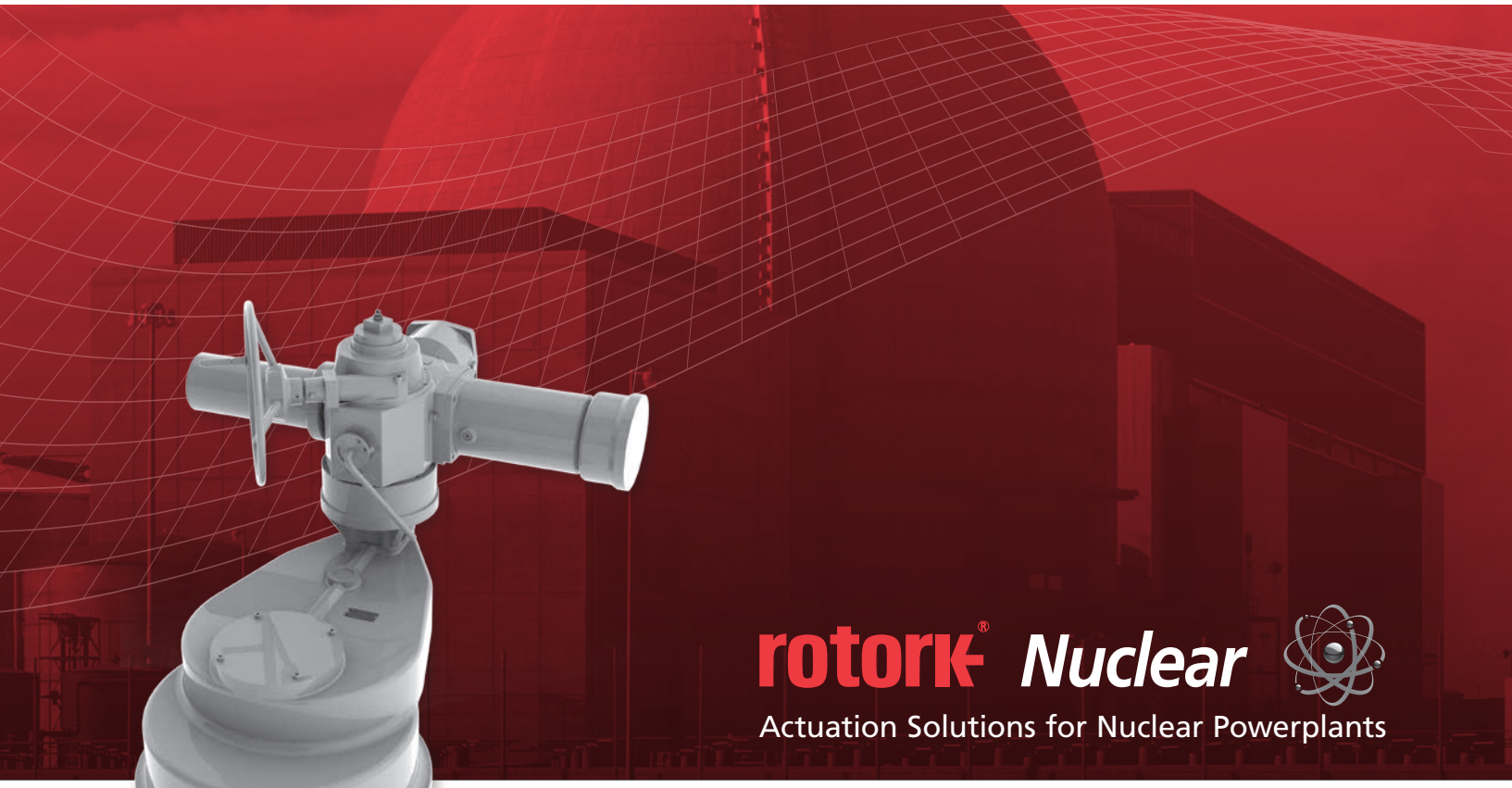
rotork®

Environmental Qualification



rotork® *Nuclear*

Actuation Solutions for Nuclear Powerplants

Environmental Qualification of Rotork
nuclear electric actuators and gearboxes

Redefining Flow Control

Contents

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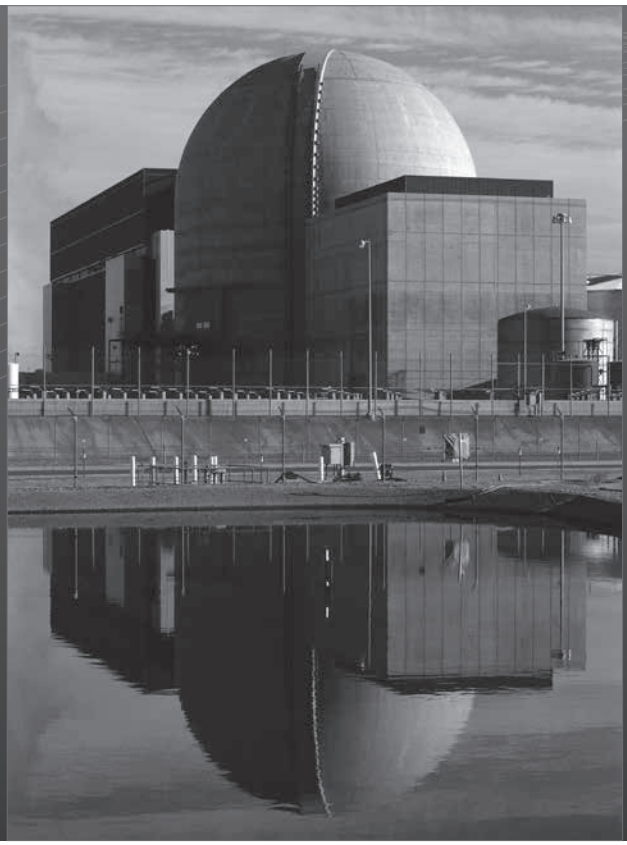
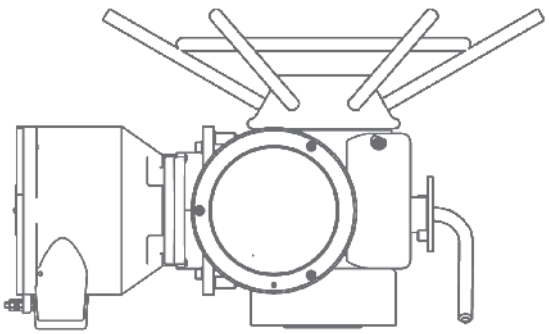
Controls





