SEALS · ELASTOMERS · GLAND DESIGN · AS568 / ISO 3601 · REFERENCE DOCUMENT · PUBLIC

O-ring selection guide

Choosing the elastomer, hardness, size and groove for a reliable O-ring seal — with the squeeze, gland-fill, extrusion and failure-mode rules that decide whether it lasts.

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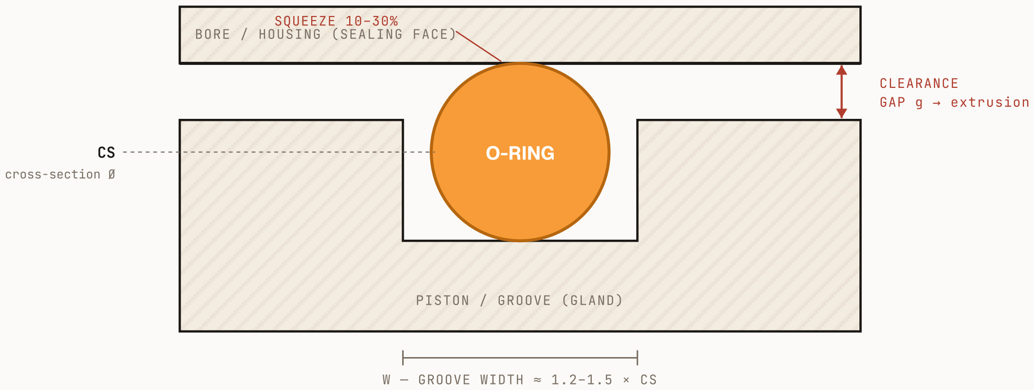
ABSTRACT

An O-ring seals by being squeezed inside a groove (the gland) so it presses against both sealing faces; system pressure then energises it harder against the downstream wall. Get four things right and it lasts: the elastomer (chemical and temperature compatibility), the hardness (durometer), the size (AS568 inch or ISO 3601 metric), and the gland (squeeze, fill, stretch, finish, clearance).

Section 1 explains how the seal works. Section 2 is material and hardness selection. Section 3 is sizing and standards. Section 4 is gland design with the squeeze / fill / finish tables. Section 5 covers pressure, extrusion and back-up rings. Section 6 is failure modes and fixes. Section 7 is a step-by-step selection checklist.

O-RING GLAND — STATIC RADIAL CROSS-SECTION



A STATIC RADIAL GLAND. THE RING IS SQUEEZED 10–30% BETWEEN THE GROOVE BOTTOM AND THE BORE; SYSTEM PRESSURE THEN ENERGISES IT AGAINST THE LOW-PRESSURE WALL, WHERE THE CLEARANCE GAP CONTROLS EXTRUSION.

CONTENTS

1. How an O-ring seals

An O-ring is a circular elastomer torus installed in a groove and compressed between two surfaces. That initial compression — the **squeeze** — creates the seal at zero pressure. When system pressure is applied, it pushes the ring across the groove against the low-pressure wall and **energises** the contact: the higher the pressure, the harder it seals. This is why a correctly sized O-ring seals across a huge pressure range from one part.

1.1 Key terms

`Gland`	The complete cavity that contains the ring — groove plus the mating sealing surface
`Squeeze`	Diametral compression of the cross-section, as a percentage of CS — typically 10–30%
`Gland fill`	Ring volume as a percentage of groove volume — keep below ~90% at hot/swollen conditions
`Stretch`	How much the ring ID is enlarged on assembly (static radial only), 1–5%
`CS`	Cross-section diameter of the ring (the "thickness")
`ID / OD`	Inside / outside diameter of the ring
`Back-up ring`	A stiff anti-extrusion ring (usually PTFE) placed on the low-pressure side

1.2 Static vs dynamic

- **Static**
  no relative motion across the seal (face/flange seals, caps, fixed fittings). Higher squeeze is fine; the main risks are compression set and extrusion.
- **Dynamic**
  a surface slides or rotates against the ring (pistons, rods, rotary). Squeeze is kept lower to limit friction, wear and heat, and surface finish and lubrication become critical.

