Attachment 6

Request 1.e – Description, Analysis, and Justification for ERV Modification Supporting EPU Operation (Including ERV Shaker Table Test Failure Evaluation)

Attachment 6

Documents included

Actuator Test Plan 1: S&A 06Q4568-DR-001, "Quad Cities ERV Actuator Vibration Testing Requirements," Revision 1 (Describes the test conducted between 2/6/06 and 2/20/06)
Actuator Similarity Analysis: GENE-0000-0051-3159, "Similarity Analysis ERV Actuator," Revision 0 (Describes the differences between the old and new actuators)
Actuator Test Plan 2: S&A 06Q4568-DR-007, "Quad Cities ERV Actuator Vibration Test Plan – Production Actuator," Revision 1 (Describes the test conducted between 3/19/06 and 3/31/06)
Actuator Test Report: S&A 06Q4568-DR-005, "Quad Cities ERV Pilot Valve Actuator Vibration Test Report," Revision 1 (Provides a summary of the test results)
Actuator Acceptance Criteria Report: MPR Associates Inc., "Vibration Acceptance Critieria for ERV Valve Actuators," Revision 1 (Provides the acceptance criteria for power operation)
Summary of Vibration Test: Table 1 – List of Actuator Shake Table Tested, Table 2 – List of Shake Table Tests, Table 3 – List of Shake Table Test Events and Their Resolutions (Provides a table of events encountered during the test)
Design Considerations Summary (EC 359513), "Electromatic Relief Valve (ERV) Actuator Replacement (Unit 2)," Revision 0 (Describes the design changes implemented to the modified actuator)
Work Planning Instructions (EC 359513) Revision 0: (Provides directions on the installation of the modified actuators)
50.59 Screening QC-S-2006-0028, Revision 0 (Prepared for the modified actuator)
50.59 Coversheet EC 359512 & EC 359513, Revision 0 (Prepared for the modified actuator)

Pictures included

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06Q4568-DR-001

Document Title: Quad Cities ERV Actuator Vibration Testing Requirements

Document Type:
Criteria ☐ Interface ☐ Report ☐ Specification ☐ Other ☒ Drawing ☐

Project Name:	Quad Cities ERVs
Job No.:	06Q4568
Client:	Exelon

This document has been prepared in accordance with the S&A Quality Assurance Program Manual, Revision 15 and project requirements.

Initial Issue: Rev. 0	
Prepared by: Steve Anagnostis	Date: 2/5/06
Reviewed by: Walter Djordjevic	Date: 2/5/06
Approved by: Walter Djordjevic	Date: 2/5/06

Revision Record:

Revision No.	Prepared by/ Date	Reviewed by/ Date	Approved by/ Date	Description of Revision
1	S.Anagnostis	W.Djordjevic	W.Djordjevic	See Section 1.0

S&A Stevenson & Associates	DOCUMENT APPROVAL SHEET Figure 2.8	CONTRACT NO. **06Q4568**

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1 INTRODUCTION

The purpose of this document is to develop the testing requirements for the vibration aging testing of the Electromatic Relief Valve (ERV) pilot valve actuator at the Quad Cities Nuclear Plant. Background information is provided in Section 2. The testing requirements are provided in Section 3.

Several components of the pilot valve actuator have degraded with operation, apparently due to high vibrations caused by flow induced acoustical resonances in the Main Steam lines. To address this, several modifications are being considered:

1. Modification of the pilot valve actuator internals to produce a more robust design,

2. Relocating the pilot valve and actuator to a location remote from the ERV to reduce the vibrations on the pilot actuator.

3. Replacing the actuator with a more robust product from another vendor.

The purpose of the testing is to develop the data required to determine the acceptable vibration levels for both the unmodified and modified actuator. These levels will be used to:

1. Determine whether the actuators are to be modified, relocated, replaced or some combination of these options,

2. Determine an acceptable level of vibration at the actuator location during plant operation.

Revision 1

- A process is added to modify the test procedure without revising this document (procedure change notice). See Section 3.6.

- Put a hold point in the test plan to review the aging motion developed after the swept sine tests prior to starting the aging tests. See Section 3.4.5.

- Prepare a form to document all inspections. See Section 3.5.4.

- Editorial changes.

2 BACKGROUND

The Quad Cities ERVs are controlled by a solenoid actuated pilot valve. The solenoid actuator is shown in Figure 1. Energizing the solenoid causes the plunger to move down, traveling along two guideposts and compressing the guidepost springs which hold the plunger up when the solenoid is de-energized.

2.1 Degradation Issues

Several components of the pilot valve actuator have degraded with operation, apparently due to high vibrations caused by flow induced acoustical resonances in the Main Steam lines. Observed degradations include:

- Excessive wear on the bushings that bear on the top of the guidepost springs.

  The bushing material was originally brass. Due to significant vibrations, the springs wore the brass bushings.

  The Unit 1 bushings and guideposts were replaced with Inconel (Alloy 750) in April 2005 (Q1R18). Unit 1 operated at pre-EPU power levels (~800 MWe) for about 90 days, then EPU power levels (~920 MWe) for about 160 days.

  In Unit 2, the original ERVs were replaced with Target Rock PORVs in 1995. The PORVs were removed and ERVs reinstalled in March 2004. Inconel (Alloy 750) bushings and guideposts were installed in the ERVs at that time. Unit 2 then operated for about 400 days at pre-EPU power levels. The actuators were visually inspected and no significant damage was observed. Unit 2 then operated at EPU power levels for about 200 days.

  Both units were shut down around 1/1/06 and the ERVs were inspected. On some of the valves, the springs had jammed between the bushing and the guideposts, resulting in damage to the springs, scoring of the guideposts, and possibly preventing the actuator from moving. The Unit 2 ERV 3D actuator, which experienced the highest vibrations (see Section 2.2), had the most significant damage. Other actuators experienced lower vibration levels and had lower levels of damage (See Figure 2 and Figure 3) supporting the conclusion that high vibration is the cause of the degradation.

  All valves in both Units had tight tolerance hardened steel washers installed on the guideposts between the top of the springs and the bushings, and the Units were restarted on 1/19/06.

- Loosened / fallen out screws that attach the limit switches.

- Worn pivot plate pins.

- Wearing indications on the brass sides of the plunger at the pivot plate and at the bottom slots.

- Wearing of the lever arm adjusting screw.

Other identified issues that may not be related to vibration induced degradation include:

- Binding of the plunger due to an improper spacer size at the roller.

- Broken or cracked rivets that attached the support brackets for the guideposts to the actuator body.

2.2 In-situ Vibration Measurements

Unit 1 measurements were made in 12/03 and again in 6/05. Unit 2 measurements were made in 4/04 and again in 5/05. Measurements were made at various plant power levels. Results at pre-EPU power levels (~800 MWe) and EPU power levels (~912 MWe) are summarized below.

(The coordinate directions used for the measurements are not completely consistent. Y is always vertical, X and Z are always horizontal, but the orientation of X and Z with respect to the steam flow is not consistent.)

Table 1. 2003/2004 Measurements (Pre Dryer Replacement)

	Grms (0 – 200 Hz)					
	Pre-EPU (1)			EPU (2)		
Location	**X**	**Y**	**Z**	**X**	**Y**	**Z**
U2 3B ERV	0.12	0.23	0.15	0.21	0.38	0.26
U2 3B Pilot	0.44	0.43	0.18	0.83	0.76	0.37
U2 3C ERV	0.13	0.39	0.13	0.27	0.77	0.27
U2 3D ERV	0.25	0.87	0.52	0.38	**1.71**	**1.35**
U2 3D Pilot	0.67	0.76	0.34	**1.18**	**1.64**	0.68
U2 3E ERV	0.24	0.76	0.08	0.49	**1.54**	0.13
U2 3E Pilot	0.41	0.91	0.23	0.54	**1.54**	0.58
U2 MSIV 1B	0.07	0.05	0.11	0.12	0.08	0.19
U1 3B ERV	0.09	0.30	0.08	0.08	0.70	0.18
U1 3B Pilot	0.69	0.87	0.22	**1.52**	**2.04**	0.56
U1 3C ERV	-	**4.14**	0.48	-	**4.17**	0.47
U1 3D ERV	0.07	0.27	0.11	0.13	0.67	0.18
U1 3D Pilot	-	0.34	0.22	-	0.75	0.56
U1 3E ERV	0.08	0.40	0.06	0.18	**1.02**	0.13
U1 MSIV 1B	0.06	0.04	0.09	0.13	0.07	0.17

(1) Unit 1: 2488 MWt (12/03) Unit 2: 820 MWe (4/04)
(2) Unit 1: 2910 MWt (12/03) Unit 2: 912 MWe (4/04)

Table 2. 2005 Measurements (Post Dryer Replacement)