1.0 Introduction

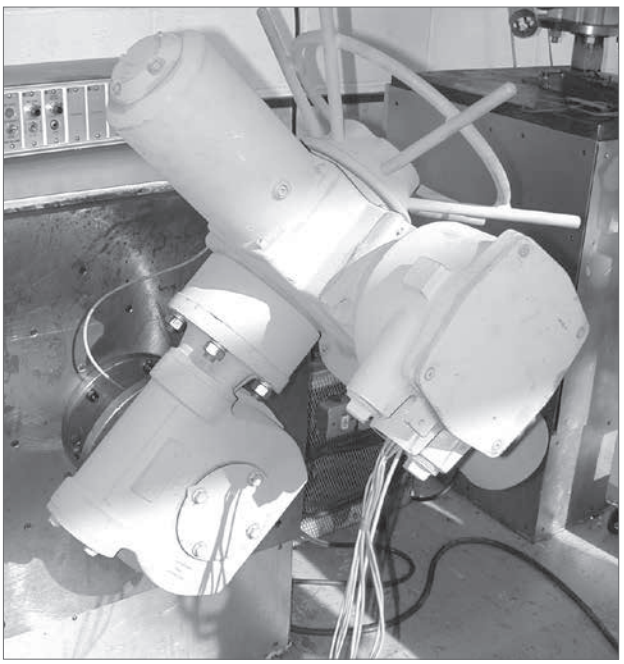
Rotork has been involved in the supply of electric actuators since the 1960's supplying product to nuclear power plants throughout the world.

Rotork has also participated in the SC2.3 sub-committee working group on Qualification of actuators of the US Standards Committee responsible for the formation of the IEEE382 "IEEE standard for qualification of safety-related actuators for Nuclear Power Generating Stations" from its inception in 1972 to the current 2006 revision.

Rotork nuclear actuators have been subjected to independent testing IEEE382 and other standards since the late 1970's.

The test laboratories used include:

- Wyle Laboratories, Huntsville, Alabama. USA
- Nuclear Logistic Inc, Fort Worth, Texas. USA
- Kinectrics Inc, Toronto. Canada.



2.0 Design specifications

2.1 Rotork nuclear actuators have the following designation

NA1 - Inside containment active

NA5 - Outside containment active

The designations are modified to demote other qualified variation of the product range.

'Z' – denotes that the actuator is fitted with a thrust taking drive coupling with increase stem acceptance. NAZ1, NAT5

'T' – denotes that the actuator is fitted with a torque limiter that is used to limit the maximum torque that the actuator can deliver under any conditions, including stall. NAT1, NAT5

'X' – denotes that the actuator is fitted with a thrust compensator. It may also be used for temperature compensation. NAX1, NAX5

'B' – denotes a non-thrust taking base is fitted. NAB1, NAB5

2.2 Mounting configurations

Actuator mounting flange dimensions comply with ISO5210 and MSS SP-102.

2.3 Gearbox ranges

Rotork nuclear gearboxes can be fitted to Rotork nuclear actuators to extend the torque or thrust capability on the stem acceptance or convert to part turn operation. All are qualified to IEEE382.

IWN – range of quarter turn gearboxes. Mounting flanges comply with ISO 5211 and MSS-SP-101

IBN – range of bevel multi-turn gearboxes. Mounting flange dimension comply with ISO 5210 and MSS-SP-102

ISN – range of spur multi-turn gearboxes. Mounting flange dimension comply with ISO 5210 and MSS-SP-102.

3.0 Qualified Actuators and Gearbox Ranges

3.1 Actuators (ref. Rotork publication PUB004-001-00)

7NA1,11NA1, 14NA1, 16NA1, 30NA1, 40NA1, 70NA1, 90NA1

7NAT1, 11NAT1, 14NAT1, 16NAT1, 30NAT1, 40NAT1, 70NAT1,90NAT1

7NAX1, 11NAX1, 14NAX1, 16NAX1, 30NAX1, 40NAX1, 70NAX1, 90NAX1

7NA5, 11NA5, 14NA5, 16NA5, 30NA5, 40NA5, 70NA5, 90NA5

7NAT5, 11NAT5, 14NAT5, 16NAT5, 30NAT5, 40NAT5, 70NAT5,90NAT5

7NAX5, 11NAX5, 14NAX5, 16NAX5, 30NAX5, 40NAX5, 70NAX5, 90NAX5

3.2 Gearboxes (Ref. Rotork publication PUB027-003-00)

IWN3, IWN4, IWN5, IWN6, IWN7, IWN8, IWN9,

IBN5, IBN7, IBN9, IBN11, IBN13, IBN14,

ISN16, ISN19, ISN20

3.3 Rotork nuclear actuator and gearboxes are qualified to be mounted in any orientation.

The qualification basis for Rotork nuclear actuators is IEEE382-1996/2006

The qualification levels are summarised in Section 5.0

4.0 Qualification Basis

Quality Assurance

All Rotork nuclear actuators are manufactured to a quality assurance program that meets the requirements of the relevant sections of the following standards:

10 CFR 50 Appendix B

ASME NQA-1

CSA Z299.1

QA 42.1

ISO 9000

5.0 Qualified Design Life

The following qualified life is applicable to actuators and gearboxes:

Mechanical	4000 cycles (open - close - open)	
Thermal	40 years at 54.5 °C (130.1 °F) 60 years at 50 °C (122 °F)	
Radiation	Normal TID 40 years 700 kGy (70 Mrad)	
Accident	130 kGy (130 Mrad)	
Pressure	Ambient (Max)	6.0 barg (87 psig)
	Accident	7.8 barg (113 psig)
Seismic	Random Multi-frequency Required Input Motion	8 g 4.5 g
Accident-LOCA	IEEE382-1996 Case IV LOCA + MSLB	

5.1 Rotork type NA5 actuators

Rotork type NA5 actuators are for outside containment duty. The design and materials used in construction are identical to the type NA1 except that standard oil is used as a lubricant and the paint finish is standard.

