

Project:

TRICON v10 NUCLEAR QUALIFICATION PROJECT

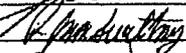
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RADIATION EXPOSURE TEST REPORT

Document No: 9600164-533

Revision 2

September 26, 2008

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Document Change History			
Revision	Date	Change	Preparer
0	07/17/07	Initial Issue	M. Albers
1	04/30/08	Revised Reference 9.12 in response to NUPIC audit corrective action (Reference CAR 2528-1). Updated References 9.1 and 9.6 accordingly.	F. Kloer
2	09/26/08	Added section 5.7, "TLD Accuracy" in response to NUPIC audit corrective action (Reference CAR 2528-1). ECO 05839	F. Kloer

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1.0 EXECUTIVE SUMMARY

The TRICON v10 Nuclear Qualification Project Radiation Exposure Test was performed on December 13-14, 2006 by National Technical Systems (NTS) Laboratories using a gamma irradiation test facility available at the University of Massachusetts. As required by the Triconex Document No. 9600164-500, “Master Test Plan,” (Reference 9.1), the Radiation Exposure Test was performed to provide reasonable assurance that the TRICON v10 Programmable Logic Controller (PLC) will not fail due to radiation exposure over the anticipated life of the equipment.

MPR Procedure No. 9600164-511, “Radiation Exposure Test Procedure,” (Reference 9.2), was developed in accordance with the requirements of EPRI TR-107330, “Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants,” (Reference 9.3), Triconex Document No. 9600164-500, “Master Test Plan,” (Reference 9.1), and Triconex Document No. 9600164-002, “Nuclear Qualification Quality Plan,” (Reference 9.4). The procedure included steps to direct: 1) proper setup of the TRICON-Under-Test (TUT) prior to testing, 2) application of the required radiation exposure levels to the TUT components, and 3) evaluation of acceptable TUT condition and performance following radiation exposure. Radiation Exposure Testing was performed by MPR certified Project Test Engineers and witnessed by Triconex Project Quality Assurance.

Triconex Drawing No. 9600164-100, “TRICON v10 Nuclear Qualification Project TRICON-Under-Test, General Arrangement,” (Reference 9.5), shows the basic configuration of the TUT components for nuclear qualification testing. For Radiation Exposure Testing, the TUT components to be tested were removed from the instrument cabinets shown in Triconex Drawing No. 9600164-100 (Reference 9.5) and positioned on a bench top located in front of the test chamber ⁶⁰Co gamma radiation source window. No additional hardware or shielding material was located inside the test chamber. The tested components were exposed to gamma radiation doses of 1000 RADS, plus margin. Each Radiation Exposure Test run was just over 2 hours in duration.

The tested components met all applicable acceptance requirements of post-radiation exposure visual inspections performed as part of Radiation Exposure Testing. Results of post-radiation exposure Operability and Prudency Tests demonstrate that the applied Radiation Exposure Test conditions had no adverse effect on the TUT performance.

The Radiation Exposure Test results demonstrate that the Triconex TRICON v10 PLC will not experience failures due to normal and abnormal service conditions of gamma radiation exposure. The specific TRICON v10 PLC hardware which was tested (chassis, power supplies, modules, external termination assemblies and interconnecting cabling) is identified in Triconex Document No. 9600164-540, “Master Configuration List,” (Reference 9.6).

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2.0 PURPOSE

The purpose of this test report is to summarize the results of Radiation Exposure Testing of the TRICON v10 Nuclear Qualification Project TRICON-Under-Test (TUT) to meet the requirements of Section 4.3.6 of EPRI TR-107330 (Reference 9.3). The format of this report conforms to Section 8.3.(4) of IEEE Standard 323-1974, “Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations,” (Reference 9.7).

Details regarding the performance and results of the Radiation Exposure Testing are recorded in the completed MPR Procedure No. 9600164-511, “Radiation Exposure Test Procedure,” (Reference 9.8). This completed procedure identifies additional Triconex procedures that were performed in support of Radiation Exposure Testing and provide additional testing details and results. Conclusions from the Radiation Exposure Testing are provided in Section 8.0 of this report.

