METALLIC SEAL DEVELOPMENT FOR ADVANCED DOCKING/BERTHING SYSTEM

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Outline of Presentation

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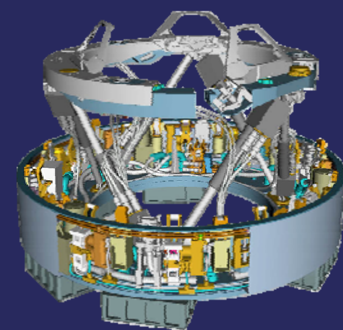
- Summary

ADBS Background

System under development by JSC to:

- Provide gender neutral (androgynous) interface permitting docking/berthing between any two space vehicles
- Become new agency standard for docking/berthing systems



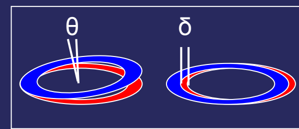
Docking/Berthing Seal Design Requirements

Performance Specifications

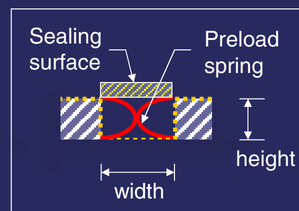
- Low leakage
  - (0.044 lbm/day for a 54" diameter seal)
- Accommodate misalignment
  - 0.050" axial misalignment (δ)
  - Angular misalignment (θ)
- Long life
  - 5-7 year life in LEO environment
  - TBD cycles

Design Constraints

- Maximum preload: 100 lbf/in
  - 1000 psi average contact pressure at 0.100" seal width
- Height: 0.250", Width: 0.250"
- Temperature Range
  - Operating: -50 to 50º C
  - Exposure: -100 to 100º C
- Environmental Conditions
  - UV radiation
  - Monatomic oxygen



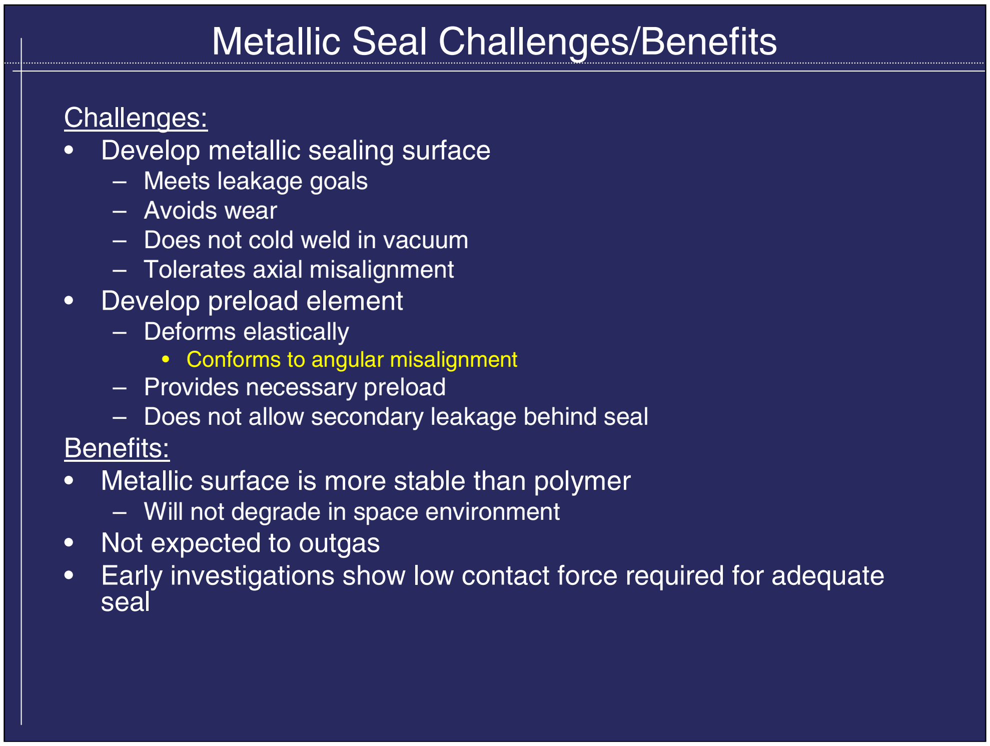
Seal misalignment drawings



Cross section of rigid with metallic preload spring

Life

Duration of cycles (how long the seals stay in contact)

