# Solutions Flash

## Corrosion-Resistant Compressor Abradable Reduces Maintenance and Operating Costs

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## Today's situation

The reality for today's aircraft fleets is exposure to multiple environments that can result in corrosion of aluminum-silicon-based compressor abradable coatings for clearance control. While these coatings have been used for more than a half century in power plants and have a highly successful track record for increased engine efficiency and safety, they can be susceptible to corrosion that is influenced by geographical location, season and aircraft usage. For example:

- Engines that are flown only occasionally or parked overnight are candidates for corrosive attack regardless of their geographical location
- Engines that operate in coastal areas and areas of high humidity are especially prone to corrosion, which can start to occur in as little as two days

Such corrosion can occur in any gas turbine exposed to these conditions, including aerospace gas turbines, marine propulsion power plants, industrial gas turbines and others.

If left unchecked, this corrosion can damage rotating components, thus reducing safety margins and decreasing operating efficiency. Smaller gas turbines tend to be more prone to these issues than larger engines, as a result of their tighter gas path clearance and surface roughness requirements where any swelling or blistering related to corrosion can seriously affect performance.

**Figure 1.** Corroded abradable coating on CFM56-7 stage 1 booster vane assembly outer shroud. Photograph courtesy of Sjap (www.sjap.nl).

Many operators have turned to daily engine washes; however, washing only mitigates the problem, it is not a cure.

A more corrosion-resistant and cost-effective abradable coating that can provide the same efficiency as legacy coatings seems to be the solution.

## The Oerlikon Metco solution

Oerlikon Metco, the original developer of Metco 601NS (Al 7Si / 40 Polyester blend) — the most widely used compressor abradable coating material worldwide for gas turbine engines — has now developed Metco 1602A, which is a new compressor abradable that:

- Provides the same clearance control efficiency as our legacy compressor abradable materials
- Maintains the safety margins needed for today's engines
- Creates abradable coatings that are significantly more corrosion resistant than legacy materials
- Does not negatively impact engine weight
- Can generally be applied using existing Metco 601NS spray parameters
- Applies more reliably and repeatedly than many legacy abradable materials

**Figure 2.** Metco 1602A produces abradable coatings for gas turbine compressors with improved corrosion resistance compared to legacy materials.

## Solution description and validation

### 1. New chemistry and manufacturing process

While it would seem that the composition of Metco 1602 is similar to that of other AlSi-polyester abradables produced by Oerlikon Metco, the modification of the composition, combined with a proprietary manufacturing process, provides a very significant difference in the way coatings of Metco 1602A act in service to resist corrosion.

| **Product** | **Weight Percent (nominal)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Al** | **Si** | **Mo** | **Cr** | **Polyester** | **Polyimide** | **Boron Nitride** | **Organic Binder** |
| Metco 601NS | Balance | 7 | --- | --- | 40 | --- | --- | --- |
| Amdry 2010 | Balance | 7 | --- | --- | 40 | --- | --- | --- |
| Amdry XPT-268 | Balance | 9 | --- | --- | 20 | --- | 6 | --- |
| Amdry 2000 | Balance | 6 | --- | --- | --- | 47 | --- | 6 |
| Metco 1602A | Balance | 6 | 1 | 1 | 40 | --- | --- | --- |