The qualified life of type NA5 actuators is identical to the NA1 type.

6.0 Environmental Qualification Summary

KINECTRICS

KINECTRICS INC.

SUMMARY TEST REPORT
FOR
NUCLEAR ENVIRONMENTAL QUALIFICATION TESTING OF AN 11NAT1E ROTORK ELECTRIC ACTUATOR WITH AN IWN4 GEARBOX

TEST REPORT NO: K-012964-RA-0051-R01

February 21, 2012

Prepared by: E Bobotsis **Date:** 21 Feb 12

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Quality Assurance Supervisor
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Approved by: **Date:** FEB 29 2012

Bert Grespan, Manager
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Kinectrics Inc.

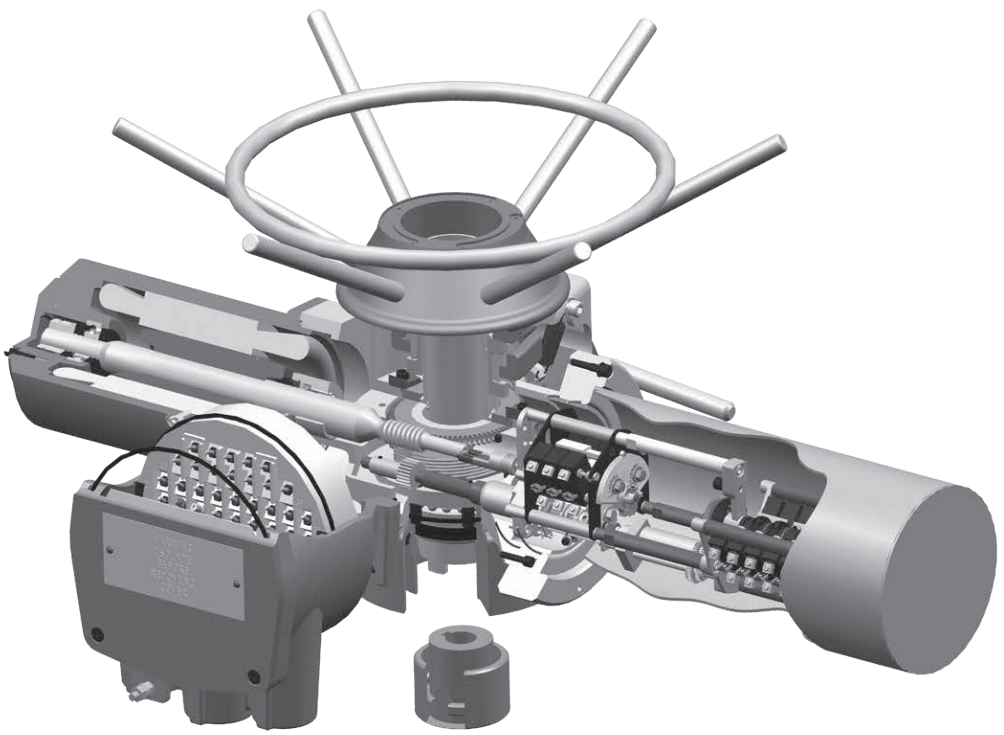
6.0 Environmental Qualification Summary

Revision Log

REV. No.	ISSUE DATE	PREPARED BY	REVIEWED BY	APPROVED BY
00	November 21, 2011	Elias Bobotsis	Steve Burany	Bert Grespan
01	February 21, 2011	Elias Bobotsis	Steve Burany	Bert Grespan

Revision History

REV. No.	SECTION/PARAGRAPH	DESCRIPTION
00		As Issued
01		Addressed customer comments



Summary Test Report

Section 2
Summary Test Report

1.0 Introduction

This nuclear qualification, summary test report briefly describes the type tests performed, test results observed, and conclusions made during environmental and seismic qualification testing of a Rotork 11 NAT1 E electric actuator attached to a Rotork IWN4 gearbox, under Rotork Controls Inc. P.O. No. 98886. The testing was performed to IEEE Std 382 -1996 Qualification Case IV requirements with the operating requirement for the actuator I gearbox assembly to maintain the specified performance capability before, during and after the environmental and seismic design basis accident (DBA) tests. Complete test descriptions and results are presented in Kinectrics Qualification Test Report K-012964-RA-0001-R01, Reference 3.