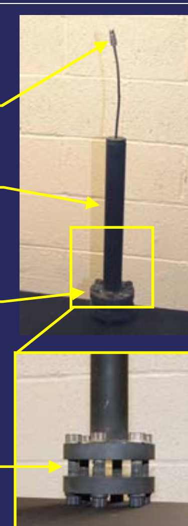


Transition to approach

Defined design goals -> look at the approach

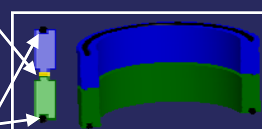
Preliminary Metallic Seal Test

- Test surface on each of two metal parts (ϕ2.5”) were ground flat
  - Ra ~ 12-14 μin
- Gold coated with ion plating process
  - gold thickness ~ 40 μin
- Sealing surfaces were mated in test fixture
- Seal leakage approached target leakage goal
  - Further refinements necessary



Grips of test fixture.

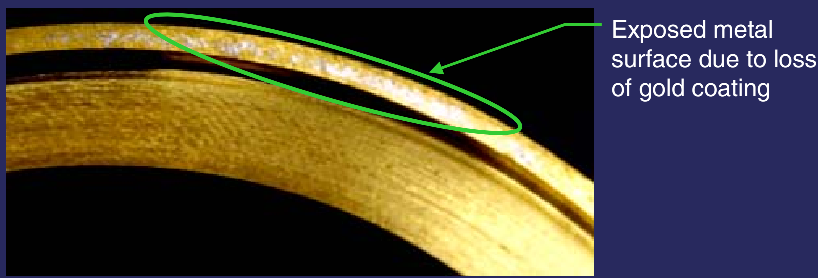
Seal surface pair after gold plating.



Test seal surface pair.

Metallic Seal Results/Lessons Learned

- Metallic surface seal was near the leakage goal
- Gold surface will not survive multiple cycles
- Possible improvements to seal surface
  - Flatness
  - Surface finish (Ra)



Damage on gold plated surface after mating cycle.

Second Generation Prototype

- **Metallic seals were fabricated in-house out of Stainless Steel Type 304.**
  - Turned on lathe
  - Hand lapped on a granite surface using progressively finer diamond lapping film, (30, 6, 1, and 0.5 micron)
  - Surface roughness measured to be Ra 1 µin
  - Ultrasonically cleaned with
    - Ethanol
    - Hexane
  - Hand cleaned with acetone

- **Dimensions are**
  - 1.492 inch I.D.
  - 1.692 inch O.D.
  - 0.100 inch seal land width

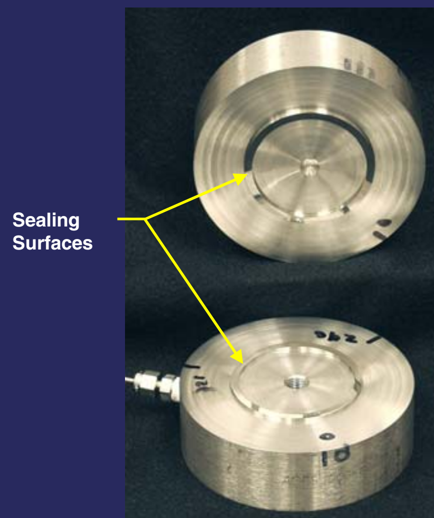
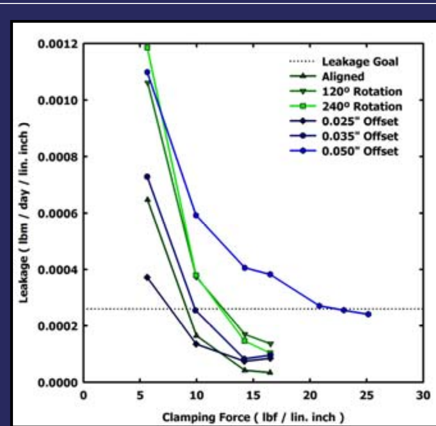


Photo of the metallic seals.

