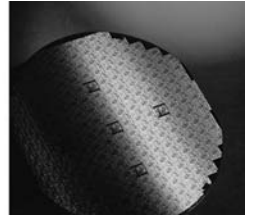
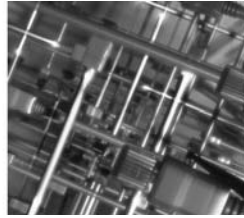


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# Seal Performance and Recommendations

## HVOF Coatings

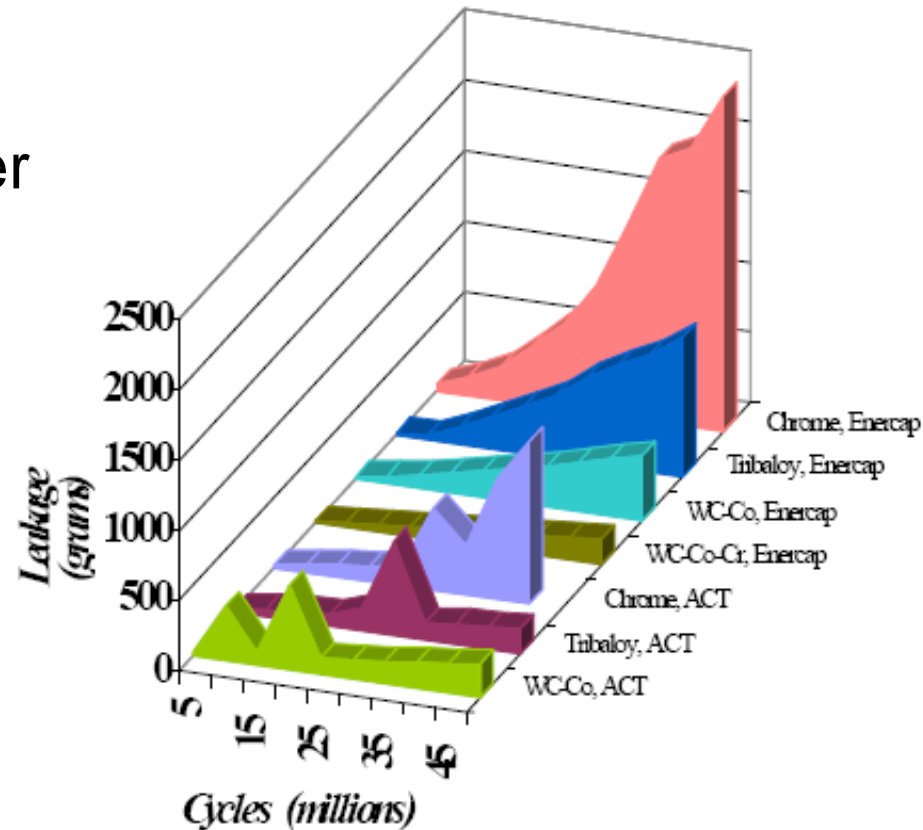
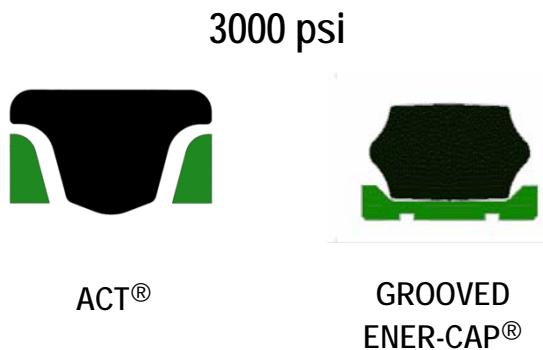