3.0 TEST OBJECTIVE

Section 4.3.6 of EPRI TR-107330 (Reference 9.3) requires that Radiation Exposure Testing provide confidence that none of the components in the PLC platform are degraded by exposure to the radiation levels given in Section 4.3.6. MPR Procedure No. 9600164-511 (Reference 9.2) states that Radiation Exposure testing shall demonstrate the TUT will not experience failures or unacceptable degradation due to expected radiation exposure during normal and abnormal service conditions. Appendix 5 of Triconex Document No. 9600164-500 (Reference 9.1) requires that Radiation Exposure Testing provide assurance that the TRICON v10 PLC does not fail due to mild environment radiation exposure over the anticipated life time of the equipment.

4.0 DESCRIPTION OF TEST SPECIMEN

The equipment tested consists of four TRICON v10 PLC chassis populated with selected main processor, input, output, communication, chassis interface and chassis power supply modules. The tested equipment also includes external termination panels (ETPs) provided for connection of field wiring to the TRICON v10 input and output modules, and interfacing cable assemblies for connection of the ETPs to the TRICON v10 chassis and for interconnection of the TRICON v10 chassis.

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Triconex Drawing No. 9600164-103, “TRICON v10 Nuclear Qualification Project System Block Diagram,” (Reference 9.9), shows the general arrangement of each TUT chassis. These chassis

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arrangements were maintained during Radiation Exposure Testing, with some modifications as described in Section 5.2 of this test report. Triconex Document No. 9600164-541, “TRICON v10 Nuclear Qualification Project System Description,” (Reference 9.10) provides an overview and description of the TUT and test system. A detailed identification of the tested equipment is provided in Triconex Document No. 9600164-540 (Reference 9.6).

5.0 TEST SETUP AND INSTRUMENTATION

The following sections describe the setup of the TUT during Radiation Exposure Testing, and the instrumentation used to measure the applied radiation doses during testing. The TUT setup is documented in the completed MPR Procedure No. 9600164-511 (Reference 9.8). Specifications for test instrumentation supplied by NTS Laboratories are included in NTS Test Procedure No. TP62987-07N-RAD, “Test Procedure for Radiation Exposure of the TRICON v10 Nuclear Qualification Project TRICON-Under-Test,” (Reference 9.11).

5.1 TRICON-Under-Test Mounting

EPRI TR-107330 (Reference 9.3) provides no requirements or guidance for mounting of the test PLC during Radiation Exposure Testing.

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5.2 TRICON-Under-Test Chassis and Module Configuration

TUT chassis configurations for Radiation Exposure Testing are documented in Triconex Document No. 9600164-540 (Reference 9.6).

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5.3 TRICON-Under-Test Operation

EPRI TR-107330 (Reference 9.3) provides no requirements or guidance for operation of the test PLC during Radiation Exposure Testing.

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5.4 NTS Instrumentation

EPRI TR-107330 (Reference 9.3) provides no requirements or guidance for instrumentation of the test specimen or test chamber during Radiation Exposure Testing. Dosimetry instrumentation was provided by the University of Massachusetts to measure the levels of TUT radiation exposure during testing. The instrumentation was oriented to monitor the uniform gamma radiation flux delivered to the front face of the TUT components during testing. The EPRI TR-107330 (Reference 9.3) required radiation exposure levels are very low (see Section 6.3 of this test report).

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No. TR62987-07N-RAD, “Test Report for Irradiation Exposure of TRICON v10 Nuclear Qualification Project TRICON-Under-Test,” (Reference 9.12).

NTS also provided instrumentation to measure the test chamber temperature and relative humidity conditions prior to the start of each Radiation Exposure Test run.

5.5 Triconex and MPR Instrumentation

The TUT components were not operated or monitored during Radiation Exposure Testing. There was therefore no Triconex or MPR supplied instrumentation used during the Radiation Exposure Test runs.

Following completion of all Radiation Exposure Test runs, the TUT and test system were reassembled and post-radiation exposure Operability and Prudency Testing was performed by Triconex.

