Parker Engineered Materials Group

Elastomers 101

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ENGINEERING YOUR SUCCESS.

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“Rubber Compound”

Mixture of base polymer and other chemicals

- Polymer
- Cure System
- Reinforcing Agents
- Plasticizers & Process Aids
- Anti-oxidants & Anti-ozonants
- Miscellaneous (Pigments, Internal lubricants, etc)

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Polymers

Base polymer determines chemical resistance, rough temperature limits, and rebound resilience

- In some materials, the high and low temp limits can be modified by other compounding ingredients.

Provides “baseline” for abrasion resistance, compression set resistance, permeation rates

- These can (and almost always are) modified – up or down – by other compounding ingredients.

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Typical Polymers

EPDM / EPR

- Ethylene-Propylene-Diene Monomer

NBR – Nitrile

- Acrylonitrile-Butadiene

HNBR / HSN – Hydrogenated Nitrile

- Hydrogenated Acrylonitrile-Butadiene

FKM – Fluorocarbon

FEPM – AFLAS®

- Tetrafluoroethylene-Propylene

FFKM - Perfluoroelastomer

Cure Systems

"Glue" polymer chains together (cross-linking)

- Long-term resilience and elasticity
- Difference between rubber and rubber-like thermoplastics
- Prevent the material from "melting"
- Type and amount are strong drivers for compression set resistance
- Affects heat age resistance
- Affects flex life
- May affect chemical resistance (especially in FKM and FFKM)
- Different cure systems used with different polymers

Reinforcing Fillers

Mechanical Reinforcement

- Increase hardness
- Increase tensile and modulus, decrease elongation
- Improve abrasion resistance
- Improve compression set

Carbon Black

- Standard for black compounds
- Hundreds of grades available

Mineral Fillers

- Common in non-black compounds
- Several types available

Plasticizers and Process Aids

Typically liquid or wax-like ingredients

- Improves process flow
- May improve low temperature performance
- Offsets some volume swell
- Lowers the hardness
- May evaporate or extract into application fluid
- Makes compression set worse
- Limits the options for cure systems
  - Peroxides may react with plasticizer instead of the polymers

Anti-oxidants & Anti-ozonants

Chemicals that protect the rubber from ozone attack or oxidation at high temperatures

- May bloom to surface & act as a barrier film
  - More common is to stay within the rubber
- Once they are consumed, protection is gone
- Common in Nitrile and EPDM
  - Can provide better heat age properties
- Can extract into process fluids

Durometer/Hardness

- Resistance to penetration of an indenter
- Poor indication of properties
- Ranges
  - 30 to 95 Shore A Pts.

Tensile Strength

- Stress required to rupture specimen

- Maximum stress in application
- Abrasion resistance
- Small indication of extrusion resistance

- Typical Ranges
  - Poor, VMQ 1200 psi
  - Good, FKM, NBR 2500 psi
  - Excellent, HNBR, XNBR, XHNBR 4500 psi

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Ultimate Elongation

- Strain at which specimen ruptures, given as a %

- Maximum strain in application
- Splitting, cracking, fracturing

- Typical Ranges
  - Poor, 95 HNBR 50%
  - Good, 90 HNBR 100%
  - Excellent, 85 HNBR 200%

