Rotor Failure Mechanism – Overheating and Galvanic Corrosion

FIGURE REDACTED

Rotor Failure Mechanism – Overheating and Galvanic Corrosion (continued)

FIGURE REDACTED

Rotor Failure Mechanism – Overheating and Galvanic Corrosion (continued)

FIGURE REDACTED

Rotor Failure Example - 1

PHOTO REDACTED

Rotor Failure Example - 2

PHOTO REDACTED

Rotor Failure Example - 3

PHOTO REDACTED

Rotor Failure Example - 4

PHOTO REDACTED

Rotor Failure Example - 5

PHOTO REDACTED

Rotor Failure – Overheating 1

PHOTO REDACTED

Rotor Failure – Overheating 2

PHOTO REDACTED

Rotor Failure – Overheating 3

PHOTO REDACTED

Rotor Failure – Overheating 4

PHOTO REDACTED

Rotor Failure – Overheating 5

PHOTO REDACTED

Industry Motor Rotor Degradation Preventive Measures

- Review MOV program and identify motors that could have rotors constructed of magnesium.
- Upgrade motor from magnesium rotor to aluminum rotor design.
- Add motor inspection ports, if needed.
- Implement periodic motor internal inspection program using borescope technology and/or motor disassembly.
- Implement new motor rotor inspection upon receipt.

Preventive Measures – Borescope 1

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Preventive Measures – Borescope 2

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Preventive Measures – Borescope 3

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Preventive Measures – Borescope 4

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Preventive Measures – Borescope 5

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Preventive Measures - Borescope 6

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Preventive Measures - Borescope 7

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NRC and Industry Actions on Motor Rotor Degradation

- NRC Information Notices 1986-02, 2006-26, and 2008-20
- NRC staff discussed topic with INPO, NEI Licensing Action Task Force, ASME OM Code Committee, MOV Users Group, IST Owners Group, BWROG, and PWROG
- Vendor technical bulletins: GE SIL 425 (1985) and Limitorque Technical Update 06-01 (2006)
- BWROG Valve Technical Resolution Group developed technical guideline for motors with magnesium rotors that provides inspection criteria, priority, disassembly and re-coating procedures.
- PWROG uses applicable guidance in BWROG document.

Motor Jogging

- During MOV testing in response to GL 89-10, many motors were damaged by repetitive testing without adequate cooling periods between motor starts.
- In a letter dated July 29, 1993, Limitorque recommended that 3-phase AC motors and DC motors be limited to 5 consecutive starts with cooling periods before restarting based on motor frame size as follows:

  Frame 48 (1 hr), 56 (1.5 hr), 182 (2 hr), 184 (2.5 hr), and 215 (3 hr).
- Licensees should be aware of the potential for motor damage where sufficient cooling periods are not provided between motor starts.
- Cooldown periods are typically exponential and dependent on motor frame size, winding type, and insulation.

MOV Grease Discussion

- Hardened grease can affect MOV operations
- March 12, 2009, Peach Bottom – Valve failed mid-stroke during line up for test
- March 21, 2009, Peach Bottom – Valve failed to fully open during surveillance test
- March 30, 2009, Vogtle – Valve stroked full open but failed to close
- August 5, 2009, Vogtle – Valve failed “as found” close test during Viper PM
- IFR 2009-009 initiated to evaluate issue

Limitorque Actuator Grease Areas

- Main Gear Box
- Stem / Stem Nut
- Limit Switch Upper/Lower Gear Frames & Intermittent Gear Cartridge Assembly

Stem Nut is threaded onto stem until splines mate up with drive sleeve assembly. Lock nut is threaded into drive sleeve assembly to maintain Stem Nut in place.

FIGURE REDACTED

FIGURE REDACTED

Grease is added to main gear box and applied to stem threads. The main gear box is filled to a level that covers the worm gear. This is approximately 75%.