Aerospace

Presented by: Steve Okladek  
Aerospace Applications Engineer

# Seal Performance of HVOF vs Chrome

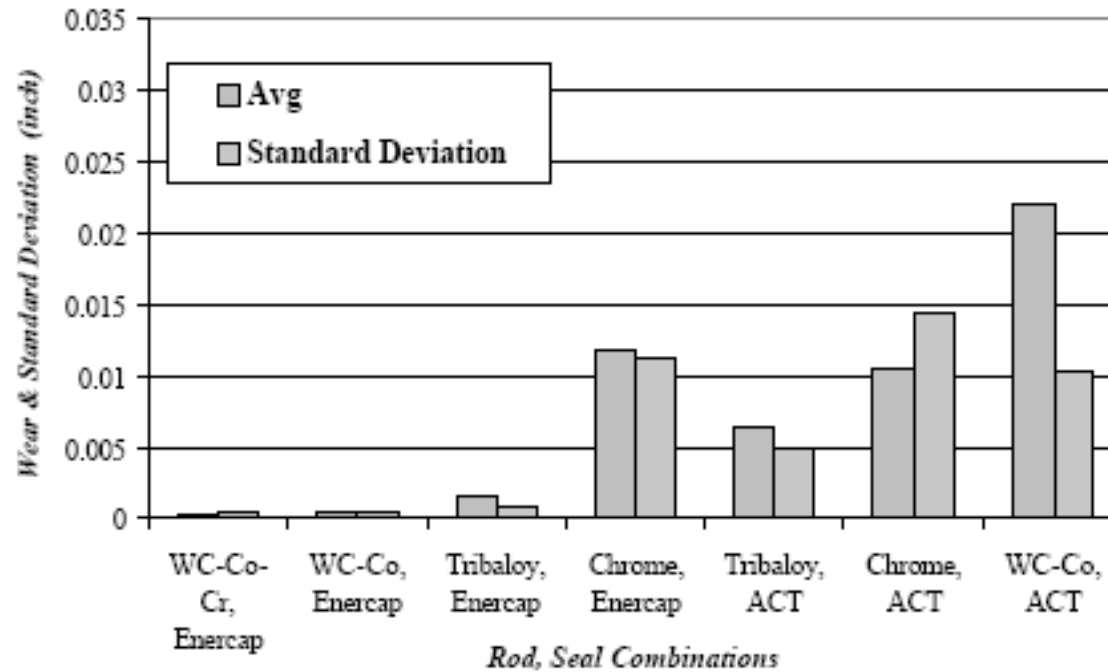
- Seal Testing of both Cap seals and Elastomeric, yield better overall sealing performance on HVOF over Chrome



*\*Note: Data source is from HCAT (Hard Chrome Alternative Team)*

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# Seal Life



- Wear of cap seals out performed against elastomerics on the different surfaces.
- Result for elastomeric contact seals:
  - High friction: Too fine a finish
  - No boundary layer of fluid
  - HVOF surface too aggressive towards seals

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# Visual Effects of the Grinding Process

- During the grinding process, the effects in changes to Ra, Rz, Rp, and Rmr, are visually apparent.
- From 180 grit to 30  $\mu\text{m}$ , changes in Ra are significant.
- From 30  $\mu\text{m}$  to 3  $\mu\text{m}$ , the remaining super finishing process affects Rmr more significantly.