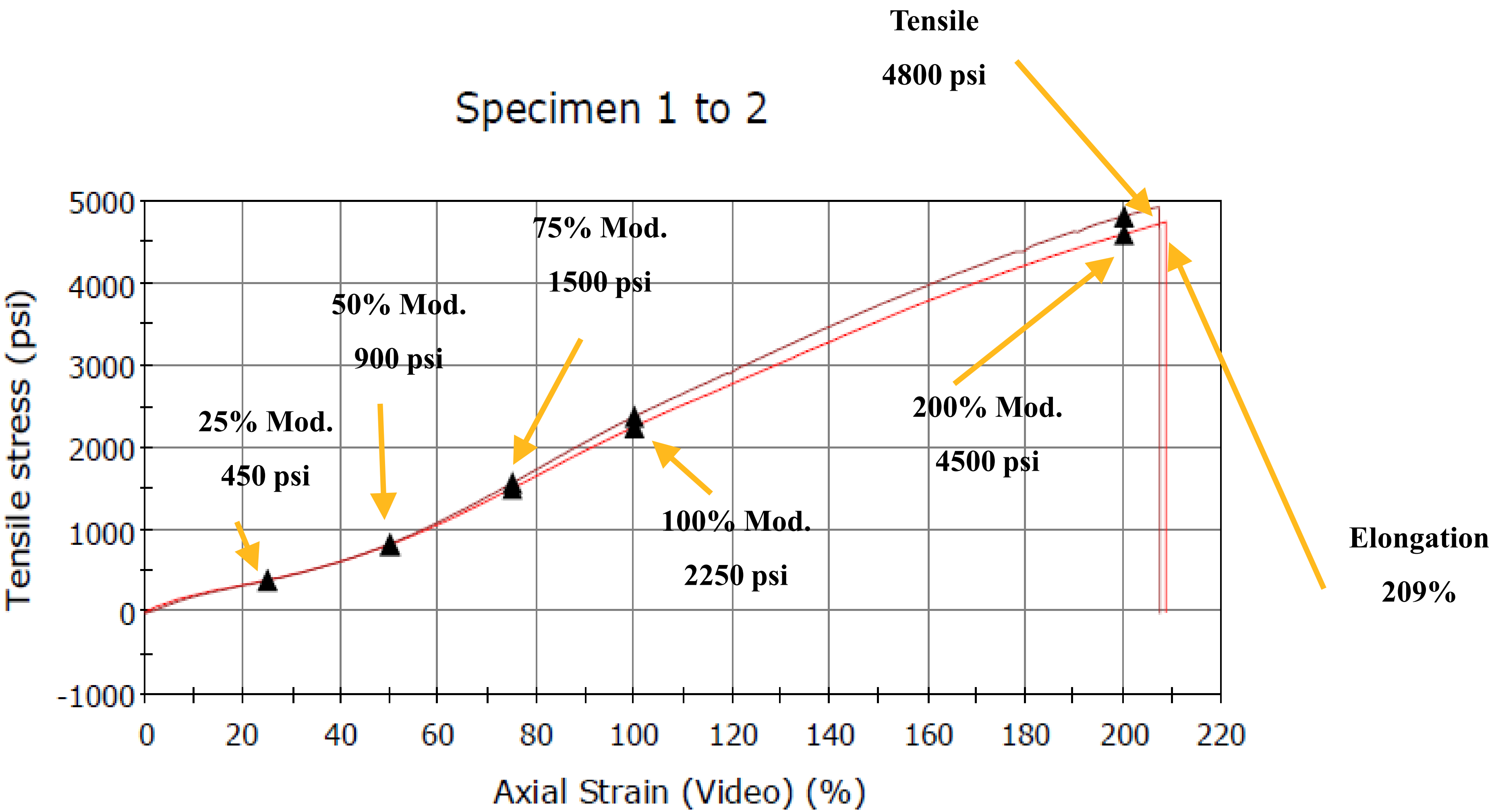
Modulus

- Stress observed for a given strain

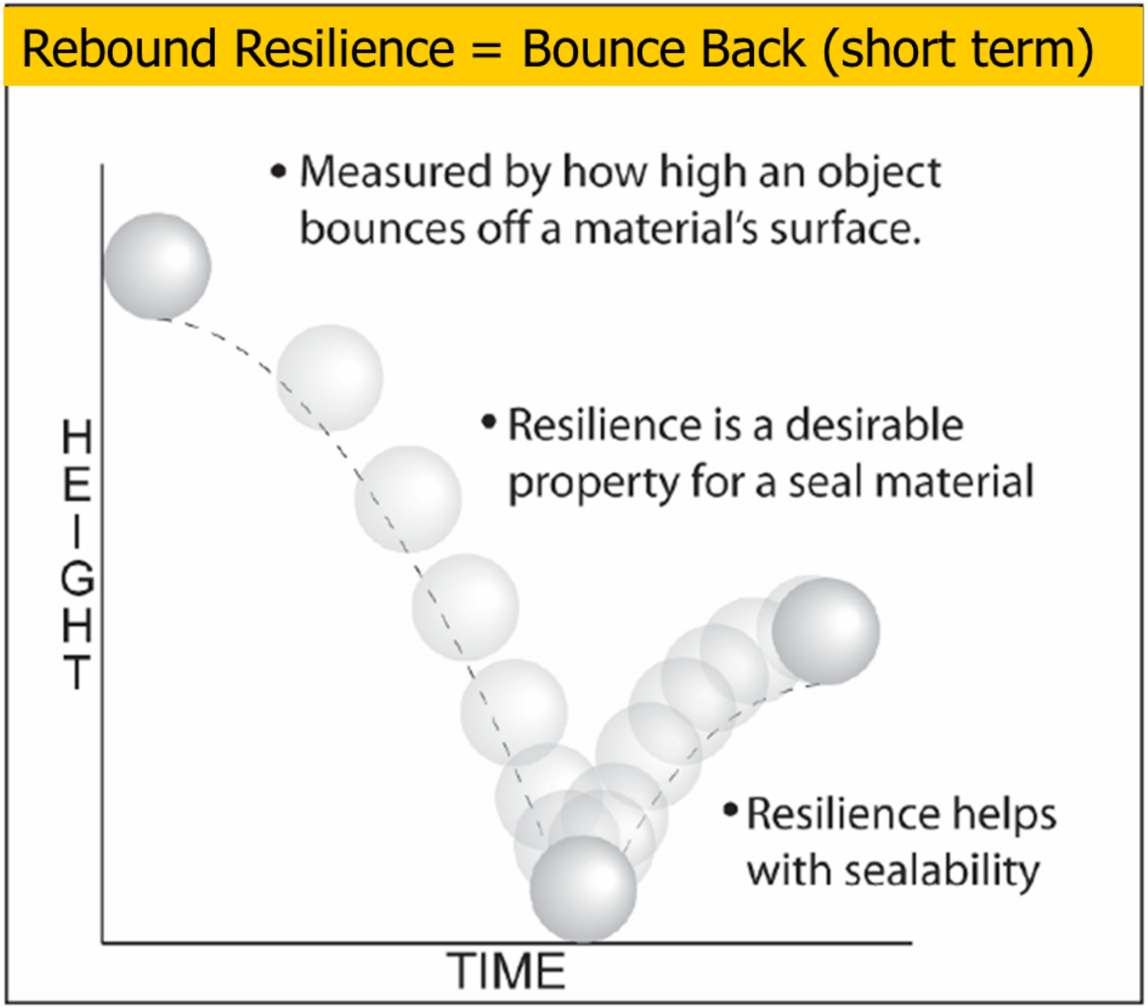
- Installation force
- Best indication of extrusion resistance

- Typical Ranges (100% Modulus)
  - Low Extrusion Resistance 1000, psi
  - Moderate Extrusion Resistance, 2000 psi
  - High Extrusion Resistance, 3500 psi

