O-Ring Safety Barriers for Rocket Motor Ignition Systems

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Presentation Overview

- Discuss explosive train vs pyrotechnic ignition train safety barrier types and how they differ
- Discuss basic operation and design considerations for pyrotechnic barrier systems
- Discuss “Stiction” – a significant seal design consideration
- Conclude with demonstrating a need for a recognized protocol in establishing ignition train safety and reliability

Barrier Types

A safety barrier is intended to interrupt ignition transfer between firing train elements as the primary safety feature in Safe and Arm (S&A) or initiation devices.

- Example, a “rotor” in a fuze S&A

Pyrotechnic Barrier versus Explosive Train Barrier

- Both prevent initiation of the next firing train element
- Explosive train barrier prevents detonation by blocking a shock wave output from a detonator from effectively reaching the next element in the detonation train
- Pyrotechnic barrier prevents ignition (deflagration, not detonation) by sealing hot gases and inhibiting a flame front from reaching the next element in the ignition train

Both types of barriers present design challenges

- Both are highly dependent on arming environments
- Pyrotechnic barrier needs a higher level of seal integrity
- ATK has extensive experience in developing both types of barriers
  - ATK is an industry leader in the development and production of fuzes and S&A devices for various types of munitions as well as in Rocket Motor Ignition Safety Devices (ISDs)

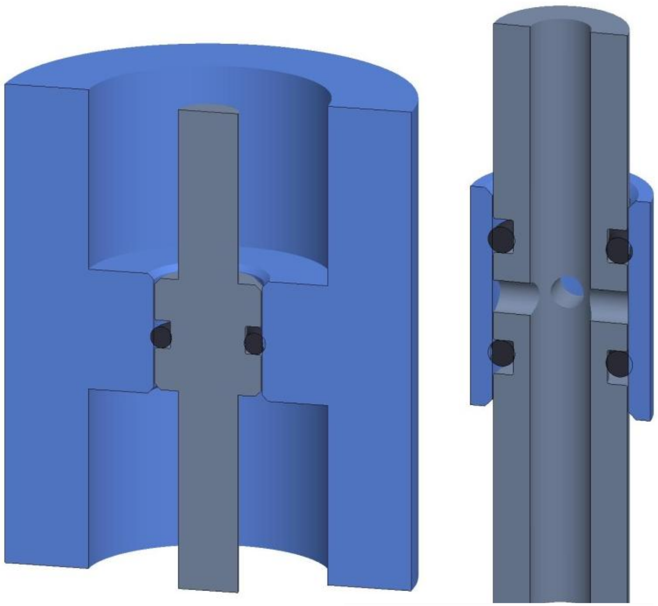
ATK Has Successfully Integrated Commercially Available O-rings as a Pyrotechnic Barrier in Rocket Motor Ignition Systems

Barrier Operation

Removal of the o-ring barrier during a valid weapon arming environment allows the firing train to function properly.

Robust environments must exist for removal of the barriers, examples

- Setback
- Pressure
- Spin



Pyrotechnic Barrier configurations:

- Piston inside a cylinder (single o-ring)
- Sleeve around a manifold (dual o-rings)
- Others

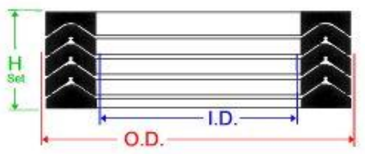
Material & Design Considerations

Material and Seal Type

- Temperature range –meet operational and storage environments
- Compression set and O-Ring Shelf Life – provide seal integrity for the entire storage and operational lifecycle
- Material compatibility – explosive compatibility, environmental contaminants
- Various Seal Geometries
  - O-ring
  - Quad-ring
  - C-seals / U-cup
  - V-Packings
  - Other more ‘exotic’ solutions (Metal seals, Labyrinth Seals, Spring energized seals)

Quad-Ring
(image credit: http://www.zdspb.com /site/disclaimer.html)

U-Cup Seal
(image credit: http://www.rtdygert.com/ catalog/index.cfm/2/Rod %20Seals)



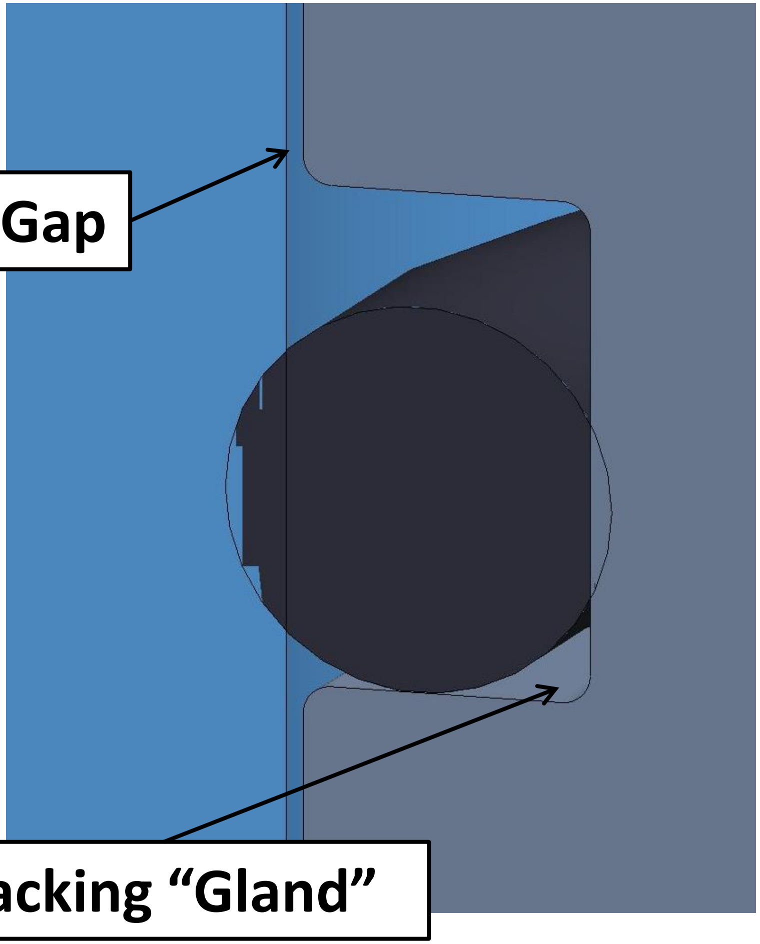
V-Packing
(image credit: http://acdepuydt.com/sp ecial_seals/seal_dimensi on_info.htm)