	Grms (0 – 200 Hz)					
	Pre-EPU (1)			EPU (2)		
Location	**X**	**Y**	**Z**	**X**	**Y**	**Z**
U2 3B ERV	0.07	0.17	0.13	0.20	0.43	0.40
U2 3B Pilot	0.42	0.36	0.12	**1.03**	0.79	0.23
U2 3C ERV	0.00	0.23	0.15	0.01	0.71	0.27
U2 3D ERV	0.55	0.58	0.55	**1.66**	**1.29**	**1.90**
U2 3D Pilot	**1.18**	0.77	0.01	**1.22**	**1.51**	0.02
U2 3E ERV	0.07	0.30	0.07	0.16	0.79	0.15
U2 3E Pilot	0.06	0.82	0.01	0.03	**1.39**	0.01
U1 3B ERV	0.10	0.20	0.12	0.16	0.35	0.25
U1 3B Pilot	0.09	0.24	0.13	0.15	0.45	0.23
U1 3C ERV	0.09	0.10	0.08	0.15	0.11	0.12
U1 3C Pilot	0.09	0.44	0.11	0.15	0.77	0.18

(1) Unit 1: 786 MWe (6/05) Unit 2: 792 MWe (5/05)
(2) Unit 1: 912 MWe (6/05) Unit 2: 930 MWe (5/05)

These measurements are typically dominated by one or more distinct spikes in the 140 Hz to 160 Hz range, with the highest measurements dominated by a spike at 151 Hz. Figure 7 and Figure 8 show typical measurements.

Structures typically respond to vibrations well below the dominant frequency range of these measurements. References 3 and 4 provide the 2005 in situ response levels for 0 – 200 Hz and 135 Hz – 165 Hz. The response level for 0 – 200 Hz excluding 135 Hz – 165 Hz is obtained by squaring the two known values, subtracting, then taking the square root of the result. Results are summarized below for EPU power levels in both units.

Table 3. 2005 EPU Power Level Measurements Banded Powers

	G rms		
Location	**135 Hz – 165 Hz**	**0 Hz – 200 Hz**	**Outside 135 Hz – 165 Hz**
U2 3E ERV (X)	0.15	0.16	0.06
U2 3E ERV (Y)	0.76	0.79	0.20
U2 3E ERV (Z)	0.13	0.15	0.07
~~U2 3E Pilot (X)~~	~~0.01~~	~~0.03~~	~~0.03~~
U2 3E Pilot (Y)	1.34	1.39	0.35
~~U2 3E Pilot (Z)~~	~~0.00~~	~~0.01~~	~~0.01~~
U2 3B ERV (X)	0.19	0.20	0.06
U2 3B ERV (Y)	0.42	0.43	0.10
U2 3B ERV (Z)	0.40	0.40	0.07
U2 3B Pilot (X)	0.99	1.03	0.27
U2 3B Pilot (Y)	0.76	0.79	0.24
U2 3B Pilot (Z)	0.21	0.23	0.08
~~U2 3C ERV (X)~~	~~0.00~~	~~0.01~~	~~0.01~~
U2 3C ERV (Y)	0.69	0.71	0.17
U2 3C ERV (Z)	0.26	0.27	0.08
U2 3D ERV (X)	1.65	1.66	0.19
U2 3D ERV (Y)	1.27	1.29	0.18
U2 3D ERV (Z)	1.89	1.90	0.20
~~U2 3D Pilot (X)~~	~~0.32~~	~~1.22~~	~~1.18~~
U2 3D Pilot (Y)	1.49	1.51	0.26
~~U2 3D Pilot (Z)~~	~~0.02~~	~~0.02~~	~~0.00~~
U1 3B ERV (X)	0.15	0.16	0.05
U1 3B ERV (Y)	0.34	0.35	0.09
U1 3B ERV (Z)	0.24	0.26	0.07
U1 3B ERV (Alt-X)	0.14	0.15	0.05
U1 3B ERV (Alt-Y)	0.43	0.45	0.11
U1 3B ERV (Alt-Z)	0.22	0.23	0.08
U1 3C ERV (X)	0.12	0.15	0.09
~~U1 3C ERV (Y)~~	~~0.07~~	~~0.11~~	~~0.09~~
U1 3C ERV (Z)	0.09	0.12	0.08
U1 3C ERV (Alt-X)	0.13	0.16	0.09
U1 3C ERV (Alt-Y)	0.76	0.77	0.11
U1 3C ERV (Alt-Z)	0.16	0.18	0.09

Note: Strike-throughs indicate invalid measurements

The following conclusions are drawn from the measurement data:

1. EPU levels are generally higher than pre-EPU levels, typically by about a factor of 2.

2. Unit 2 levels are higher than Unit 1 levels, except that the 2003/2004 U1 ERV 3C Y-axis measurement showed higher vibrations in Unit 1. This measurement is believed to be erroneous because:

   - The pre-EPU value (4.14g) is substantially higher than any other 2003/2004 pre-EPU measurement.

   - The post-EPU value (4.17g) is the same as the pre-EPU measurement and substantially higher than any other 2003/2004 post-EPU measurement.

   - The corresponding 2005 measurements (.10g pre-EPU and .11g EPU) are substantially lower.

3. Unit 2 2005 levels (post dryer replacement) are about the same as Unit 2 2003/2004 levels (pre dryer replacement). The Unit 1 2005 levels are lower than the Unit 1 2003/2004 levels.

4. The maximum observed damage was on the U2 3D actuator, which has the highest 2005 measurements (and the highest 2003/2004 measurements with exception of the U1 3C measurement discussed above.)

   The power spectra for the U2 3D measurements are shown in Figure 9. XYZ measurements are available for the ERV, but only the Y measurement is available for the pilot due to instrumentation problems. The XYZ ERV spectra are essentially identical. All are dominated by a single frequency at 151 Hz. The Y Pilot spectrum has a comparable amplitude peak at 151 Hz, and some additional energy at lower frequencies (probably due to the structural modes of the pilot valve assembly).

   The orbital plots for the U2 3D ERV measurements are displayed in Figure 10. The plots show that the ERV is moving in an approximately circular motion in a vertical plane located about 45 degrees from the X axis.

5. From Tables 1 and 2, 2.0g rms is a reasonable upper bound estimate of the narrow band motion induced by the acoustic resonances. It was observed at a frequency of 151 Hz for the U2 3D ERV.. For this testing effort it will be assumed it has the potential to occur anywhere in the 20 Hz – 200 Hz frequency range, with an amplitude of 2.0g rms in the 100 Hz – 200 Hz, and at decreasing amplitudes in the frequency range from 20 Hz to 100 Hz (see Section 2.3.)

From Table 3, 0.3g rms is a reasonable upper bound estimate of the broad motion from 0 to 200 Hz, excluding the effect of the acoustic resonances.

2.3 Effect of the Acoustic Side Branch Modification

Based on an extensive testing and analysis effort to address issues with the steam dryer, the measured plant vibrations are believed to be caused by flow-induced acoustic resonances in the standpipes leading to the main steam relief valves. Currently, these acoustic resonances are in the 140 Hz to 160 Hz frequency range. To reduce these acoustic resonances, a plant modification is being considered to install an acoustic side branch (ASB) on each standpipe. These ASBs are intended to both reduce the amplitude of the acoustic resonances and lower the frequencies of those resonances.

The testing and analysis to predict the acoustic frequencies and resultant pipe vibrations has not been completed. For the purposes of this test, the following is assumed:

- Acoustic resonances can occur anywhere from 100 Hz to 200 Hz and will produce an acceleration of 2.0 grms.

- Acoustic resonances can occur from 20 Hz to 100 Hz, but will have a displacement amplitude equivalent to that of a 2 grms acceleration at 100 Hz.

  2 grms at 100 Hz = 2 x 386 in/s^2 / (6.28 x 100)^2 = 0.002" rms
  0.002" rms at 70 Hz (for example) = 0.002 x (6.28 x 70)^2 / 386 = 1 grms

2.4 Testing Strategy

The rate at which damage occurs to the actuator depends on the magnitude and frequency content of the vibration spectrum it is subjected to, the state of the actuator as a result of prior damage, the time the actuator is subjected to the vibration, and the mechanism that generates the damage. These effects can be highly non-linear. For example, doubling the magnitude of vibration can result in significantly more than double the rate at which the damage accumulates. As another example, increased gaps due to wear can result in higher impact forces as wear progresses, thereby resulting in accelerated wear rates.