Mechanical Properties

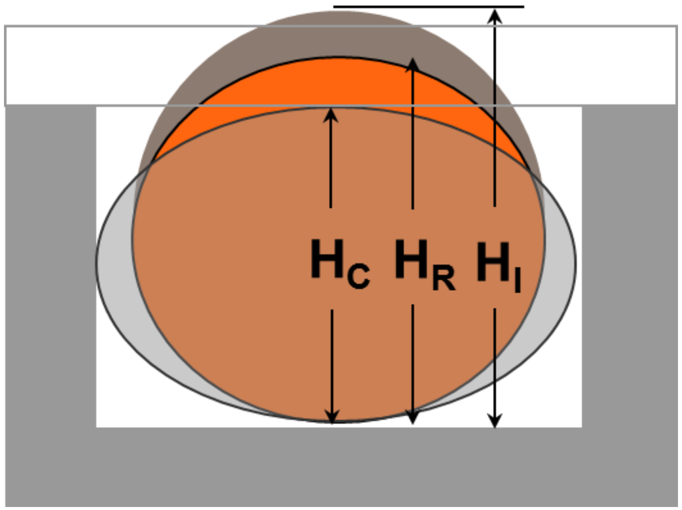


Rebound Resilience



Compression Set

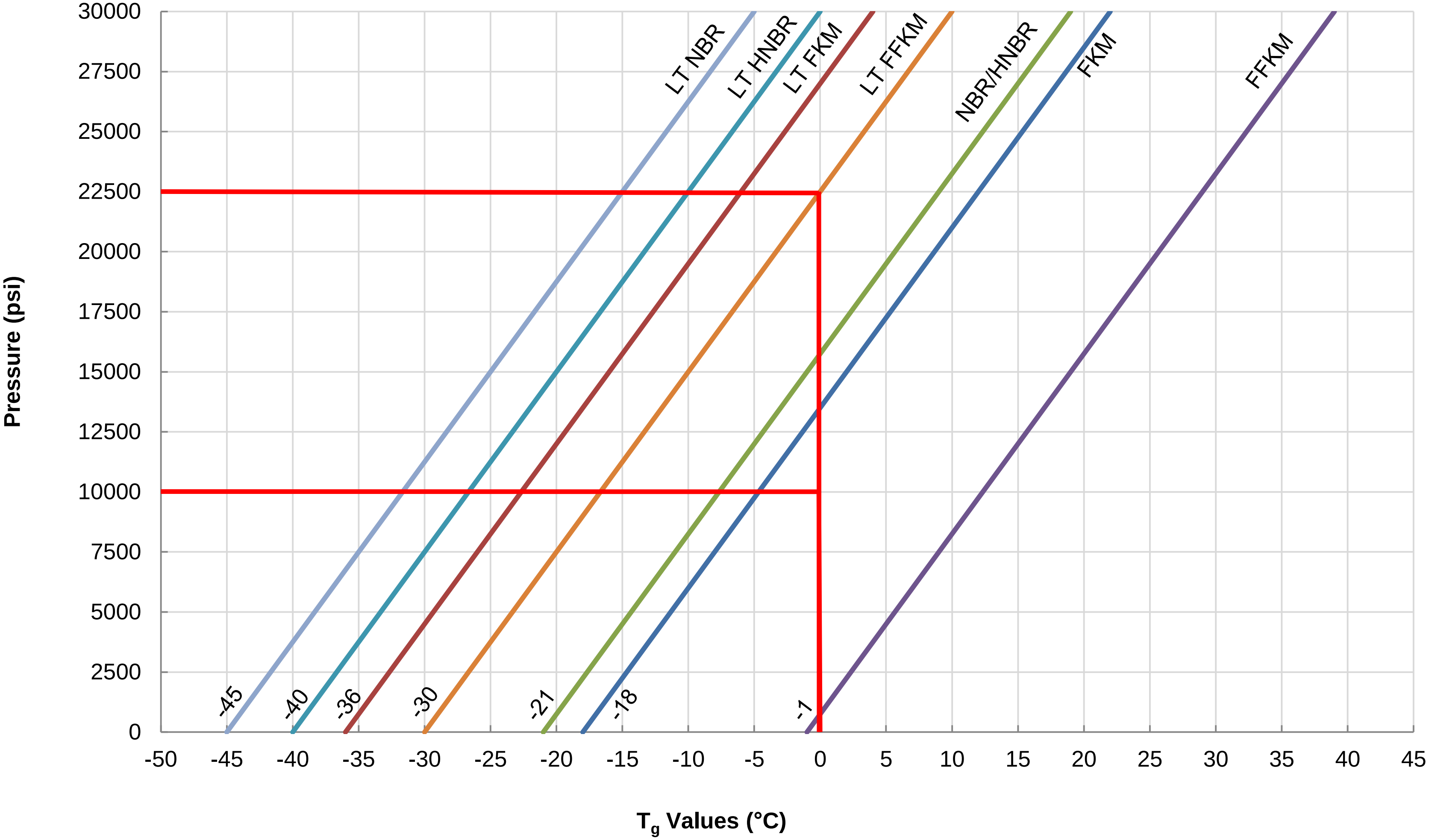
- Permanent deformation under compressive load
- Maintained Resilience
- Long term seal ability



H_I = Initial Height
H_C = Compressed Height
H_R = Recovered Height

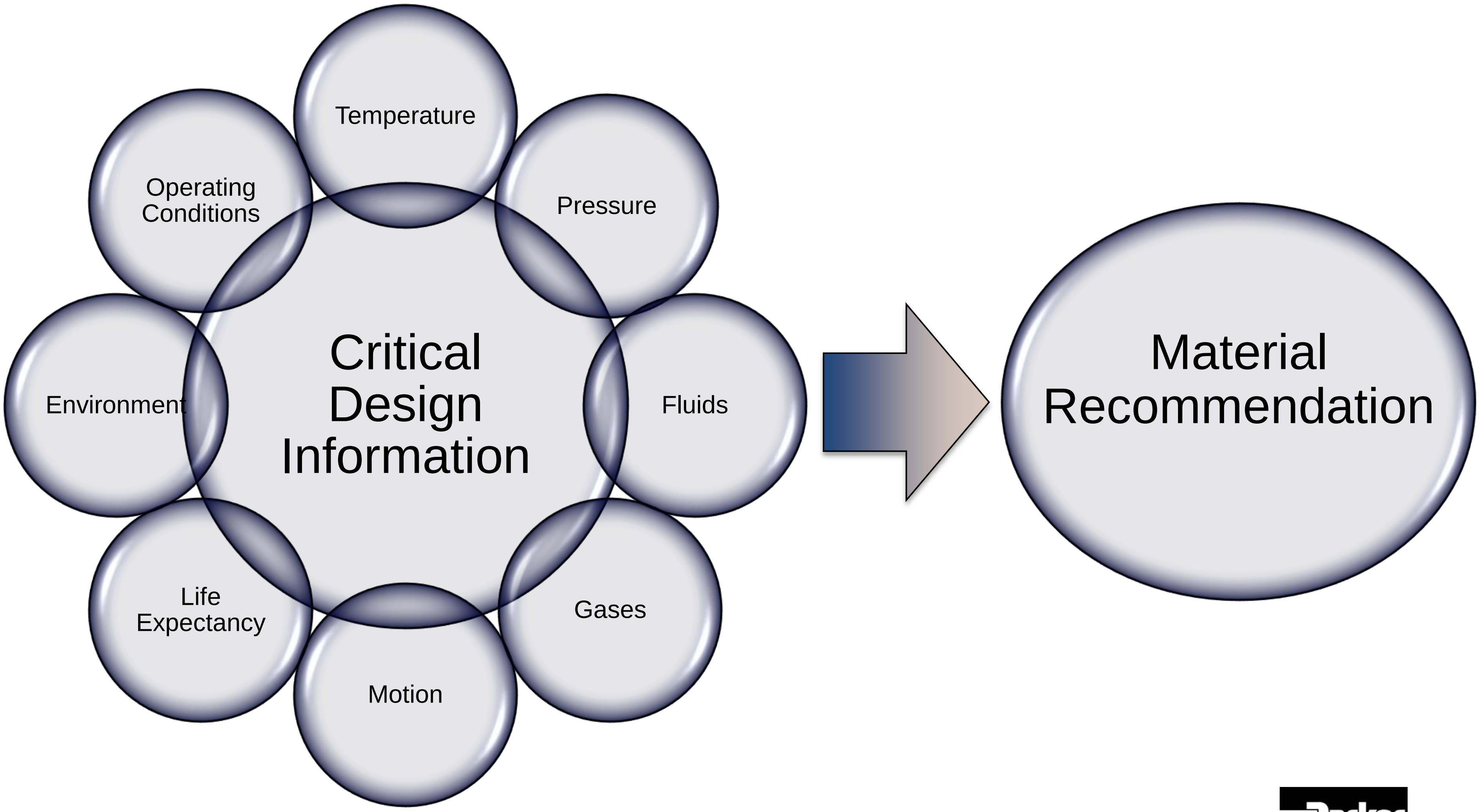
$$CS(\%) = \frac{H_I - H_R}{H_I - H_C} = \frac{amount\_of\_loss}{initial\_deformation}$$