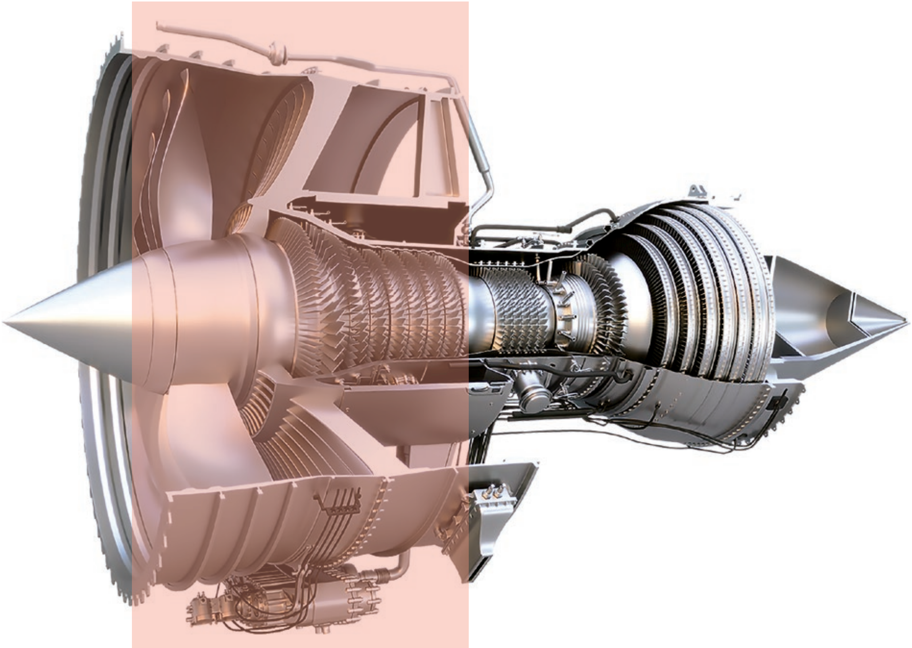


**Figure 3.** Gas turbine sections where Metco 1602A is used: Booster / Low Pressure and Intermediate Pressure Compressor for temperatures up to 325°C (615 °F).

## 2. Effect on engine efficiency

The performance driver for abradable coatings on gas turbine engines is to control the clearance between the rotating blade tips and the respective stationary shrouds. A smaller gap size reduces losses arising from vortex-induced air flow at the blade tips, thereby maintaining the efficiency of the stage and increasing the overall surge margin (stall margin) for the engine.

This can be calculated as a loss of efficiency for each stage of the engine. When the same tip clearances are used in a large diameter engine (Figure 4A) as that of a smaller diameter engine (Figure 4B), the efficiency loss for the smaller engine is significantly higher. Therefore, tip clearances in the smaller engine must be reduced to achieve an equivalent efficiency (Figure 4C).

The smaller clearances also mean that engines with smaller diameters are more susceptible to the surface roughness of the stationary shroud. The abradable coating on the shroud must be as smooth as possible — both pre- and post-rub — to minimize ‘grooving’ and material transfer onto the blade tips.

Post rub surface roughnesses of aluminum-based abradable coatings on shrouds can be degraded by the phenomena of grooving in the rubbed areas, arising from transfer of aluminum alloy to blade tips (Figure 5). Here under specific rub conditions, the grooving phenomena deteriorates engine efficiencies by effectively opening up the clearances and introducing unwanted air flow effects.

Unfortunately, when the abradable coating on the shroud is affected by corrosion, it tends to become very rough due to swelling, blister formation and accumulation of corrosion by-products, all of which can obstruct the clearance with resultant uneven irregularities (Figure 5). The likelihood of rubbing is much higher with increased risk of spallation (Figure 1) of the corrosion degraded coating.

$$\textbf{\% stage efficiency loss} = \frac{\text{tip clearance}}{\text{blade height}} \cdot 100$$