Due to highly non-linear wear rates that can occur as a function of vibration amplitude, time, and changing wear mechanism, it is difficult to extrapolate wear or damage to extended time periods based on short-term wear rate testing. Typically, an accelerated wear mechanism must be used by increasing vibration levels so that an equivalent amount of wear can be generated in a short time period as would occur in the actual environment during the planned lifetime of a component. In order to provide reasonable assurance that the tests conducted are representative of at least one operating cycle, the original actuator is included in the testing to provide a reference for comparison of the accumulated damage to the damage observed from operating in the plant at EPU vibration levels. With this in mind, the test will consist of the following steps:

1. Run sine sweeps on the actuators that are to be tested to identify their natural frequencies and modes. The actuators to be tested are:

   a. The actuator as installed in the plant prior to January 2006. This design has Inconel guideposts and bushings.

   b. The actuator as installed in the plant in January 2006. This is the same design as #1, except that a tighter tolerance, hardened steel washer is placed between the guidepost springs and the bushings.

   c. A modified version of the current actuator to be provided by GE.

   d. A replacement design being supplied by Target Rock. See Figure 6.

2. Select a spectrum that covers the vibration for all possibilities in the plant. The spectrum needs to envelop the worst valve EPU spectrum (measured on the pilot valve), the worst anticipated spectrum of the structural steel where the actuator would be located if it were to be moved off the pipe, and the anticipated vibration spectrum for EPU operation with the ASBs in place.

3. Add specific sine dwells to the spectrum to include the frequency of any modes identified during the sine sweep testing. These specific sine dwells should be broadened by a few Hz to ensure the resonances involved are excited. The magnitude of the sine dwell input levels should be equivalent to the magnitude of the acoustic response in the highest measured spectrum from the plant.

4. Select a scaling multiplier for the spectrum and the sine dwells to multiply the magnitude of the spectrum and the sine dwells at each frequency.

5. Run a short interval of vibration using the selected spectrum with the sine dwells and a scaling multiplier of 0.5 to determine whether the response at resonance for each mode of the actuators responds to the expected level. If not, adjust the input level of each sine dwell to obtain the desired response.

6. Run the wear tests to the selected spectrum including the sine dwells. Vary the scaling multiplier for each wear test as follows:

   0.5
   1.0
   2.0
   4.0
   6.0

8.0

After each test cycle, operate the actuators 3 times to see if they operate. Inspect the actuators to look for wear and/or damage.

7. If there is measurable wear damage for a particular actuator at a location where the wear does not mitigate contact forces, the spectrum that caused the wear is considered too high and the previous spectrum that the operator sustained without damage will be considered to be the allowable spectrum for that actuator.

8. Use the damage accumulated by the original actuator as verification that the spectrum applied is representative (as an accelerated aging spectrum) of the current EPU spectrum in the plant.

9. Once an actuator is selected for installation in the plant, the actuator should be located where the in-situ spectrum is less than the allowed spectrum for that actuator.

3 TESTING PLAN & REQUIREMENTS

3.1 Purpose

The purpose of this document is to provide the vibration aging test requirements for the pilot valve actuator of a Dresser 6"-1525VX-3-XFB11-NC120 Electromatic Relief Valve (ERV). Four actuators are to be tested:

Dresser #1: The design used at the Quad Cities Nuclear Plant prior to January 2006 (Inconel posts and bushings)

Dresser #2: The design currently installed at the Quad Cities Nuclear Plant prior to January 2006 (same as Actuator #1 plus a tight tolerance hardened steel washer placed on the guidepost between the spring and the bushing).

Dresser/GE: A modification of the Dresser design being developed by GE.

Actuator #4: A replacement actuator from Target Rock.

3.2 Mounting of the Test Specimens

The test lab will be provided with four test specimens consisting of a pilot valve actuator mounted to a support stand using the bolts which normally attach the actuator to the pilot valve yoke (see Figure 4, Figure 5).

Mount the test specimens by bolting the support stands to the test table. Orient all test specimens so that the plungers are vertical. See Sections for 3.4.1 and 3.5.1 for the horizontal orientations.

All specimens are to be tested with the cover installed (see Figure 4). As instructed by the test engineer, small holes (up to 3" x 3") may be cut in the cover for observation. No more than four such holes may be cut in any one cover.

3.3 Electrical Requirements

125 V DC power is required to operate the Dresser actuators. Labeled electrical leads will be provided.

125 V DC power is required to operate the Target Rock actuator. Labeled electrical leads or wiring diagrams will be provided.

3.4 Swept Sine Tests

3.4.1 Test Specimen Mounting

For one horizontal test, mount the Dresser actuators so that the plane of the guideposts is parallel to the direction of table motion. For the other horizontal test, mount the

Dresser actuators so that the plane of the guideposts is normal to the direction of table motion.

The internal details of the Target Rock actuator shall be assessed by the test engineer and an Exelon representative to determine whether swept sine tests are required in one or both horizontal directions.

3.4.2 Vibration Instrumentation

Instrument the Dresser actuators with:

- a triaxial accelerometer at or near the top of each guidepost (if this is not practical, place the accelerometer on the support plate near the base of the guidepost.)
- a triaxial accelerometer near the top of the solenoid frame,
- a triaxial accelerometer near the projecting end of the base plate.

The internal details of the Target Rock actuator shall be assessed by the test engineer and an Exelon representative to determine accelerometer locations for the swept sine tests.

3.4.3 Excitation

Direction: Test each specimen in all three directions of table motions. Separate tests are to be performed for each direction of table motion. For each direction of table motion, multiple specimens may be tested simultaneously.

Frequency: Swept sine, 20 Hz – 200 Hz, 2 minute / octave or slower

Amplitude: 0.2g

3.4.4 Data Collection Requirements

Response plot (g versus frequency) for each accelerometer.

3.4.5 Develop and Calibrate the Shake Table Motion for the Aging Tests

From the response plots, develop a list of significant modes from 20 Hz to 200 Hz. Significant modes may be identified by peaks in the response plots with amplitudes greater than about 10x the input acceleration level (It is not the intention of this plan to require that all peaks greater than 10x the input be identified as significant. The experience and judgment of the test engineers may be used, but the basis for selecting the modes must be documented.)

Use the shake table to dwell (0.2g input) at the significant mode frequencies to (a) ensure that the precise frequency is known, (b) and the level of amplification is known.

Construct a steady state motion that consists of the following components:

- 0.0005 g^2/Hz from 20 Hz to 200 Hz.

  This is a broad band signal with an amplitude of 0.3 g rms.

- For each significant mode with a frequency of 100 Hz to 200 Hz:

  1.0 g^2/Hz over a 4 Hz band centered on the frequency of the mode.

  This is a narrow band signal with an amplitude of 2.0 grms, centered on the frequency of the mode.

- For each significant mode with a frequency of 20 Hz to 100 Hz:

  ($f^3/10^6$) g^2/Hz over a 0.04f Hz band centered on f, where f is the frequency of the mode.

  This is a narrow band signal with an amplitude of 0.0002f^2 grms, centered on the frequency of the mode. This results in a signal with an amplitude of 0.002" rms, irrespective of frequency.

  This is done because (a) maintaining the acceleration level at 2g for lower frequency modes would result in unrealistically large displacements and associated damge, and (b) if the ASBs do shift the acoustic resonances, it is expected that the associated amplitudes will be significantly reduced.

The above is the nominal motion (scale factor = 1.0) to be used for the vibration aging test.

Decrease the nominal motion by a factor of 10, so it is approximately the same amplitude as 0.2g swept sine test. Run a sufficient number of tests to develop a power spectrum (20 Hz – 200 Hz) for all accelerometer locations and directions used in the swept sine tests. This data will be used to determine how the response induced by the nominal motion compares to the response induced by the swept sine tests.

Prior to proceeding with the aging tests, conduct a review of the nominal motion as directed by the responsible Exelon engineer. This review and the final aging motion is to be documented using the change procedure in Section 3.6.

3.5 Vibration Aging Tests

3.5.1 Test Specimen Mounting

For the horizontal tests, mount the Dresser actuators so that the plane defined by the two guideposts is at 45 degrees to the direction of the table motion.

The results of the Target Rock actuator swept sine tests shall be assessed by the test engineer and an Exelon representative to determine how to mount the actuator for the aging tests.

3.5.2 Vibration Instrumentation

Instrument each Dresser actuator with two accelerometers. Install one accelerometer near the base, and the other accelerometer on or near the top of the plunger (see Figure 5). Orient the accelerometers in the direction of table motion.

The results of the Target Rock actuator swept sine tests shall be assessed by the test engineer and an Exelon representative to determine how to instrument the actuator for the aging tests.

3.5.3 Excitation

Type and Frequency Range: The nominal motion as defined in Section 3.4.5.

Amplitude: per table below

Direction, Duration: 10 hours horizontal (table X or Z), then 10 hours in the vertical (table Y) at each amplitude listed below

Amplitude*
0.25
0.50
1.00
2.00
4.00
6.00
8.00
(to be determined)
(to be determined)
(to be determined)

*The amplitude is a scale factor on the nominal motion defined in Section 3.4.5

Note: The table motions may be adjusted by the test engineer (with concurrence from Exelon) based on the observed behavior of the test specimens.

The "to be determined" will be determined by the test engineer (with concurrence from Exelon) based on the observed behavior of the test specimens.

