Troubleshooting Fluid Sealing in Pump Systems for Safety and Reliability

Leaders in Sealing Integrity
Introduction

» Partnering to create a cleaner and safer world

» We understand the frustrations with servicing our industry where the minimizing downtime and costs in industrial plants seem to be driving every decision.

» We have seen through our global applications engineering team that fluid sealing failures seem to be one of the most frustrating experiences and wanted to share some insights we have learned.
Introduction

Reliability Engineers are now responsible for a lot more pieces of equipment or areas of the plant than in the past.
Forces Acting on a Gasketed Joint

- Bolt Force
- Internal Pressure
- Hydrostatic End Force
- Atmosphere
- Media
- Flange
- Gasket
- FLANGE

Garlock
Gasket Failure Analysis

Review of a 100 Failed Gaskets

- Not Recommended: 13
- Miscellaneous: 4
- Gasket Crushing: 13
- Lack of Load: 70

83% of Failures were due to Installation Errors
Gasket Failure Analysis

» Gaskets located either at either face of the pump inlet/outlet along with any flange to flange connection in the pump system

» Around pump flanges there are many possible failure modes
  » Gasket Blow-out
  » Chemical Attack
  » Erosion
  » Crush
  » Under compression

» Some failure modes can be hard to identify or be confused with others
Gasket Failure Analysis – Blow-out

» Gasket blow-out is probably the most common gasket failure and has the most causes
» Identification: Usually most of the gasket remains in place and either part of the gasket is pushed out past the sealing area (egg shaped), sections missing, or split and gasket open
Gasket Failure Analysis – Blow-out

Causes & Mitigation

» Under-compression of the gasket
  » Will discuss this in later slides

» Uneven compression of the gasket/Rocking of the flange
  » Ensure proper installation procedure to bring flanges down evenly, rocking of flange more common in smaller flanges

» Pump dead heads
  » Avoid this occurring, not much can stop the gasket from blowing out if this is the cause

» Media freezes and expands
  » Pressure builds as ice expands—heat tracing to ensure solids do not build up when media is located in freezing situations

» Gasket not suitable for pressure
  » Review pressure rating for material and determine if torque/stress appropriate for pressure rating

» Pump turned on too quickly
  » Add a pressure regulator or increase pressure ramp uptime if that is possible
Gasket Failure Analysis – Chemical attack

Identification
» Gasket frayed or missing (jagged) at ID where gasket in contact with media
» Extremely soft or disintegrated appearance

Causes & Mitigation
» Gasket is not compatible with the media
  » Ensure that the components of the gasket are suitable for contact with media—consult chemist or chemical textbook
  » Ensure concentration or temperature does not adversely affect gasket or components of gasket
Gasket Failure Analysis – Erosion

Identification
  » Gasket missing at ID (smooth cut away)

Causes & Mitigation
  » Media is highly abrasive – high solids
  » Abrasiveness is worse due to turbulent flow – near 90degree turn or outlet of pump
    » Upgrade to a materials with better abrasion resistance – such as HNBR for rubber or PTFE for sheet materials
    » Use thinner gasket and/or more highly compressible material – less height exposure to media and less likely to be eroded
Gasket Failure Analysis – Crush

Identification
- Gasket is cracked or split in concentric fashion
- Rubber gaskets may be shredded at ID
- Possibly liquid present on gasket (shiny)

Causes & Mitigation
- Gasket is not suitable for flange facing
  - Eg. rubber gaskets used in raised face flanges—switch to higher crush material
- Liquid sealant or anti-stick was applied to surface of gasket
  - Do not use liquid on gasket surface—ensure dry and oil free before installation
  - If gasket removal a concern upgrade to more anti-stick material such as PTFE or graphite, or use dry anti-stick coating
Gasket Failure Analysis – Under compression

Identification
» No to little notable compression on gasket
» possibly blown out

Causes & Mitigation
» Bolts are not strong enough
  » Ensure bolts are proper strength to achieve a reliable seal based on material. Harder materials and higher pressures will typically require more stress and stronger bolts
» Lubricant/torque wrench are not used
  » Lubricant on bolts/threads – 2x-3x efficiency of torque
  » Using a calibrated torque wrench at a predetermined/calculated torque for material
» Torque limited due to flange material – Brittle or Plastic
  » Flanges such as PVC/CPVC usually require a low load gasket (options out there) or rubber. Cast iron may or may not seal fiber/ptfe if torque is limited.
Gasket Problem Solver - 3510 EPX

- Same chemical resistance as 3510 for strong caustics
- Hex face pattern to reduce area – increase stress concentrations
- Increased compressibility over traditional PTFEs
- Better blowout resistance