Second Generation Results

- **Second generation met leakage goal with very low required contact pressure**
  - **Metallic surface design functions well with any angular orientation**
  - **Accommodates axial offsets of 0.050”**
- **Seal needed to be manufactured to very tight tolerances to function properly**

- **Further analysis required to determine which tolerances are important:**
  - Surface finish
  - Flatness



Flexible metallic seal test results showing the effects of metallic surface thickness on leakage rates.

Average seal surface roughness
- Ra = <1 μin, σ = n/a

Flatness of seal surface
- Flat to 12 μin

Metallic Seal Development: Experimental Analyses

- POST- FLOW TEST ANALYSES

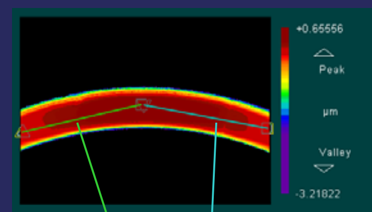
- **An estimate of fabrication tolerances was needed for future iterations of metallic seal designs**

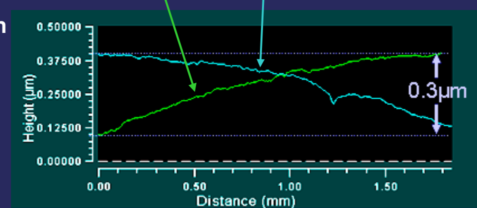
- **An optical comparator was used to determine the surface conditions of a seal fabricated using simple techniques**

- **Measurements showed a wavy surface with**
  - –Amplitude = 0.3 µm ≈ 12 µin
  - –Wavelength = 4 mm ≈ 0.150 in

- **These parameters formed the basis for the subsequent numerical analyses**

Surface condition measurements showing a top view of the metallic seal surface and the variation from flat around the seal.





Surface condition measurements at two locations showing variation from flat across the metallic seal surface.

Metallic Seal Development: Analytical Model

Description of the Analyses

- **ANSYS used to model circumferentially wavy seal surface, with**
  - Variable seal thickness
  - Constant wave amplitude
- **Seal material**
  - Generic steel
  - ($E = 30x10^6$ psi)
- **Force applied**
  - 100 lbf / linear inch

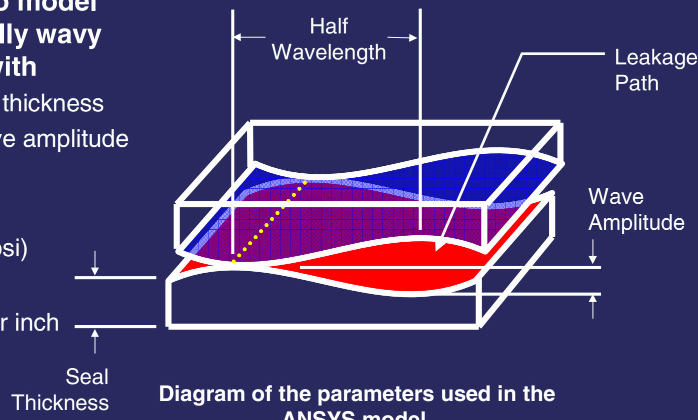
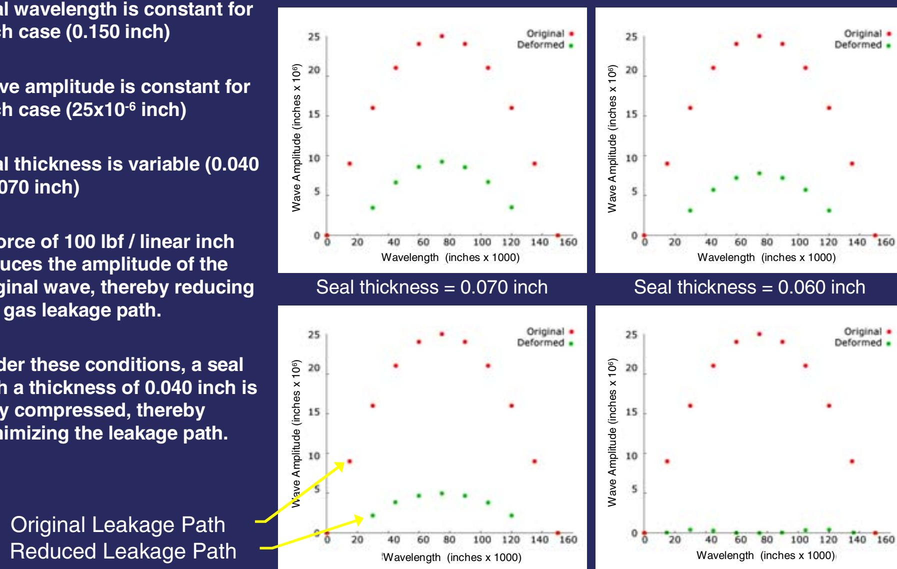