Thermal Glass Transition Temp (Tg)



~ Every 750 psi = Tg of material > +1°C

Application Engineering



Parker O-Ring Division

O-Ring Design Basics

ENGINEERING YOUR SUCCESS.

O-Ring Gland Design

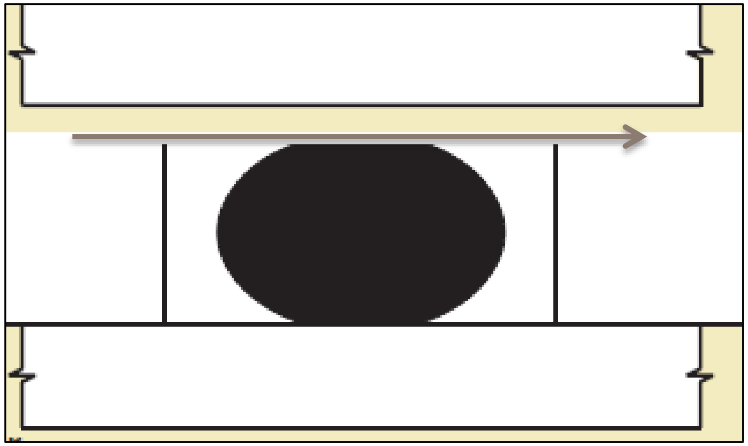
The best O-rings in the world won’t work if the gland they’re in isn’t designed correctly.

- Probably 25 - 50% of all leakage problems are a problem with gland design.
  - The remainder are caused by poor seal material selection, seal damage, and / or reaching the end of the seal’s service life (they just wear out.)
- Gland Design / Analysis = Number Crunching
- Mobile inPhorm does most of the work:
  - Material Selection
  - Stretch, Squeeze, & Fill
  - Tolerance Stack-ups

O-Ring Design

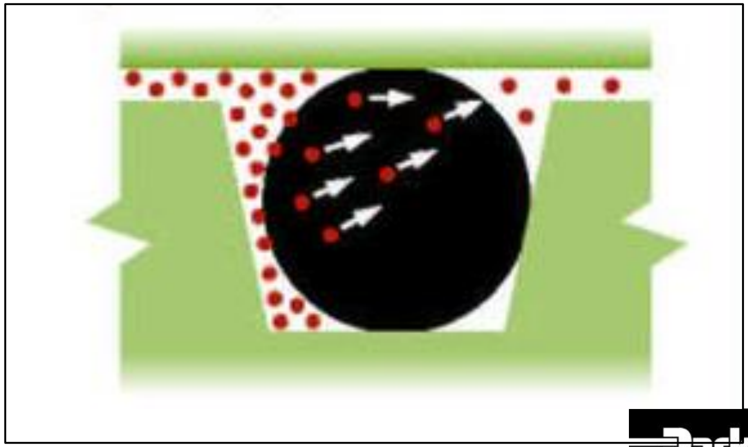
Tangential Leaks

- Leakage around the seal



Permeation

- Leakage through the seal



O-Ring Design

Primary Considerations

- Material Selection
  - Hardness, Permeability, Media Compatibility
- Squeeze
  - Amount of Compression on the Seal
- Gland Fill
  - Amount of void space filled by the seal
- Stretch
  - Amount the seal is stretched in the installed state

Squeeze

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

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

- Too little shortens seal life
- Too much overstresses material
- 25% optimum nominal design squeeze
- Recommended squeeze different for different gland configurations and different sizes

Gland Fill

Gland volume vs. O-ring volume

$$\frac{\text{O-ring Volume}}{\text{Gland Volume}}$$

- Recommend 75% nominal fill
- 95% maximum gland fill
- Allow for volume swell, thermal expansion, and increasing width due to squeeze
- Overfill can damage o-ring by causing extrusion into clearance gap.

Stretch

% inside diameter stretch installed in groove

$$\frac{\text{(Groove Diameter – O-ring ID)}}{\text{O-ring ID}}$$

- General rule is 0-5%
- Excessive stretch can overstress material
- Thins cross section and reduces % squeeze
- % CS reduction approx. 1/2 of the % ID stretch10%

  (10% Stretch = 5% CS Reduction)

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Static O-Ring Sealing

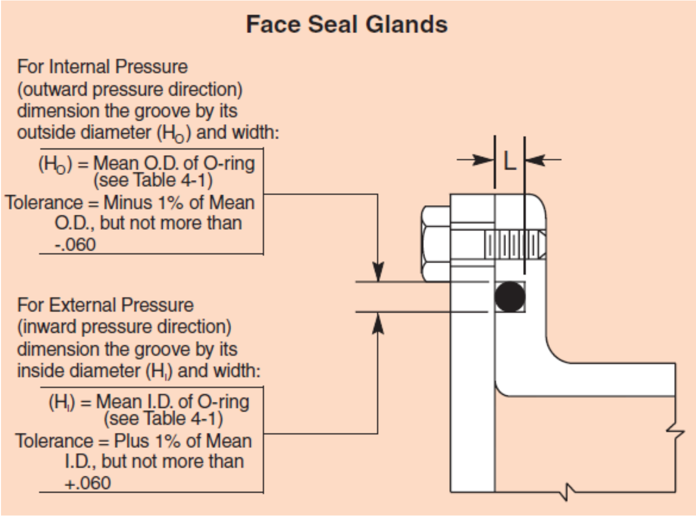
- **Face Seal**
  - Design Chart 4-3
- **Radial (Male and Female)**
  - Design Chart 4-2
- **Dovetail/Half Dovetail**
  - Design Charts 4-4 and 4-5
- **Crush (Triangular)**
  - Design Chart 4-6

