Decreasing packing friction by utilizing innovative packing construction

MUG 2009
Abstract

In the Nuclear Industry stem packing friction is a real concern. This presentation will focus on ways to reduce packing friction by using innovative packing construction and a simplified gland load formula. Laboratory testing on packing friction, packing construction, and gland load matrix to achieve better Valve performance will be discussed. Today it is important to utilize best available packing technology that can enhance MOV operability without sacrificing long-term valve sealing.
Industry Challenges
Industry Challenges

- Shorter Outages
- Longer life with older equipment
- Smaller Maintenance Teams
Nuclear packing needs

- Sealability
- Packing Friction
- Ease of installation
- Reliability  gland load / friction
NUCLEAR VALVE PACKING CHALLENGES

- **Stem Friction**
  - Create the lowest coefficient of friction from packing set with the largest operability window for the actuator

- **Long Term Sealing**
  - Have a packing set that will perform leak free for many nuclear plant fuel cycles without maintenance issues

- **Consistent gland load**
  - Packing gland load calculations that can be easily applied without complication and chance for error
Valve leakage / performance impacts overall revenue for utilities
“.. The valve stem binding was the result of packing-induced friction”

“The packing-induced fiction was attributed to hardening of the valve packing due to heat, inadequate lubrication, and over-torqued packing glands.”

Prepared for
U.S. Nuclear Regulatory Commission

MOV 2009
Braided Packing variables impact time and add increase costs

- Braided packing old technology to seal valves
Braided Packing technology

- Inconsistent density
  - non homogenous product
  - voids (consolidation)
- Leak path / wicking
- Surface finish/void allow solid embedment and leak path (Steam / Boric Acid)
Braided Packing

- Length flexibility
  - Creates inaccurate packing length
  - Bad overlay & leak path

- Error in cutting of packing
  - Unsharp knife
  - Uneven cut
  - Correctly sized
Increased friction
- Movement on irregular surface causes more friction
- Relative smooth on smooth surface lower friction
Braided Packing yarns

- PTFE
- Carbon/graphite fiber
- PTFE / carbon hybrid
- Exfoliated graphite tape
Pure PTFE (Teflon) yarns

- High thermal growth
- Insulator (holds heat)
- Low coefficient of friction
- 0-14 pH range
- Large gland load
  - Take out voids
- 550°F glass transition point
  (turns hard and off-gases)
PTFE/carbon hybrid yarns

- “…the binding was attributed to thermal expansion of the stem material, extrusion of the packing material into the clearance gap between the stem and cover bushing…”

- “…excessive corrosion growth from fluoride released from the extruded Teflon packing material.”

- MCGUIRE NUCLEAR STATION - NRC INTEGRATED INSPECTION REPORT 05000369/2005003 AND 05000370/2005003 July 2005
Braided packing has a large margin of error when determining correct gland loading
- Large gland loads are needed

Friction variables
Simple / Consistent product line
Torque

- All Chesterton product types have same gland load & torque calculations
  - 1400 PSI Minimum gland formula
  - All services / all valve types
  - Standard density (same mold tolerance)
Torque Formula

- Torque = \( \mu DF/12N \)
  - \( \mu \) = Coef. of friction between the bolts and the stud (default = .2)
  - D = Stud Diameter
  - F = Area x Pressure
  - Packing area = \((OD^2 – ID^2) \times \pi/4\)
  - P = System Pressure x Safety Factor (default 1.75)
  - N = Number of Bolts
  - 12 = the conversion from Inches to ft
Simple / Consistent product line
Friction

- Use standard EPRI friction formula with lab testing
  - Each packing style has unique friction coefficient
    - 5300 (GTP) with 1601 End rings
      - 5 Cross Sections in Height
      - Static Coef. Of Friction .15
      - Dynamic Coef. Of Friction .10
      - Minimum Gland Load 1400 PSI
    - 5800 Wedge Packing (Graphite)
      - 4 Cross Sections in Height
      - Static Coef. Of Friction .085
      - Dynamic Coef. Of Friction .085
      - Minimum Gland Load 1400 PSI
    - 5800T Wedge Packing (Graphite with PTFE hybrid)
      - 4 Cross Sections in Height
      - Static Coef. Of Friction .065
      - Dynamic Coef. Of Friction .065
      - Minimum Gland Load 1400 PSI
Packing Friction

Gland Load (PSI)