Limitorque Valve Actuator Secured to Valve Yoke

FIGURE REDACTED

Upper and lower gear frames are filled to about 80% with grease – enough to cover gear trains

Limitorque Actuator Grease Recommendations

- Routine check every 18 months minimum. Frequency can increase based on frequency of operation and ambient environment conditions.
- Clean and lubricate valve stem in accordance with valve manufacturer's lubricant recommendation.
- For nuclear applications, Exxon Nebula EP-0 & EP-1 and Crompton MOV Long Life Grade 0 (27 year installed life) were only approved lubricants for actuator gear case.
- Exxon Nebula grease is now obsolete for MOV use with licensees switching to MOV Long Life.

Limitorque Actuator Grease Recommendations (continued)

- Ensure that actuator has enough lubricant in gear case to completely immerse worm and worm gear.
- Typical inspection interval for main gearcase grease is 6 years to determine whether replacement is necessary.
- Geared Limit Switch uses Mobil 28 grease.
- Motors furnished for Limitorque actuators have motor bearings that are lubricated for life.

Power Screw Equation

$$SF = \frac{T_{output}}{Th_{stem}} = \frac{d(0.96815 \tan \alpha + \mu)}{24(0.96815 - \mu \tan \alpha)}$$

Where:

T_{output}	=	Output torque of valve actuator (foot-pounds)
Th_{stem}	=	Valve stem thrust (pounds force)
d	=	OD_{stem} – ½ Pitch
$\tan \alpha$	=	Lead / (πd)
μ	=	Stem / Stem Nut coefficient of friction
OD_{stem}	=	Outside diameter of stem (inches)
Pitch	=	Distance from peak of one thread to peak of an adjacent thread (inches / thread)
Lead	=	Distance stem travels in one revolution of Stem Nut (inches / revolution)

Stem Threads

FIGURE REDACTED

Power Screw Equation

- Equation is based on standard Acme thread design.
- The only variable in power screw equation is Stem to Stem Nut coefficient of friction (μ).
- Ratio of torque to thrust is known as Stem Factor.

Stem / Stem Nut Interface Facts

- EPRI testing confirmed that clean, lubricated Stem / Stem Nut yielded stable coefficient of friction (COF) factors equal to or less than 0.15
- EPRI establishes 0.20 Stem Nut COF as bounding upper value
- Stem Nut COF can be much lower than 0.15

Stem / Stem Nut Interface Facts
(continued)

- Valve stems typically are pre-lubricated from manufacturer with Never Seize type product.
- Never Seize products consist of solids in volatile solvent, oil, resin or grease carrier.
- Limitorque has found poor results from Never Seize products when used on valve stem.
- Historical testing of Never Seize type products yield that COF factors can fluctuate.

Stem / Stem Nut Interface Facts
(continued)

- Valve stem threads to fit Stem Nut are cut usually on a lathe using standard Acme Left Hand Thread Design
- Stem Nut is “Married” to the Stem. The threads are cut via lathe or tap
- Although both Stem and Stem Nut are cut to standard Acme Thread design, many do not fit on first cut pass due to manufacturing tolerances. It is sometimes necessary to take off a few thousands on Stem Nut in order to match the threads.
- This is one reason why COF factors can vary from valve to valve.

Safety Significance of Stem Nut COF

- High COF yields less thrust force on valve stem with same actuator input torque.
- Valves set with low margins run risk of not being able to perform their safety-related function should COF increase over time or with operation.
- Low COF yields more stem thrust from same actuator output and torque switch trip that can exceed weak link assumptions.

Stem Lube Degradation Operating Experience

- REDACTED

Stem Lube Degradation Contributing Factors

- Incorrect grease for application.
- Stem cleaning and lube preventive maintenance (PM) intervals are being extended without data to support.
- Stem cleaning and lube PM not being performed properly.
- Poor feedback from maintenance personnel on actual "as found" grease condition.
- Ineffective corrective action process.
- Available industry information not effectively applied.
- Environmental changes not factored into PM program.
- Cross contamination of greases can accelerate grease degradation.

