ENVIRO**Strip**® XL CORN HYBRID POLYMER DRY STRIPPING MEDIA

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ABSTRACT

Advances in polymer engineering and ADM/Ogilvie manufacturing technology have made possible the development of a new dry stripping polymer media for the aerospace industry. At last year's DoD/Industry Aerospace Coatings Conference[1], ADM/Ogilvie development efforts regarding two candidate products were presented. One of these products, referred to as XL7 in previous work, has since been launched commercially as ENVIRO**Strip**® **XL** corn hybrid polymer. This corn derived, organic-based polymer media is the subject of a pending patent application. **XL**'s moisture resistance, UV fluorescence, and longer product life make this corn hybrid polymer media a logical alternative to Type V acrylic media.

ENVIRO**Strip**® **XL** has been tested on a large scale to determine its performance characteristics versus other commercially available media blast abrasives; specifically Type V acrylic media and US Technology's PolyMedia Lite 75, which is described as starch-g acrylic media. The following paper outlines the methodology used and the test results obtained for individual blast media properties, mechanical effects, coating removal rates and product consumption rates. The mechanical effects on 2024 T-3 clad aluminum are reported and compared for each media type studied, and include residual stress saturation data, surface roughness, and surface examination.

INTRODUCTION

Over the last decade aerospace organizations have investigated and successfully developed dry media stripping techniques to remove coatings from aircraft. For example, these techniques have eliminated methylene chloride from production use at many military maintenance depots, providing a method that meets corrosion control requirements.

Now that dry media stripping has become a baseline method for coatings removal from aircraft, several military organizations are searching for improvements to dry stripping application technology. One area of focus has been the development of a successor to Type V acrylic media. The goal here has been to establish a new generation of blast media that combines the productivity/economics of Type V acrylic media with the more benign mechanical effects of ADM/Ogilvie's wheat starch media. Some recently developed starch-based media products do not appear to offer a clear advantage over Type V acrylic media. Shortcomings include high product consumption rates, moisture sensitivity, and equipment-related limitations.

ENVIRO**Strip**® **XL** corn hybrid polymer is an effective alternative to Type V acrylic media. **XL** meets productivity/economic goals while minimizing mechanical effects on thin aluminum skin substrates. By virtue of its moisture resistance and flowability, this corn hybrid polymer is a true "drop-in" replacement for acrylic media as it can be used in any type of plastic media blast facility. ADM/Ogilvie offers the following test data for review and invites others to confirm these findings.

DISCUSSION

EXPERIMENTAL PROCEDURES

1. Water Sensitivity

To illustrate how each media type responds when immersed in water, the following basic test was performed. Approximately 150 ml of water was poured into a small individual laboratory dish containing 75 grams of the blast media sample. Observations were made of the particles of the product as they came into contact with the water, and it was noted whether the media swelled and/or softened. After each sample had been immersed for 30 minutes, the water was then decanted and the samples were allowed to dry at ambient conditions for 48 hours. The condition of the blast media after drying was also then noted, specifically whether the media remained in a particulate form.

2. Hydration Capacity

The hydration capacity method is used to measure or evaluate a material's water absorbing ability. The test can help to predict how a blast media will respond when encountering condensation within pressurized blast equipment. A pre-weighed 2-gram sample of each media type was immersed in 40 ml of distilled water and shaken to ensure thorough wetting of the dry matter. After ten minutes, each sample was centrifuged at 5000 RPM (see Photos 1 and 2). The supernatant was carefully decanted to ensure that the top layer of the wetted sample was not disturbed. The final weight of the wetted material (after decanting) was determined. The total water absorbed was reported as a multiple of the original dry sample weight.

3. Blasting Test Equipment

Testing was conducted in both a hand-cabinet and in a blast room facility. A modified Pauli Systems RAM 31 hand cabinet, equipped with a computer controlled x-y table, served for media breakdown comparisons using a $^{3}/_{8}$-inch nozzle. For manual strip rate evaluations, testing was conducted in a 10'x15' blast room using a ½-inch nozzle. Almen arc height saturation data and surface roughness data were generated in the blast room as well, using parameters identical to those for strip rate determinations.