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Details on the identification, configuration and calibration of this equipment are included in the completed Pre-Qualification Testing Run No. 3.2 of Triconex Procedure No. 9600164-502, “System Setup and Checkout Procedure,” (Reference 9.13). Similar detailed information on various handheld instrumentation used during Operability and Prudency Testing performed following Radiation Exposure Testing is included in the following Triconex documents:

- The completed Post-Radiation Exposure Testing Run No. 3.2 of Triconex Procedure No. 9600164-503, “Operability Test Procedure” (Reference 9.14),
- The completed Post-Radiation Exposure Testing Run No. 3.2 of Triconex Procedure No. 9600164-504, “Prudency Test Procedure” (Reference 9.15).

5.6 Instrument Calibration

All tests were performed using calibrated test instruments. Calibration certifications are held by NTS Laboratories, MPR and Triconex. National Technical Systems Test Report No. TR62987-07N-RAD (Reference 9.12) documents the calibration status of the test instrumentation used by

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NTS and the University of Massachusetts. The completed Triconex Setup and Checkout, Operability and Prudency Procedures (References 9.13, 9.14 and 9.15) document the calibration status of the test instrumentation used by Triconex.

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6.0 TEST PROCEDURES

Radiation Exposure Testing of the TUT was performed to the specific requirements of Sections 4.3.6.1 and 4.3.6.2 of EPRI TR-107330 (Reference 9.3), and the general requirements of IEEE 381-1977, “Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations,” (Reference 9.16). The following sections describe the approach to satisfying the requirements of the referenced documents during Radiation Exposure Testing of

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the TUT. The test procedure used by NTS Laboratories to perform Radiation Exposure Testing is NTS Procedure No. TP62987-07N-RAD (Reference 9.11). The test procedure used by MPR to perform Radiation Exposure Testing is MPR Procedure No. 9600164-511,” (Reference 9.2). The test procedures used by Triconex to perform Operability and Prudency Testing following Radiation Exposure Testing are Triconex Procedure No. 9600164-503 (Reference 9.17) and No. 9600164-504 (Reference No. 9.18).

6.1 Test Sequence

Figure 2 of Triconex Document No. 9600164-500 (Reference 9.1) shows the sequence of qualification testing performed on the TUT. In accordance with the test sequence shown in Figure 2, Radiation Exposure Testing was performed prior to all other qualification testing (i.e., Temperature and Humidity, Seismic, EMI/RFI, Electrical Fast Transient, Surge Withstand, Electrostatic Discharge and Class 1E to Non-1E Isolation Testing).

6.2 Test Method

Radiation Exposure Testing of the TUT was performed by NTS Laboratories using a gamma irradiation test facility available at the University of Massachusetts. Inside the test chamber, the equipment was subjected to gamma radiation from a ⁶⁰Co gamma ray source. The testing was performed in accordance with NTS Test Procedure No. TP62987-07N-RAD (Reference 9.11). This procedure implements Radiation Exposure Testing in accordance with standard University of Massachusetts facility practices. In accordance with MPR Procedure No. 9600164-511 (Reference 9.2), the material condition of the tested TUT components was visually assessed following completion of each Radiation Exposure Test run. In addition, detailed performance tests were performed on the reassembled TUT system following completion of all Radiation Exposure Testing.

6.3 Test Levels

Section 4.3.6 of EPRI TR-107330 (Reference 9.3) requires that the PLC under qualification operate within specification for radiation exposure of up to 1000 RADS. As stated in Section 4.1 of EPRI TR-107330 (Reference 9.3), the normal and abnormal environmental radiation exposure levels (1000 RAD) given in Section 4.3.6 are characteristic of “mild” plant operating environments (i.e., plant environments that are not exposed to harsh environmental conditions during design basis events). Section 6.3 (Table 6.6) of EPRI TR-100516, “Nuclear Power Plant Equipment Qualification Reference Manual,” (Reference 9.19), provides a basis for the specified 1000 RAD radiation exposure level. Section 6.3 further defines the 1000 RAD exposure as the gamma 40-year dose from normal/abnormal service (approximately 2.9 millirem per hour). IEEE Standard 323-1974 (Reference 9.7) imposes an additional margin of +10% on the qualification test level.