3.5.4 Data Collection Requirements

Prior to performing any data collection function, prepare a form to document to the data collection. Use the change procedure (Section 3.6) to review and approve this form.

3.5.4.1 Vibration Data

Digitally store 60 seconds of data for each accelerometer at 60 minute intervals. This includes all accelerometers on the actuators and the table accelerometer. At a minimum, the following information is to be digitally stored for each measurement:

Test Description
Channel #
Channel description
Date and time of measurement
60 seconds of accelerometer data at a minimum rate of 2000 data points / sec (delta T = 0.0005 seconds).

3.5.4.2 Actuation

After each test period, remove the cover from each actuator. Visually inspect the actuator for any damage. Repair or remove any damaged test instrumentation that could interfere with actuation (e.g, loose wires, displaced accelerometers), but do not repair any damage to the actuator (e.g., loose screws, displaced components) After the visual inspection, cycle each actuator three (3) times. At a minimum, record the following information:

Actuator Type
Date and time of actuation
Photograph of the actuator with the cover off and prior to actuation.
Any damage observed based on the visual inspection.

On actuation:

Did the plunger depress fully and freely?
Did the pivot plate depress fully so that the contacts lifted (visual observation, Dresser valves only)?
Photograph of the actuator after actuation (plunger down).

On de-actuation:

Did the plunger return to up position fully and freely?
Is the roller in contact with the bottom actuator plate (Dresser valves only)?

Did the pivot plate return to the upright position so that the contacts are firmly against the contact plate (Dresser valves only)?.
Photograph of the actuator after de-actuation (plunger up).

3.5.4.3 Wear Data

After each test period, remove the test specimens from the table, inspect the actuators for wear, photograph and quantify the wear. At a minimum, the following information is to be collected:

Test Description
Actuator Design
Date and time of wear assessment
For each wear mechanism
- Photograph
- Written description
- Quantification of wear

Based on operating experience and previous testing, the wear inspections for the Dresser/GE actuators should, at a minimum, consist of:

- measuring the inside diameter of the guidepost bushings,
- measuring the outside diameter of the guideposts and the depth of any grooves worn into the guideposts by the springs,
- measuring the depth of any grooves worn into the plunger side plates where they bear against the pivot plate,
- measuring the depth of any grooves worn into the plunger side plates where they bear against the slots in the actuator's bottom plate,
- measuring thinning of the guidepost springs due to wearing against the guideposts,
- measuring any loss of length of the guidepost springs, particularly due wear if the springs get caught in the bushings,
- checking fasteners for loosening, particularly the pivot plate pins and the screws that fasten the limit switches to the solenoid frame.

The internals of the Target Rock actuator shall be assessed by the test engineer and an Exelon representative to determine how to perform the wear inspections.

3.6 Changes to the Test Plan

This test plan involves previously untested components and unusual testing requirements. As a result, it is expected that changes to the test plan may be required as the testing proceeds. Depending on the extent of these changes, a change may be reviewed, approved, and documented by either (a) revising this document per established procedures, or (b) using the Test Plan Change Notice included as Attachment A.

The responsible Exelon engineer shall decide which method is to be used.

The Test Plan Change Notice requires the following:

- The test plan number (06Q4568-DR-002).
- The test plan revision number current at the time of the change.
- A change notice number. Number sequentially starting with 1 (one).
- A description of the change.
- The basis for making the change.
- The responsible Exelon engineer shall designate a preparer, reviewer and approver. All three individuals shall sign the Test Plan Change Notice.

All Test Plan Change Notices shall be included with the test report.

4 REFERENCES

1. Structural Integrity Associates Calculation No. QC-11Q-302, "Quad Cities Unit 1 Main Steam Line Vibration Data Reduction", Rev. 0, 1/7/04.

2. Structural Integrity Associates Calculation No. QC-16Q-303, "Quad Cities Unit 2 ERV Vibration Data Reduction", Rev. 0, 4/12/04.

3. Stevenson & Associates Calculation No. 06Q4568-C-001, "Quad Cities Unit 1 2005 ERV Vibration Data Reduction", Rev. 0, 1/24/06.

4. Stevenson & Associates Calculation No. 06Q4568-C-002, "Quad Cities Unit 2 2005 ERV Vibration Data Reduction", Rev. 0, 1/24/06.

5. Stevenson & Associates Calculation No. 06Q4568-C-003, "Quad Cities Unit 2 January 2006 ERV Vibration Data Reduction", Rev. 0, 1/24/06.

5 FIGURES

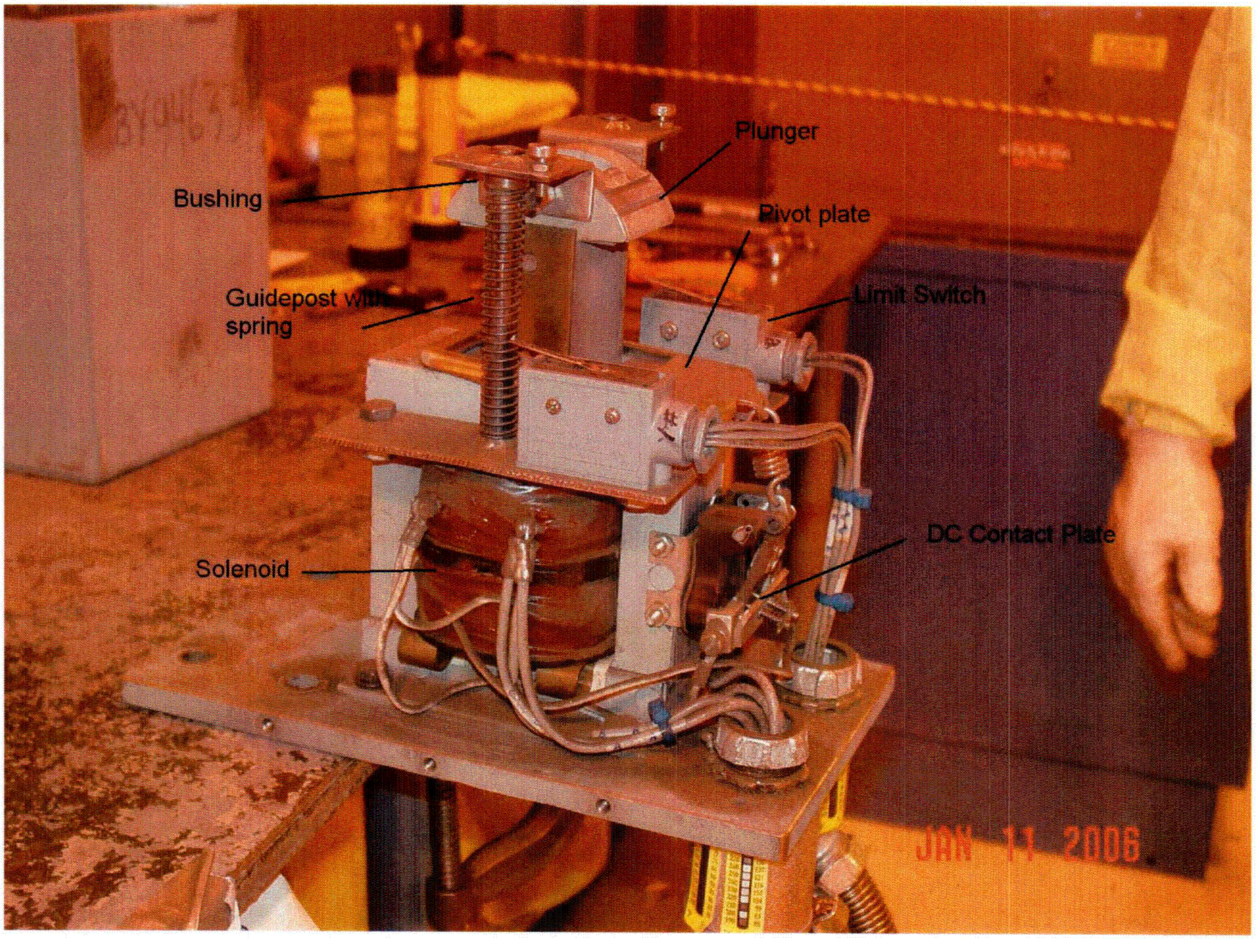


Figure 1. ERV pilot valve actuator as configured prior to January 2006.