In all tests conducted, blast pressures were continuously monitored at the pressure pot by a digital pressure gauge. Nozzle pressures were verified at the beginning of every blast cycle by two different needle gauges. In the blast room facility, nozzle pressure was continuously monitored and controlled by a digital pressure gauge.

4. Product Breakdown/Consumption Rates

For media breakdown tests, thirty-pound batch quantities of each product were evaluated in the hand-cabinet. A 0.250-inch thick plate of 7075 T-6 aluminum was used as the blast target. Using samples of ENVIRO**Strip**® **XL** and PolyMedia Lite 75, a six-blast cycle test was performed to determine the amount of media waste that would be produced when tested under the following identical parameters.

ENVIROStrip® XL & PolyMedia Lite 75 Parameters

Nozzle type	$^3/_8$-inch Double Venturi
Nozzle pressure	35 ± 1 psi
Media flow rate	8 - 9 lb/minute
Nozzle angle	45 degrees
Nozzle distance	6 inches

5. Almen Arc Height Measurements

Aero Almen strips (bare 2024 T-3 aluminum, 0.032-inch thick) were blasted with the parameters listed below. This work was performed in a blast room with a ½-inch diameter nozzle using the same procedures as when determining comparative strip rates.

All Almen specimens were pre-measured and verified not to exceed 0.0005 inches before blasting. Using a multiple-specimen mounting block, eight Almen specimens were positioned to cover an area of approximately 3 inches by 12 inches, or 0.25 ft^2.

Blasting Parameters for Strip Rate/Mechanical Effects

ENVIROStrip® XL chp Parameters

Nozzle type	½-inch Double Venturi
Nozzle pressure	35 ± 1 psi
Media flow rate	12 ± 1 lb/minute
Nozzle angle	45 ± 10 degrees
Nozzle distance	4, 8, 12 inches

Type V Acrylic Parameters

Nozzle type	½-inch Venturi
Nozzle pressure	30 ± 1 psi
Media flow rate	10 ± 1 lb/minute
Nozzle angle	60 ± 10 degrees
Nozzle distance	6, 12, 18 inches

PolyMedia Lite 75 Parameters

Nozzle type	½-inch Double Venturi
Nozzle pressure	35 ± 1 psi
Media flow rate	12 ± 1 lb/minute
Nozzle angle	45 ± 10 degrees
Nozzle distance	4, 8, 12 inches

Under each set of parameters, the Almen specimens were then blasted initially for the time required to strip 0.25 ft^2, or the equivalent of one strip cycle. The specimens were removed and measured using an Electronics Inc. Almen gauge instrument. The procedure was then repeated on the same specimens to give the equivalent of four strip cycles in all.

6. Coated Test Panels

Aerospace contractors prepared the coated test panels in accordance with USAF guidelines. The substrate material was 0.032-inch 2024 T-3 clad aluminum. The coating system applied in each case was Mil-P-23377 epoxy polyamide primer followed by a Mil-C-83286 polyurethane top coat. All panels were artificially aged using a 7-day room temperature cure followed by a 210°F oven bake for 96 hours. All panels met or exceeded coating hardness and adhesion properties (see Table 1).

Coating removal rates are influenced by a number of variables attributable to the coating system involved. These include the type of coating, the coating manufacturer, the application process, and, perhaps most importantly, the aging process. Other factors that influence dry stripping efficiency are coating thickness, hardness and adhesion properties.

The coating thickness of the panels was measured with an Elcometer instrument and the results are presented in Table 1. Note panel types B and C had coating thickness values outside of USAF specifications. These panels were included in order to determine the effect of coating thickness on production rates. Panel type C was prepared by a contractor to simulate a build up of paint as a consequence of multiple "scuff sand and paint" operations.