2. Material selection

Pick the compound that survives **every** fluid it touches (including cleaning agents) across the **full** temperature range. This is the decision that most often determines seal life.

ELASTOMER	TEMP RANGE (°C)	GOOD WITH	AVOID
NBR (nitrile / Buna-N)	−35 to +120	Petroleum oils, fuels, hydraulic fluid, water, air; low cost — the default	Ozone & weather, ketones, esters, strong acids, brake fluid
HNBR (hydrogenated nitrile)	−35 to +150	NBR media plus heat, abrasion, refrigerants; automotive, A/C	Aromatics, strong acids, ozone (better than NBR)
FKM (fluoroelastomer / Viton)	−20 to +205	Fuels, oils, many solvents and chemicals, high temp; broad resistance	Low temp, ketones, esters, amines, hot water / steam, brake fluid
EPDM	−50 to +150	Water, steam, brake fluid (glycol), weather, ozone, polar fluids, outdoors	Petroleum oils, fuels, greases (swells badly)
VMQ (silicone)	−60 to +200	Extreme hot/cold, dry air, food & medical, inert; static only	Dynamic use (poor wear), fuels, oils, steam
FVMQ (fluorosilicone)	−55 to +175	Silicone temperature range plus fuel / oil resistance; aerospace	Steam, high-pressure dynamic service
CR (chloroprene / Neoprene)	−40 to +110	Refrigerants (ammonia), weather, ozone, mild chemicals	Strong acids, aromatics, oxidisers
FFKM (perfluoro / Kalrez)	−15 to +260	Near-universal chemical + high-temp resistance; semiconductor, aggressive media	Cost (very high); confirm low-temp grade
AU / EU (polyurethane)	−30 to +90	Outstanding abrasion & extrusion resistance, high-pressure hydraulics	Hot water / steam (hydrolysis), high temp, ketones

2.1 Hardness (durometer, Shore A)

- **70 A
  the default.** Best balance of sealing, friction and assembly. Use unless you have a reason not to.
- **90 A
  high pressure / anti-extrusion / hard, precise mating faces.** Higher friction and assembly force; resists being forced into the clearance gap.
- **50 A
  low closure force, rough or compliant surfaces, vacuum.** Seals easily but takes more compression set and extrudes sooner.

Always confirm the specific compound against the fluid supplier's chemical-compatibility chart — "FKM" covers families with different low-temperature and chemical grades.

3. Size and standards

Specify a **standard** size wherever possible — non-standard tooling is slow and expensive.

- **AS568 (SAE, inch-based) is the de-facto global standard. Sizes are given by a dash number whose series sets the cross-section: –0xx ≈ CS 1.02 mm, –1xx ≈ 1.78 mm, –2xx ≈ 2.62 mm, –3xx ≈ 3.53 mm, –4xx ≈ 5.33 mm.**
- **ISO 3601-1 (metric) specifies by ID × CS, e.g. `20.0 × 2.5`. Common cross-sections: 1.0, 1.5, 1.8, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0, 6.0, 7.0 mm.**
- **Tolerance & quality: ISO 3601-1 gives dimensional class A/B; ISO 3601-3 gives surface-quality grades (flash, defects) N (standard) or S (critical). State both for sealing-critical parts.**

A complete callout names: **compound + hardness + size + tolerance class + surface grade** — e.g. *"FKM 75 Shore A, 20.0 × 2.5 ISO 3601-1 Class A, grade N."*

4. Gland (groove) design

The groove turns the chosen ring into a working seal. Design it for the right squeeze and fill, and a clearance small enough to prevent extrusion.

