# *NRC MOV Course*

## *Design Basis Operation*

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# Background

- *Much of what the nuclear industry knows about MOV design-basis operation comes from NRC-sponsored research and subsequent industry research.*
- *Observed anomalous performance of MOVs in the early 1980s identified questions about standard sizing equations and performance assumptions.*

# NRC Sponsored MOV Research

- From 1984 to 2001, the NRC sponsored MOV research at the Idaho National Laboratory (INL).
- The purpose was to evaluate MOV operation at design basis conditions – conditions beyond the existing knowledge base.
- The Design Basis Operation chapter in this course presents MOV performance characteristics and analytical methods developed from this research.
- It is therefore appropriate to review the major research efforts.

# NRC MOV Research Supported

- *NUREG-0660, NRC Action plan resulting from the TMI-2 Accident.*
  - *II.E.4.2 - Containment Isolation Dependability*
  - *II.E.6.1 - In Situ Testing of Valves*
- *Generic Issue 87, "Failure of HPCI Steamline Without Isolation"*
- *Generic Letter 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance"*
- *Generic Letter 95-07, "Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves"*
- *Generic Letter 96-05, "Periodic Verification of Design-Basis Capability of Safety-Related Motor-Operated Valves"*

# *Generic Issue 87 Research*

- *Research was performed to determine if MOVs used for containment isolation were capable of performing their design basis function.*
- *Their design basis included the requirement to isolate flow in the event of a guillotine pipe break outside of containment.*
- *Systems of interest included BWR RWCU, RCIC, and HPCI systems*

# *Historical Industry Gate Valve Stem Force Equation*

$$F_{stem} = \mu_d A_d \Delta P \pm A_s P + F_{pack}$$

- *+ for closing*
- *- for opening*

# *Historical Industry Gate Valve Stem Force Equation - Continued*

- *The disc factor was assumed to be a constant 0.3, although some valves after 1980 have been sized with a 0.5 disc factor.*
- *In some applications, the disc area was based on the valve orifice area.*
- *The equation was used for all gate valves, parallel disc as well as wedge type gate valves.*
- *The equation was used to estimate the maximum stem force just before wedging (a bounding equation).*

# *The Phase I Program*

- *The testing was performed in 1988 at Wyle Laboratory, Huntsville Alabama.*
- *Two gate valves were tested*
  - *6-inch Anchor/Darling 900 lb flexwedge gate valve, and*
  - *6-inch Velan 900 lb flexwedge gate valve.*

# *Phase I Results*

*This testing found two distinct valve performance parameters that were inconsistent with previous industry positions.*

- *One valve damaged itself during closure under high loads, and*
- *Both valves required more thrust to close than the industry would have predicted.*