**EPX**

High density zone

**Traditional PTFE**

Damaged areas often only can be filled roughly.
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Compression Packing
Troubleshooting and Failure Analysis of Pumps with Packing

Standard Procedure
Adjusting the gland (compression packing) > desired leakage level outboard

- Leakage Level
- Leakage Actual
- Leakage Target
- Leakage Adjustment

Problem with either or a combination of, the packing, the pump and the system.
Troubleshooting – Compression Packing

People: What do they know?
» Operator
» Installer
» Maintenance personnel
» Process engineer

Running equipment and system anomalies:

Observations that can only be done when up and running:
» Vibrations
» Grinding
» Fluctuations
» Smell
» Smoke

Failure Definition:
» Excessive leakage?
» Overheating?
» High rate of flush water consumption?
» Excessive friction load?
» Blowout?
» Chronic seal failures in this application?
» OR, was this an unexpected event?
» Were there any changes to the seal material, the equipment, or the overall process that preceded the failure?
» Were there any system upsets or cleaning cycles that preceded the failure?
» Can you describe the installation procedure?
Troubleshooting – Compression Packing

The usual suspects

- Over Tightening
- Excessive Speed
- Abrasive Wear
- Excessive Heat
- Chemical Attack
- Improper Installation
Troubleshooting – Compression Packing

- Over Tightening
- Excessive Speed
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- Excessive Heat
- Chemical Attack
- Improper Installation
**Abrasive Wear**

**Occurrence:**

- Abrasives in media enter the stuffing box getting inside the packing, in between the shaft sleeve and the packing
  - Generating wear on both packing and sleeve, thus increasing the clearance and leakage.
**Abrasive Wear**

**Occurrence:**

» Abrasives in media enter the stuffing box getting inside the packing, in between the shaft sleeve and the packing
  
  » Generating wear on both packing and sleeve, thus increasing the clearance and leakage.
  
  » Re-tightening the gland to reduce the leakage might make things worse.
Abrasive Wear

Troubleshooting:

» Equipment condition
  » Replace worn parts
» Clearances
» Alignment
» Flush working properly
  » Fluid
  » Pressure

Abraded packing
Damaged sleeve
Excessive leakage
# Abrasive Wear

## Media Abrasiveness & Chemical Compatibility

## Packing Selection

### Abrasive Resistance

<table>
<thead>
<tr>
<th></th>
<th>Flexible Graphite</th>
<th>PTFE (virgin)</th>
<th>P-Aramid</th>
<th>Carbon fiber</th>
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<td>Abrasive</td>
<td>0</td>
<td>2</td>
<td>9</td>
<td>7</td>
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<tr>
<td>Heat</td>
<td>9</td>
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<tr>
<td>Speed</td>
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<tr>
<td>Creep</td>
<td>4</td>
<td>1</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Sealing ability</td>
<td>9</td>
<td>7</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

**Note**
- Clean media only
- Last resort only for Chemical resistance
- Need hardened sleeve to match
- Not all created equal - Fit

*In some cases, flush might not be required*
Abrasive Wear

- Abraded packing
- Excessive leakage
- Damaged sleeve
- Packing style selection
- Fit
- Design
- Lantern ring – Flush alignment
- Excluder ring
Abrasive Wear

High Solid and Abrasives Option =
- Wear control
- Caustic resistance

Low Solid Option = Water conservation
- Leakage control

Style 98/GYLON 3510 Ring Set

8091 – Hydra-Just Set
Abrasive wear

Packing Installation Basics

Design, dimensions, components
» Stuffing box
  » Clean (old packing all removed)
  » Good condition – Flat bottom
» Clearances
» Flush - Flow and pressure

» Install and sit each component individually and in the correct order, staggering the seam
» Lantern ring – alignment
» Apply gland load evenly – gland nut finger tight

Start-up:
1. Flush
2. System

Gland Adjustments
» Proportionate to leakage
» Leakage stable before re-adjusting
Expansion Joints

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**Standard Design**

**Tube**
- Protects body from media
- Critically important to be compatible with pipe media

**Body**
- Fabric - Provides strength and flexibility for pressure
- Metal - Provides strength for vacuum

**Cover**
- Protects body from mechanical and environmental damage

**Arch**
- Allows for movement; can be filled to prevent solids entrapment

**Flange**
- Provides sealing surface without use of a gasket

![Diagram of Standard Design with labels for Tube, Body, Cover, Arch, Flange, Fabric, Metal, and Tube]
Reasons for Failure

Common Service Related Causes of Failure

- Ozone: 21%
- Chemical: 26%
- Comp. Set: 12%
- Heat: 17%
- Abrasion: 12%
- Fatigue: 7%
- Tear: 5%
Insufficient Torque on Installation
Design Considerations

- Multiple Plies in Flange
  - Increase Sealability
  - Reduce Bolt Load Creep

- Very Little Fabric
  - Poor Sealability
  - Rubber Creeps and Bolts Loosen
Installation

**Step 1** – Insert bolts with washers through retaining rings on the arched side of the expansion joint and then through to the mating flanges in a cross pattern. (Where there is not enough room for a bolt, **fully threaded rod** can be used with nut on each end. All thread past the nut on arched side should be kept to a minimum.)