**Table 1: Example of Reference Chart for Surface Finishing at 150 RPM**

| Grit/<br>Micron<br>Size | Expected Roughness<br>Values (95%<br>Confidence) |                            | Images -5x, 20x, 50x optical lens |     |     |
|-------------------------|--|----------------------------|-----------------------------------|-----|-----|
|                         |  |                            | 5x                                | 20x | 50x |
| 180 Grit                | Ra   | 10.7-13.3 $\mu\text{in}$   |                                   |     |     |
|                         | Rz   | 83.4-104 $\mu\text{in}$    |                                   |     |     |
|                         | Rp   | 20.0-25.1 $\mu\text{in}$   |                                   |     |     |
|                         | Rmr  | 67.6-73.7 %                |                                   |     |     |
| 240 Grit                | Ra   | 8.43-10.9 $\mu\text{in}$   |                                   |     |     |
|                         | Rz   | 68.5-84.4 $\mu\text{in}$   |                                   |     |     |
|                         | Rp   | 17.8-23.3 $\mu\text{in}$   |                                   |     |     |
|                         | Rmr  | 63.7-70.8 %                |                                   |     |     |
| 30 microns              | Ra   | 0.771-0.869 $\mu\text{in}$ |                                   |     |     |
|                         | Rz   | 7.45-9.91 $\mu\text{in}$   |                                   |     |     |
|                         | Rp   | 2.21-2.55 $\mu\text{in}$   |                                   |     |     |
|                         | Rmr  | 65.8-76.7 %                |                                   |     |     |
| 15 microns              | Ra   | 0.832-0.938 $\mu\text{in}$ |                                   |     |     |
|                         | Rz   | 8.68-11.42 $\mu\text{in}$  |                                   |     |     |
|                         | Rp   | 2.41-3.11 $\mu\text{in}$   |                                   |     |     |
|                         | Rmr  | 72.7-80.8 %                |                                   |     |     |
| 9 microns               | Ra   | 0.557-0.733 $\mu\text{in}$ |                                   |     |     |
|                         | Rz   | 8.13-12.0 $\mu\text{in}$   |                                   |     |     |
|                         | Rp   | 1.63-1.93 $\mu\text{in}$   |                                   |     |     |
|                         | Rmr  | 93.5-97.6 %                |                                   |     |     |
| 3 microns               | Ra   | 0.545-0.655 $\mu\text{in}$ |                                   |     |     |
|                         | Rz   | 9.72-12.7 $\mu\text{in}$   |                                   |     |     |
|                         | Rp   | 1.35-1.81 $\mu\text{in}$   |                                   |     |     |
|                         | Rmr  | 95.4-96.9 %                |                                   |     |     |

# Seal Performance on an improper finish

- Machined lines and/or HVOF grinding marks on the surface of the rod can be easily felt by thumbnail test



# HVOF Comparison Discussion

Visual representation of the HVOF surfaces. Note, all surfaces are HVOF coated WC-Co-Cr