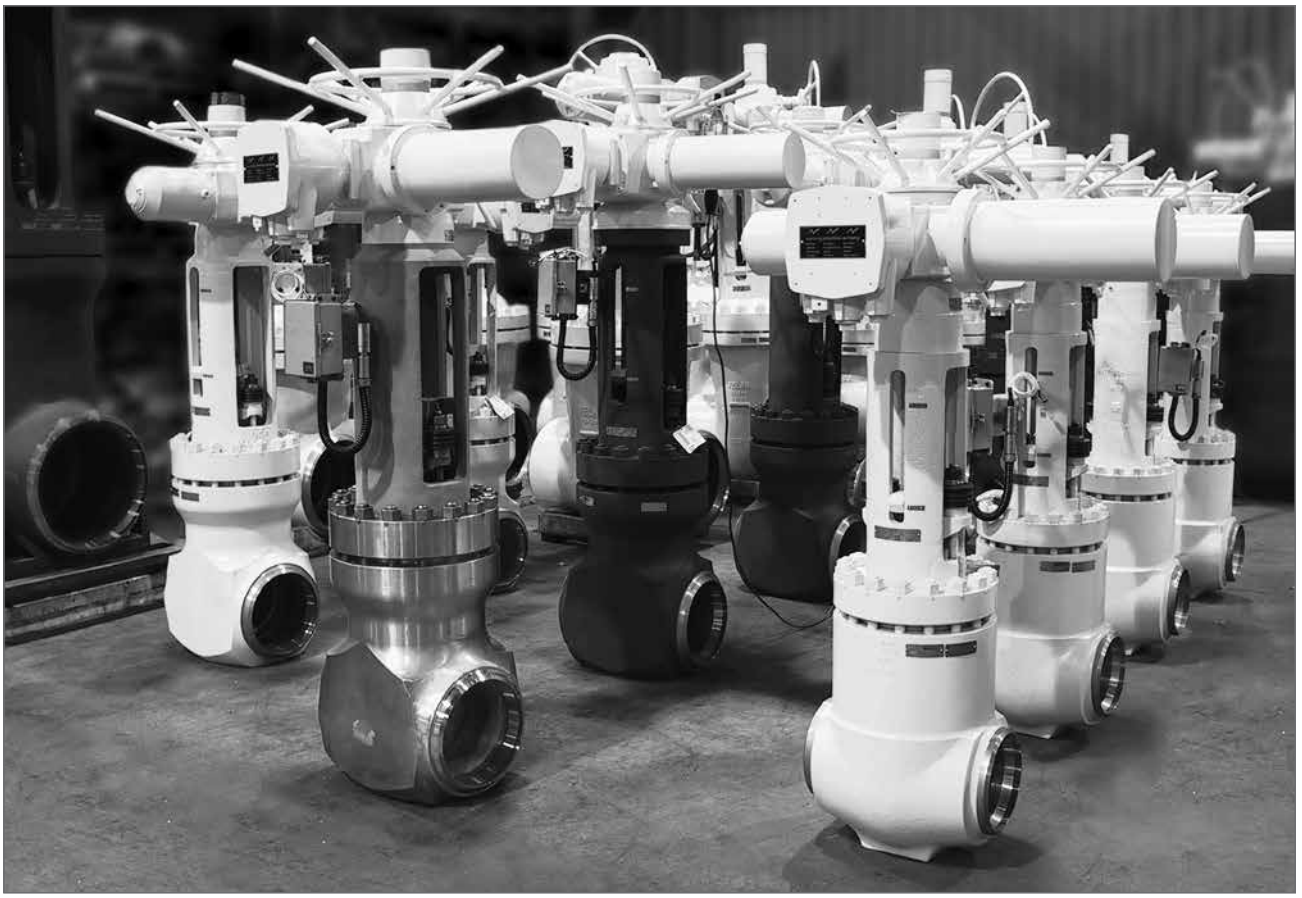
The 11 NAT1 E electric actuator attached to the IWN4 gearbox was selected in the Kinectrics Qualification Analysis Report, K-011368-ANAL-0001-ROO, Reference 1, as the representative test specimen combination to demonstrate a generic qualification of the NA 1 E I IWN actuator I gearbox group, as well as the NA 1 E I IBN and NA 1 E / ISN actuator I gearbox groups, to the IEEE Case IV qualification level.

2.0 Test Objectives

The test objectives were to:

1. Test the electric actuator test specimen model 11 NAT1 E complete with a Rotork IWN4 gearbox to the environmental qualification test sequence specified in IEEE Std 382-1996.
2. Demonstrate a 40-year qualified life at a normal service temperature of 54.5 °C, 70 Mrads gamma radiation, 4,000 mechanical cycles, and 15 external pressurizations to 65 psig (448 kPag).

   Alternatively, the thermal qualified life of this electric actuator test specimen is calculated at over 60 years at a normal service temperature of 50 °C using Arrhenius methodology with an activation energy of 0.86 eV and the same radiation, mechanical cycles and external pressurizations aging as above.
3. Demonstrate that the test specimen actuator functions normally before, during and after the seismic tests, including opening and closing on demand.
4. Demonstrate that the test specimen actuator functions normally before, during and after the DBA test corresponding to the IEEE Std 382-1996, Qualification Case IV conditions, including opening and closing on demand as required by Figure 4 in IEEE Std 382-1996.



3.0 Test Specimen Description

The Rotork nuclear type electric actuator model 11 NA T1 E with an attached nuclear type gearbox modellWN4 test specimen had the specifications as listed in Table 1.

Table 1: Test Specimen Specifications

Specification	Description
Actuator Model Number	Rotork 11 NAT1 E
Gearbox Model Number	Rotork IWN4
Motor ratings	575 V, 3 phase, 60 Hz, 29 rpm
Switch options	Twelve Switch AOP
Torque Limiting Brake	Yes
Drive Bushing	Type A
Breather Installed	Yes
Gearbox ratio	70:1
Wiring Diagram	2023VNO
Potentiometer Installed	Yes
Serial Number	Z42950070101

4.0 Reference Standards and Specifications

The following list includes some of the references associated with this qualification program.

The complete list is included in the Kinectrics Qualification Test Report K-012964-RA-0001-R01, Reference 3.

1. "Qualification Analysis for Generic Qualification of Rotork NA 1 E Series Electric Actuators and IWN, IBN, and ISN Series Gearboxes to IEEE Std 382-1996 Case IV Qualification Level", Analysis No: K-011368-ANAL-0001-ROO, June 10, 2005.
2. "Test Procedure for Environmental Qualification Testing of an 11 NAT1 E Rotork Electric Actuator With an IWN4 Gearbox to IEEE Std 382-1996 Case IV Qualification Level", Test Procedure No: K-012964-PSWI-0001-R05, July 29, 2010.
3. "Test Report for Environmental Qualification Testing of an 11 NAT1 E Rotork Electric Actuator With an IWN4 Gearbox", Test Report No: K-012964-RA-0001-R01, October 11, 2011.
4. ANSI/IEEE Std 344-1975, "IEEE Recommended Practices for Seismic Qualification of Class 1 E Equipment for Nuclear Power Generating Stations."
5. IEEE 382-1996, "IEEE Standard for Qualification of Actuators for Power Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants."
6. 1 OCFR50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants."

5.0 Test Program Sequence and Results

The type tests for this qualification test program were performed in the sequence outlined in the following Table 2, along with the results obtained during the qualification steps.