**where:**

tip clearance = (D2 - D1) / 2

blade height = D1 / 2

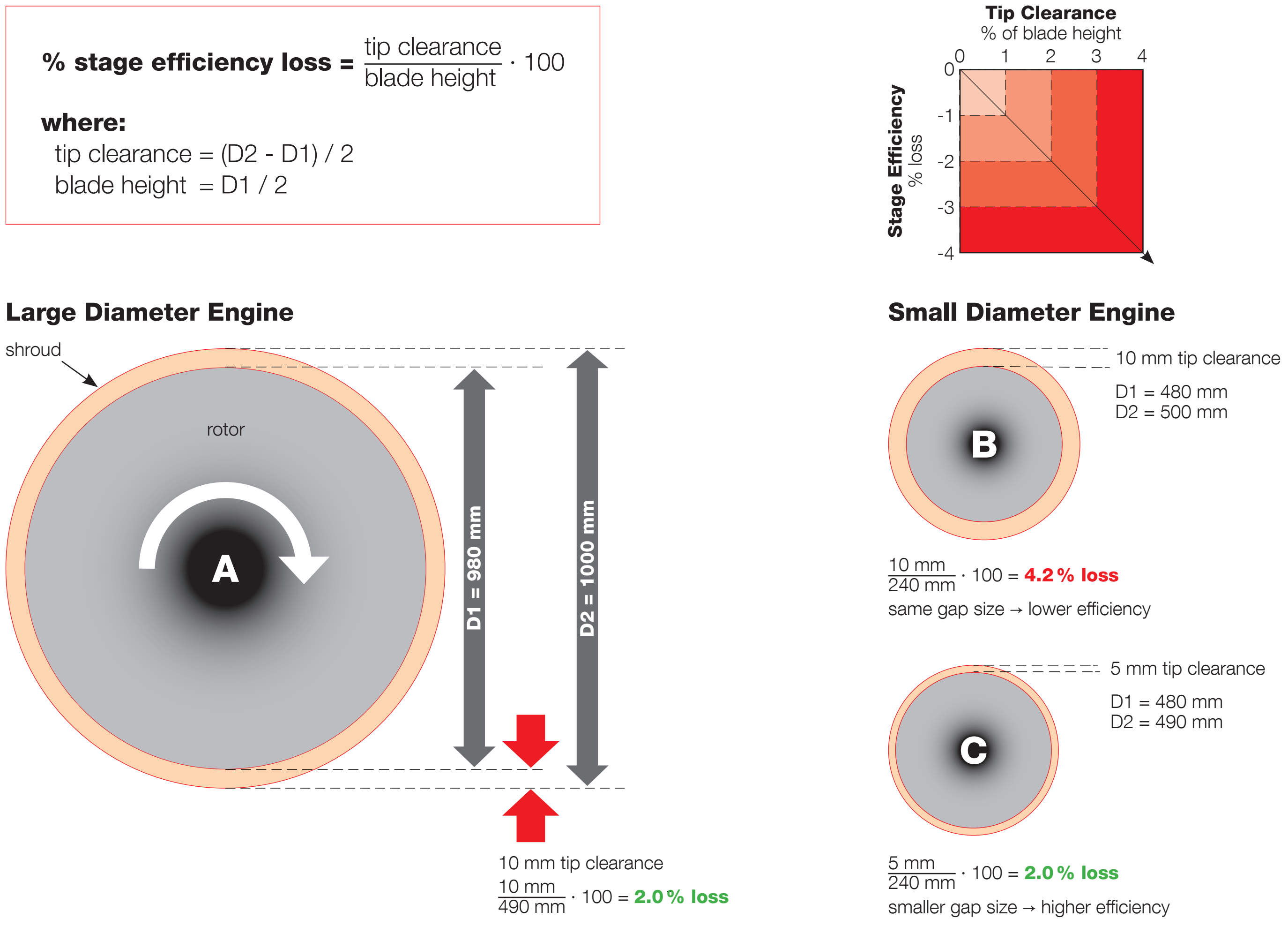


**Figure 4.** Engine efficiency, is dependent on the blade tip clearance between the rotating blades and the shroud, which can be expressed as the percent of stage efficiency loss. **A:** A large diameter engine stage (rotor diameter of 980 mm) with a tip clearance of 10 mm all around achieves an efficiency loss of, for example, 2 % for a typical compressor stage utilizing unshrouded blades. **B:** The efficiency loss increases in a smaller diameter engine stage (rotor diameter of 480 mm) with the same tip clearance as the large engine. **C:** To achieve a lower efficiency loss that is equivalent to that of the large engine, the tip clearance for the smaller engine has to be reduced significantly to just 5 mm.