**Finish shows chatter marks and rotary 'barber poling'**

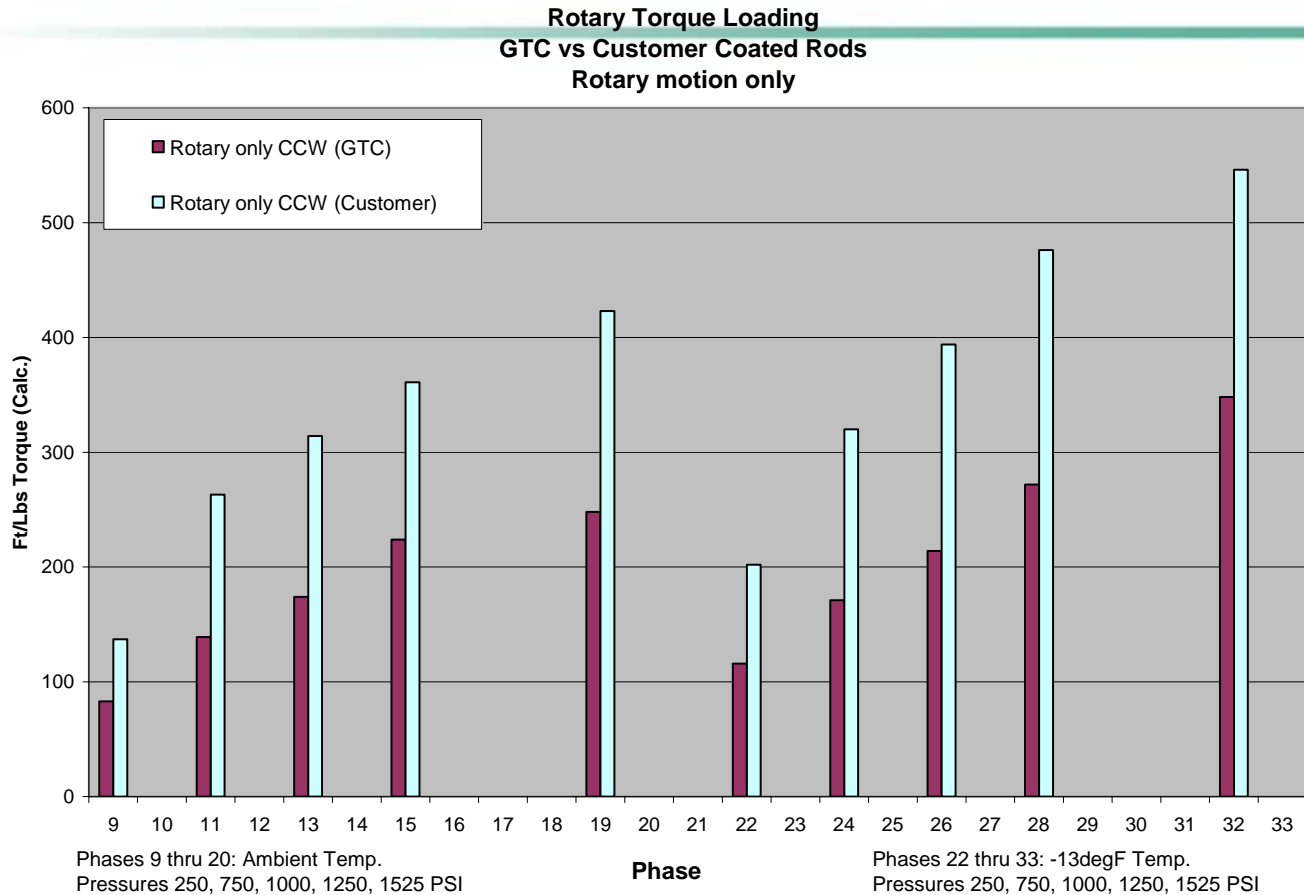


**Finish shows circumferential finish profile and "polishing" affect of the bearing interaction (roughly 3,500 Landing Sequences)**



**Large HVOF Slider (After 21,550 Landing Sequences)  
Shows the reflection of the overhead in the lab ceiling – no visible dynamic affects from testing**

# Performance on different finishes



- Seal performance on HVOF surfaces can vary significantly depending on the quality of the superfinishing
- The chart above shows how significant changes in finish can affect the forces acting on the seals with a 50% reduction in torque on the GTC finished rod

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# GTC's Current Recommendations for both Chrome and HVOF

## Chrome Surface Finish parameters are as follows:

- **Dynamic Applications (Elastomeric Seals)**
  - Ra = 16 uin MAX;
  - Ra = 8 to 12 uin recommended optimum finish

Note - This recommendations is in accordance with SAE Aerospace Seal Gland Standard **AS 4716** section 3.1.4

- **Dynamic Applications (PTFE Cap Seals)**
  - Ra = 4 to 8 uin
- **Static Applications**
  - Ra = 32 Max. uin.

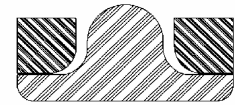
## HVOF Surface Finish parameters are as follows:

- **Dynamic Applications (PTFE Cap Seals)**
  - Ra = 4 Max. uin.
  - Rz = 40 Max. uin.
  - Rp = 8 Max. uin.
  - Rmr (Tp) = 70 to 95% at a depth of Co = 5% and C1 = 0.25Rz from Co;
  - Negative skew, neutral grain

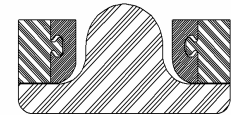
# Common Seal Selections by Location

## Landing Gear

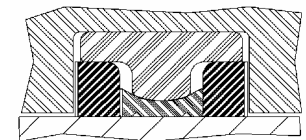
- Active Static Lower Bearing Seal – High Squeeze AGT
- Metering Pin Static Seal – High Squeeze AGT
- Bulk Head Static Seal – High Squeeze Flash Free AGT
- Active Dynamic Seal –
  - (HVOF) High Squeeze ACGT/ACGTL
  - (Chrome) Enhanced Squeeze AGT Ring
- Upper Bearing Dynamic – ACGT or Piston Rings
- Upper Bearing Static Seal – High Squeeze AGT
- Dynamic Scraper – Finger Spring MSE
- Dust Scraper – Coil Spring MSE
- Orifice Tube Static Seal – High Squeeze AGT
- Spare Dynamic Seal (Where Required) - AGT