4.b Testing experience

Generic Issue 87

- NRC sponsored valve testing program by Idaho National Laboratory (INL) to evaluate Generic Issue 87, “Failure of HPCI Steam Line Without Isolation”
- Phase 1 (1988): Valve flow testing at Wyle including:
  - 6-inch Anchor/Darling FWG
  - 6-inch Velan FWG
- Phase 2 (1989): Valve flow testing at Karlstein FRG including:
  - 6-inch Anchor/Darling FWG
  - 6-inch Velan FWG
  - 6-inch Walworth FWG
  - 10-inch Anchor/Darling FWG
  - 10-inch Powell FWG
  - 10-inch Velan FWG

NRC-Sponsored INL Research

- Valve flow performance
- AC-powered MOV output
- DC-powered MOV output
- Stem friction coefficient
- Temperature effects
- Actuator efficiency
- Valve aging

INL Test Stand

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INL MOV Research Reports

NUREG/CR-5406 (10/1989) - Gate Valve Flow Tests
NUREG/CR-5558 (1/1991) – Gate Valve Flow Tests
NUREG/CR-5720 (6/1992) – MOV Research Update
NUREG/CR-6100 (9/1995) – Gate Valve & Operator
NUREG/CR-6478 (7/1997) – Actuator Motor and Gearbox
NREG/CR-6611 (5/1998) – Pressure Locking
NUREG/CR-6620 (5/1999) – DC-Powered MOVs
NUREG/CR-6750 (10/2001) – Stem Lubricant Performance
NUREG/CR-6806 (9/2002) – Stem Lubricant Aging
NUREG/CR-6807 (3/2003) – Stellite Aging

Industry Testing

- Electric Power Research Institute (EPRI) developed test-based valve performance methodology.
- Joint Owners Group (JOG) developed MOV dynamic testing program in response to GL 96-05.
- ComEd conducted motor output study.
- BWROG developed DC motor actuator output methodology.

EPRI MOV Performance Prediction Program

- Test-based methodology for predicting operating requirements for gate, globe, and butterfly valves described in EPRI TR-103237 (Rev. 2, 1997).
- NRC accepted EPRI MOV PPM with conditions in SE (3/15/96) with supplements:
  - Supplement 1 (2/20/97) accepted EPRI PPM hand-calculation methods for two additional valve designs
  - Supplement 2 (4/20/01) accepted modeling improvements in PPM Addendum 1
  - Supplement 3 (9/30/02) accepted thrust uncertainty method in PPM Addendum 2
  - Supplement 4 (2/24/09) accepted various PPM improvements in PPM Addenda 3 to 7.

NRC SER Conditions

- SER specified the following conditions on use of the EPRI MOV PPM by licensees:
  - Unwedging data need to be evaluated.
  - Internal valve preventive maintenance program needed. A documented engineering analysis of valves that have been determined to have no degradation will not require an internal examination.
  - Cannot extrapolate to blowdown conditions from pump flow conditions.
  - Licensee is responsible for actuator output.
  - Uncertainties need to be addressed.

EPRI MOV Guides

- EPRI MOV Application Guide TR-106563:
  - Volume 1: Gate and Globe valves
  - Volume 2: Butterfly valves.
- EPRI Technical Repair Guidelines NP-6229 (SMB-000) and NP-6631 (SMB-00).
- EPRI guides provide significant information on MOV design, operation, and lessons learned, including EPRI MOV testing program.

JOG Program on MOV Periodic Verification

- Risk-informed program to share test information on valve operating requirements for responding to GL 96-05.
- 5-year dynamic testing of sample MOVs at each participating plant.
- Static and dynamic testing based on program results and margin.
- Test frequency based on risk and margin.
- NRC accepted in SE dated September 2006.
- RIS 2011-13 indicates licensees may implement ASME OM Code Appendix III or Code Case OMN-1 for JOG Class D valves outside scope of JOG program.

JOG Program Highlights

- JOG addressed gate, globe, and butterfly valves.
- JOG did not identify any significant aging issues with tested valves after reaching their valve factor plateau.
- JOG did not test a sufficient number of valves to establish a valve factor database.
- JOG did not address actuator output.