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Accelerated exposure rate testing was performed to achieve a practical total test time. The exposure rate resulted in delivery of the required total dose over an approximate 2 hour test exposure period.

6.4 TRICON-Under-Test Operation

EPRI TR-107330 (Reference 9.3) provides no requirements or guidance for operation of the test PLC during Radiation Exposure Testing.

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6.5 TRICON-Under-Test Performance Monitoring

EPRI TR-107330 (Reference 9.3) provides no requirements or guidance for performance monitoring of the test PLC during Radiation Exposure Testing.

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6.6 Test Acceptance Criteria

The Radiation Exposure Test acceptance criteria are as given below. These criteria were developed based on Appendix 4 of Triconex Document No. 9600164-500 (Reference 9.1), and Section 4.3.6 of EPRI TR-107330 (Reference 9.3).

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- (a) The TUT shall not exhibit any exterior damage or degradation as a result of gamma radiation exposure based on visual examinations performed following Radiation Exposure Testing. Such conditions include, but are not limited to, blistered protective coatings, deformation, crazing or discoloration of plastic components, and deformed or visually embrittled cable insulation.
- (b) The TUT shall meet all acceptance criteria of the post-radiation exposure Operability and Prudency Tests, as implemented by Triconex Procedure Nos. 9600164-503 (Reference 9.17) and 9600164-504 (Reference 9.18), following completion of the Radiation Exposure Testing.

7.0 TEST RESULTS

This section summarizes the results of Radiation Exposure Testing of the TUT. This section also discusses performance or data anomalies which were observed or recorded during the testing.

7.1 Pre-Radiation Exposure Test Setup and Checkout Testing

Triconex Procedure No. 9600164-502, “System Setup and Checkout Procedure,” (Reference 9.20) directs setup of the TUT for the different qualification tests to be performed, and verifies proper operation of the TUT and test system prior to start of testing. Radiation Exposure Testing of the TUT was performed by MPR Associates just prior to start of Environmental (Temperature and Humidity) Testing. On completion of the Pre-Qualification Testing Run No. 3.2 of the System Setup and Checkout Procedure (the run performed just prior to the start of Environmental Testing) by Triconex, the TUT components to undergo Radiation Exposure Testing were removed from the test setup and transported to the radiation exposure test facility. Results of the Pre-Qualification Testing Run No. 3.2 of the System Setup and Checkout Procedure are included in the completed Triconex Document No. 9600164-502 (Reference 9.13). As reported by Triconex, the test results show that the system was operating correctly prior to start of Radiation Exposure Testing.

7.2 Radiation Exposure Testing

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7.3 TRICON-Under-Test Material Condition

In accordance with MPR Procedure No. 9600164-511 (Reference 9.2), a thorough visual examination of the tested components was performed on completion of each Radiation Exposure test run. The conditions inspected for included, but were not limited to, blistered protective coatings, deformation, crazing or discoloration of plastic components, and deformed or visually embrittled cable insulation. The tested components showed no indications of exterior damage or degradation as a result of the gamma radiation exposure.

7.4 Post-Radiation Exposure Operability and Prudency Tests

Operability and Prudency Tests were performed by Triconex following completion of Radiation Exposure Testing in order to assess the effect of radiation exposure on the TUT performance. The completed Post-Radiation Exposure Test Runs of Triconex Procedure Nos. 9600164-503 (Reference 9.14) and 9600164-504 (Reference 9.15) document performance of the post-radiation exposure Operability and Prudency Tests, and provide analyses of the test data and test results. As reported by Triconex, the test results shows that radiation exposure had no adverse effect on the TUT performance.

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7.6 Test Anomalies

There were no TUT material condition, operational or performance anomalies observed during or after Radiation Exposure Testing.