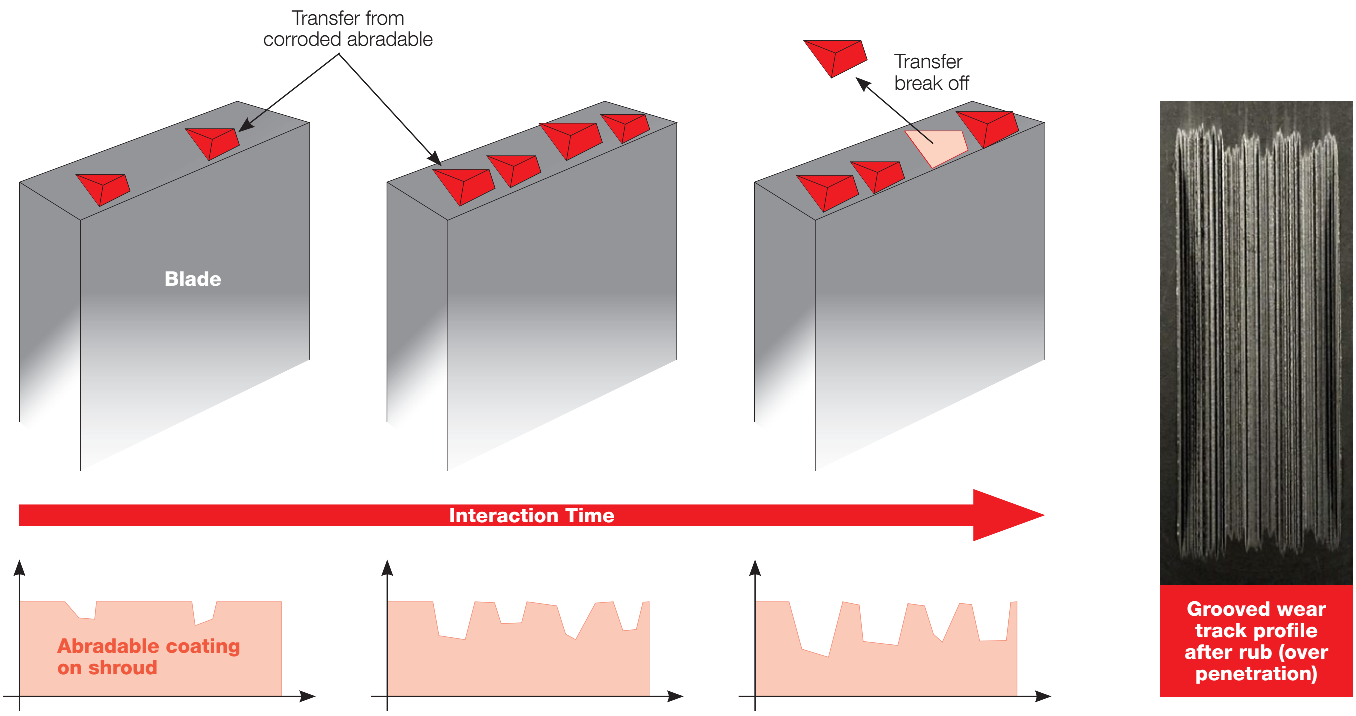


**Figure 5.** Development of the roughness profile as measured on the abradable surface. The resulting wear track profile is an especially undesirable result in smaller engines.

## 3. Corrosion testing

To test the corrosion characteristics of Metco 1602A compared to traditional AlSi-polymer materials, half of a titanium alloy shroud ring was coated with Metco 1602A and the other half coated with the traditional abradable material. The ring was then immersed in a salt spray bath for three weeks. Where the traditional AlSi-polymer coating exhibited severe corrosion, the half of the ring coated with Metco 1602A exhibited almost no corrosion.

