Aperture Valve for the Mars Organic Molecule Analyzer (MOMA)

Charles Engler
NASA Goddard Space Flight Center

Claef Hakun, Willie Barber
NASA Goddard Space Flight Center

John Canham
ATK Space Systems

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### Overview: ExoMars Mission Overview

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch Date</td>
<td>2018</td>
</tr>
<tr>
<td>Launch Vehicle</td>
<td>Proton</td>
</tr>
<tr>
<td>Mission Cruise</td>
<td>10 months</td>
</tr>
<tr>
<td>Duration</td>
<td></td>
</tr>
<tr>
<td>Operation Duration</td>
<td>180 sols (~6 months)</td>
</tr>
<tr>
<td>Nominal Science</td>
<td>~80 sample analyses</td>
</tr>
<tr>
<td>Rover Mass</td>
<td>300 kg</td>
</tr>
<tr>
<td>Rover Mobility Range</td>
<td>Several km</td>
</tr>
<tr>
<td>Planetary Protection</td>
<td>Class IV</td>
</tr>
<tr>
<td>Power System</td>
<td>Solar Panels</td>
</tr>
</tbody>
</table>

- Managed by ESA
- Instrument Payload being built by Thales Alenia Space – Italia (TAS-I)
Mars Organic Molecule Analyzer

- MOMA is a Mass Spectrometer designed to look for a wide range of organic molecules on Mars
- Led by the PI in Gottingen Germany
  - Includes partners from United States, Italy, Germany
- GSFC is delivering a portion of MOMA designated: MOMA-MS
  - Includes the Mass Spectrometer, plumbing and supporting Electronic boxes.
Overview - Aperture Valve placement within MS

Functional purpose:

- **Provides a path to the ion trap** that can be opened or closed on-demand.
- **Transfers ions formed from laser desorption from Mars ambient (7 Torr)** into the ion trap via a conductance limiting capillary (Ion Tubes)
- **Provides a seal to the mass spectrometer** during mass measurements.

**Mass Spectrometer**

- Ultra Clean Zone
- Mars
- Sample
- Aperture Valve
MOMA Aperture Valve

Driving Requirements

<table>
<thead>
<tr>
<th>Driving Requirement</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Pressure leak rate</td>
<td>10E-3 cc/sec He</td>
</tr>
<tr>
<td>Operational cycle life</td>
<td>125,000 cycles</td>
</tr>
<tr>
<td>Operational temperature</td>
<td>-20°C to 50°C</td>
</tr>
<tr>
<td>Valve open/close time</td>
<td>&lt;50ms</td>
</tr>
<tr>
<td>Mass</td>
<td>90 grams</td>
</tr>
<tr>
<td>Failure Mode</td>
<td>Fail closed</td>
</tr>
<tr>
<td>Power</td>
<td>5 watts peak</td>
</tr>
<tr>
<td>Material limitations</td>
<td>Non-magnetic</td>
</tr>
</tbody>
</table>
Issue: PVD Coatings on titanium base material

Advantages of PVD coatings
• TiN and DLC exhibit desirable combination of low coefficient of friction and high micro-hardness >80Rc - above the hardness of tool steel.
• Thin coating (.0001”) produces negligible change in part dimension.

Problems discovered during early breadboard design
• Delamination of TiN coating within the bore of the valve body.
• Multi-layer PVD coatings such as TiN over DLC produced poor adhesion.

Lessons learned
• The PVD process used to apply TiN onto internal cavities and bore holes does not produce acceptable adhesion of the TiN film
• Consider having the vendor provide a witness sample prior to coating parts.
Issue: Solenoid thermal control in near vacuum

Problems discovered during initial vacuum chamber testing
- Thermal isolation of the valve from the test chamber at 7 torr caused the solenoid to overheat.
- Non-metal solenoid parts warped from excessive heat causing solenoid failure.

Lesson learned
- Thermal strap was necessary to avoid solenoid failure.
- Thermal heat sink was incorporated into ETU and Flight valve designs.
Issue: Mechanical assembly using Small fasteners

Problems discovered during vibration and life testing
• Estimating proper preload of #1, #2 size fasteners was not exact.
• Threaded solenoid lost preload during repeated open /close cycles of the valve.

Lesson learned
• Arathane 5753 A/B applied to threads eliminated loss of fastener preload.
• Locking Helicoils were successfully used when Arathane was prohibited.
ETU /Flight Aperture valve design

Incorporation of lessons learned

• All threaded features are secured with locking helicoils.
• PVD coatings (TiN and DLC) eliminated in favor of CRES alloy steels.
• Thermal strap was engineered into valve design.
• Plastic solenoid components eliminated in favor of metal parts.
ETU /Flight Aperture valve design

Salient features of ETU /Flight Aperture Valve

- Efficient sealing feature accomplished using check-ball type design.
- Compact footprint 96mm x 24mm x 20mm (L x W x H). @ 102g.
- Sealing capability > 1E-6 cc/sec He.
- High reliability >280,000 cycles.
Conclusions - Lessons Learned

Coatings
- The PVD process used to apply TiN onto internal cavities and bore holes does not produce acceptable adhesion of the TiN film
- Consider having the vendor provide a witness sample prior to coating parts.

Thermal control
- Thermal control was necessary to avoid solenoid failure at 7 torr atmosphere.
- Thermal heat sink was incorporated into ETU and Flight valve designs.

Mechanical fasteners
- Arathane 5753 A/B applied to threads eliminated loss of fastener preload.
- Locking Helicoils were successfully used when Arathane was prohibited.