**Step 2** – Attach and tighten nuts (with washers) until hand tight.

**Step 3** – Torque each bolt to full torque with the cross-bolt pattern until the outside edge of the expansion joint flange bulges slightly. Recommended torque specifications are available at Garlock.com.

**NOTE:** Check bolt tightness within 1-2 weeks after installation and periodically thereafter to ensure the seal is maintained.
Excess Temperature
Safety Considerations

» The closer the material is to the temperature limit, the faster it degrades
» Temperature ratings are subjective
» No industry standard to set temperature limits
» Vary from manufacturers and between different compounds
  » Cure systems, polymer grades, and formulations all affect actual performance
How to Specify

- **Minimum - ASTM D2000 Call Out:**
  - Typical properties of elastomers from Fluid Sealing Association: FSA-PSJ-703-19
  - M2BA 607 A13 Z1 Z2

- **Heat resistance, Test Method D573, 70 h at 70°C:**
  - Max change in hardness, ±15 points
  - Max change in tensile strength, ±30%
  - Max change in ultimate elongation, -50%

- **Preferred**
    - Create specifications for actual values, not change in value
    - Use longer time spans than 70 h
Weathering/Aging
Common Resistance to UV & Ozone

- Outstanding: 7
- Excellent: 6
- Very Good: 5
- Good: 4
- Fair to Good: 3
- Fair: 2
- Poor to Fair: 1
- Poor: 0

Diagram shows the resistance of various materials to UV and Ozone, with EPDM and FKM having the highest resistance.
How to Specify

» Typical properties of elastomers from Fluid Sealing Association: FSA-PSJ-703-19
  » DOES NOT INCLUDE OZONE STANDARDS

» Preferred
  » ASTM D1171-18, Standard Test Method for Rubber Deterioration—Surface Ozone Cracking Outdoors
    » Exposure Method B
    » Result: Pass

» Summary: Rubber is exposed for 70 hr at 40 +/- 1°C (104 +/- 2°F) at an ozone level of 50 +/- 5 mPa partial ozone. Rubber is viewed under 2x magnification and no cracks shall be permitted.
Insufficient Vacuum Support
Design Considerations

Multiple Plies in Arch
- Improve strength
- Reduce chance of vacuum inversion

Metal Body Rings
- Improve strength
- Reduce chance of vacuum inversion
- Tied into arch to prevent migration

Wire Reinforcement
- Lower Strength than Body Rings
- Higher chance of vacuum inversion

Joint Type
- Wide arches are more geometrically susceptible to collapse due to vacuum forces
Preventative Maintenance & Reliability Service
Garlock Expansion Joints

Expansion Joint Inspections

» All expansion joint manufacturers recommend a periodic inspection of rubber expansion joints as part of an effective reliability and preventative maintenance program.

» Average frequency is annually but can be less or more based on severity of service.

» Unlike most system components, rubber expansion joints exhibit obvious outward signs of deterioration.

» While these characteristics may be obvious during visual inspection, it can be difficult for untrained personnel to judge the severity of the deterioration.
Proven Success
PMR Service

Pulp and Paper Mill - Southeastern US

- **Size:** 1.5” - 48” ID
- **Temperature:** 70°F - 250°F
- **Application:** Various throughout mill
- **Media:** Water, pulp, black/white liquor, bleach, and CLO2
- **Pressure:** Vacuum to 200psi

**OBSERVATION:**
After the inspection, 3 expansion joints failed, and all were marked in Garlock’s inspection as “Replace” but were not replaced during the next outage. The last joint that failed resulted in a flooded administration building floor with 4 feet of pulp.

**SOLUTION AND BENEFITS**
A sense of urgency is now in place and a reliability engineer has asked Garlock to write the spec for all rubber expansion joint. Now, all rubber expansion joints for this mill are spec'd Garlock. Replacement recommendations are now accepted with high priority.
PMR Service Benefits

- **Inspect**
  - Garlock can help FREE OF CHARGE

- **Plan**
  - When replacements are planned, the correct expansion joint can be ordered for the application.

- **Optimize**
  - With proper fit and materials, expansion joints last longer.
  - Don’t pull the black one off the shelf

**Operate Failure Free**
We're Here to Help

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