ComEd MOV Output Methodology

- In 1990s, ComEd tested motors to evaluate output capability and degraded voltage factors.
- ComEd evaluated test data from other sources for actuator performance.
- ComEd White Paper 125 (Rev. 3, 2/8/99) provides methodology for sizing motor actuators.
- NRC staff accepted use of ComEd White Paper 125 during GL 89-10 inspections.
- Exelon preparing update to White Paper 125

White Paper 125 Highlights

- Higher motor output than nameplate for some motors.
- Degraded voltage ratio for some ac motors greater than squared term.
- Margin factor necessary when applying White Paper 125 method.
- ComEd White Paper 125 will predict more or less output than Limitorque equation depending on the specific motor and its application.

BWROG DC MOV Methodology

- Based on research identifying effects on DC MOV output from temperature, voltage, and loading, BWROG developed updated methodology for DC MOV output and stroke time.
- BWROG used vendor motor curves and test data from INL and industry sources in developing its methodology.
- BWROG indicated that methodology would be made available to PWR licensees.
- NRC discussed BWROG methodology in RIS 2001-15.

BWROG DC MOV Methodology Highlights

- BWROG method solves for output and stroke time for each stroke increment.
- BWROG method calculates:
  - Capability margin
  - Maximum allowable thrust at TS trip and unwedging
  - Stroke time
- BWROG used data from only 7 MOVs.
- As discussed in RIS 2001-15, NRC considered BWROG methodology acceptable but noted limited data.

RIS 2001-15

Performance of DC-Powered Motor-Operated Valve Actuators

- Alerted licensees to updated methodology developed by BWROG to evaluate capability of DC-powered MOVs to perform their safety functions.
- Based on INL sample testing, NRC staff considered BWROG methodology to represent a reasonable approach in improving past industry guidance for predicting DC-powered MOV output.
- Noted BWROG recommended schedule for BWR licensees to implement methodology.
- Indicated that methodology also applicable to DC-powered MOVs in PWR plants.

5. MOV Performance and Design Analysis

Overview

a. Differential pressure and flow conditions
b. Valve operating requirements
c. Motor actuator output capability
d. Uncertainties
e. Margins
f. Weak link analysis
g. Example calculations

5.a Differential pressure and flow conditions

Differential pressure and flow assumptions

- During GL 89-10 implementation, licensees re-evaluated design-basis differential pressure and flow assumptions for safety-related MOVs.
- Westinghouse and GE provided assistance in updating differential pressure and flow assumptions.
- Licensees should rely on updated differential pressure and flow assumptions developed as part of GL 89-10 programs.
- If not available, licensees should rely on UFSAR provisions.

5.b Valve operating requirements

Gate and Globe Valve Operating Requirements

- ASME Standard QME-1-2007 qualification program (RG 1.100)
- EPRI MOV PPM calculation
- EPRI MOV Application Guide TR-106563 (Volume 1)
- Plant-specific test data
- Vendor or industry test data where justified

- Gate valve thrust operating requirements

  REDACTED

- Differential pressure force

REDACTED

- Stem piston effect

  $F_{PE} = A_s * P$

  where

  A_s = valve stem area

  P = system pressure

- Sealing load (F_S)
  - see EPRI method

- Globe valve thrust operating requirements
- REDACTED

- Required Actuator Output Torque (Gate and Globe)

$RO_{TOR} = RV_{THR} * SF$

where

SF = stem factor based on stem diameter, thread pitch and lead, and stem friction coefficient

- Stem Factor Calculation for ACME threads

$$SF = \frac{d\,(0.96815 \tan\alpha + \mu)}{24\,(0.96815 - \mu \tan\alpha)}$$

where

$$\tan\alpha = \frac{\text{Stem lead}}{\pi * d}$$

$$d = D_s - \frac{\text{Pitch}}{2}$$

TPI = Stem threads per inch

$$\text{Pitch} = \frac{1}{\text{TPI}}$$

Lead = Pitch * Thread type (single, double, triple)

μ = Stem to Stem Nut friction coefficient

D_S = Stem diameter

- Butterfly valve torque operating requirements
  - ASME Standard QME-1-2007 qualification program (RG 1.100)
  - EPRI MOV PPM calculation
  - Plant-specific test data
  - Vendor or industry test data where justified
  - EPRI MOV Application Guide TR-106563 (Volume 2)