# *The Phase II Program*

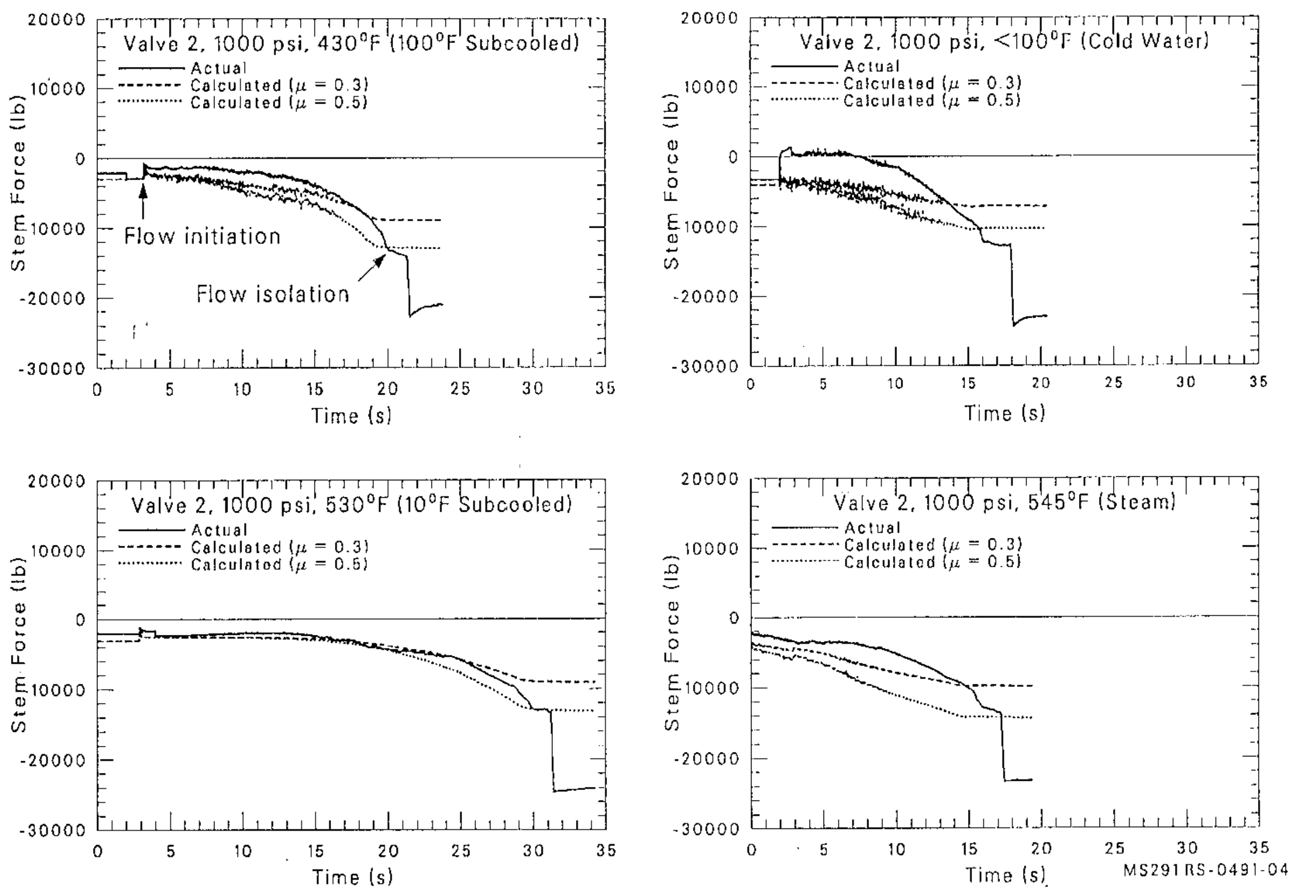
- *The testing was performed in 1989 at KWU, Federal Republic of Germany.*
- *Six gate valves were tested*
  - *6-inch Anchor/Darling 900 lb flexwedge gate valve,*
  - *6-inch Velan 900 lb flexwedge gate valve,*
  - *6-inch Walworth 600 lb flexwedge gate valve,*
  - *10-inch Anchor/Darling 900 lb flexwedge gate valve,*
  - *10-inch William Powell 900 lb flexwedge gate valve,*
  - *10-inch Velan 600 lb flexwedge gate valve.*

# *Phase II Results*

- *Verified the earlier Phase I test results obtained at Wyle.*
- *Highlighted the industry's inability to calculate the stem thrust of a valve.*
- *The apparent inconsistencies in the industry's stem thrust equation caused us to investigate the flow and pressure dependencies in the valves and the resultant effect on stem thrust.*

# *GI-87 Video*

# *Gate Valve Performance Was Influenced by Fluid Subcooling*

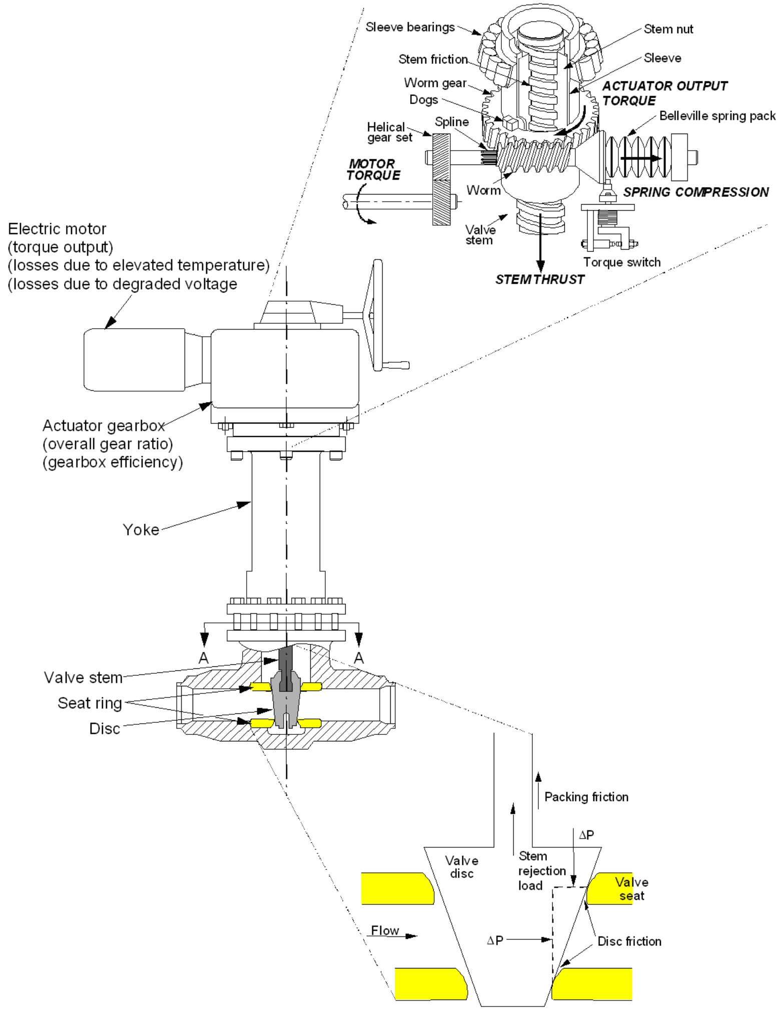


# *MOV Functional Margin*

# *MOV Functional Margin*

- *The evaluation of an MOV to determine it's ability to function begins with two questions.*
  1. *How much torque or thrust will be needed to close or open the valve? This is called the <u>required</u> torque or thrust.*
  2. *How much torque or thrust is the actuator capable of delivering? This is called the <u>available</u> torque or thrust.*