O-Ring Seals

- Gland geometry
  - Gland fill percentage
  - Extrusion gap
  - Backing rings

- Surface finish of parts contacting the seal

- Surface finish of the seal itself
  - Can be specified via several different specifications

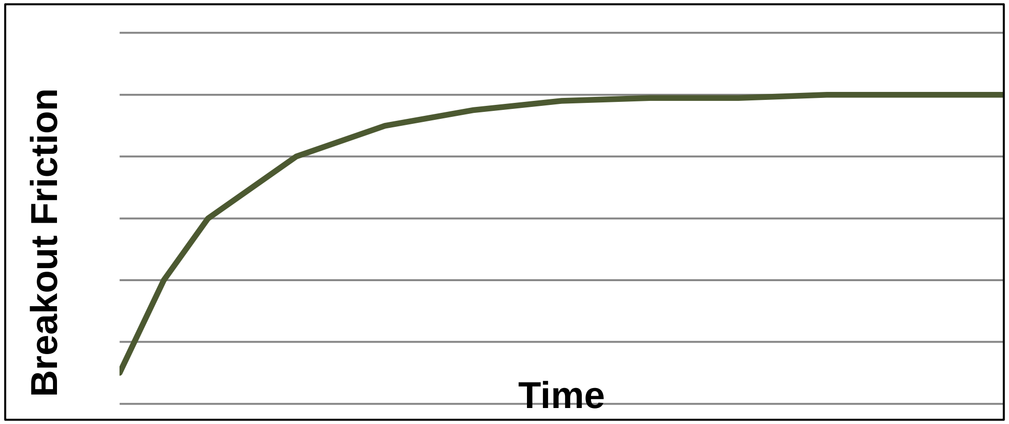


Design and Control of The Sealing Surfaces Is Critical To Seal Effectiveness

Operational Considerations

"Stiction" or Breakout Friction

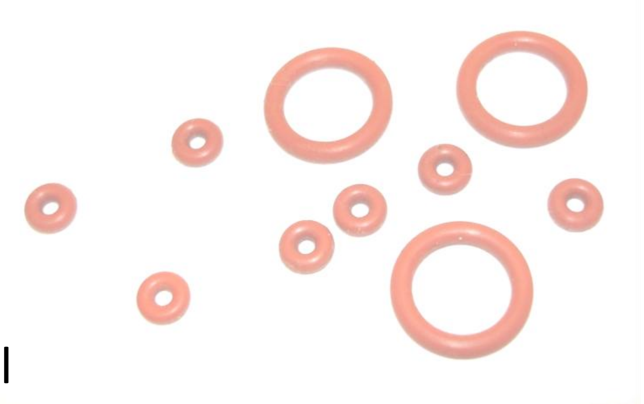
- Force required to break o-ring seal, ie: during an arming event
- Different than O-ring running friction – stiction is dependent on the length of time an O-ring remains in a sealed (at rest) state
- Especially problematic for munitions as they tend to sit for extended periods of time
- Stiction tends to increase to a maximum amount, dependent on material, packing gland configuration, seal type, and time at rest



ATK has conducted o-ring aging studies to characterize breakout friction over time

Operational Considerations

Methods To Overcome Stiction



- Add lubrication
  - Internal or External
- Improve surface finish of parts in contact with seal
  - Care must be taken to specify a surface finish that will allow sealing, reduce stiction, and be cost-effective
- Relax the extrusion gap
  - Extreme caution must be exercised in order to preserve the seal’s integrity
- Utilize robust arming environments
  - Provide significant arming energy margin over worst-case stiction levels

Stiction Can Be Minimized, But Ultimately Must Overcome It With A Robust Design

Qualification Considerations

Like an explosive train barrier, a pyrotechnic barrier is required to demonstrate reliable performance in blocking ignition transfer

Explosive train barrier elements are 'certified' effective via testing methods

- Varicomp, Varidrive, Gap testing, Penalty testing, Margin testing
- Varicomp, Varidrive utilize calibrated donors or explosive outputs to predict a confidence level

Relatively few methods are available to assess Pyrotechnic train barriers

- Penalty testing or Margin testing are most feasible, however little calibrated data exists to make Varicomp or Varidrive methods useful
- High sample size required to establish a confidence level

A Recognized Pyrotechnic Ignition Train Reliability and Safety Effectiveness Protocol Is Needed In The Industry

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