PARAMETER	STATIC RADIAL	STATIC FACE (AXIAL)	DYNAMIC RECIPROCATING
Squeeze	15–30% (≈0.25–0.50 mm)	18–30%	8–16%
Gland fill (volume)	60–85%	60–85%	60–80%
Stretch at ID	1–5% (≤5%)	n/a (axial)	≤2% (never compress)
Sealing-face finish Ra	≤0.8 µm	≤0.8 µm	0.10–0.40 µm
Groove side / bottom Ra	≤1.6 µm	≤1.6 µm	≤0.8 µm
Groove width	1.2–1.5 × CS	1.2–1.5 × CS	≈1.4 × CS

4.1 Rules that matter

- **Never exceed ~90% gland fill at the hottest, most-swollen condition. The groove must have room for thermal expansion and fluid swell, or the ring over-stresses and extrudes. This is why the groove is wider than the ring.**
- **Face (axial) seals: place the groove so pressure pushes the ring toward the groove wall that backs it up**
  toward the OD for internal pressure, toward the ID for external pressure or vacuum.
- **Dynamic: keep squeeze low (8–16%) to limit friction and heat, and the sliding surface very smooth (Ra ≤ 0.4 µm) with no axial scratches. A plunge-ground or honed counterface seals best.**
- **Stretch reduces effective CS (and therefore squeeze) and raises ID tension**
  keep it under 5% and re-check squeeze after stretch.

5. Pressure, extrusion and back-up rings

Extrusion (the ring shaved or nibbled on its low-pressure edge) is the classic high-pressure failure. It gets worse with **higher pressure, larger clearance gap, softer durometer and higher temperature** — all of which let the ring creep into the gap.

Three levers, in order of preference: **tighten the clearance gap**, **raise the hardness (90 A)**, then **add a back-up ring** (PTFE anti-extrusion ring) on the low-pressure side — both sides if pressure alternates.

SYSTEM PRESSURE	70 SHORE A	90 SHORE A
≤ 5 MPa (~700 psi)	diametral gap ≤ ~0.15 mm	gap ≤ ~0.25 mm
5–10 MPa	gap ≤ ~0.08 mm, or add back-up	gap ≤ ~0.13 mm
> 10 MPa (~1500 psi)	back-up ring	back-up ring

Values are indicative diametral clearances — always confirm against the seal supplier's pressure-vs-gap chart for the actual compound and temperature.

6. Failure modes and fixes

MODE	LOOKS LIKE	CAUSE	FIX
Extrusion / nibbling	shaved or chewed low-pressure edge	gap too large, pressure too high, ring too soft	back-up ring, 90 A compound, reduce clearance
Compression set	flattened, won't spring back	over-squeeze, heat, wrong compound, long static life	low-set compound (FKM/HNBR), reduce squeeze, lower temp
Spiral failure	clean ~45° cuts (dynamic)	ring slides and rolls in the groove	better finish & lubrication, correct squeeze, harder ring
Thermal / chemical attack	hardening, cracking, swelling or softening	over temperature or wrong media	reselect compound for media + temp (Section 2)
Explosive decompression	blisters / splits after rapid gas vent	absorbed gas expands faster than it escapes	ED-resistant compound, higher hardness, slow depressurisation
Abrasion (dynamic)	worn flat, scored surface	rough counterface, no lubrication, debris	finer finish (Ra ≤ 0.4 μm), lubrication, filtration, harder ring
Installation damage	nicks, cuts, twist marks	sharp edges, no lead-in, dry assembly	15–20° lead-in chamfers, deburr, lubricate, protect threads/splines

7. Selection checklist

- **Media**
  list every fluid and gas the seal contacts, including cleaning and sterilisation agents.
- **Temperature**
  record the minimum and maximum, including short transient spikes.
- **Pressure**
  steady value, peak, and whether it cycles or alternates direction.
- **Motion**
  static, or dynamic (reciprocating / rotary)? This sets the squeeze band.
- **Material**
  choose the compound that survives media and temperature (Section 2), then verify on the supplier chart.
- **Hardness**
  70 A by default; 90 A for high pressure or extrusion risk; 50 A for low force or rough faces.
- **Size**
  pick a standard AS568 dash or ISO 3601 ID × CS; favour common cross-sections for availability.
- **Gland**
  set squeeze, fill (≤ 90% hot), stretch, surface finish and clearance per Section 4.
- **Extrusion**
  check gap against pressure and hardness; add back-up rings if needed (Section 5).
- **Assembly**
  provide 15–20° lead-in chamfers, deburr all edges, and use a lubricant compatible with both the elastomer and the media.
- **Specify fully on the drawing**
  compound, hardness, size, tolerance class, surface grade and any back-up ring.