**Grit-Blast**
- Clean / profile surface

**Coating**
- Atmospheric plasma spray
- 1/2 coated with Metco 1602A
- 1/2 coated with traditional AlSi-polyester abradable

**Salt Bath Immersion**
- 5 % NaCl in distilled water
- Stabilized at 35 °C (95 °F)
- Immersed for 3 weeks

**Inspection for Corrosion**
- Corrosion visible on traditional abradable coating
- No corrosion on Metco 1602A coating

**Figure 6.** Salt bath immersion testing

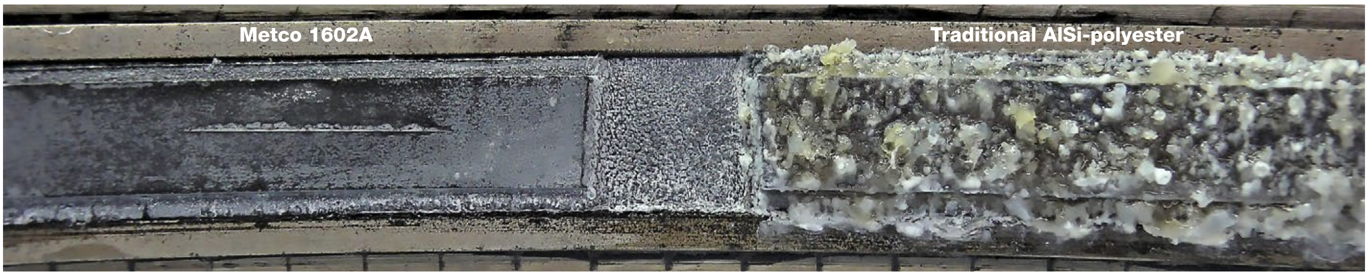


**Figure 7.** Salt bath immersion testing results, prior to cleaning. **Left:** Metco 1602A coating. **Right:** Traditional AlSi-polyester.