Diagram of the parameters used in the ANSYS model.

Numerical Analyses: Effect of Seal Thickness

- Seal wavelength is constant for each case (0.150 inch)
- Wave amplitude is constant for each case (25x10^{-6} inch)
- Seal thickness is variable (0.040 - 0.070 inch)
- A force of 100 lbf / linear inch reduces the amplitude of the original wave, thereby reducing the gas leakage path.
- Under these conditions, a seal with a thickness of 0.040 inch is fully compressed, thereby minimizing the leakage path.



Seal thickness = 0.070 inch

Seal thickness = 0.060 inch

Seal thickness = 0.050 inch

Seal thickness = 0.040 inch

Advanced Metallic Seal Concepts

- **Feasibility of metal-to-metal androgenous seals has been demonstrated**
- **Techniques to minimize surface irregularities must be examined**

Two concepts investigated:

- **Flexible metal interface with elastomeric preloader**
  - Flexibility will accommodate any surface irregularities from the mating surface
- **Rigid metal interface with elastomeric preloader**
  - Rigidity of the metal surface will prevent irregularities (waves) from occurring

Photo of flexible metal interface concept test specimens

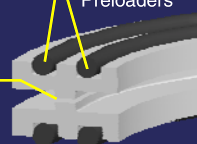


Diagram of rigid metal interface concept test specimens

Photo of rigid metal interface concept test specimens

Flexible Metallic Seals: Performance

- **Conforming metallic surfaces are well suited to make a suitable seal**
- **Circular shims of various thicknesses were bonded to of square o-rings**
  - Shims: Stainless Steel 18-8
  - Adhesive: Loctite 404

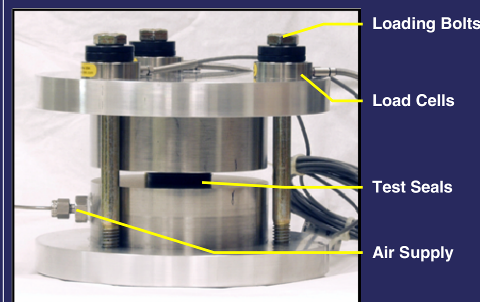
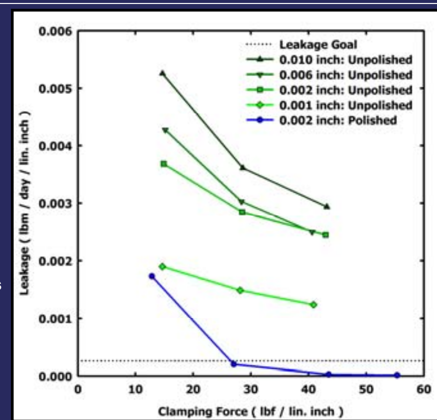


Photo of the test fixture.



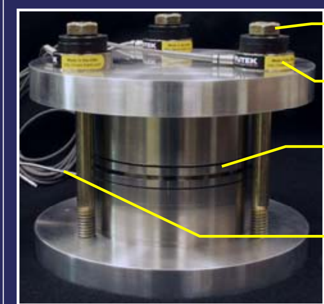
Graph of the flexible metallic seal test results showing the effects of metallic surface thickness on leakage rates.