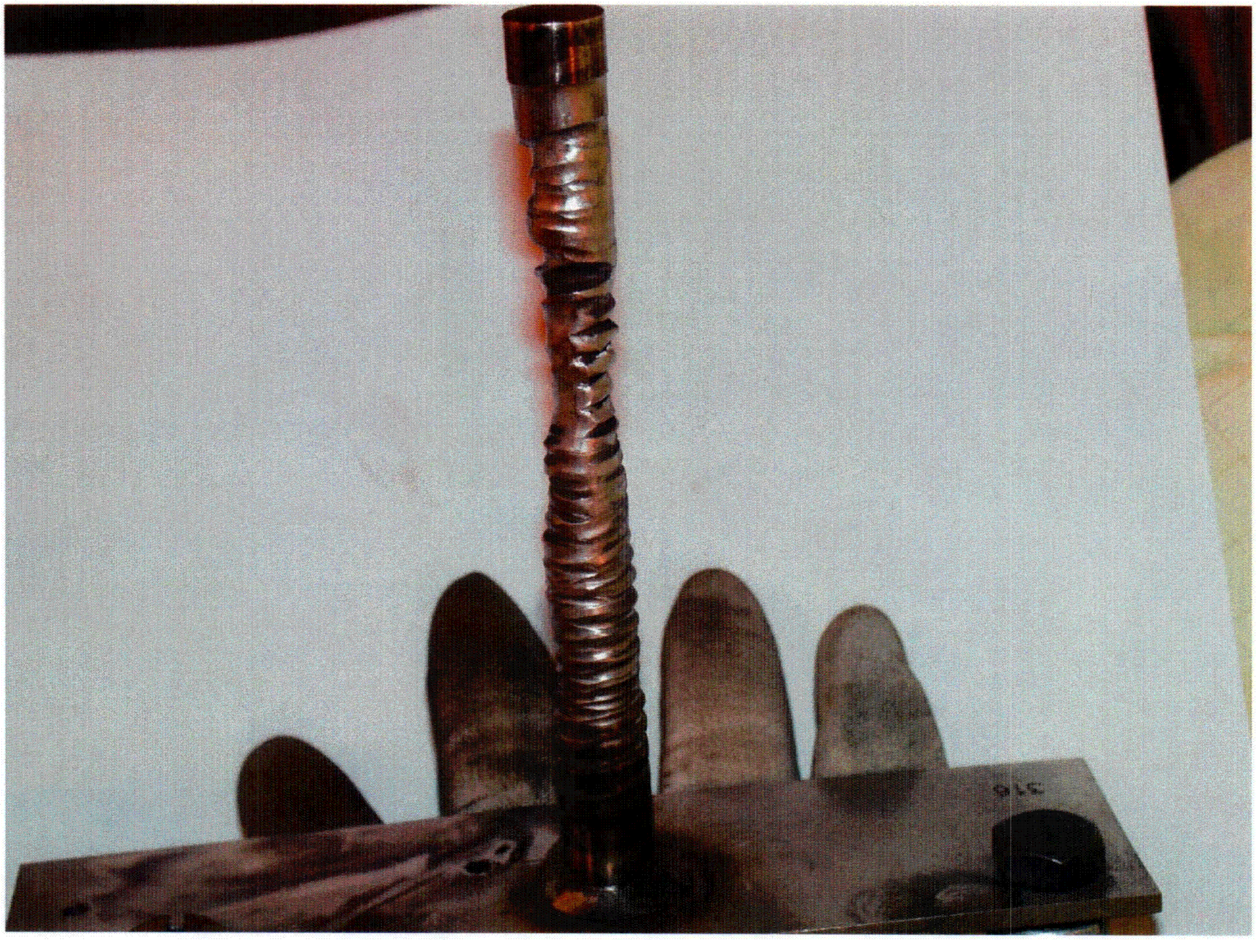


Figure 2. Unit 2 ERV 3D actuator guide post after operating at EPU power levels for about 200 days. Measured acceleration levels were 1.5g rms to 2g rms.

Stevenson & Associates

DOCUMENT SHEET

PROJECT	Quad Cities ERVs
SUBJECT	Quad Cities ERV Actuator Vibration Testing Requirements

NO.	O6Q4568-DR-001 Rev. 1
SHEET NO.	23 OF 30
DATE	2/6/06
COMP BY	SA
C'K'D BY	WD

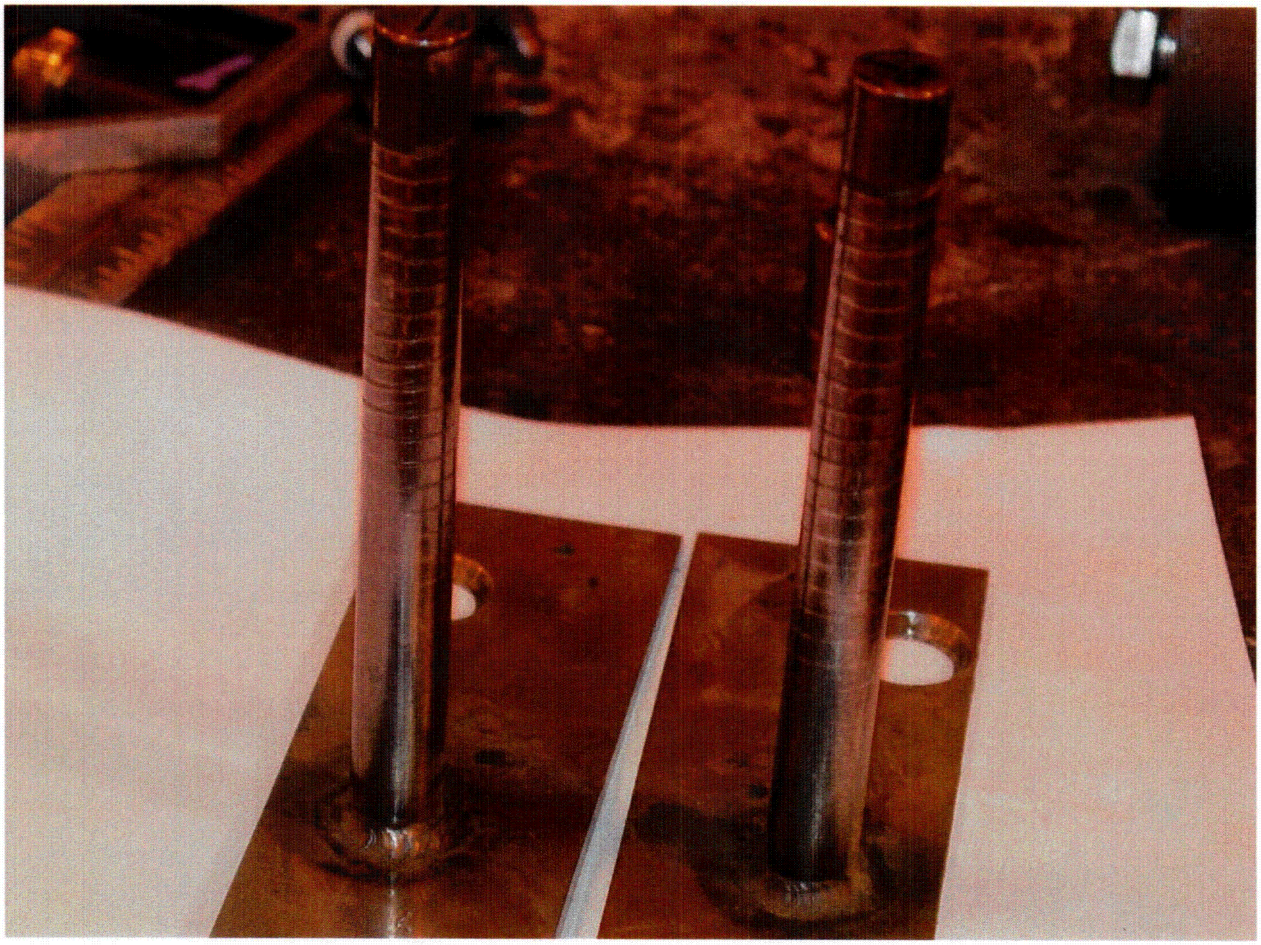


Figure 3. Unit 2 ERV 3B actuator guide post after operating at EPU power levels for about 200 days. Measured acceleration levels were about 0.4g rms to 1g rms.