**AGT Ring with Standard BU rings**



**AGT Ring with staged BU rings (Large Clearances)**

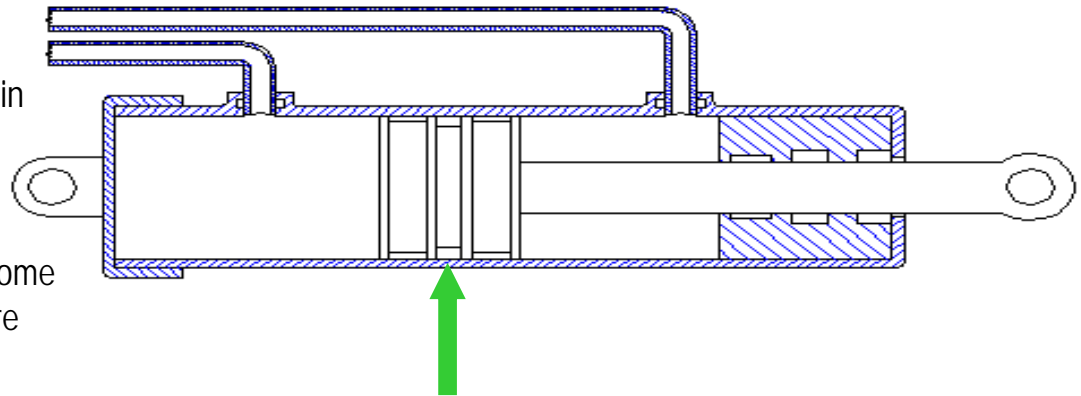


**ACGT Ring with standard BU rings**

# Common Seal Selections by Location Actuation

- Typical arrangements – piston seals

Piston Seals can come in many configurations depending upon the pressure, leakage and friction requirements. Some typical configurations are shown below



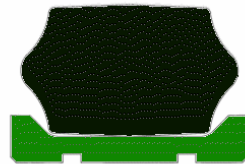
3000 - 4000 psi

5000 psi

DUAL PISTON RING



GROOVED ENER-CAP



ACGT RING



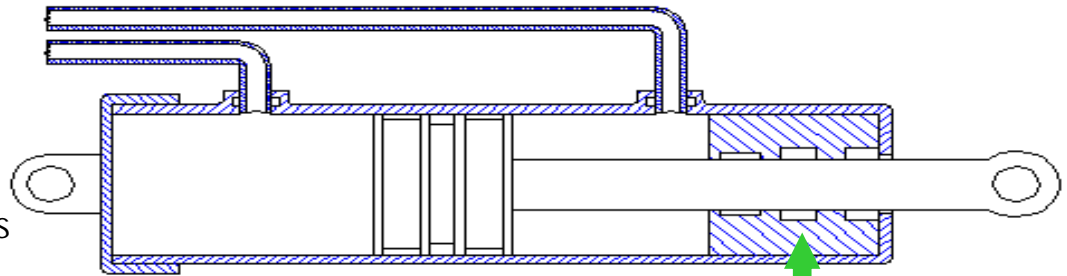
NON-GROOVED ENER-CAP HP



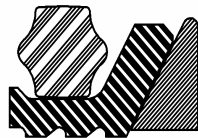
# Common Seal Selections by Location Actuation

- Typical arrangements – rod (single) seal

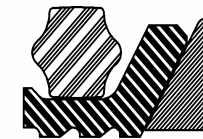
Although in general PFCU systems consist of tandem seal configurations, it is possible that some actuators use a single seal arrangement