# Limitorque Actuator With A Flexible Wedge Gate Valve

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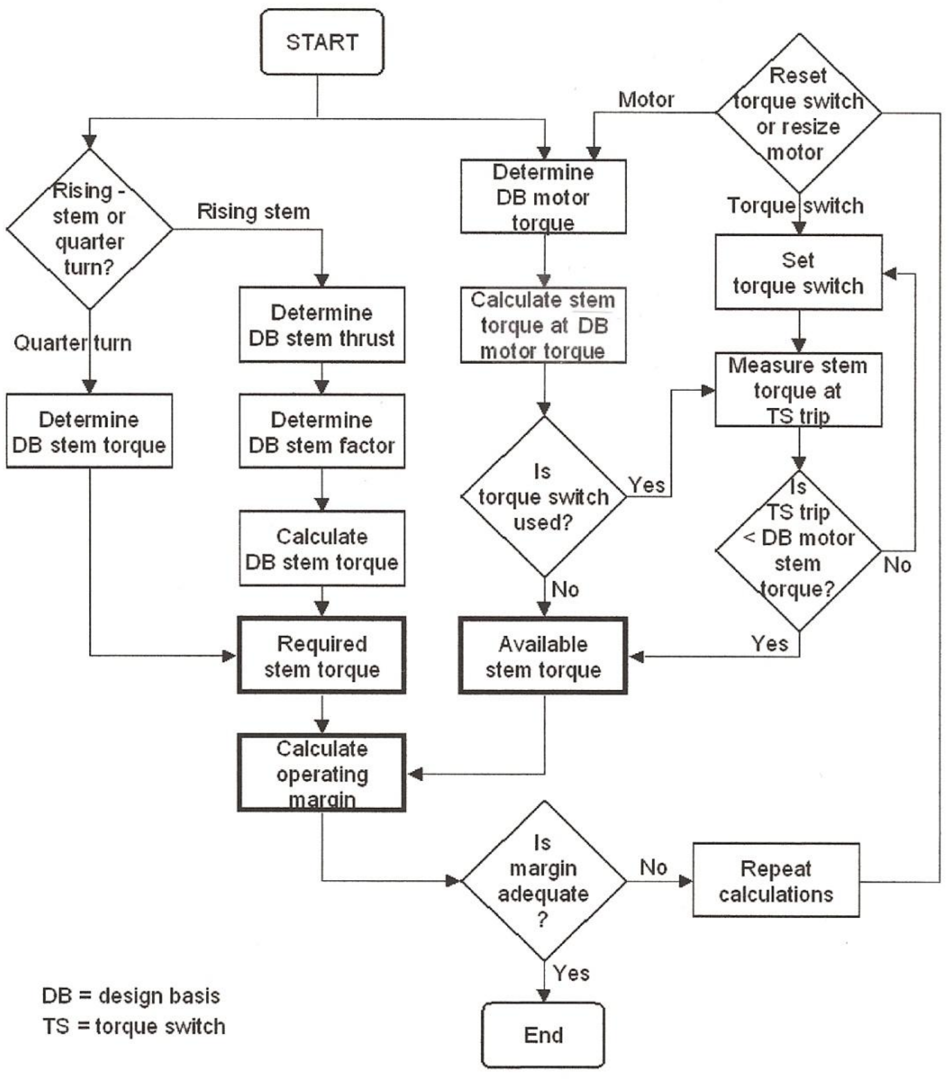
# *Functional Margin Flow Chart*



# *Required Torque*

*The analysis determines the required torque for the valve's design basis, including*

- *Packing load*
- *Stem rejection load*
- *Differential pressure (flow, seat friction, and guide friction)*
- *Stem factor (conversion of torque to thrust, including stem thread friction)*

# Available Torque

*The analysis determines the available torque for the actuator's design basis, including*

- *Torque switch setting*
- *Rated motor torque*
- *Motor torque losses at design basis (reduced voltage and elevated temperature)*
- *Overall gear ratio of the actuator*
- *Gearbox efficiency at design basis (speed and lubrication)*
- *Structural limits of the actuator and valve*