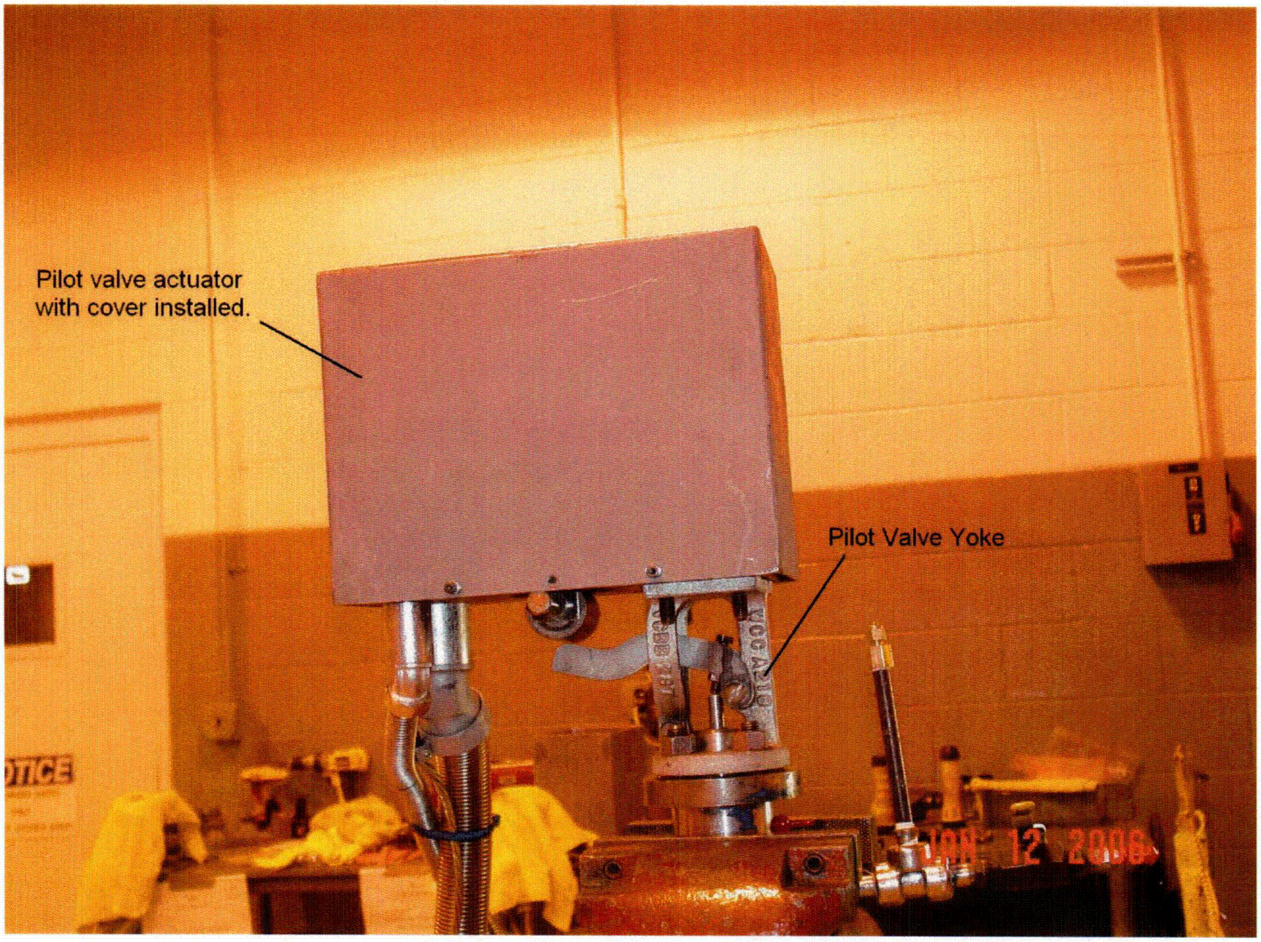


Figure 4. Pilot valve actuator (with cover) mounted on yoke.

Stevenson & Associates

DOCUMENT SHEET

NO.	O6Q4568-DR-001 Rev. 1
SHEET NO.	25 OF 30
DATE	2/6/06
COMP BY	SA
C'K'D BY	WD

PROJECT Quad Cities ERVs

SUBJECT Quad Cities ERV Actuator Vibration Testing Requirements

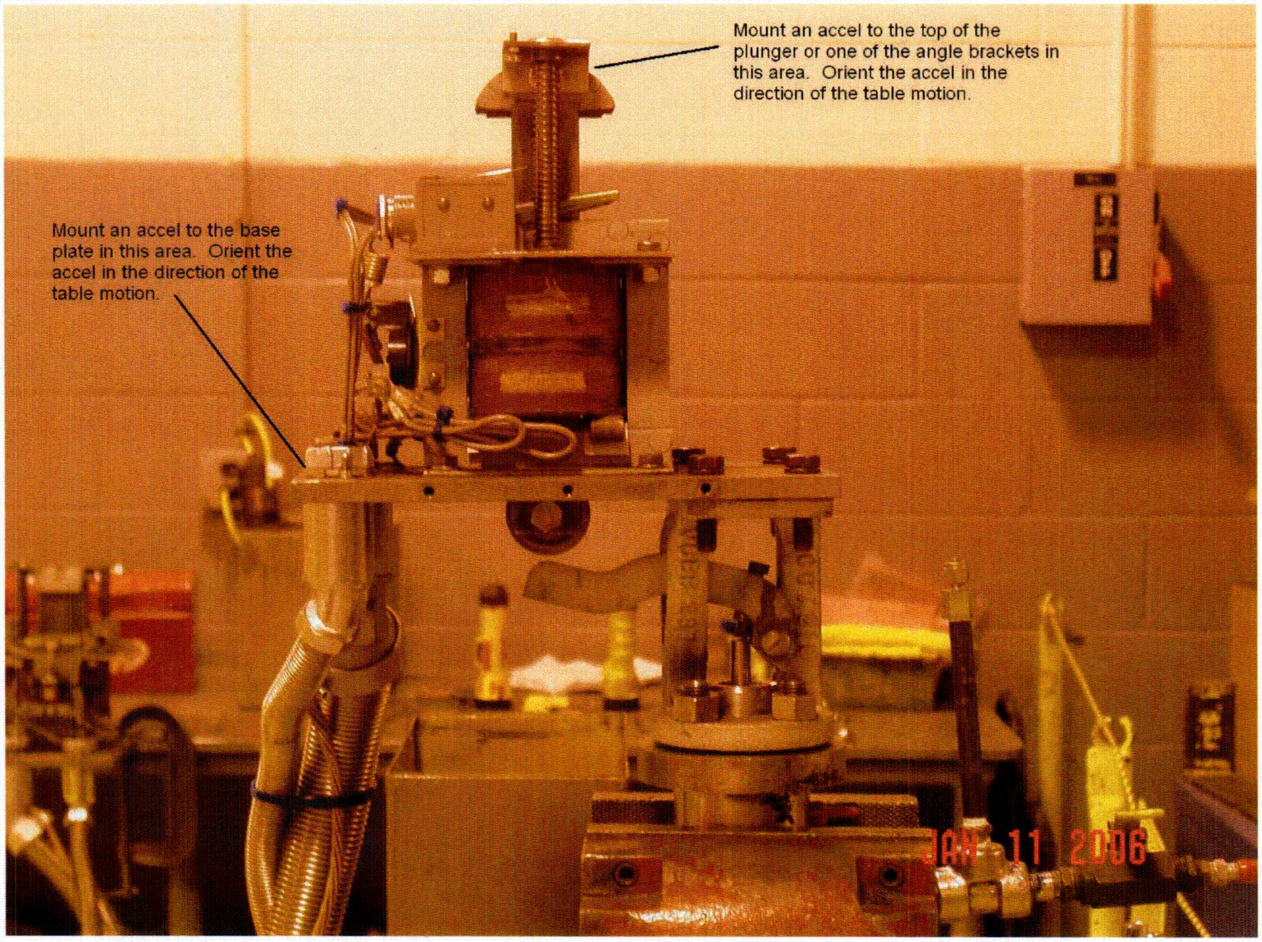


Figure 5. Actuator and yoke, accelerometer locations.

PROJECT Quad Cities ERVs

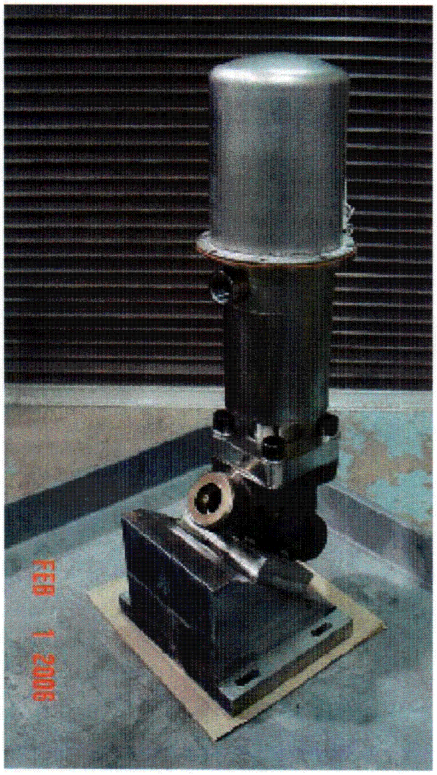
SUBJECT Quad Cities ERV Actuator Vibration Testing Requirements

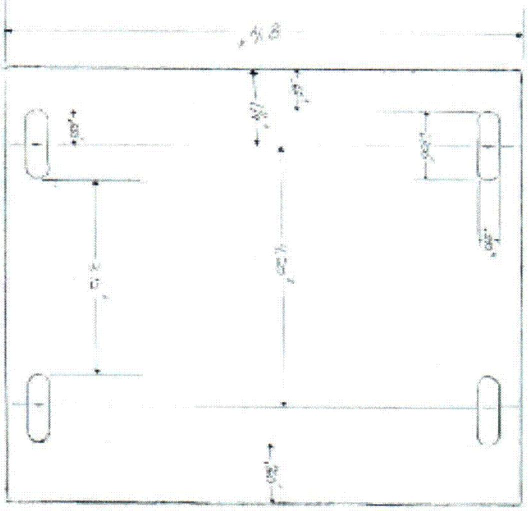
CURTISS WRIGHT FLOW CONTROL CORPORATION

Target Rock

QUAD CITIES PORV
<u>Target Rock Pilot Valve</u>

Test Specimen Weight = 99 lb.