Face Seal

- NO STRETCH
- INTERNAL PRESSURE: DESIGN TO GROOVE OD
- EXTERNAL PRESSURE: DESIGN TO GROOVE ID
- “0” CLEARANCE: HIGH PRESSURE
- 20-32% SQUEEZE
- SURFACE FINISH

LIQUIDS – 32 micro-inches RMS

GASES – 16 micro-inches RMS



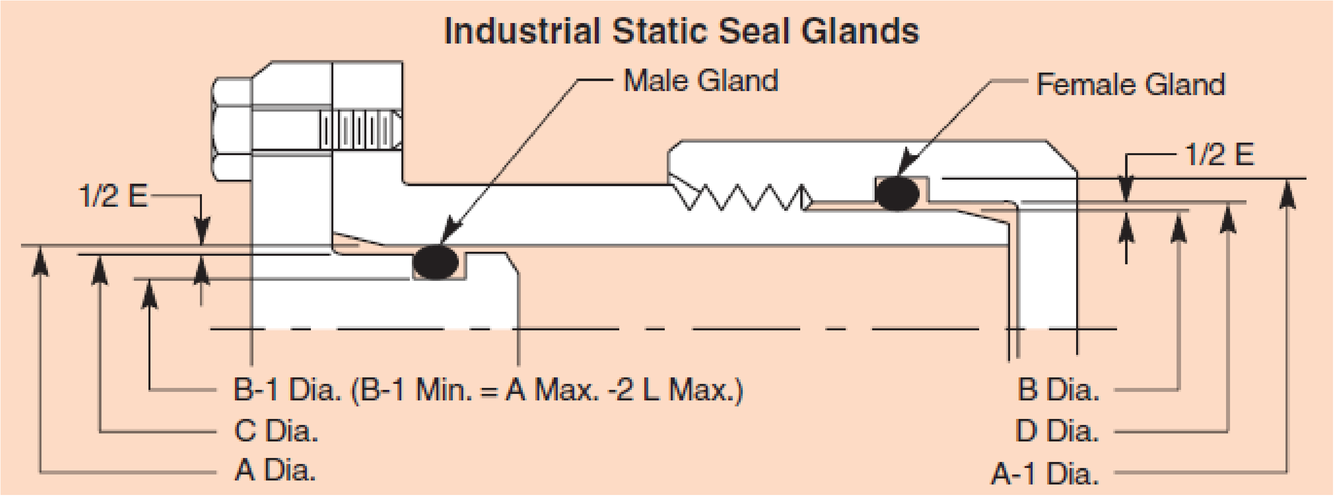
Static O-Ring Sealing

Radial Seal

- 0-5% STRETCH
- 15-30% SQUEEZE
- CLEARANCE GAP
- SURFACE FINISH

LIQUIDS – 32 micro-inches RMS

GASES – 16 micro-inches RMS



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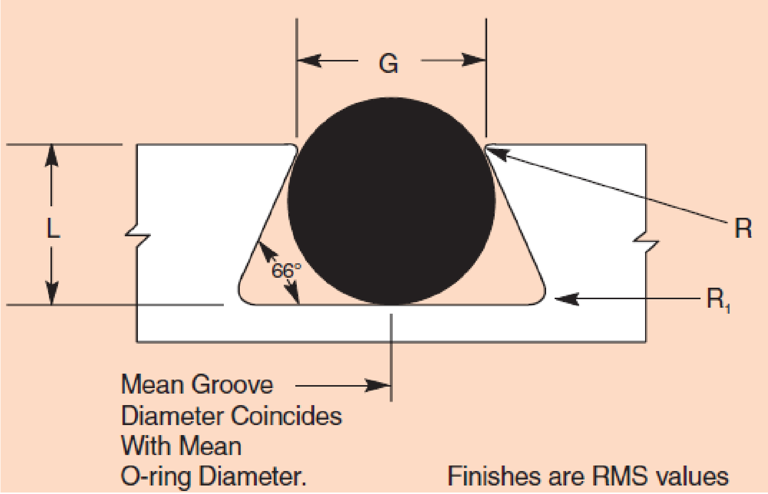
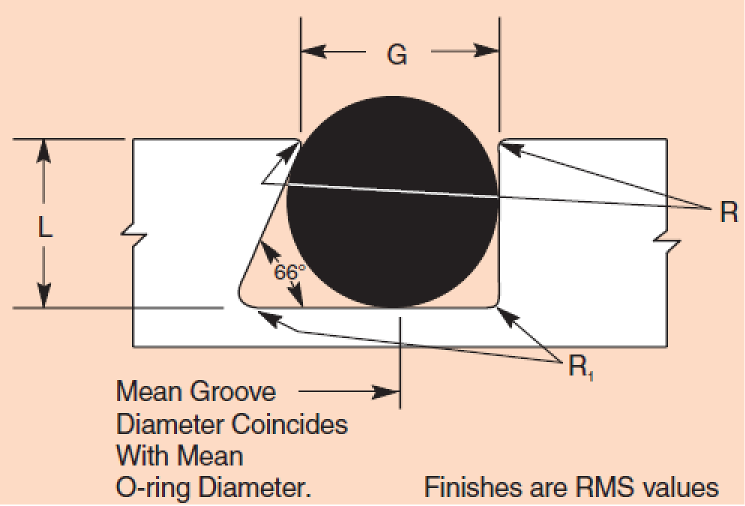
Dovetail/Half Dovetail