Butterfly Valve Operating Torque (EPRI)

- REDACTED

5.c Motor actuator output capability

- AC Motor Actuator Capability (Gate and Globe)

(Limitorque Technical Update 98-01, S1)

$$ACT_{TOR} = M_T * Eff * AF * OAR * Temp * \left(\frac{V_{MIN}}{V_{RAT}}\right)^n$$

$$ACT_{THR} = \frac{ACT_{TOR}}{SF}$$

where

ACT_{TOR} = motor actuator output torque capability

ACT_{THR} = motor actuator output thrust capability

M_T = motor rated torque

V_{MIN} = minimum voltage at motor

V_{RAT} = rated motor voltage

If voltage drop > 10%, n = 2 (but n = 0 if ≤ 10%)

Eff = pullout efficiency

AF = application factor

OAR = overall actuator ratio

Temp = temperature degradation factor (Limitorque TU 93-03)

- Degraded Voltage Considerations
  - No degraded voltage factor (n=0) if voltage drop less than or equal to 10% because motor design with application factor (typically 0.9) compensates for up to 10% reduced voltage.
  - Degraded grid relay setpoint should be used as the starting point for calculating the minimum voltage at the motor terminals.
  - Supplement 1 to GL 89-10 provides guidance for the voltage reduction calculation with in-rush or locked rotor current.

- DC Motor Actuator Capability (Gate and Globe)
  - BWROG methodology discussed in RIS 2001-15
  - BWROG methodology iterates over entire stroke length to determine changes in output capability and actuator speed
  - BWROG calculates final stroke time and capability margin

- Torque Switch Available Thrust Output

$$TST_{THU} =$$

$$TST_{MEAS}\left(1 - B_{ROL} - \sqrt{U_{ROL}^2 + U_{DIA}^2 + U_{TSR}^2}\right)$$

where

TST_{MEAS} = measured thrust at torque switch trip

B_{ROL} = bias uncertainty due to rate of loading

U_{ROL} = random uncertainty due to rate of loading

U_{DIA} = random uncertainty due to diagnostic equipment

U_{TSR} = random uncertainty due to torque switch repeatability

Also, consider spring pack relaxation and stem lubricant degradation

- Rate of Loading (Load Sensitive Behavior)

$$ROL\% = \frac{Thrust_{TST\ Static} - Thrust_{TST\ Dynamic}}{Thrust_{TST\ Static}} * 100\%$$

Use statistical method with 95% confidence to establish random and bias uncertainties

- Available MOV output least of:
  - motor actuator output capability (adjusted for degradation)
  - torque switch available output
  - operator torque/thrust rating (or justified extension)
  - maximum spring pack setting
  - valve torque/thrust weak link

- Motor Actuator Capability (Butterfly valve)

  Output Torque =

  SMB output * HBC Gear Ratio * HBC Gear Efficiency

  where HBC Gear Ratio and Efficiency obtained from Limitorque SEL documents.

- For high flow velocities, actuator might need to exert a restraining torque to prevent disc from slamming into or through the valve seat (see EPRI Application Guide).

5.d Uncertainties

- Gate and Globe MOV Output Uncertainty Examples
  - Test Equipment Inaccuracy
  - Control Switch Repeatability
  - Rate of Loading (Load Sensitive Behavior)
  - Spring Pack Relaxation
  - Stem Lubricant Degradation

Limit or torque switch control, and use of diagnostics, will determine applicability of uncertainties.

- Butterfly Valve MOV Output Uncertainty Examples
  - Test Equipment Inaccuracy
  - Control Switch Repeatability
  - Spring Pack Relaxation
  - Seat Degradation (e.g., seat hardening)

Limit or torque switch control, and use of diagnostics, will determine applicability of uncertainties.