Table 2: Test Program Sequence

Step #	Sequence Step	Description
1	Receipt Inspection	Rotork 11 NAT1 E.
2	Baseline Functional Tests	Rotork IWN4.
3	Normal Radiation Aging	575 V, 3 phase, 60 Hz, 29 rpm.
4	Post-Normal Radiation Aging Functional Tests	Post-Normal Radiation Aging functional tests were performed.
5	Mechanical Cycle Aging Phase I, (2,000 cycles)	The test specimen was cycled for a total of 2,000 cycles, equally split with power input of 402.5 VAC, 575 VAC and 632.5 VAC.
6	Post-Mechanical Cycle Aging Phase I Functional Tests	Post-Mechanical Cycle Aging Phase I functional tests were performed.
7	Thermal Aging	The test specimen was placed in a forced convection thermal aging oven with fresh air replenishment to prevent oxygen depletion, for 21.4 days at 125 °C.
8	Post-Thermal Aging Functional Tests	Post-Thermal Aging functional tests were performed.
9	Mechanical Cycle Aging Phase II, (2,000 cycles)	The test specimen was cycled for another total of 2,000 cycles, equally split at 402.5 VAC, 575 VAC and 632.5 VAC. A failure of the limit switches operation is addressed in Notice of Anomaly K-012964-NOA-0004 R02.
10	Replacement of AOP and Thermal Aging of Static O-rings	A change-out of the metallic parts in the Add-On-Pack was done and aging of new parts to the existing level of the actuator was performed.
11	After Replacement of AOP Static O-rings Baseline Functional Tests	After Replacement of AOP Baseline functional tests were performed.
12	Mechanical Cycle Aging Phase II, (Part of 2,000 cycles remaining)	The test specimen was cycled as required to complete the total of 2,000 cycles.
13	Post-Mechanical Cycle Aging Phase II Functional Tests	Post-Mechanical Cycle Aging Phase II functional tests were performed.
14	Normal Pressurization Cycle Tests	The test specimen was placed in a test chamber and subjected to 15 external pressurization cycles of 65 psig (448 kPag) by pressurizing the chamber with compressed air.
15	Post-Normal Pressurization Cycle Tests Functional Tests	Post-Normal Pressurization Cycle Tests functional tests were performed.
16	Resonance Search Tests	The test rig with attached actuator test specimen was attached to a 36" x 36" x 1" mounting plate and bolted to the tri-axial shaker table. A low level sine sweep (0.2 g peak acceleration or lower) from 1 Hz to 100 Hz, was performed for each axis.
17	Vibration Aging	Vibration aging consisting of minimum 0.75 g peak (0.53 g RMS) sine sweeps from 5 Hz to 100 Hz was performed for a minimum of 90 minutes in each X, Y and Z direction. To also provide conservatism for rigid mounted applications, the test specimen was also subjected to white noise vibration of at least 0.75 g RMS over the 1 Hz to 100 Hz range.
18	Seismic Testing	See Section 5.1 after this table. Failures of the limit switches operation is addressed in Notice of Anomaly K-012964-NOA-0012 ROO and in Notice of Anomaly K-012964-NOA-0014 ROO. The test rig resonance is addressed in Notice of Anomaly K-012964-NOA-0013, ROO.
19	Post-Vibration Aging and Seismic Testing Functional Tests	Post-Vibration Aging and Seismic Testing functional tests were performed.
20	Design Basis Event (DBE) Radiation	The test specimen was irradiated to at least a total gamma radiation dose of 147 Mrads, (130 Mrads gamma for DBE radiation plus an additional 17 Mrads for 10 yrs of normal radiation aging of some AOP components).
21	Post-DBE Radiation Functional Tests	Post-DBE Radiation functional tests were performed.
22	DBE Test	See Section 5.2 after this table. A failure of the limit switches operation is addressed in Notice of Anomaly K-012964-NOA-0016 R01.
23	Post-DBE Test Functional Tests	Post-DBE Test functional tests were performed.
24	Post-Testing Final Inspection	Post-Testing Final Inspection external viewing indicated that the test specimen actuator appeared intact. The test specimen actuator was then returned to Rotork for a post-test, internal inspection at their facility.

5.0 Test Program Sequence and Results

5.1 Seismic Tests

The seismic qualification tests included Line Mounted Sine Sweep Tests, Single Frequency Tests and Rigid Mounted Tests, (Broadband Random Motion). These seismic tests were performed using the setup shown in Figure 1.

Line Mounted Qualification Tests included OBE sine sweeps of 2 Hz to 35 Hz to 2 Hz applied at a rate of 1.0 octave/minute or less in each of the X. Y and Z axes. Subsequently two SSE tests were performed in each of the X. Y and Z axes using the SSE minimum control acceleration levels. as shown in Table 3. The test specimen was operated during the SSE testing.

Table 3: Minimum Control Acceleration Levels for Tests

Frequency (Hz)	IEEE 382 SSE Peak Acceleration (g)	IEEE 382 OBE (2/3 of SSE) Acceleration (g)
2.0	1.2	0.80
2.52	1.5	1.00
3.17	1.9	1.27
4.0	2.4	1.60
5.04	3.0	2.00
6.35	3.8	2.53
8.0	4.5	3.00
32.0	4.5	3.00

Single Frequency Seismic Tests were performed at the following frequencies:

Table 4: Single Frequency Sine Tests

Frequency (Hz)	IEEE 382 Peak Acceleration (g)	Equivalent RMS Acceleration (g RMS)
2.0	1.2	0.85
2.52	1.5	1.06
3.17	1.9	1.34
4.0	2.4	1.70
5.04	3.0	2.12
6.35	3.8	2.69
8.0	4.5	3.18
10.08	4.5	3.18
12.7	4.5	3.18
16.0	4.5	3.18
20.16	4.5	3.18
25.4	4.5	3.18
32.0	4.5	3.18

Rigid Mounted Qualification Tests, (Broadband Random Motion), included aBE and SSE tests with broadband random seismic excitation which enveloped the Required Response Spectra (RRS) of Table 6 in all three directions for at least 30 seconds. The test specimen was operated twice during the SSE tests.