Table 1. **Summary of Coating Properties of Painted Panels Tested.**

	Coated Test Panels MIL-C-83286 POLY-URETHANE TOPCOAT, MIL-P-23377 POLY-AMIDE EPOXY PRIMER		
	SERIES A	SERIES B	SERIES C
COATING THICKNESS (MIL)	2.2 - 3.2	1.1 - 1.6	7.3 – 10.6
COATING ADHESION (DRY)	4B	4B	4B
COATING HARDNESS	5H	5H	4H

DISCUSSION OF RESULTS

1. Water Sensitivity

When the water sensitivity test described earlier was performed on PolyMedia Lite 75, it was immediately observed that when PolyMedia Lite 75 comes into contact with water, the media swells and softens. Upon drying, PolyMedia Lite 75 formed a solid, fused mass (see Photos 3 and 4). ADM/Ogilvie's original wheat starch media would exhibit similar characteristics.

The ENVIRO**Strip**® **XL** product, like that of Type V acrylic, returned to its original, particulate state after drying. This is an important property. It demonstrates that ENVIRO**Strip**® **XL** possesses moisture resistance that alleviates moisture problems caused by condensation within blast equipment.

2. Hydration Capacity

The hydration capacity results are presented in Table 2. While all three materials will absorb some water, Type V acrylic and ENVIRO**Strip**® **XL** took on significantly less water than PolyMedia Lite 75 did. The higher affinity for water displayed by PolyMedia Lite 75 is similar to ADM/Ogilvie's original wheat starch media.

Table 2. **Hydration Capacity Results for Type V Acrylic, ENVIRO**Strip**® XL, and PolyMedia Lite 75.**

Blast Media Product	Hydration Capacity (multiple of original weight)
Type V Acrylic	1.9
ENVIRO**Strip**® XL	3.1
PolyMedia Lite 75	7.8

3. Ultraviolet Response

ENVIRO**Strip**® **XL** has a significant UV fluorescence when illuminated by black light. This characteristic can enhance post-stripping inspections for possible media ingress. Photos 5 and 6 shows Type V acrylic, PolyMedia Lite 75, and ENVIRO**Strip**® **XL** under normal visible light, and under UV illumination. As one can see from photo 6, the **XL** corn hybrid polymer media gives, by far, the brightest response.

Photos 7 and 8 demonstrate the usefulness of this product feature in a production situation. A small amount of ENVIRO**Strip**® **XL** was placed on a flight control surface in an area prone to media ingress. A similar amount of Type V acrylic was placed next to the **XL** corn hybrid polymer media for visual comparison. As can be seen in photo 8, the **XL** media is clearly visible while Type V (depicted as "T 5") cannot be detected.

4. Product Breakdown/Consumption Rates

The results showed that after six cycles, approximately 20.3 pounds of the starting 30 pounds of PolyMedia Lite 75 was collected as waste (i.e. <100 mesh US Std.). This compared to approximately 9.3 pounds for ENVIRO**Strip**® **XL**. Mesh size distribution data were recorded on samples before and after testing (see Appendix A).

Product consumption for ENVIRO**Strip**® **XL,** when used at the parameters listed on page 3, is estimated to be approximately 5% per cycle.

5. Almen Arc Height Results

The cumulative residual stress imparted by Type V acrylic is compared to ENVIRO**Strip**® **XL** and PolyMedia Lite 75 in Figures 1, 2 and 3.

The Almen Arc height values obtained were typical of ENVIRO**Strip**® **XL** and Type V acrylic when the process was applied in a manual mode. At the nozzle distances of 4 to 12 inches tested for ENVIRO**Strip**® **XL**, the arc height saturation values never varied much from 0.004-inch. **Figure 1. Plot of Almen Arc Height versus Strip Cycle forType V Acrylic (6-inch distance), ENVIROStrip® XL and PolyMedia Lite 75 (4-inch distance)** saturation data is very similar to ENVIRO**Strip**® wheat starch media, which was ADM/Ogilvie's goal in developing the new **XL** product.