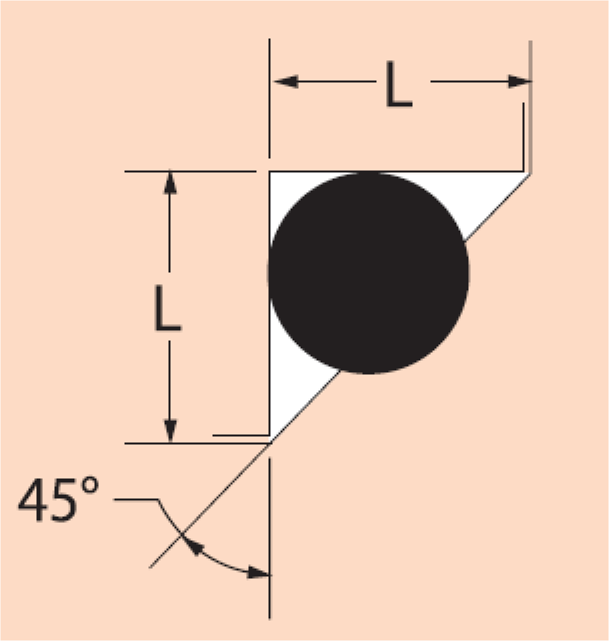
- PRE-DESIGNED CUTTING TOOLS
- HOLD O-RING IN GROOVE
- MORE DIFFICULT/EXPENSIVE TO MACHINE





Crush Seal

- 45 DEGREE ANGLE
- L = 1.321 x CS
- Following this yields:
- 85%-95% Volume Fill



O-Ring Design

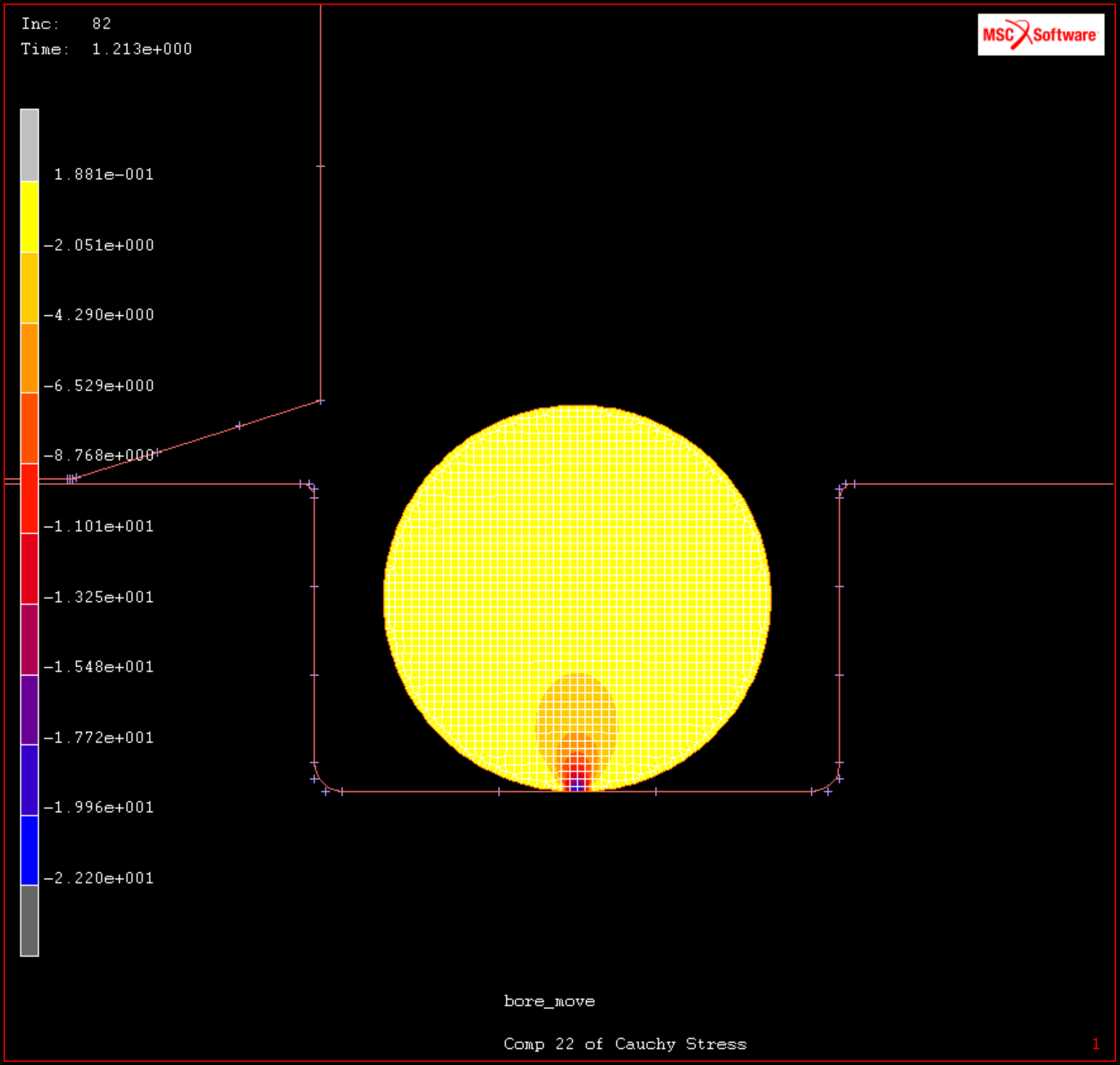
Other Considerations

- Sharp Corners
  - Installation difficulties, Pinching/Cutting
- Surface Finish
- Tolerance Stack-ups
  - Min, Nominal and Max
- Eccentricity & Side Loading
- Pressure vs. Clearance
  - Extrusion, Back-up rings

Installation Damage

- **Sharp Corners**
- **Sheared, torn, nicked**
- **Cut appearance**
- **Causes**
  - Sliding over threads
  - Insufficient lead-in chamfer
  - Improperly sized O-ring
  - No lubrication used