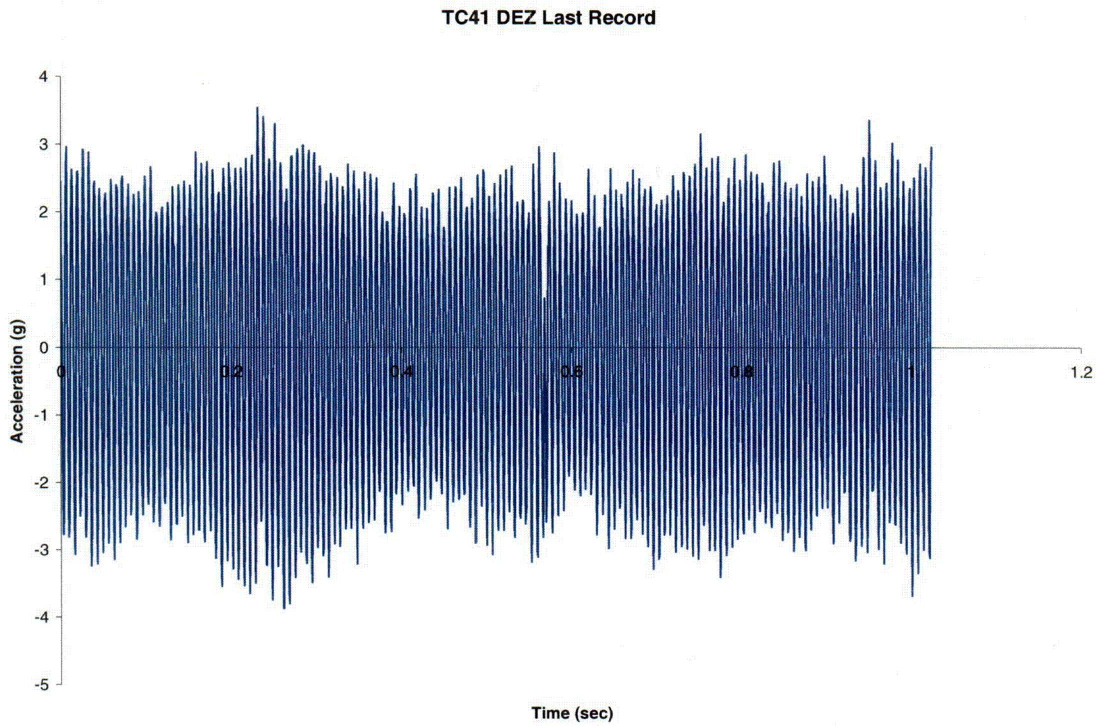




06X901 (ACTUAL SIZE)

Target Rock and Enertech are Divisions of Curtiss-Wright Flow Control Corporation
Enertech - 2950 Birch Street, Brea, CA 92821 USA - email@et.curtisswright.com - Fax 714-528-0128 - Phone 714-528-2301
Target Rock - 1966 E Broadhollow Road, E. Farmingdale, NY 11735 USA - email: cwfc@trc.curtisswright.com - Fax 631-293-4949 - Phone 631-293-3800

Figure 6. Target Rock Actuator



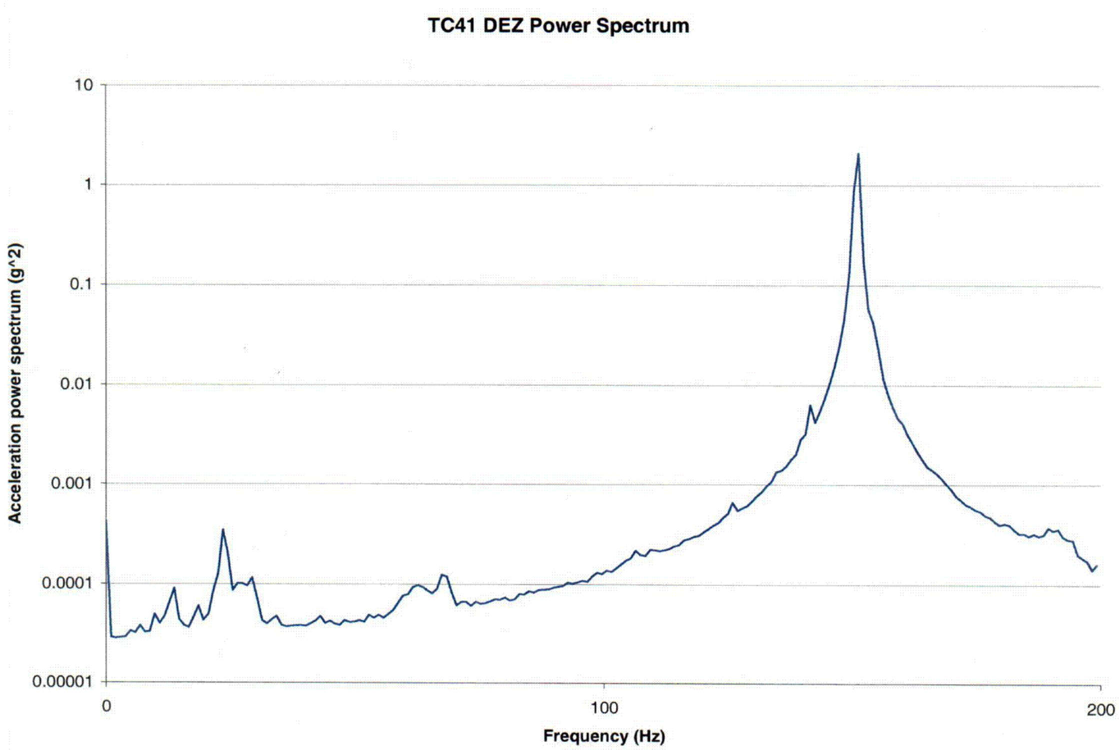
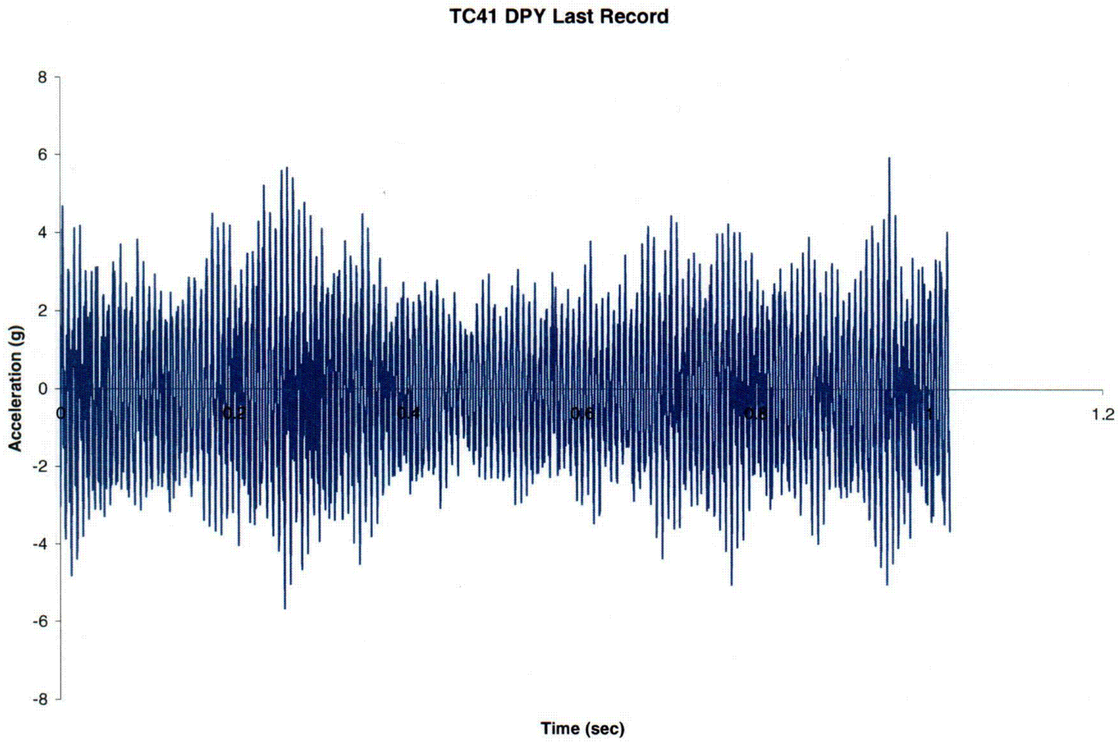


Figure 7. 2005 in-situ measurement data, EPU power level, U2 3D ERV Z direction.