# *Functional Margin*

*Limitorque actuators are torque producing devices.*

*The analysis must determine that*

- *The torque switch setting is adequate to close or open the valve against design basis loads*
- *The motor is powerful enough to trip the torque switch under design basis conditions*
- *The torque switch setting does not exceed the physical displacement limits of the torque spring*
- *The torque switch setting does not exceed the maximum load limits of the valve or actuator*

# *Design Basis Valve Stem Thrust*

# *Rising-Stem Valves*

# Design Basis Valve Stem Thrust

*For rising-stem valves (gate and globe), the thrust needed to operate the valve is a summation of two types of loads:*

- *Loads not dependent on fluid conditions*
  - *Disc and stem weight (usually very small compared to other loads)*
  - *Stem packing drag*
- *Loads dependent on fluid conditions*
  - *Stem rejection load (piston-like effect)*
  - *Differential pressure load*

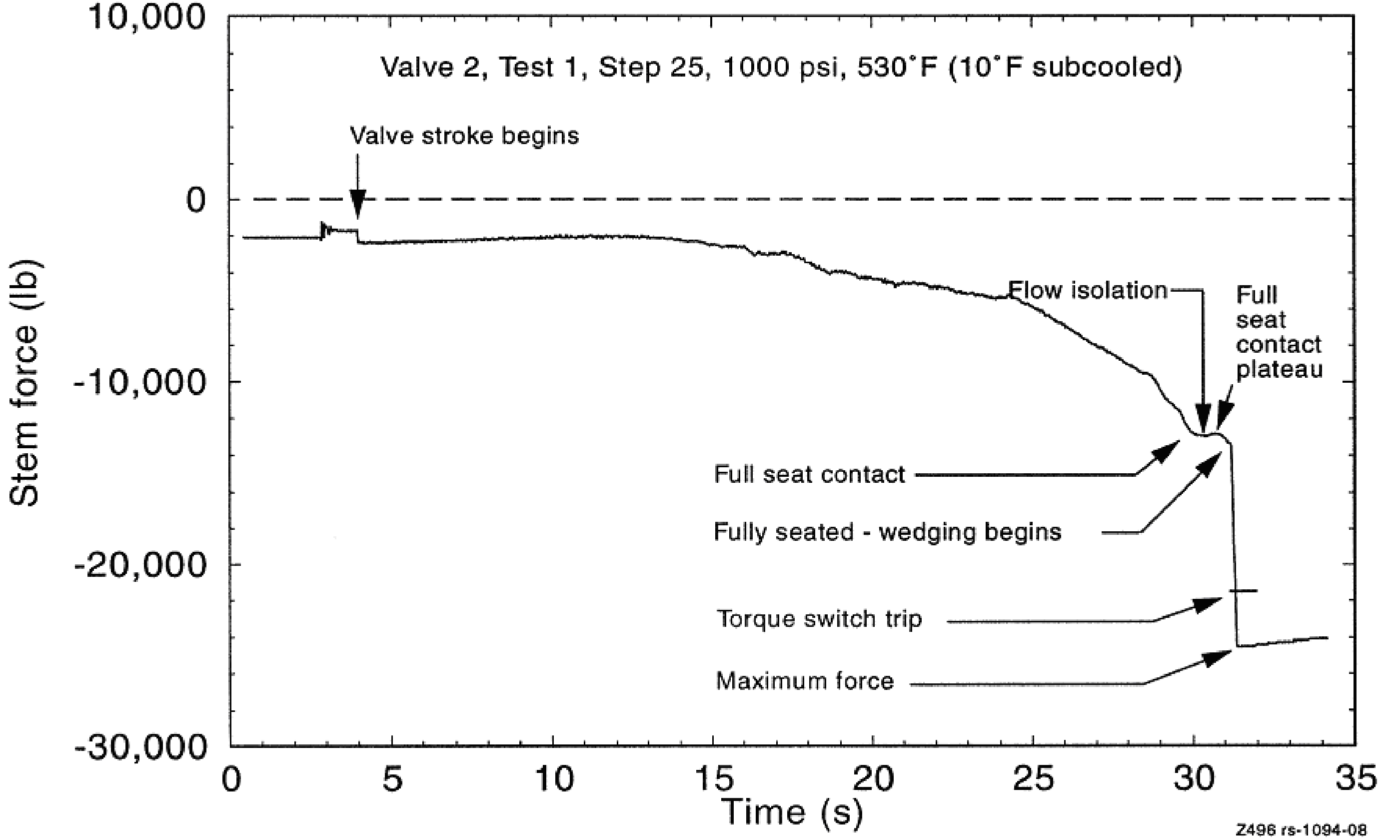
# Basic Stem Thrust Equation

$$F_{Stem} = F_{Packing} \pm F_{Stem\ rejection} + F_{Disc}$$

- *Note the  sign for the stem rejection load.  This appears because the stem rejection load is always out of the valve body, thus it resists closure and assists opening.*