3000 - 4000 psi



NEW GT ENERCAM



NEW GT ENERCAM

5000 psi



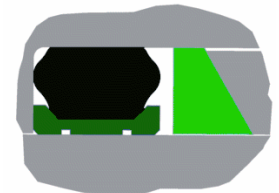
ACGTL



GROOVED ENER-CAP



GROOVED ENER-CAP HP

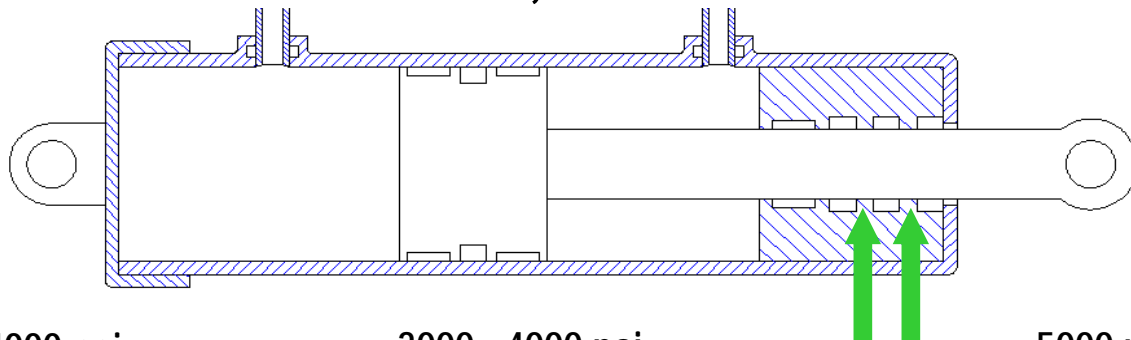


GROOVED ENER-CAP w/ WEDGE ADAPTER

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# Common Seal Selections by Location Actuation

- Rod seals – tandem, non-vented



3000 - 4000 psi

3000 - 4000 psi

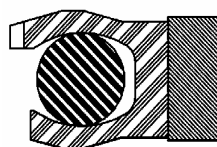
5000 psi



Primary  
\*Not advised for closed grooves

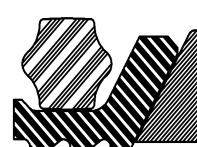


Secondary



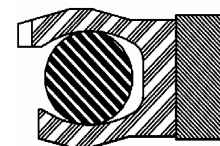
NEW O-RING MSE

Primary



NEW ENERCAM

Secondary



NEW O-RING MSE

Primary

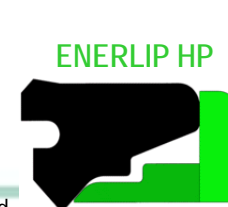


NEW ENERCAM

Secondary



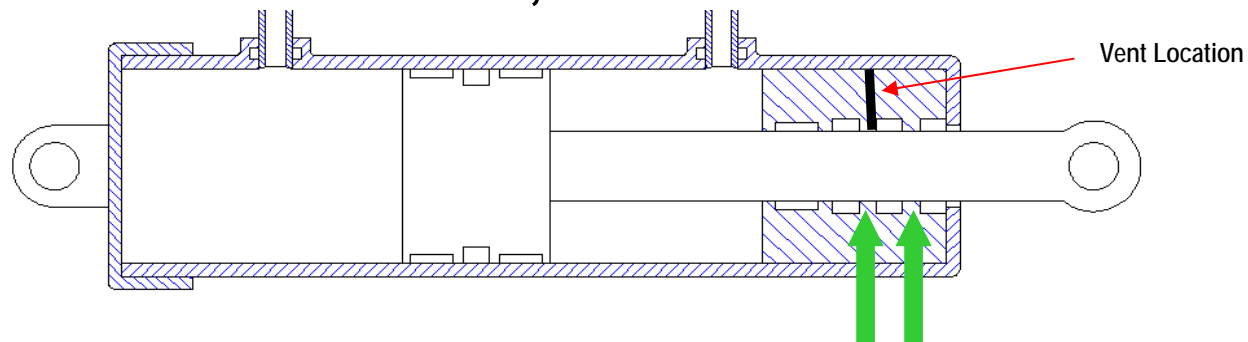
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# Common Seal Selections by Location Actuation

- Rod seals – tandem, vented



3000 - 4000 psi

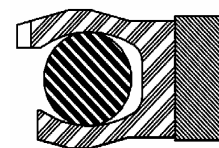
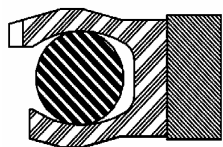
5000 psi

NEW  
O-RING MSE®

NEW  
ENERCAM

NEW  
O-RING MSE

NEW  
ENERCAM



Primary

Secondary

Primary

Secondary

GROOVED  
ENER-CAP®

ACT®

GROOVED  
ENER-CAP® HP

ACT®



# Questions??

- ??