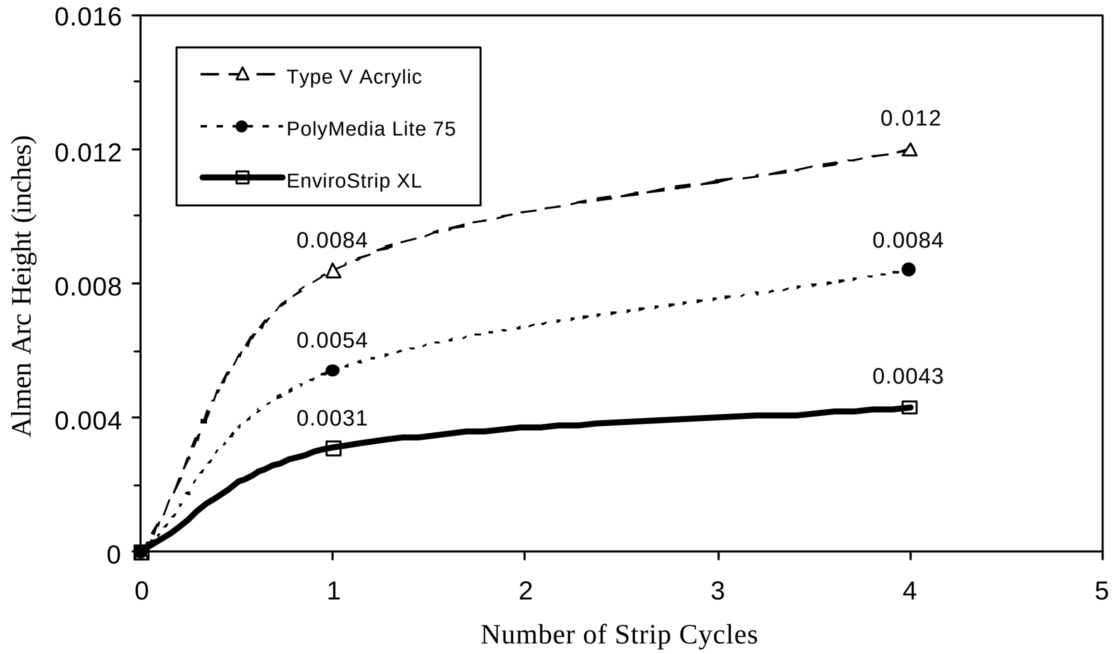

Figure 1. **Plot of Almen Arc Height versus Strip Cycle for Type V Acrylic (6-inch distance), ENVIROStrip® XL and PolyMedia Lite 75 (4-inch distance)**