<table>
<thead>
<tr>
<th>System Pressure (PSI)</th>
<th>Chesterton Die Formed</th>
<th>Braided</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>3600</td>
<td>3400</td>
</tr>
<tr>
<td>800</td>
<td>3200</td>
<td>3200</td>
</tr>
<tr>
<td>1200</td>
<td>2800</td>
<td>2800</td>
</tr>
<tr>
<td>1600</td>
<td>2400</td>
<td>2400</td>
</tr>
</tbody>
</table>
Packing Friction: EPRI Formula

- \( F = (f) \cdot (Y) \cdot (\sigma g) \cdot (\pi) \cdot (d) \cdot (L) \)
- \( F \) = Packing Stem Friction Load
- \( f \) = Coefficient of Friction between Stem and Packing
- \( Y \) = Ratio of Radial to Axial Stress in Packing
- \( \sigma g \) = Average Contact Stress between Packing and Gland Follower
- \( \pi \) = 3.1416 Constant
- \( d \) = Stem Diameter
- \( L \) = Packing Length or Height of 5 Ring Set uncompressed
The Coefficient of friction is the ratio of force reduction between two materials either to get in motion (static) or while in motion (dynamic/kinetic).

Physics tells us that the value does not change with a change in force on the two materials.

There are basic ASME tests that can determine basic Coef. of frictions but they are in laboratory conditions and rough surfaces will effect the values.
This theoretical value is the ratio of valve packing load applied to the packing over the load applied to the stem and box.

This value has always been stated as “.5” from when the report was first written and the original friction testing was completed.

Chesterton has used the value of “.5” for its testing while imputing actual friction data.
\( \sigma_g = \text{Average Contact Stress between Packing and Gland} \)

- This is the actual load (gland load) onto the packing set.
  - Chesterton has always used a safety factor of 1.75 that is multiplied by the system pressure.
  - Chesterton also has a minimum gland load that is needed to “spread” our graphite rings and create a seal. This value for all of our live loading sets is 1400 PSI (or 1400/1.75 = 800 PSI minimum system pressure)
5800 wedge design

End caps

ID sealers

OD sealer
5800 Packing set

- Designed to lower packing friction, utilizing unique alternating wedge shape
- 3 sealing rings with precise density
- 2 end caps of higher density for anti-extrusion
- 4 x cross section in height
- Static coef. of friction: 0.085
- Dynamic coef. of friction: 0.085
- Minimum Gland Load: 1400 PSI
  - (800 PSI system pressure x 1.75 safety factor)
  - Passive corrosion inhibitor
Combination “Wedge” and mesh technology to lower stem friction

- 2 sealing rings of PTFE/graphite hybrid
  - PTFE mesh around graphite tape center yarn

- Lowers stem friction

- 4 x cross section in Height

- Static coef. of friction: .065
- Dynamic coef. of friction: .065

- Minimum gland load: 1400 PSI
  - (800 PSI system pressure x 1.75 safety factor)

- Passive corrosion inhibitor
# 5800T Chemistry

<table>
<thead>
<tr>
<th>Physical &amp; Chemical properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon, %</td>
<td>77.9</td>
</tr>
<tr>
<td>Ash, %</td>
<td>0.2</td>
</tr>
<tr>
<td>Volatiles (at 1000 C) %</td>
<td>21.9</td>
</tr>
<tr>
<td>Volatiles (at 600 F) %</td>
<td>0.1</td>
</tr>
<tr>
<td>Moisture, %</td>
<td>0.02</td>
</tr>
<tr>
<td>Total Chloride PPM</td>
<td>2197, 2098</td>
</tr>
<tr>
<td>Total Fluoride PPM</td>
<td>140716, 128575</td>
</tr>
<tr>
<td>Total Phosphorus, PPM</td>
<td></td>
</tr>
<tr>
<td>Total Sulfur PPM</td>
<td>1739, 1567</td>
</tr>
<tr>
<td>Total Iodide PPM</td>
<td></td>
</tr>
<tr>
<td>Total Bromide PPM</td>
<td></td>
</tr>
</tbody>
</table>
Yarn technology in 5800T

- PTFE fiber mesh around exfoliated graphite strands
- Only 2 of the 5 rings (ID Sealers)
Breakdown of parts (weight)

- End caps: 31%
- OD Sealers: 52%
- ID Sealers: 17%

Breakdown of PTFE in ID rings (weight)*

- PTFE %: 10%
- Graphite: 90%

Total % of PTFE in complete set*

- PTFE %: 3%
- Graphite: 97%

* Used .250" size as reference, PTFE content changes slightly with cross section.
Minimum gland load