Table 5: SSE and aBE Required Response Spectra

Frequency (Hz)	SSE Acceleration (g peak)	OBE Acceleration (g peak)
1.0	1.00	0.67
3.0	9.00	6.00
10.0	9.00	6.00
40.0	3.00	2.00
100.0	3.00	2.00

5.0 Test Program Sequence and Results

5.2 DBE Simulation Test

The DBE test was intended to simulate the effects of temperature. pressure and steam (superheat and saturated) conditions on the test specimen actuator. The temperature and pressure profiles were as per IEEE Std 382-1996 qualification Case IV profile conditions, with a peak temperature of 256 °C and a peak pressure of 779 kPag.

Three thermocouples were installed in the test chamber to measure the steam chamber temperature. They were located adjacent to but not touching the test specimen and not in the direct impingement direction of the incoming steam.

The average temperature of the three thermocouple readings was used for chamber temperature control purposes.

The chamber was pre-heated to 49 °C and held for at least 0.5 hour before injecting superheated steam into the chamber to envelop the temperature and pressure conditions specified in Table 6a for the first transient and Table 6b for the second transient. The test specimen actuator was cycled before the start of the DBE test and then at numerous times during the temperature I pressure profile.

Table 6a: Required Design Basis Accident Temperature and Pressure Profiles First Transient

Time	Temperature		Pressure	
	°C	°F	kPag	psig
0	49	120	0	0
10 seconds	196	385	469	68
40 seconds	256	492	469	68
2 minutes	256	492	469	68
4 minutes	185	365	469	68
10 minutes	185	365	469	68
12 minutes	174	346	779	113
3 hours	174	346	779	113
5 hours	49	120	0	0
6 hours	49	120	0	0

Table 6a: Required Design Basis Accident Temperature and Pressure Profiles First Transient

Time	Temperature		Pressure	
	°C	°F	kPag	psig
00 (6 hours in IEEE profile)	49	120	0	0
10 seconds	196	385	469	68
40 seconds	256	492	469	68
2 minutes	256	492	469	68
4 minutes	185	365	469	68
10 minutes	185	365	469	68
12 minutes	174	346	779	113
9 hours*	174	346	779	113
9.5 hours	164	328	586	85
11 hours	164	328	586	85
12 hours	156	312	448	65
24 hours	156	312	448	65
36 hours	138	280	248	36
4 days, 12 hours	138	280	248	36
5 days	126	159	138	16
30 days	126	159	138	16

* This time and subsequent times include the 6 hours of the first transient peak.

6.0 Quality Assurance

The test program was performed and all reports were prepared in accordance with the Kinectrics QA Program which complies with the requirements of 1 OCFR50 Appendix B.

7.0 Conclusions

A nuclear qualification test program was performed on an 11 NAT1 E Rotork electric actuator with an IWN4 gearbox test specimen per the requirements of its qualification test procedure, Kinectrics document K-012964-PSWI-0001-R05, Reference 2. The test program was performed and all reports were prepared in accordance with the Kinectrics QA Program which complies with the requirements of 1 OCFR50 Appendix B.

The qualification test program comprised Radiation , Thermal, Mechanical Cycle, Pressurization and Vibration Aging in addition to the Seismic and DBE Harsh Environment qualification testing.

The actuator test specimen completed the required qualification testing and met the specified acceptance criteria throughout the test program, except as noted in the dispositioned Notice of Anomalies.

Therefore, as per the imposed aging, seismic, temperature and pressure stressors, and the dispositioned NOAs, the test specimen comprising an 11 NAT1 E Rotork electric actuator with SS gears in the Add-On Pack and with an IWN4 gearbox is environmentally qualified per the requirements of its approved, qualification test procedure, Kinectrics document K-012964-PSWI-0001-R05. The primary objectives accomplished by this test specimen actuator per its qualification test procedure include:

a) It passed the environmental qualification test sequence specified in IEEE Std 382-1996;

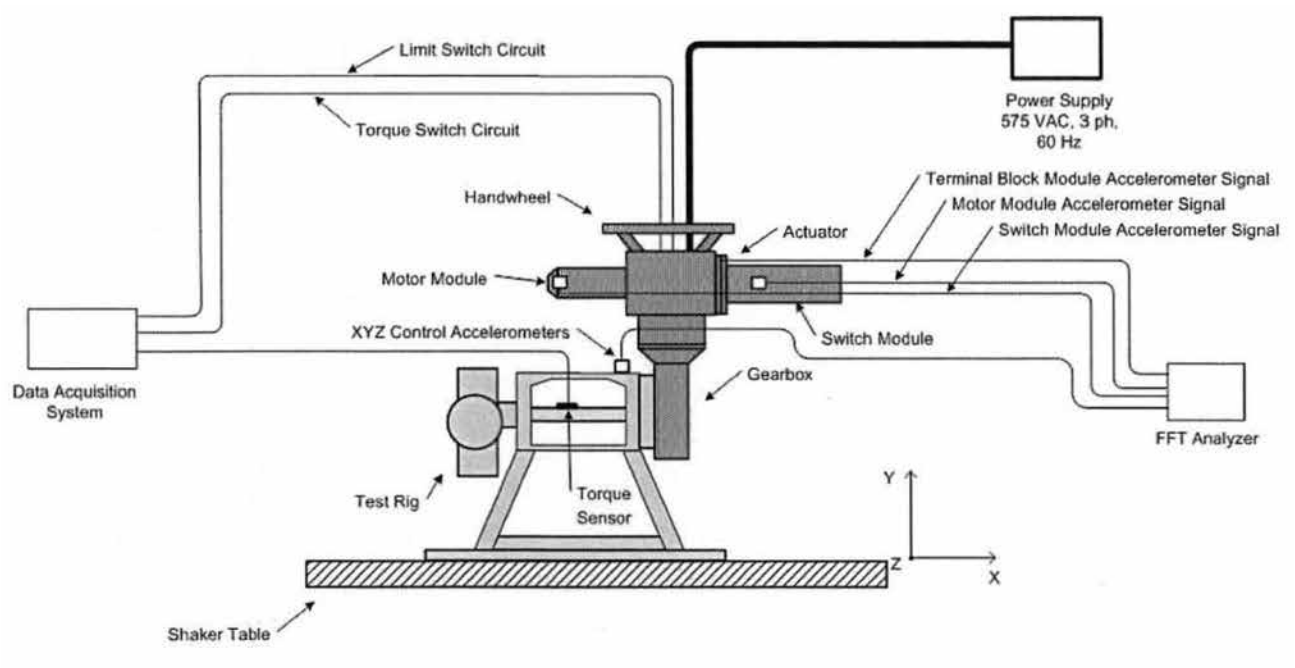
b) It was qualified to 40 years at a normal service temperature of 54.5 °C, (or alternatively to over 60 years qualified life at a normal service temperature of 50 °C using Arrhenius methodology with an activation energy of 0.86 eV), 70 Mrads gamma radiation at a dose rate of 0.49 Mrad/hour, 4,000 mechanical cycles, and 15 external pressurizations to 65 psig (448 kPag);