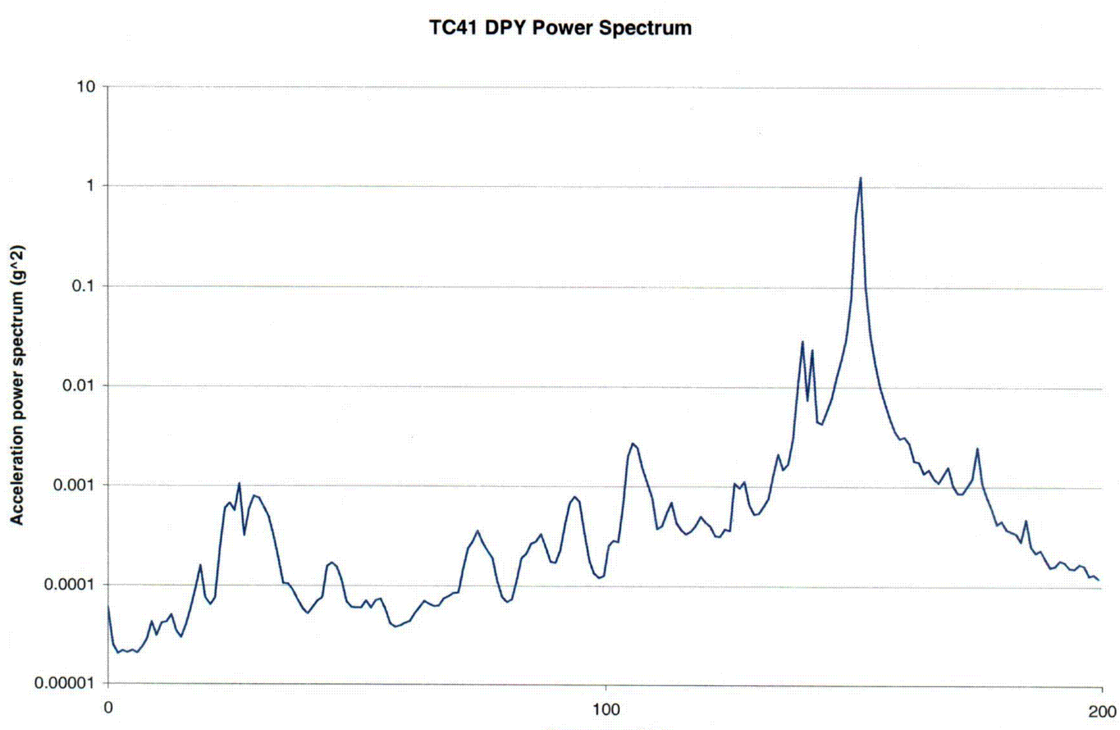


Figure 8. 2005 in-situ measurement data, EPU power level, U2 3D Pilot Y direction.

Stevenson & Associates	DOCUMENT SHEET
PROJECT Quad Cities ERVs	NO. O6Q4568-DR-001 Rev. 1
	SHEET NO. 29 OF 30
SUBJECT Quad Cities ERV Actuator Vibration Testing Requirements	DATE 2/6/06
	COMP BY SA C'K'D BY WD

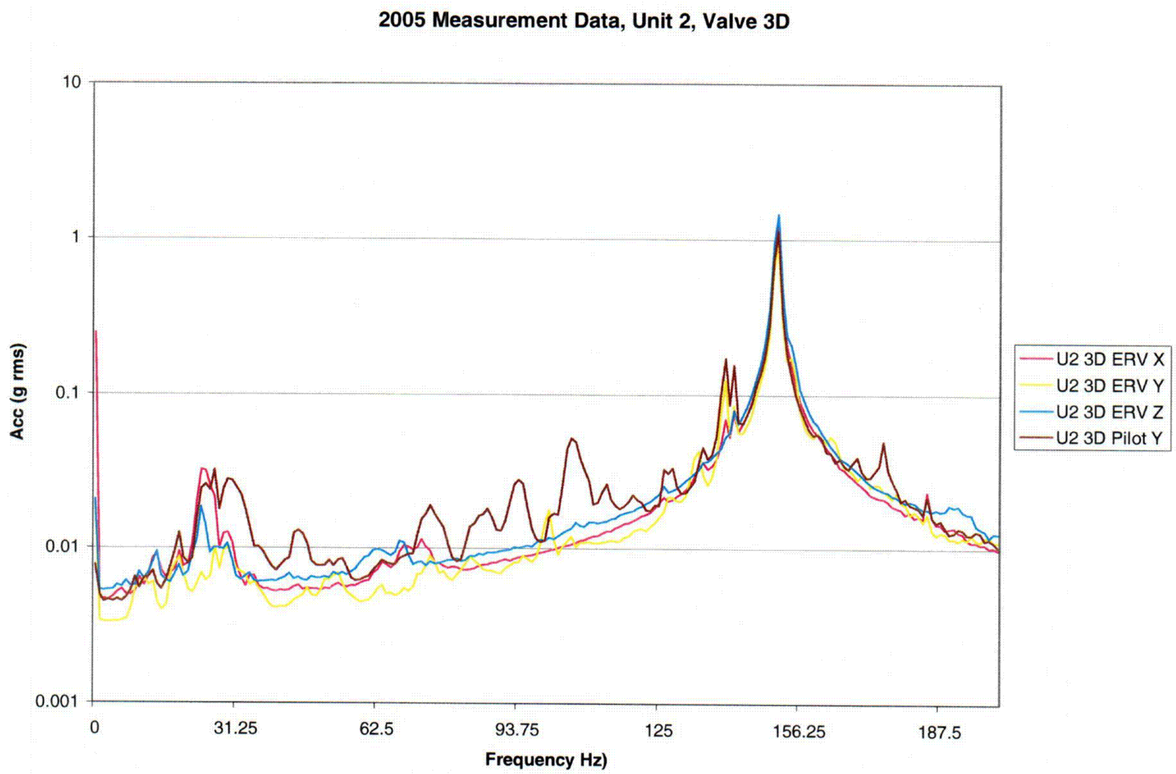


Figure 9. 2005 in-situ measurement data, EPU power level, U2 3D ERV and Pilot

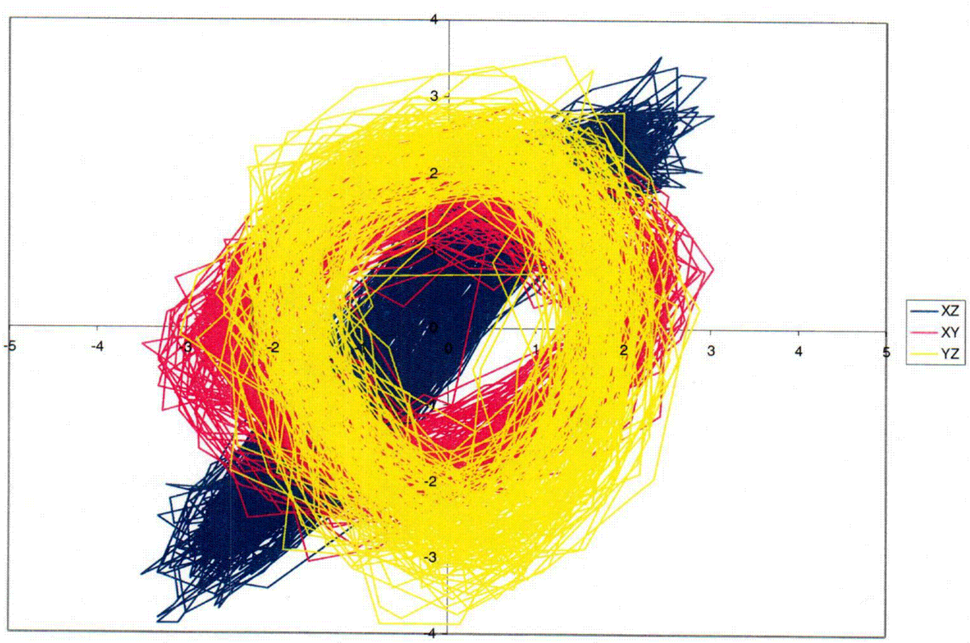


Figure 10. 2005 in-situ measurement data, EPU power level, U2 3D ERV Orbit Plot

TEST PLAN CHANGE NOTICE			
Test Plan No:	06Q4568-DR-002		
Revision No:			
Change No:			
Description Of Change:			
Basis For Change:			
Prepared by:	Name	Signature	Date
Reviewed by:	Name	Signature	Date
Approved by:	Name	Signature	Date