# *Gate Valve Stem Thrust*

# Typical Gate Valve Closure Thrust



# Gate Valve Closing Stem Force Equation

$$F_{stem} = F_{pack} + F_{stem\ rej} - F_{elps} + F_{net\ stem}$$

*Where*

| | | |
|---|---|---|
| $F_{stem}$ | = | *total stem load* |
| $F_{pack}$ | = | *stem packing load* |
| $F_{stem\ rej}$ | = | *stem rejection load* |
| $F_{elps}$ | = | *elliptical pressure load* |
| $F_{net\ stem}$ | = | *net stem load (discussed in detail later)* |

# Gate Valve Closing Stem Force Equation – Stem Rejection

$$F_{stem\ rej} = P_{up} A_{stem}$$

*Where*

| | | |
|---|---|---|
| $F_{stem\ rej}$ | = | *stem rejection load* |
| $P_{up}$ | = | *upstream pressure* |
| $A_{stem}$ | = | *stem area* |

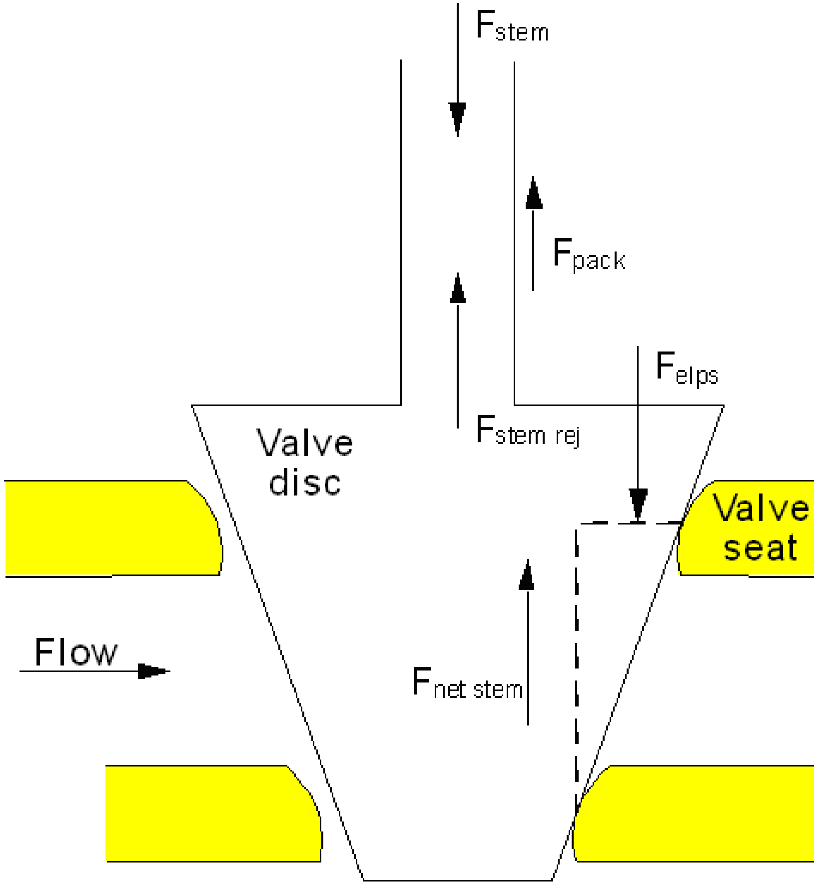
# Gate Valve Closing Stem Force Equation – Elliptical Pressure