c) It stroked on demand (opened and closed) before, during and after the seismic tests, and

d) I t stroked on demand (opened and closed) before, during and after the DBE test corresponding to the IEEE Std 382-1996, Qualification Case IV conditions with 147.5 Mrads gamma radiation at a dose rate of 1.0 Mrad/hour.

This successful completion of the above test specification demonstrates a generic qualification of the Rotork NA 1 E I IWN actuator I gearbox group, as well as the NA 1 E I IBN and NA 1 E I ISN actuator I gearbox groups, to the IEEE Case IV qualification level per the generic qualification analysis report K-011368-ANAL-0001-ROO of Reference 1.

7.0 Conclusions



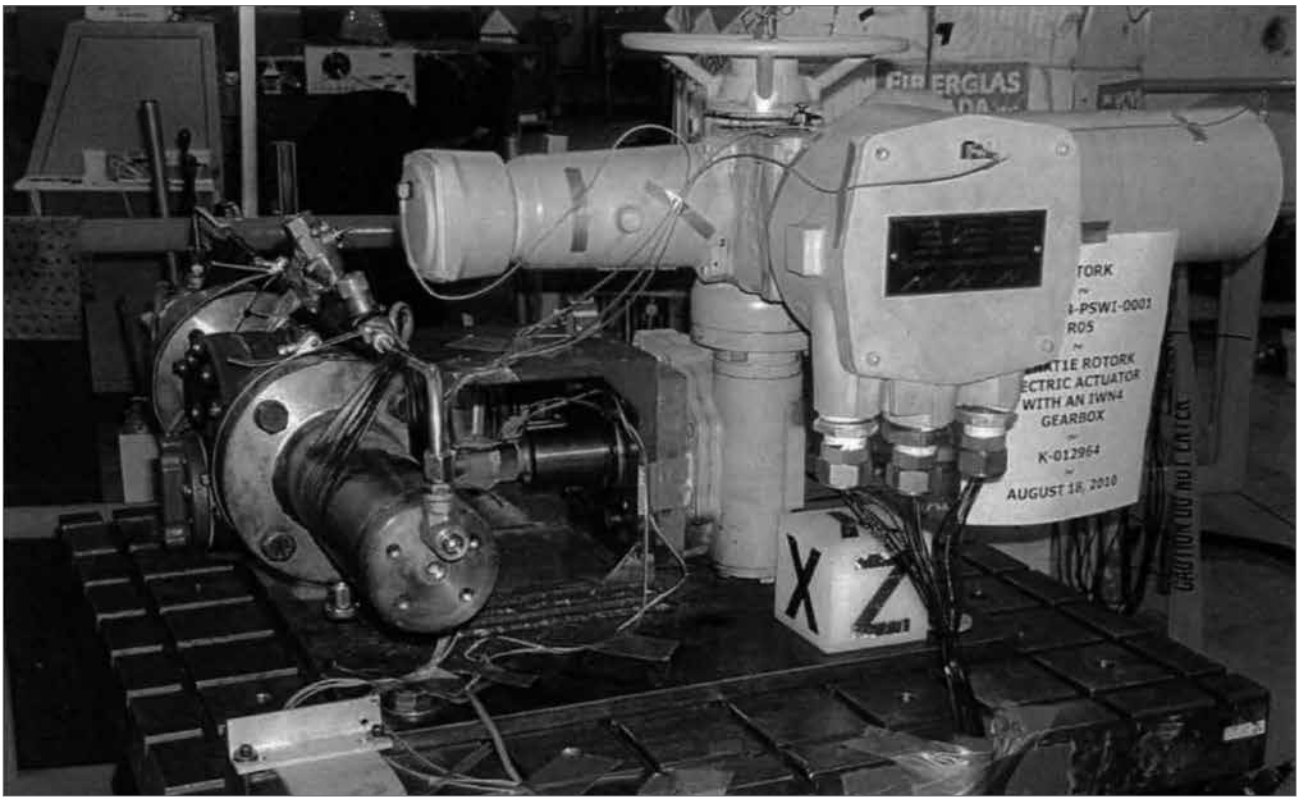
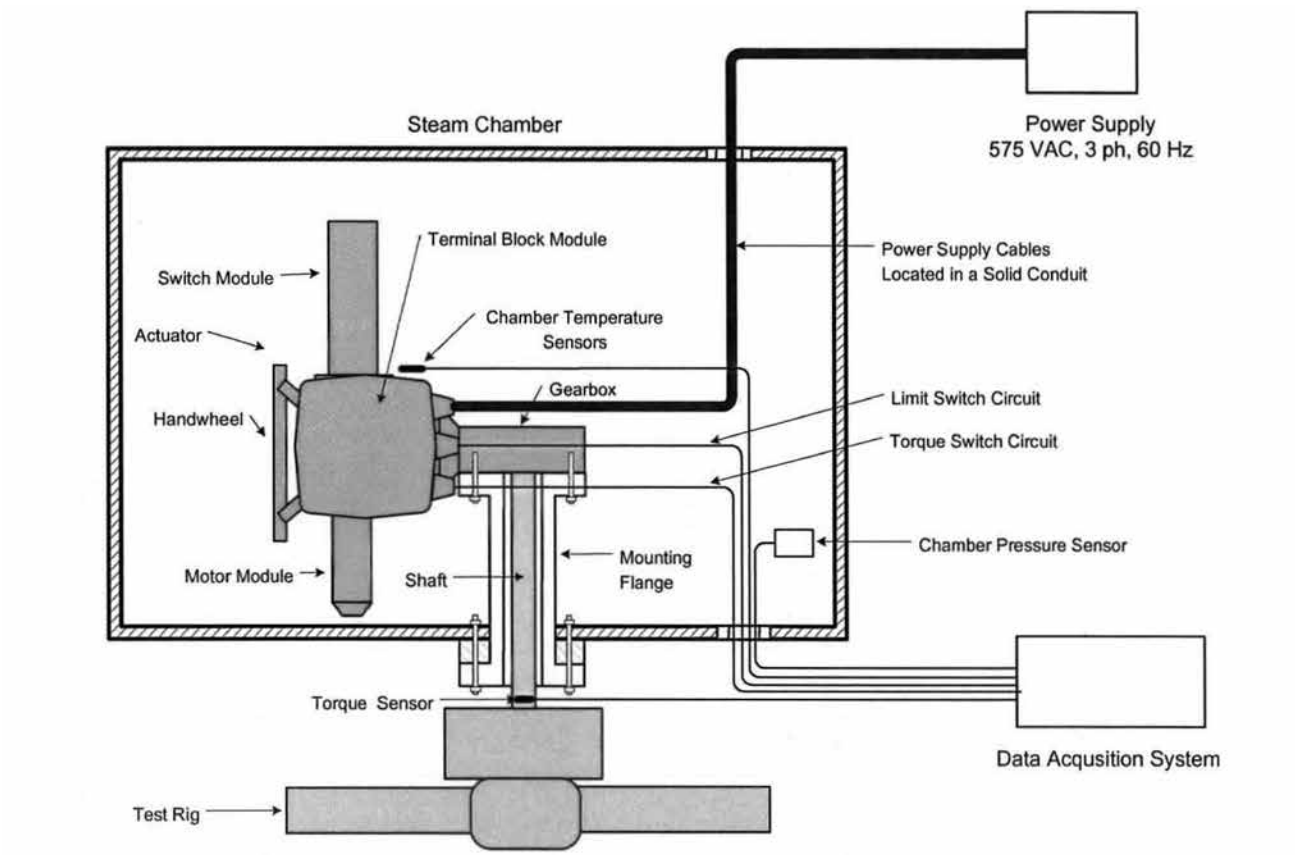