- All Chesterton Die Formed packing uses 1400 minimum gland loads

- Large operability window
Graphite vs. Graphite Friction
.500”x1.000” Valve

Friction (Lbs)

System Pressure (PSI)

AWC 5800
AWC 5300/1601
Typcial
Graphite vs. Graphite Friction
1.000”x1.500” Valve

![Graphite vs. Graphite Friction Graph](image)

- AWC 5800
- AWC 5300/1601
- Typical

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Graphite vs. Graphite Friction
1.500”x2.500” Valve

Friction (Lbs)

System Pressure (PSI)

AWC 5800
AWC 5300/S1
Typical

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PTFE vs. PTFE Friction
.500”x1.000” Valve

Friction (lbs)

System Pressure (PSI)

AWC 5800T

PTFE/Carbon Yarn
Hybrid
PTFE vs. PTFE Friction
1.000”x1.500” Valve

Friction (lbs)

System Pressure (PSI)

AWC 5800T
PTFE/Carbon Yarn Hybrid
PTFE vs. PTFE Friction
1.500”x2.500” Valve

Friction (lbs)

- AWC 5800T
- PTFE/Carbon Yarn Hybrid

System Pressure (PSI)

MOV 2009
CHESTERTON VALVE PACKING
FRICITION TESTING PROGRAM FOR AOV/MOV
APPLICATIONS

Team
P. Michael Paltert, David Leary, Kevin McArthur
Phil Mahoney, Ron Frousard, Ned Richason

Written By: Philip M Pelcher
Donee Engineers III
A.W. Chesterton Co.

Date: 7/13/09

Approved By: Kevin McArthur
Manager Technical Services
A.W. Chesterton Co.

Date: 7/13/09
LESLIE VALVE TEST RIG

MINIATURE E/P TRANSUDUCER:
Type 900X CONTROLAIR Inc

TESTPOINT 4.0 SOFTWARE

STRAINSERT ST:
Strainsert ST series Standard Studs (ST-FB) ⅝-13NC x 4-1/2" lg. (350 ohm)

LESLIE AOV:
1500lb class Aeroflow

KEITHLEY 1800 AO DATA ACQUISITION BOARD

CELESCO:
PTIDC 4.5 to 40 VDC

SHRADERBELLOWS SOLENOID VALVES:
MOPD 75, 11 WATSS, Volts 120/60 – 110/50, Orifice 3/32 – 3/32
PHASE I DRY FRICTION TEST PROCEDURE

Parameters
- Leslie Aeroflow 1500# Piston Operated Valve
- Limit EDA (Effective Diaphragm Area)
- Removed Spring & Plug to reduce valve issues
- Temperature and Pressure: 75 °F & 0 psig
- Stem: 8 – 15 rms
- Valve Actuations: 50 Cycles (40 cycles during consolidation 10 initial strokes)

Installation / Consolidation
- Install 5-Ring Packing Set
- Tighten Gland Studs to Specified Torque
- Packing Consolidation (10 Cycles X 4)
- 10 Cycles - Collecting friction data
- Inspect Packing Set
- Analyze and Plot Test Data
**PHASE I THERMAL CYCLE TEST PROCEDURE**

**Parameters**

- Temperature and Pressure: 600 °F & 1550 psig
- Stem: 8 – 15 rms
- Valve Actuations: 200-300 Cycles

**Installation / Consolidation**

- Install 5-Ring Packing Set
- Tighten Gland Studs to Specified Torque
- Packing Consolidation (10 Cycles X 4)
- **10 Cycles - Collecting friction data**
- At 1550 psi 600 °F collect data 10 Cycles
- Actuate valve 100 cycles
- **Collect data 10 cycles after 100 cycles**
- Overnight system cool down & **collect 10 cycles @ 75 °F / 0 PSIG**
- Repeat steps 5-9
- Check Torque after second cool down and re-torque gland.
- **Collect 10 cycles**
PHASE II TEST PROCEDURE

Parameters

- Temperature and Pressure: 600 °F & 1550 psig
- Stem: 8 – 15 rms
- Valve Actuations: 2500 (part A)-15000 (part B) Cycles