Installation Damage



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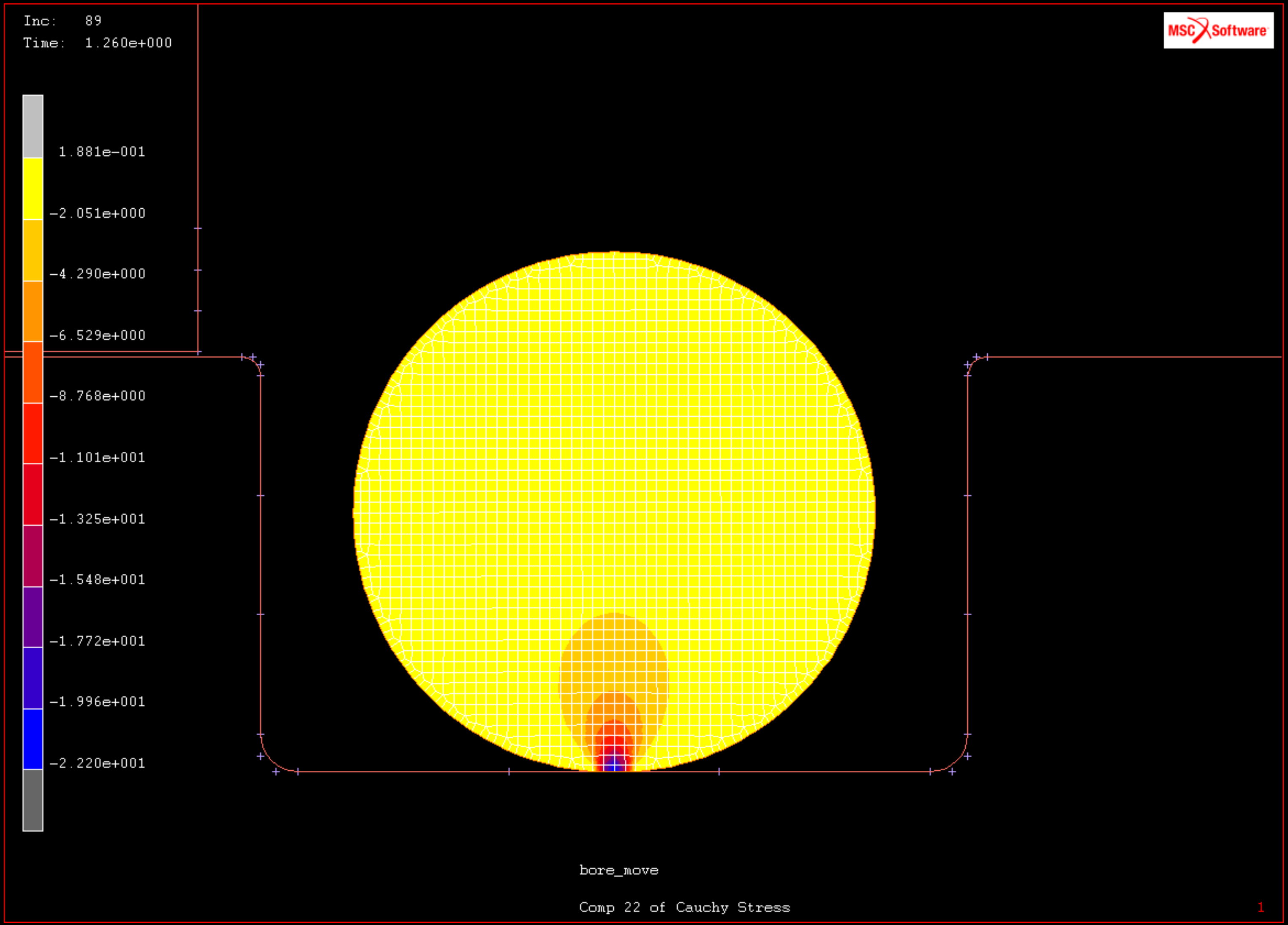
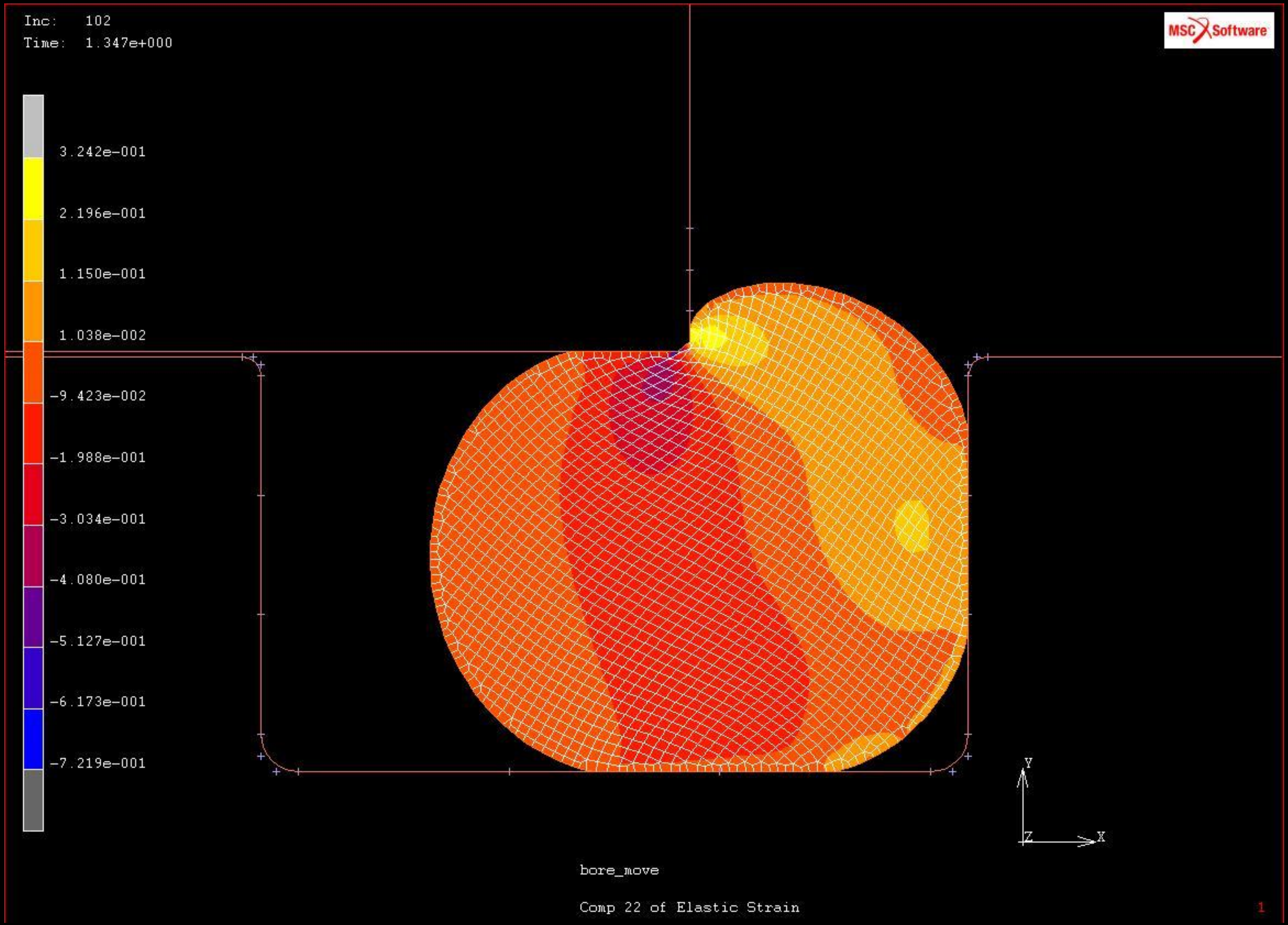
Installation Damage



Installation Damage



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Installation Damage

Solutions

- Cover threads during installation.
- Recommend using lubrication, when possible.
- Proper Lead-in chamfers and smooth edges.
- Make sure the correct O-ring size is being utilized.