5.e Margins

- MOV Margin for Gate and Globe Valves

Static Test

Close Margin = $Thrust_{TST\ MEAS}$ – Uncertainties – Required Thrust

Open Margin = Actuator Available Thrust – Uncertainties – Required Thrust

Dynamic Test

Close Margin =

$Thrust_{TST\ MEAS}$ – Uncertainties – Extrapolated Required Thrust with uncertainties

Open Margin =

Act. Avail Thrust – Uncertainties - Extrapolated Required Thrust with uncertainties

Example Torque Switch Thrust Window for Gate and Globe Valves

Maximum Thrust Allowed (including actuator, valve, stem-disc connection, motor, and spring pack)

Maximum reduced for Diagnostic Uncertainty, Torque Switch Repeatability (TSR), and others as applicable

Upper Limit of Thrust Window

Lower Limit of Thrust Window

Minimum increased for Margin, Stem Factor Degradation, TSR, Diagnostic Uncertainty, Load Sensitive Behavior, and others as applicable

Minimum Required Operating Thrust

- MOV Margin for Butterfly Valve (Limit Control)

Static Test

Margin =

Actuator Available Torque – Uncertainties - Required Torque

Dynamic Test

Margin =

Actuator Available Torque – Uncertainties - Extrapolated Required Torque with uncertainties

5.f Weak link analysis

- MOV Stall Overtorque and Overthrust Output (Gate and Globe)

$$ACT_{TOR} = M_{ST} * SEff * OAR * \left(\frac{V_{MAX}}{V_{RAT}}\right)^{n}$$

$$ACT_{THR} = \frac{ACT_{TOR}}{SF}$$

where

ACT_{TOR} = motor actuator output torque capability

ACT_{THR} = motor actuator output thrust capability

M_{ST} = motor stall torque (1.1 times rated motor torque)

SEff = actuator stall efficiency

V_{MAX} = maximum voltage at motor (elevated voltage)

V_{RAT} = rated motor voltage

n = 2 for ac motor and n = 1 for dc motor if $V_{MAX} > 100\%$

Otherwise, n = 0

Weak Link Considerations

- Actuator structural thrust and torque capability
- Valve structural thrust and torque capability
- Stem to disc connection structural capability (including T-Head connections and threaded connections)
- Motor torque output capability
- Spring pack compression limit

5.g Example calculations

MOV Calculations

- Review determination of design-basis functional requirements.
- Review methodologies used for thrust/torque calculations:
  - Industry valve factor method
  - EPRI Application Guide TR-106563 on MOVs
  - EPRI MOV PPM for valve thrust/torque requirements
  - Limitorque Technical Update 98-01 (S1) for AC MOV output
  - ComEd White Paper 125 for MOV output
  - BWROG DC MOV methodology for stroke time and output
  - EPRI MOV Thrust Uncertainty Method for torque switch setting

- Review bases for MOV performance assumptions
  - Valve factor (VF)
  - Stem friction coefficient (SFC)
  - Load sensitive behavior or rate of loading (LSB or ROL)
  - Margins for stem lubrication degradation and springpack relaxation
  - Motor performance
    - rating
    - efficiencies (pullout, run, and stall)
    - application factor
    - degraded voltage factor
    - ambient temperature
  - Actuator efficiency
  - Degraded voltage

- Review bases for MOV performance assumptions (continued)
  - Differential pressure (DP) load extrapolation
  - Control switch trip (CST) repeatability
  - Thrust/torque limit extrapolation
  - Equipment error
  - Degradation
  - Grouping (GL 89-10 Supplement 6)

- Evaluate design-basis capability of sampled MOVs
  - Request table of safety-related MOVs indicating ID number; description; open/close safety function; calculation method; MOV type and size (ac/dc motor, actuator, and valve); risk significance; DP; VF; SFC; LSB or ROL; design thrust/torque; CST thrust/torque; and margin (as applicable)
  - Review MOV table for assumptions and margin to demonstrate that all MOVs have design-basis capability
  - Select 3 to 5 MOVs for detailed review based on risk and margin, plus other items of interest (such as questions on identified parameters)
  - Review design calculations for sampled MOVs for operating requirements, actuator output capability, and margin, including consideration of uncertainties
    - MOVs should have 5% margin after all uncertainties addressed to avoid operability calls for minor items
  - Review stall thrust and torque evaluations
  - Expand sample as necessary