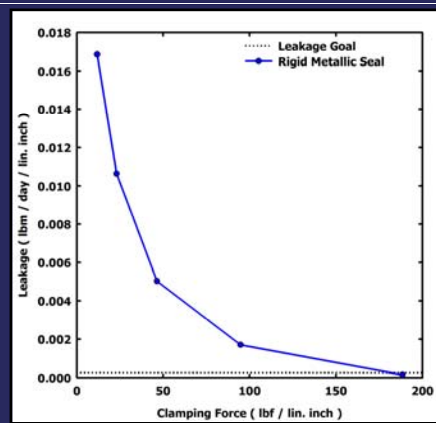
Seal	Ra (µin)	σ
0.010 inch: Unpolished	11.6	7.1
0.006 inch: Unpolished	8.6	2.2
0.002 inch: Unpolished	8.6	2.7
0.001 inch: Unpolished	12.7	5.9
0.002 inch: Polished	<1	n/a

Table showing the surface roughness of the flexible metallic seals.

Rigid Metallic Seal: Performance

- Rigid metallic surfaces are not suited for a suitable seal
- Seal does not conform to surface irregularities
- A uniform surface over a 54” diameter seal would be impossible to manufacture



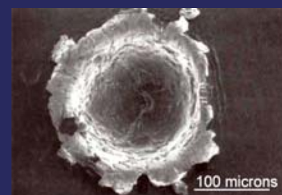


Graph of the rigid metallic seal test results showing the effect of clamping force on leakage rates.

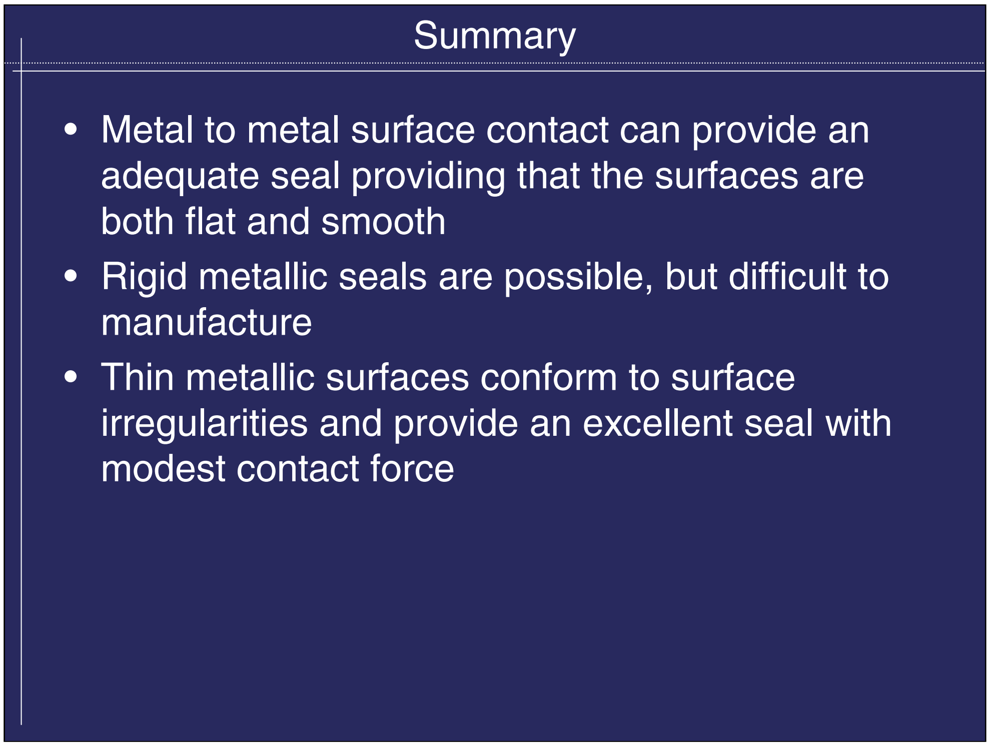
Average seal surface roughness
- Ra = <1 μin, σ = n/a

Future Work

- Investigate effects of environmental conditions on metallic surfaces
  - AO, UV, debris, micrometeoroid impacts
- Investigate whether smooth metallic surfaces will cold weld at low temperatures at 100 lbf/in contact force (1000 psi contact pressure)
- Develop full scale flexible metallic seal for further testing



Aluminum impact crater from micrometeoroid



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