$$F_{elps} = \Delta P A_{disc} \tan\alpha$$

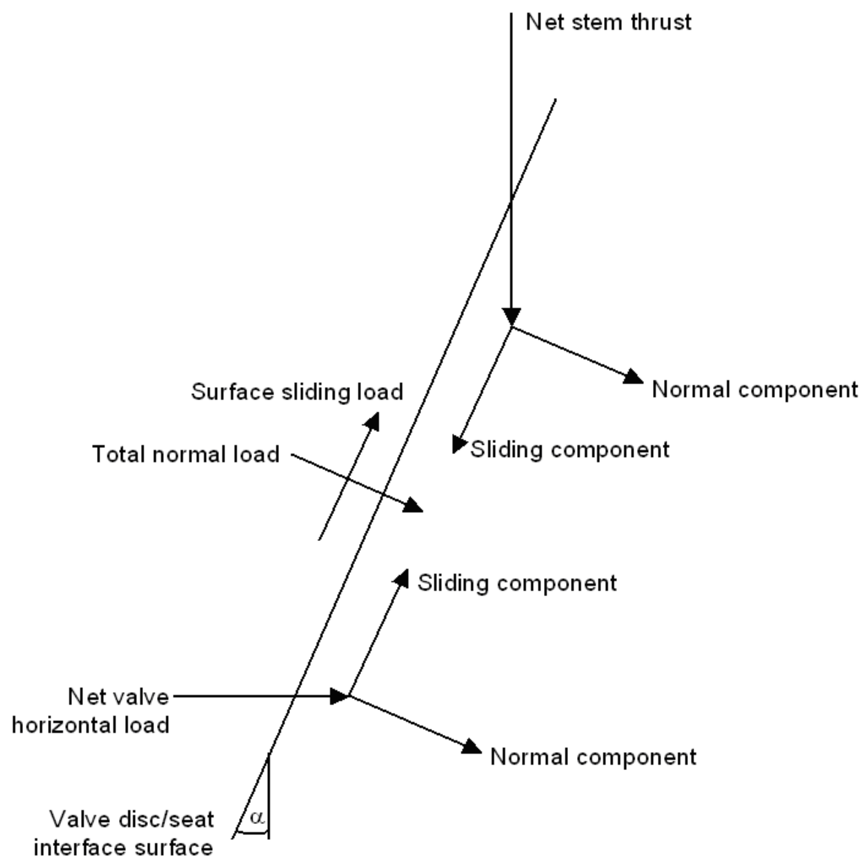
*Where*

| | | |
|---|---|---|
| $F_{elps}$ | = | *elliptical pressure load* |
| $\Delta P$ | = | *differential pressure across the disc* |
| $A_{disc}$ | = | *disc area (based on mean seat diameter)* |
| $\alpha$ | = | *disc seat angle* |

# *Gate Valve Stem Loads*



# *Net Gate Valve Stem Loads During Closure*



# Normal and Sliding Force

$$F_n = \Delta P A_{disc} \cos\alpha + F_{net\ stem} \sin\alpha$$

$$F_s = \Delta P A_{disc} \sin\alpha - F_{net\ stem} \cos\alpha$$

*Where*

| | | |
|---|---|---|
| $F_n$ | = | *normal force* |
| $F_s$ | = | *sliding force* |
| $\Delta P$ | = | *differential pressure across the disc* |
| $A_{disc}$ | = | *disc area (based on mean seat diameter)* |
| $\alpha$ | = | *disc seat angle* |
| $F_{net\ stem}$ | = | *net stem load* |

# *Disc/Seat Coefficient of Friction*

- *Coefficient of friction is defined as the sliding load divided by the normal load.*
- *Previous equation was solved for net stem load.*

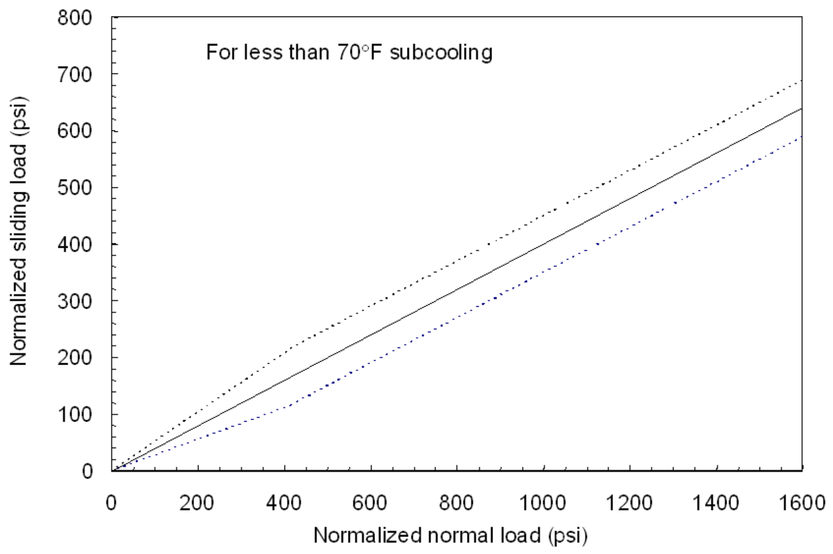
# Gate Valve Closing Stem Force Equation – Net Stem Load

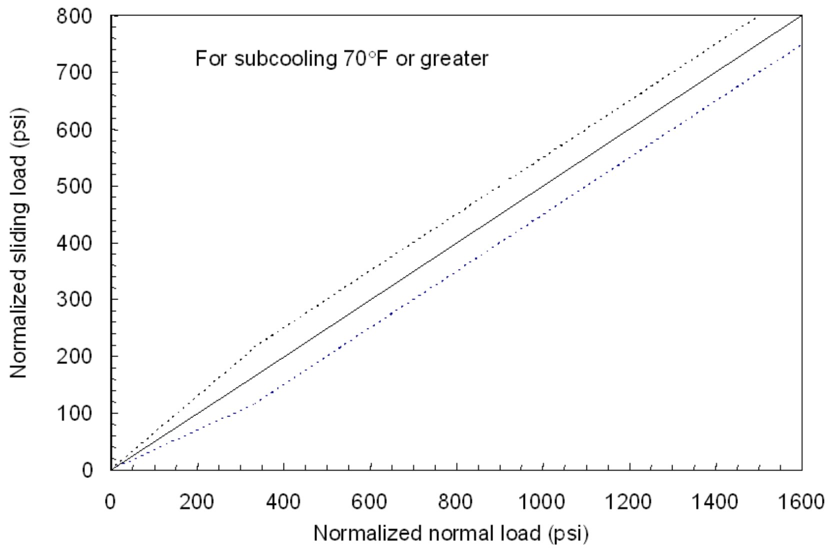
$$F_{net\ stem} = \frac{\Delta P A_{disc} \left( f \cos\alpha + \sin\alpha \right)}{\cos\alpha - f \sin\alpha}$$