- MOV Operating Requirements
  - ASME Standard QME-1-2007 qualification program (RG 1.100)
  - EPRI MOV PPM calculation
  - Plant-specific test data
  - Vendor or industry test data where justified

- AC motor actuator capability (gate and globe)

(Limitorque Technical Update 98-01, S1)

$$ACT_{TOR} = M_T * Eff * AF * OAR * Temp * \left(\frac{V_{MIN}}{V_{RAT}}\right)^n$$

$$ACT_{THR} = \frac{ACT_{TOR}}{SF}$$

where

ACT_{TOR} = motor actuator output torque capability

ACT_{THR} = motor actuator output thrust capability

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Eff = pullout efficiency

AF = application factor

OAR = overall actuator ratio

Temp = temperature degradation factor (Limitorque TU 93-03)

- DC motor actuator capability (gate and globe)
  - BWROG methodology discussed in RIS 2001-15
  - BWROG methodology iterates over entire stroke length to determine changes in output capability and actuator speed
  - BWROG calculates final stroke time and capability margin

- Butterfly valve motor actuator capability

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  SMB output * HBC Gear Ratio * HBC Gear Efficiency

  where HBC Gear Ratio and Efficiency obtained from Limitorque SEL documents

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  - motor actuator output capability (adjusted for degradation)
  - control switch available output
  - operator torque/thrust rating (or justified extension)
  - maximum spring pack setting
  - valve torque/thrust weak link

- MOV output uncertainty examples
  - Test Equipment Inaccuracy
  - Control Switch Repeatability
  - Rate of Loading or Load Sensitive Behavior
  - Spring Pack Relaxation
  - Stem Lubricant Degradation
  - Butterfly Valve Seat Degradation (e.g., seat hardening)

Limit or torque switch control, and use of diagnostics, will determine applicability of uncertainties

- MOV Margin for Gate and Globe Valves

<u>Static Test</u>

Close Margin = $Thrust_{TST\ MEAS}$ – Uncertainties – Required Thrust

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<u>Dynamic Test</u>

Close Margin =

$Thrust_{TST\ MEAS}$ – Uncertainties – Extrapolated Required Thrust with uncertainties

Open Margin =

Act. Avail Thrust – Uncertainties - Extrapolated Required Thrust with uncertainties

- MOV Margin for Butterfly Valve (Limit Control)

Static Test

Margin =

Actuator Available Torque – Uncertainties - Required Torque

Dynamic Test

Margin =

Actuator Available Torque – Uncertainties - Extrapolated Required Torque with uncertainties

Example Calculation

MOV Actuator YouTube Videos

SMB-2 Actuator Failure (Kalsi)

https://www.youtube.com/watch?v=TVsUTbUIUSQ

Limitorque SMB-0 Internals

https://www.youtube.com/watch?v=00Uu_rmPLDs

Limitorque SMB-000 Tripper Finger Adjustment

https://www.youtube.com/watch?v=5J8yuapOPPk

Limitorque Limit Switch Operation

https://www.youtube.com/watch?v=85oepWJAVbU

Limitorque Limit Switch L Bracket Tension

https://www.youtube.com/watch?v=WhT2IMNdLCw

MOV Diagnostic YouTube Videos

QuikLook Diagnostic Setup https://www.youtube.com/watch?v=7yo6Dphp2Co

Viper Diagnostic Testing https://www.youtube.com/watch?v=ke6ko3KB5_k

QuikLook Test Setup https://www.youtube.com/watch?v=OEB1LTKdJjc

Open Globe Valve Analysis https://www.youtube.com/watch?v=97kjiaXe2OA

SB-2 Close Analysis https://www.youtube.com/watch?v=jNXrvRKX-BE

Globe Valve Analysis https://www.youtube.com/watch?v=OsJurrkKDFY

MOV Analysis – Crane https://www.youtube.com/watch?v=Ltj_wfqBZhA

Viper Switch Contact https://www.youtube.com/watch?v=ke6ko3KB5_k&t=56s

MOV Close Stroke https://www.youtube.com/watch?v=OsJurrkKDFY&t=72s

Questions?