Figure 1: Seismic Test Setup and Photograph

7.0 Conclusions



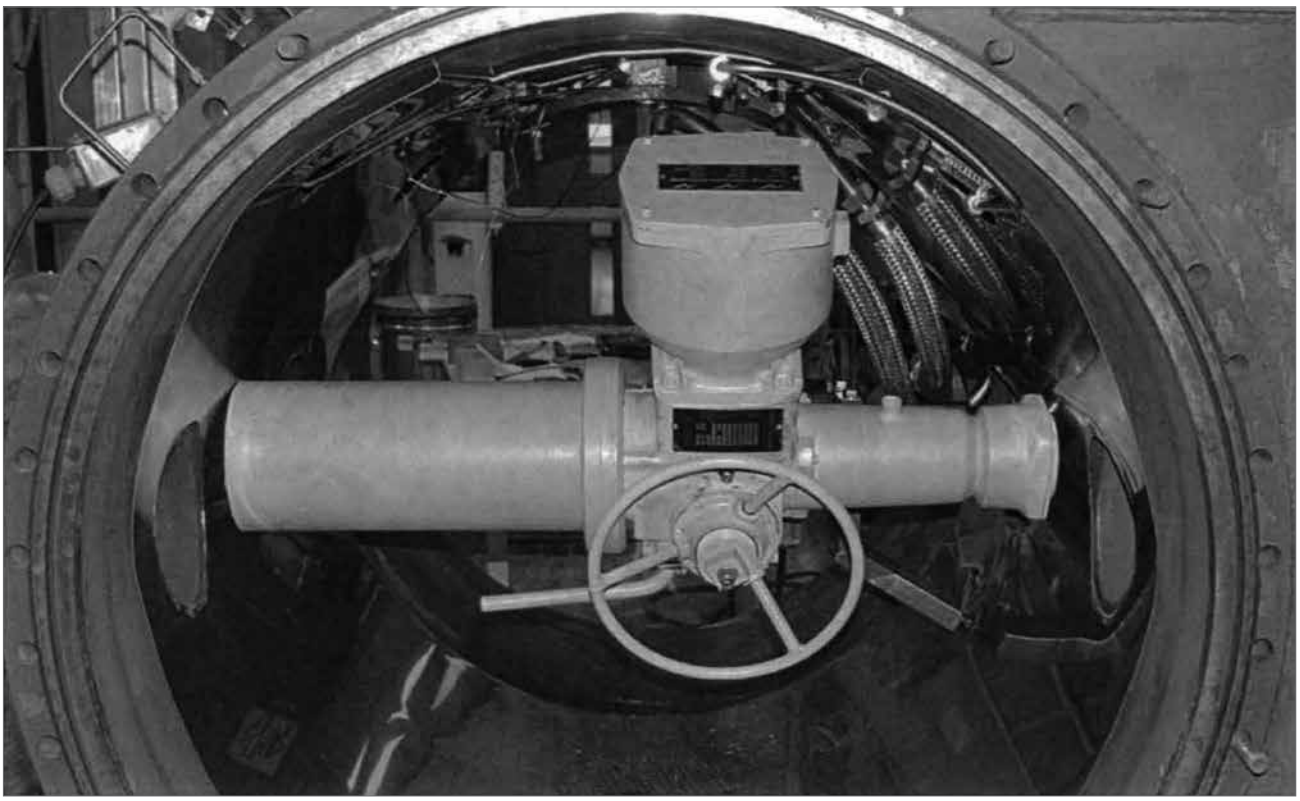


Figure 2: DBE Test Setup, Plan View and as Installed in Chamber Photograph

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