Installation / Consolidation

- Install 5-Ring Packing Set
- Tighten Gland Studs to Specified Torque
- Packing Consolidation (10 Cycles X 4)
- Measure spring height before and after every nut adjustment
- 10 Cycles - Collecting friction data
- At 1550 psi 600 °F collect data 10 Cycles
- Actuate valve 1,200 cycles
- Overnight system cool down & collect 10 cycles @ 75 °F / 0 PSIG
- Check spring height after every cool down
- Repeat steps until 15,000 cycles is reached
- Collect friction data at room temperature after 15000 cycles
- Re-tighten gland nuts to original spring height and collect friction data
PHASE II OF TESTING

- **Parameters of testing**
  - 15,000 full stroke cycles

- **ISO/DIS 15848-1**
  - 20% of full stroke length = 1 stroke

- **75,000 cycles**
  - 30,000 full strokes = 150,00 ISO strokes
  - 150,00 ISO strokes = 75,000 ISO cycles

- **Re-tighten valve packing**
  - Adjust to original consolidated spring height
5800 LIVE LOADED OVER 15,000 CYCLES

<table>
<thead>
<tr>
<th>DAYS</th>
<th>SPRING HEIGHT</th>
<th>AVERAGE FRICTION COEFFICIENT</th>
<th>LOAD</th>
<th>CYCLES</th>
<th>RUNNING TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.14</td>
<td>0.1364</td>
<td>1336</td>
<td>692</td>
<td>692</td>
</tr>
<tr>
<td>2</td>
<td>1.14</td>
<td>0.135</td>
<td>1275</td>
<td>122</td>
<td>814</td>
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<tr>
<td>3</td>
<td>1.14</td>
<td>0.114</td>
<td>1075</td>
<td>1679</td>
<td>2493</td>
</tr>
<tr>
<td>4</td>
<td>1.14</td>
<td>0.104</td>
<td>1072</td>
<td>1720</td>
<td>4213</td>
</tr>
<tr>
<td>5</td>
<td>1.14</td>
<td>0.103</td>
<td>1050</td>
<td>1656</td>
<td>5869</td>
</tr>
<tr>
<td>6</td>
<td>1.14</td>
<td>0.102</td>
<td>1030</td>
<td>1522</td>
<td>7391</td>
</tr>
<tr>
<td>7</td>
<td>1.145</td>
<td>0.102</td>
<td>1025</td>
<td>636</td>
<td>8027</td>
</tr>
<tr>
<td>8</td>
<td>1.147</td>
<td>0.102</td>
<td>1019</td>
<td>1103</td>
<td>9130</td>
</tr>
<tr>
<td>9</td>
<td>1.152</td>
<td>0.1</td>
<td>1013</td>
<td>1182</td>
<td>10312</td>
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<tr>
<td>10</td>
<td>1.155</td>
<td>0.095</td>
<td>1000</td>
<td>1000</td>
<td>11312</td>
</tr>
<tr>
<td>11</td>
<td>1.16</td>
<td>0.09</td>
<td>998</td>
<td>1562</td>
<td>12874</td>
</tr>
<tr>
<td>12</td>
<td>1.1</td>
<td>0.1159</td>
<td>1420</td>
<td>1063</td>
<td>13937</td>
</tr>
<tr>
<td>13</td>
<td>1.1</td>
<td>0.1142</td>
<td>1358</td>
<td>1063</td>
<td>15000</td>
</tr>
</tbody>
</table>

TOTAL CYCLES AT TEMPERATURE 15000

TOTAL NUMBER OF THERMAL CYCLES 13
Re-tightening to original spring height occurred after 12,874 cycles.
Re-torque = 9 ftlbs

- Consolidation: 9 ftlbs = 1.17” of compressed spring height

- After Cycles: 9 ftlbs = 1.188” of compressed spring height
  - Dried Anti Seize
How accurate is Anti-seize “wet”