*Where*

| | | |
|---|---|---|
| $F_{net\ stem}$ | = | *net stem load* |
| $\Delta P$ | = | *differential pressure across the disc* |
| $A_{disc}$ | = | *disc area (based on mean seat diameter)* |
| $f$ | = | *disc/seat coefficient of friction* |
| $\alpha$ | = | *disc seat angle* |

# *INL Secondary Equation Correlation*



# *INL Gate Valve Closing Correlations*

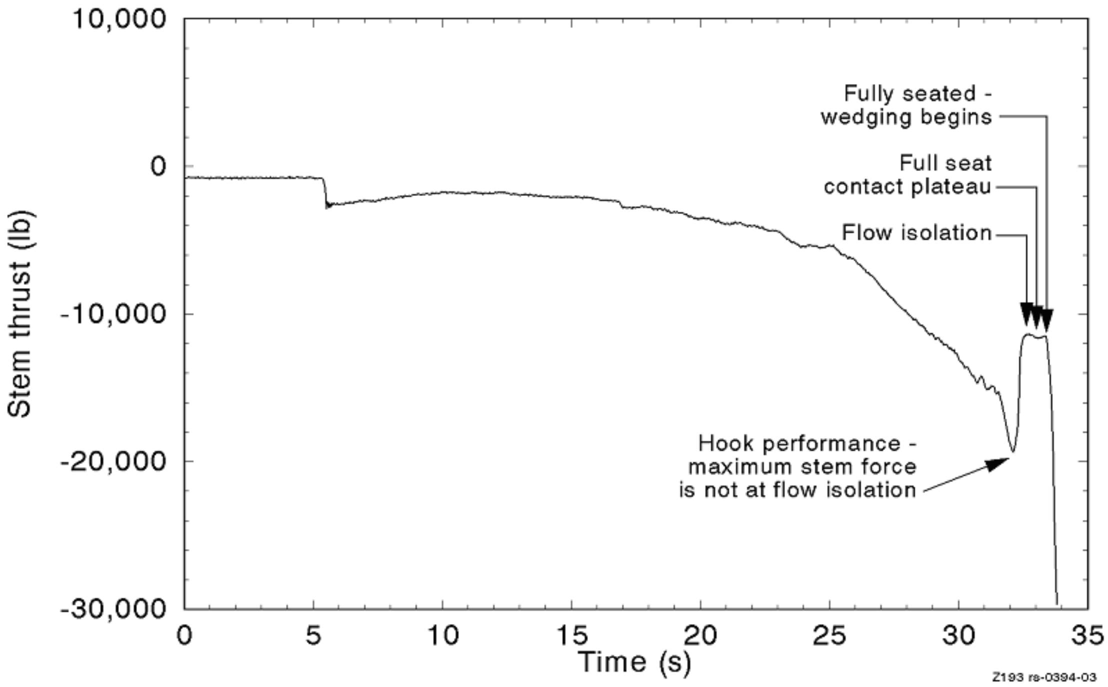
*For DP > 415 psi (330 psi if the fluid subcooling is greater than 70°F)*

$$F_{stem} = F_{pack} + F_{stem\,rej} - F_{elps} + \frac{\Delta P A_{disc} \left( f \cos\alpha + \sin\alpha \right) \pm 50 A_{disc}}{\cos\alpha - f \sin\alpha}$$

*For DP < 415 psi (330 psi if the fluid subcooling is greater than 70°F)*

$$F_{stem} = F_{pack} + F_{stem\,rej} - F_{elps} + \frac{\Delta P A_{disc} \left( f \cos\alpha \left( 1.0 \pm 0.3 \right) + \sin\alpha \right)}{\cos\alpha - f \sin\alpha \left( 1.0 \pm 0.3 \right)}$$

# Nonlinear Gate Valve Stem Thrust Measurement

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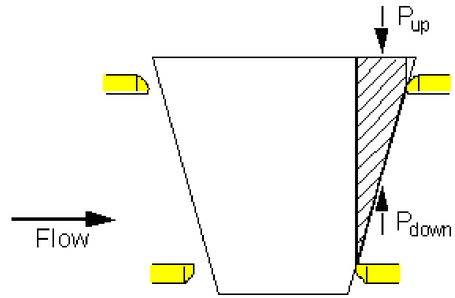
# *Valve Disc Tipping*

