open Item #120-5

Section 5.13.3.5 and 5.14.3.5 (Data Presentation) of MIL-STD-461E require oscilloscope photographs of injected waveforms with test data. Please provide this information.

Toshiba provided document No. E2-2017-000132 to address this item. This document includes test equipment setup and oscilloscope images for CS115 and for CS116 taken during these tests for each injection point, as well as tables identifying the test points, test duration, and results. This document also listed the test points in Table B8 (CS115) and Table B9 (CS116) in the Qualification Test Summary Report. Toshiba found that these tests comply with the standard.

- Open Items #120-6a/6b/6c

Provide the following information for the SWC [Surge Withstand Capability] Tests IEC 61000-4-4, 4-5, and 4-12, Section 10 of the standards: (a) Drawings and/or pictures of the test setup and EUT arrangement. (Described in Section 10 of IEC 61000-4-4 and 4-5), (b) Test configuration (hardware) including the coupling method used (Described in Section 10 of IEC 61000-4-5), and (c) Any specific conditions of use, for example cable length or type, shielding or grounding, or EUT operating conditions, which are required to achieve compliance. (Described in Section 10 of IEC 61000-4-4 and 4-12).

Toshiba provided document No. E2-2016-000937 Rev. 3 to address these items. This document included a figure and a photo of the EFT power/cabinet ground lines test setup (IEC 61000 4-4), a figure of the surge test setup (IEC 61000 4-5), figure of the coupling method, and photos of the test setup (IEC 61000 4-5).

This document also included a figure identifying the specific items used during the test setup, such as varistors, shields, bundles, coil (if used during CE101), etc. In this document Toshiba noted that for US customers they would acquire and supply qualified line filter and varistors with similar capabilities to demonstrate that CE101 limits are not exceeded with the varistors and line filters installed.

Open Item #121

Toshiba states in Section 6.4.1 of the Qualification Test Summary Report that during EMI/RFI testing it applied specific test patterns in repetition. It shows these test patterns in Table 6.4.2 of the Qualification Test Summary Report. It states in Section 6.4.1 of the Qualification Test Summary Report that during susceptibility tests, the output data were continuously compared to the expected values (with tolerance). Please provide the test results showing this comparison to expected values for each of the susceptibility tests and state the required tolerance.

Toshiba provided document No. E2-2017-000023 to address this open item. This document shows EMI/RFI performance results to support Toshiba's statement in the qualification test summary report: "... during susceptibility tests, the output data were continuously compared to the expected values (with tolerance)." In particular, Toshiba provided the test records for CS101, CS114 (power), CS114 (signal), CS115 (signal), CS116 (signal), RS101, RS103, CE101 (without choke-coil), CE101 (with choke-coil), CE102, RE101, RE102. These records were extracted from the Test Record No. FPG-06-ETR-002, dated November 2007, "Record Sheet for Susceptibility Test."

Toshiba observed susceptibility during CS114 (power) within a predefined range in cable #10 (line). Toshiba retested the cable four times to replicate this susceptibility. However, Toshiba did not observe susceptibility in the retests of the cable. Therefore, Toshiba concluded that the initial susceptibility was due to the recorder that was used to record AO and DO. The recorder had the wrong setting for the test. Toshiba corrected it. To show that everything was correct, Toshiba redid the test four times in a specified range to confirm that the EUT worked as expected.

For the CE101 tests, the frequency range used was 60HZ to 10KHz, even though the specified range was 120 Hz to 10 KHz. Toshiba decided to expand the frequency range for this test. This is also discussed in open item #116-1a.

Toshiba performed CE101 with and without a choke coil of 100mH added (in series) between the terminal of the test specimen rack and L-line of cable 10. During testing, Toshiba observed that the limit for CE101 was exceeded. For example, the CE101 test (without choke) for the cable #10 (line) shows that the test was completed, but the limit was exceeded. As described in Open Item #116-6 (document E2-2017-000088), Toshiba added additional lines to the figures that were misinterpreted in the test summary report. During the audit Toshiba explained (and showed test reports) that Toshiba measures the current used for the instrument, but in the lab they used a separate instrument to measure the current (which Toshiba does not consider appropriate). Toshiba will update the red-dotted lines labeled as "Allowable Level (With Correction)" in Figures B.3.1 through B.3.9 in accordance with the values of the dB relaxation limit of CE101 shown in the column "CE101 Limit (Corrected with 60 Hz actual Data)" in Tables B.3.2 through B.3.6. Toshiba considers that the test was passed. The correct information was reported in Table B.3.3 in the test qualification summary report.

To address emission encountered during CE101 test, Toshiba performed CE101 with two choke-coils of 60mH (for a total of 120) in series to cable #10 (line). In this case the test was complete and within limit (no emissions observed). Based on these test results, Toshiba included the AC/DC convertor with choke coils in the design of the Power Factor Correction (PFC) module that suppressed the AC harmonic noises for the OPRM unit. The

PFC module was part of the OPRM unit qualification testing. However, the PFC module is not part of the scope of NRC review. Based on this, Toshiba recommends that the PRM system should include the PFC module tested with the OPRM unit.

- Open Item #122

At the end of EMI/RFI testing (including SWC, ESD, and Class 1E to non 1E Isolation) testing, Toshiba performed operability testing. Please provide the operability test results.

Toshiba provided document No. E2-2016-000938 to address this open item. After EMI/RFI testing, the operability tests were performed as part of the post qualification test records, as described in open item #108. This included operability tests for the enhanced noise withstand capabilities modules.

This document included post qualification tests records (FPG-06-ETR-002), showing how the original modules and the enhanced noise withstand capability modules met the acceptance criteria, defined in LTR Table IV-4-1. (These tests are similar than those reviewed for open item #100). In particular, the tests included LPRM input adjustment, LPRM level analog output, APRM/TPM level analog output, FLOW linearity record (at different flow input levels), flow level/TPM-H setpoint level analog output, APRM inoperative trip record sheet, safety-related setpoint change by digital input status record sheet, low voltage power supply failure test-record sheet (for LPRM, LPRM/APRM, and FLOW units), test steps for loss of power, test steps for power interruption.

3. Exit Meeting

During the exit meeting, Toshiba was provided with a summary of the audit's observations. Also, NRC staff identified the open items that could not be resolved during the audit, and for which NRC staff will issue RAIs in a separate letter.

Conclusions

The NRC staff successfully completed all supplemental audit activities outlined in the audit plan. Several EQ documents were reviewed to ensure testing was properly performed. NRC staff did not have any findings during this supplemental audit.

Several responses to the open items will require RAIs. These RAIs will be transmitted via a separate letter. The NRC staff expects Toshiba to address these open items in the RAI responses.

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