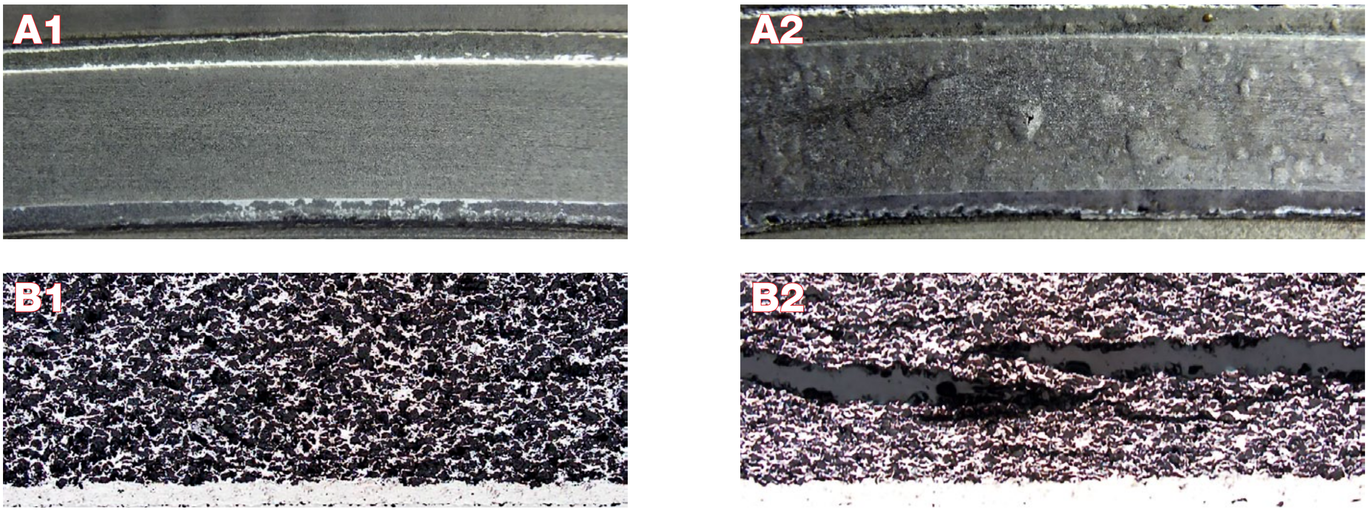


**Figure 8.** Salt bath immersion testing results, post cleaning. **A1:** Metco 1602A coating exhibits no corrosion. **A2:** The traditional AlSi-polyester coating exhibits corrosion and blistering. **B1:** A photomicrograph of the Metco 1602 coating shows an intact structure that is identical to that of the as-sprayed coating microstructure. **B2:** The traditional AlSi-polyester coating microstructure exhibits delamination as a result of corrosion.

## 4. Abradability testing

Abradability testing for Metco 1602A was done on Oerlikon Metco's abradability test rig, using titanium-alloy dummy blades. The test rig can control tip speed, incursion rate and depth and temperature. The results of our test rig are well known within the industry to correlate very closely to actual engine operating conditions.

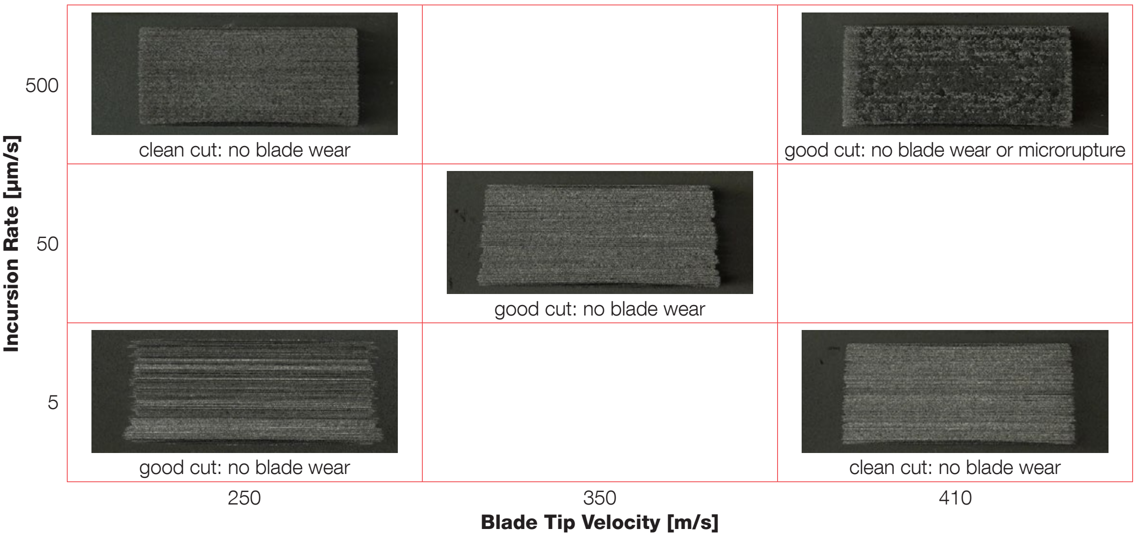


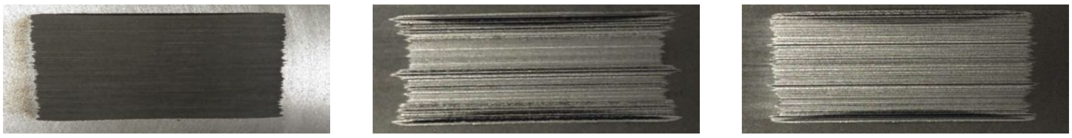
**Figure 9.** Abradability testing using the Oerlikon Metco test rig at various incursion rates and blade tip velocities.