8.0 CONCLUSIONS

1. Radiation Exposure Testing of the TUT was performed in accordance with the requirements of EPRI TR-107330 (Reference 9.3) and following the guidelines provided in IEEE Standard 381-1977 (Reference 9.16). All of the tested TUT components were exposed to gamma radiation doses of 1000 RADS, plus margin. Each Radiation Exposure Test run was just over 2 hours in duration.
2. The TUT met the Test Acceptance Criteria given in Section 6.6 of this report. Specifically, during Radiation Exposure Testing:
 - (a) The TUT did not exhibit any exterior damage or degradation as a result of gamma radiation exposure based on visual examinations performed following Radiation Exposure Testing.
 - (b) As reported by Triconex, the TUT met all acceptance criteria of the Operability and Prudency Tests performed on completion of Radiation Exposure Testing.
3. The Radiation Exposure Test results demonstrate that the Triconex TRICON v10 PLC will not experience failures due to normal and abnormal service conditions of gamma radiation exposure. The specific TRICON hardware which was tested (chassis, power supplies, modules, external termination assemblies and interconnecting cabling) is identified in Triconex Document No. 9600164-540 (Reference 9.6).

9.0 REFERENCES

Note: Triconex qualification project documentation and hardware is configuration controlled under the Triconex Quality Assurance Program. Triconex Document No. 9600164-540, "Master Configuration List," (Reference 9.6) provides a record of the currently applicable revision level of all Triconex documents, procedures and drawings throughout performance of the qualification

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program. As recorded in the completed MPR Procedure No. 9600164-511 (Reference 9.8), Triconex Document No. 9600164-540, Rev. 3 was in effect at the start of Radiation Exposure Testing.

- 9.1 Triconex Document No. 9600164-500, “Master Test Plan,” Rev. 45
- 9.2 MPR Procedure No. 9600164-511, “Radiation Exposure Test Procedure,” Rev. 0
- 9.3 EPRI TR-107330, “Generic Requirements for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants,” Final Report dated December, 1996
- 9.4 Triconex Document No. 9600164-002, “Nuclear Qualification Quality Plan,” Rev. 3
- 9.5 Triconex Drawing No. 9600164-100, “TRICON v10 Nuclear Qualification Project Tricon Under Test - General Arrangement,” Rev. 1
- 9.6 Triconex Document No. 9600164-540, “Master Configuration List,” Rev. 1821
- 9.7 IEEE Standard 323-1974, “Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations”
- 9.8 Completed MPR Procedure No. 9600164-511, “Radiation Exposure Test Procedure,” Rev. 0, MPR Review and Approval Dated April 12, 2007
- 9.9 Triconex Drawing No. 9600164-103, “TRICON v10 Nuclear Qualification Project System Block Diagram,” Rev. 2
- 9.10 Triconex Document No. 9600164-541, TRICON v10 Nuclear Qualification Project, System Description,” Rev. 0
- 9.11 National Technical Systems Test Procedure No. TP62987-07N-RAD, “Test Procedure for Radiation Exposure of the TRICON v10 Nuclear Qualification Project TRICON-Under-Test,” Rev. 0
- 9.12 National Technical Systems Test Report No. TR62987-07N-RAD, “Test Report for Irradiation Exposure of TRICON v10 Nuclear Qualification Project TRICON-Under-Test,” Rev. 1
- 9.13 Completed Pre-Qualification Testing Run No. 3.2 of Triconex Procedure No. 9600164-502, “System Setup and Checkout Procedure,” Rev. 4

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- 9.14 Completed Post-Radiation Exposure Testing Run No. 3.2 of Triconex Procedure No. 9600164-503, “Operability Test Procedure,” Rev. 3
- 9.15 Completed Post-Radiation Exposure Testing Run No. 3.2 of Triconex Procedure No. 9600164-504, “Prudency Test Procedure,” Rev. 1
- 9.16 IEEE Standard 381-1977, “Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations”
- 9.17 Triconex Procedure No. 9600164-503, “Operability Test Procedure,” Rev. 3
- 9.18 Triconex Procedure No. 9600164-504, “Prudency Test Procedure,” Rev. 1
- 9.19 EPRI TR-100516, “Nuclear Power Plant Equipment Qualification Reference Manual,” 1992
- 9.20 Triconex Procedure No. 9600164-502, “System Setup and Checkout Procedure,” Rev. 4