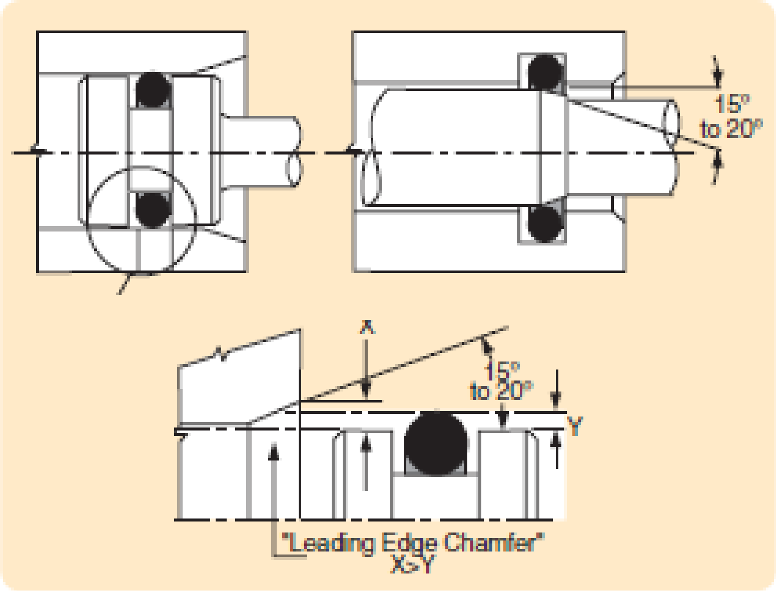

Figure 10-6: Chamfers

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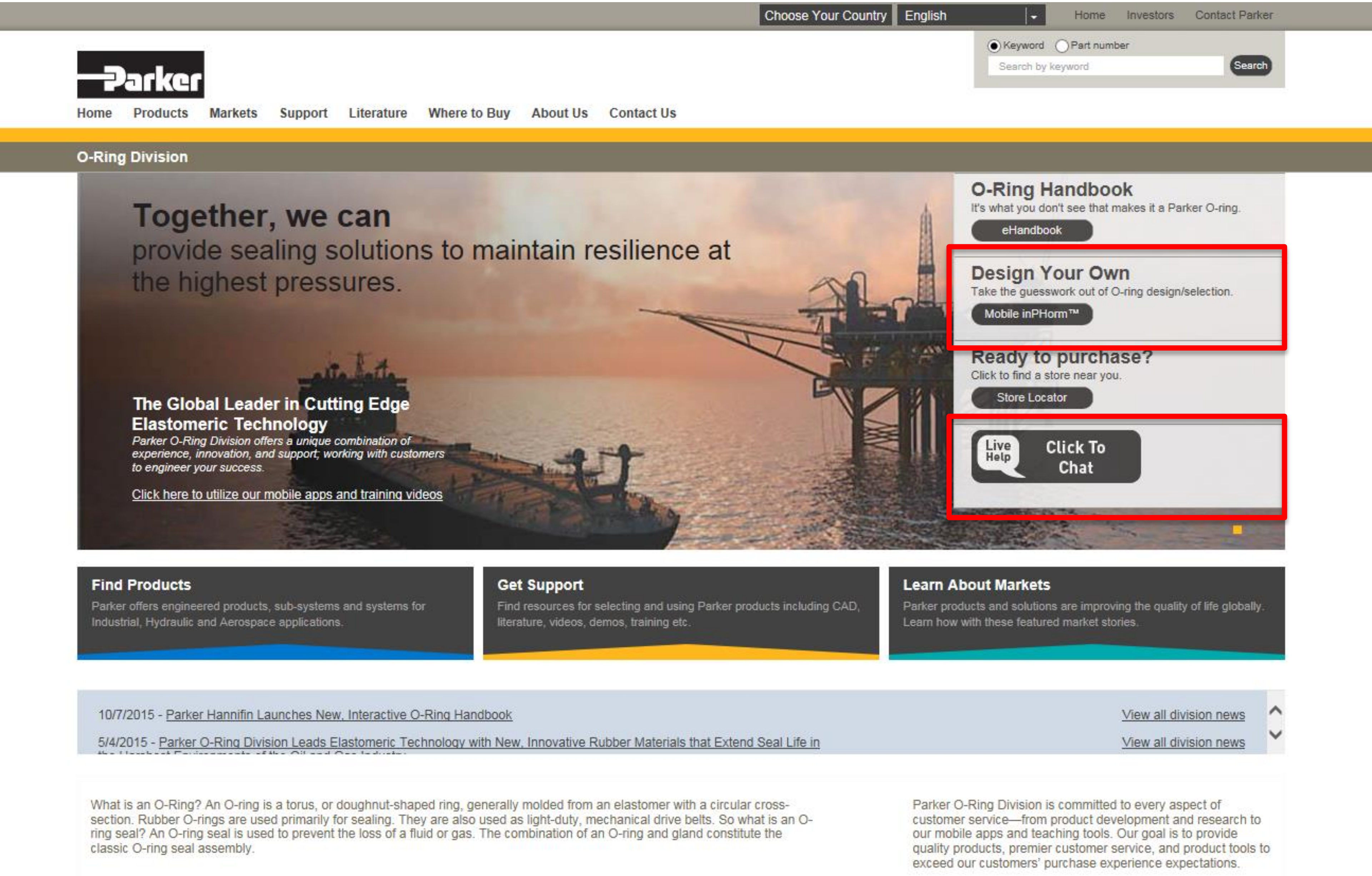

Any Questions?

Applications Engineering

- ORDmailbox@parker.com
- (859)335-5101
  - Applications Hotline
- Online Chat
- Material Recommendations
- Gland Design
- Failure Analysis
- FEA Capabilities
- Proper Assembly
- Leakage Troubleshooting

Thank you