<u>Flow isolation point, disc on seat</u>

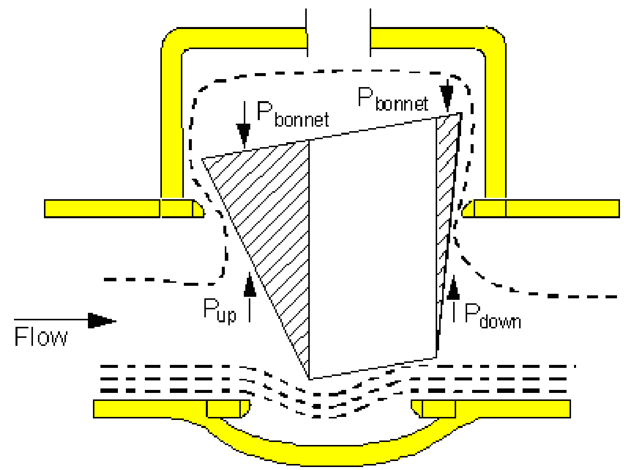
$P_{up} > P_{down}$




<u>Disc on guide</u>

$P_{up} > P_{bonnet} > P_{down}$

Disc tipped before isolation



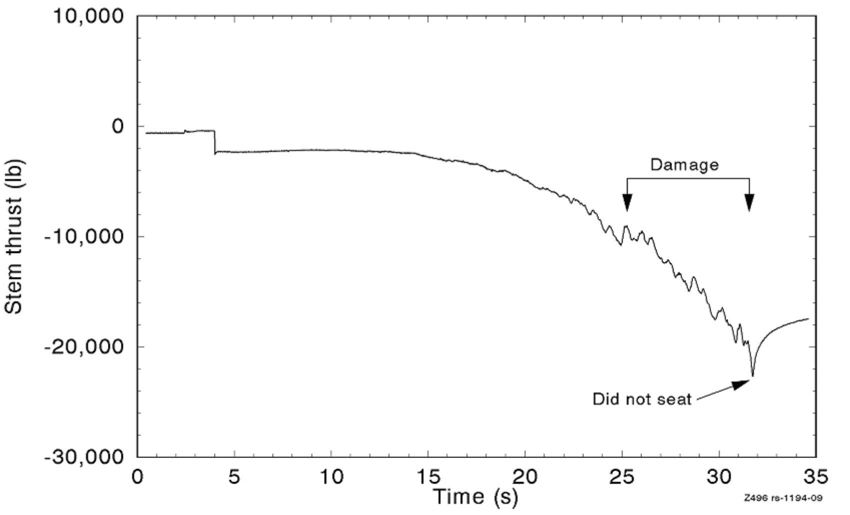
# Nonlinear Gate Valve Closing Correlation

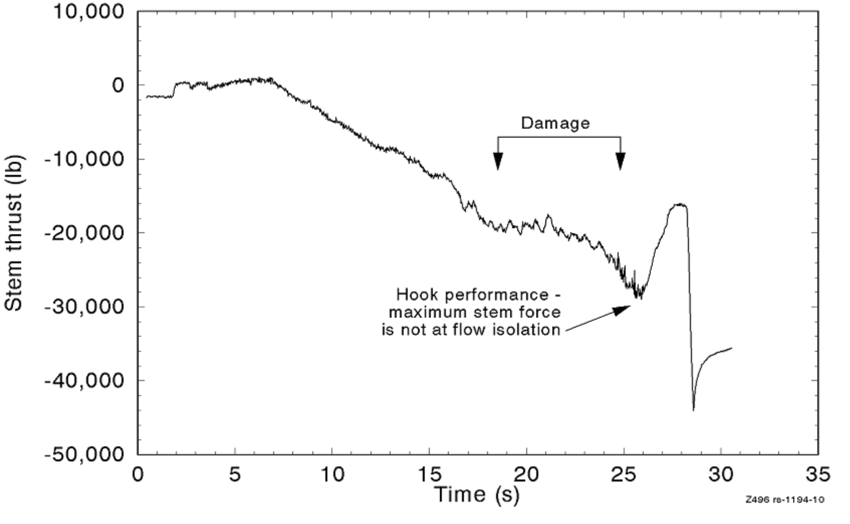
$$F_{stem} = C_{hook}\Delta P + F_{stem\ rej} + F_{pack}$$

*Where*

| | | |
|---|---|---|
| $F_{stem}$ | = | *total stem load* |
| $C_{hook}$ | = | *hooking factor* |
| $\Delta P$ | = | *differential pressure across the disc* |
| $F_{pack}$ | = | *stem packing load* |
| $F_{stem\ rej}$ | = | *stem rejection load* |

# *Stem Thrust Measurement During Damage*



# *Valve Damage To Disc Guides*

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# *Point of Contact Damage*