<table>
<thead>
<tr>
<th>Metal/Lubricant</th>
<th>Minimum Nut Factor</th>
<th>Mean Nut Factor</th>
<th>Maximum Nut Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>As Received Alloy or Mild Steel Fasteners</td>
<td>0.158</td>
<td>0.2</td>
<td>0.267</td>
</tr>
<tr>
<td>As Received Stainless Steel Fasteners</td>
<td>---</td>
<td>0.3</td>
<td>---</td>
</tr>
<tr>
<td>Cadmium Plate (Dry)</td>
<td>0.106</td>
<td>0.2</td>
<td>0.328</td>
</tr>
<tr>
<td>Copper Based Anti-Seize</td>
<td>0.08</td>
<td>0.132</td>
<td>0.23</td>
</tr>
<tr>
<td>Cadmium Plate (Waxed)</td>
<td>0.17</td>
<td>0.187</td>
<td>0.198</td>
</tr>
<tr>
<td>Fel-Pro C54</td>
<td>0.08</td>
<td>0.132</td>
<td>0.23</td>
</tr>
<tr>
<td>Fel-Pro C-670</td>
<td>0.08</td>
<td>0.095</td>
<td>0.15</td>
</tr>
<tr>
<td>Fel-Pro N 5000 (Paste)</td>
<td>0.13</td>
<td>0.15</td>
<td>0.27</td>
</tr>
<tr>
<td>Machine Oil</td>
<td>0.10</td>
<td>0.21</td>
<td>0.225</td>
</tr>
<tr>
<td>Moly Paste or Grease</td>
<td>0.10</td>
<td>0.13</td>
<td>0.18</td>
</tr>
<tr>
<td>Never-Seize (Paste)</td>
<td>0.11</td>
<td>0.17</td>
<td>0.21</td>
</tr>
<tr>
<td>Neolube</td>
<td>0.14</td>
<td>0.18</td>
<td>0.20</td>
</tr>
</tbody>
</table>
Live loading as a “load gauge”
Chesterton Valve Springs

- Creates stored energy with Belleville springs to postpone gland load loss
- Springs sets designed for specific valve data
  - System pressure
  - Dimensions (packing and bolt size)
- Chesterton live loading designed over 30 years
- What to live load
  - Thermal Cycling
  - Vibration
  - Critical Dynamic Applications
  - Anywhere you want to measure gland load!!!
Outer Guide Technology
Outer Guides

- Easier to re-energize then inner guide assembly
- Do not need scale to measure height; can use flat washer / outer guide as visual
- Springs stay together “in-line” / easier installation compared to inner guide
If a valve is leaking do you first re-torque?
First attempt: Re-torque to same values

Ensure adequate packing gland adjustment is left before attempting to adjust. If not, then repack or add additional rings of packing.

Basically retorque gland packing studs per the Packing Gland Assembly and Packing Consolidation sections using the same initial values. Use higher values with Engineering concurrence.
Maybe you are concerned about a valve and ask to verify what the torque is now??
Re-torque = shooting in the dark

- Anti Seize thread pastes are made of oil, thickeners and lubricating solids. K nut factors are based on the “WET” or oily paste at installation only.

- One time use!

- Once exposed to heat cycles, oil is flashed off. “Dry” Anti-Seize properties K nut factor maybe up to 200-300%+ higher with wide variance

- CANNOT get the same gland load when re-applying original torque after any heat on the valve
“Dry” anti-Seize testing

- Using Skidmore device torque bolt to 100 ft-lbs, record LOAD and calculate K nut factor (coefficient of friction) of “wet” thread paste.

- Remove bolts, re-lube and place in oven at 500C for 6 hours to “flash” off oil

- Put bolt back in Skidmore and apply 100ft-lbs, record Load and calculate K nut factor of “DRY” thread paste.
### “Dry” anti-Seize testing

<table>
<thead>
<tr>
<th>Anti-Seize</th>
<th>Torque Cf wet</th>
<th>Cf dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loctite Nickel 100</td>
<td>0.154</td>
<td>0.71</td>
</tr>
<tr>
<td>Bostick Ni Nuclear 100</td>
<td>0.151</td>
<td>Seized</td>
</tr>
<tr>
<td>Loctite N-7000 100</td>
<td>0.135</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>3 cycles, 4&lt;sup&gt;th&lt;/sup&gt; seized</td>
<td></td>
</tr>
<tr>
<td>Chesterton 772 100</td>
<td>0.164</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>2 cycles, 3&lt;sup&gt;rd&lt;/sup&gt; seized</td>
<td></td>
</tr>
<tr>
<td>Loctite Marine 100</td>
<td>0.12</td>
<td>Seized</td>
</tr>
<tr>
<td>Loctite Heavy Duty 100</td>
<td>0.13</td>
<td>Seized</td>
</tr>
<tr>
<td>Molykote P37</td>
<td>0.121</td>
<td>0.349</td>
</tr>
</tbody>
</table>

- Data average of 6 re-torquing cycles (wide range)
- Seized values attained 100 ft-lbs with NO Load transfer to stud. Threads galled during re-torquing
- N-7000, coarse texture when dry, surface galling got worse with cycles dry coating on threads being scraped off under load.
- Chesterton 772, ultrafine particles, smooth film when dry, surface galling with repeat cycles. Coating present yet not sufficient film strength to resist load.