**Test Conditions:**
- Shroud temperature: 300 °C
- Incursion depth: 1.0 mm
- Blade material: Ti 6Al 4V
- Tip width: 0.7 mm

**Coating Data:**
- Material: Metco 1602A
- Hardness: 73 HR15Y
- Tensile strength: 10.3 MPa
- Erosion: 5.7 s/0.001 in

## 5. Abradability versus traditional AlSi-polymer coatings

The abradability of Metco 1602A coatings compare very well against traditional AlSi-polymer coatings, with abradability that is as good as, or even somewhat better. Even for stringent aerospace OEM criteria for “over-penetration and anti-grooving”, the Metco 1602A outperformed known traditional coatings (Figure 10).



**Metco 1602A**
17 % over penetration

**Traditional AlSi-polyester**
39 % over penetration

**Traditional AlSi-polyester**
21 % over penetration

**Test Conditions:**
- Maximum allowable over penetration: 40 %
- Incursion rate: 150 µm/s
- Blade tip velocity: 200 m/s
- Blade material: Ti 6Al 4V

**Figure 10.** Comparison of Metco 1602A coating to traditional abradable coating for over-penetration and anti grooving criteria employed by aerospace OEMs.

## 6. Comparison of Metco 1602A to traditional AlSi-polymer abradables

Metco 1602A compares very favorably with traditional AlSi-polymer abradable materials in application, performance and cost criteria.

| Feature | | Metco 1602A | Traditional AlSi-Polymer | Competitive Product |
|---|---|---|---|---|
| Cyclic corrosion | 6 wk, 5% NaCl<br>(10 to 15 yr on engine) | Excellent | Complete coating failure (swelling / blistering / delamination | Complete coating failure (swelling / blistering / delamination |
| | 12 wk, 5% NaCl<br>(20 to 30 yr on engine) | Very good | | |
| Spray parameter | | = Metco 601NS | Varies with chosen product | Large deviation from Metco 601NS |
| As-sprayed hardness | HR15Y | 55 to 85, **robust!** | 50 to 85 | 50 to 80, often erratic |
| Spray process | | APS | APS | APS |
| Deposition efficiency | % | > 65 | > 65 | > 65 |
| Rub incursion | Titanium blades | Excellent | Excellent | Excellent |
| | Grooving resistance | Very good | Good | Good |
| Erosion resistance | | ≈ 0.216 s/µm<br>≈ (5.5 s/0.001 in) | ≈ 0.197 s/µm<br>≈ (5.0 s/0.001 in) | ≈ 0.197 s/µm<br>≈ (5.0 s/0.001 in) |
| Coating density | | ≈ 1.55 g/cm$^3$ | ≈ 1.55 g/cm$^3$ | ≈ 1.55 g/cm$^3$ |
| Service temperature | | 325 °C (615 °F) | 325 °C (615 °F) | 325 °C (615 °F) |
| QESH / REACH | | Less impactful | More impactful | More impactful |
| Material cost | | Moderate | High | Moderate |
| **Value** | **Performance / Cost** | **Excellent** | **Fair** | **Fair** |

## Customer Benefits

### Experience

- New and improved abradable material from the leading developer of thermal sprayed clearance control solutions

### Efficient

- Uses the same spray parameters as Metco 601NS, with little or no adjustment necessary
- Provides the same abradability as traditional LPC abradables
- Maintains engine safety margins and efficiency
- Coatings apply more reliably in terms of overall coating hardness and porosity
- No negative weight impact on the engine as coatings have same density as traditional LPC abradables

### Effective

- Excellent corrosion resistance compared to traditional LPC abradables
- Abradable material designed for LPC clearance control applications
- Provides abradability that is as good or better than traditional AlSi-polymer abradables

### Economical

- Cost competitive with moderately-priced traditional LPC abradable materials
- More robust sprayability can reduce processing time and rework
- Corrosion resistance can lead to fewer inspections and reprocessing of corroded parts