O-Ring Optimization
Why Use an O-Ring?

• Most robust/reliable static seal
• Very high sealing pressure with moderate squeeze
• Off the shelf standard sizes
• Limited space for groove sizing
• Self-Retention in groove not necessary
• Lowest cost
Design Considerations

1. Material Selection
2. Proper Squeeze
3. Gland Fill
4. Stretch
5. Pressure vs Clearance
6. Eccentricity & Side Loading
7. Tolerances
8. Surface Finish
9. Sharp Corners
What is Squeeze?

Compression expressed as a percentage of the free-state cross-sectional thickness of the O-ring.

\[
\frac{(\text{O-Ring C/S}) - \text{Gland Depth}}{(\text{O-Ring C/S})}
\]

- Face Seal (Axial): 20-32%
- Static Male/Female (Radial): 18-28%
- Reciprocating: 8-20%
- Rotary: 0-10%
Squeeze

• Affects resiliency property of material
• Too little shortens seal life
  – Minimum .007” deflection required
• Too much overstresses material
  – 50 to 60% can rupture seal
• Side-by-side testing showed 2X set on 50% squeeze compared to 30%
• Recommended squeeze different for different gland configurations and different sizes
Gland Fill

O-Ring volume as a percentage of Gland volume.

\[
\frac{\text{O-Ring Volume}}{\text{Gland Volume}}
\]

• About 25% void space or 75% nominal fill
• Need space in groove to allow for:
  – Volume swell
  – Thermal expansion
  – Increasing width due to squeeze
• Narrower groove for sealing vacuum or gas
• Approaching/achieving 100% fill is undesirable
  – Results in pinching, tearing, or incomplete assembly.
Excessive Gland Fill

- Rubber acts as incompressible fluid, like water.
- Overfill results in excessive stress, distortion of mating parts, and increases chances of installation damage.
Stretch (in Application)

Groove diameter as a percentage of O-ring free-state ID.

\[
\text{(Groove Diameter)} - \frac{\text{(O-Ring ID)}}{\text{(O-Ring ID)}}
\]

- General rule is 0-5%
- Excessive stretch can overstress material
  - Thins cross section and reduces squeeze
  - % cross section reduction due to stretch equal about half of the % ID stretch
- Safe installation stretch is 50% regardless of elastomer compound
  - Possibility of breakage during installation at >50%
Pressure vs Clearance

Pressure + Clearance = Extrusion
Tolerances

• Must be considered for O-ring and the gland
• Affect on squeeze and pressure rating
• Less a factor on larger cross sections
• Use inPHorm Gland Design software to model your gland with production tolerances
• inPHorm advises if within recommended ranges
  – Stretch
  – Gland Fill
  – Squeeze
Surface Finish

• Seal material **must** fill in voids in surface.
• Static surfaces
  – 32-64 rms to seal liquid
  – 16 rms to seal gas
• Dynamic Surfaces
  – 8 - 20 rms
• Excessive surface roughness can result in abrasion or spiralling, even with a static seal
Other Design Considerations

• Eccentricity and Side-Loading
  – Excessive squeeze on one side and not enough (or none) on the other
  – Can open too wide a clearance gap and result in extrusion of one portion of seal
  – O-Rings are excellent seals but poor bushings

• Non-round groove configurations
  – Minimum acceptable corner radius
    • Varies by o-ring cross section
O-Ring Gland Types

• Static
  – Face Seal
  – Dovetail Seal
  – Radial (Male / Female) Seal
  – Crush Seal
  – Tube Fitting Seal

• Dynamic
  – Radial (Male / Female) Seal
  – Rotary Seal (Female only)
Face Seal

- No stretch
- 20 – 32% squeeze
- Up to 93% fill
- Internal Pressure
  - Match OD of groove to OD of o-ring
Static Radial

- 1-5% stretch ideal
- 15 - 25% squeeze
- 70 - 93% gland fill

Female O-Ring Gland

Male O-Ring Gland
Crush Seal

- Machine using a 45° chamfer tool
  - Sink the tool to the required value for o-ring cross-section.
- “Legs” of chamfer equal to 1.321 times o-ring cross section
Engineer’s Resource

www.darc oid.com