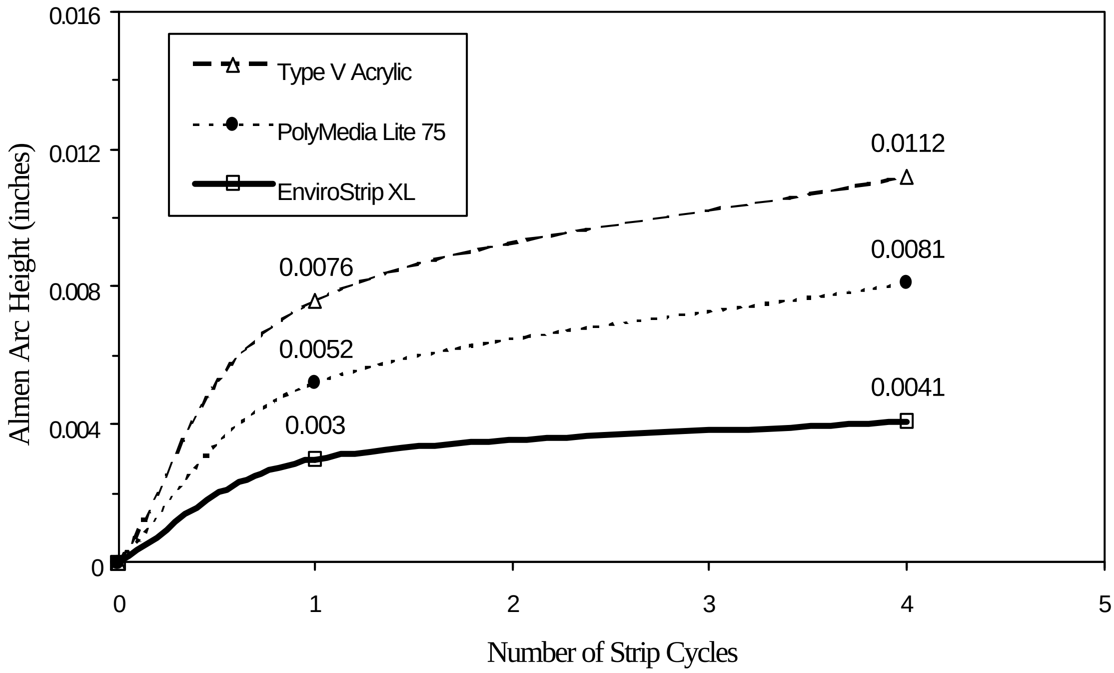

Figure 2. **Plot of Almen Arc Height versus Strip Cycle for Type V Acrylic (12-inch distance), ENVIROStrip® XL and PolyMedia Lite 75 (8-inch distance)**

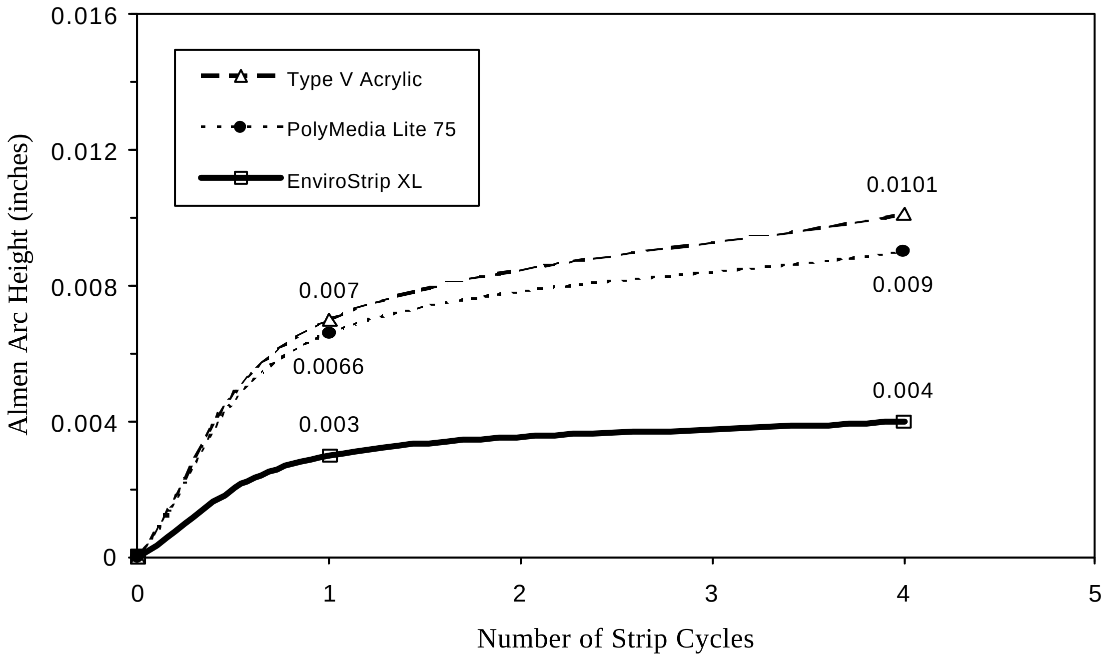

Figure 3. **Plot of Almen Arc Height versus Strip Cycle forType V Acrylic (18-inch distance), ENVIROStrip° XL and PolyMedia Lite 75 (12-inch distance)**

The arc height saturation results obtained with PolyMedia Lite 75 were higher than previously reported[2]. Based on published data and ADM/Ogilvie's previous in-house testing, the saturation level for PolyMedia Lite 75 was expected to be approximately 0.006 – 0.007-inch for the nozzle distances of 4 – 12 inches used. The Almen Arc heights were repeated a second time using the same PolyMedia Lite 75 lot number and similar results were obtained.

6. Surface Roughness

Surface roughness measurements were performed on the stripped clad aluminum (0.032-inch, 2024 T-3) panels using a Mitutoyo MST 301 profilometer. Panels marked series A, B and C were stripped to the bare metal and the surface roughness was measured on the exposed clad layer for each abrasive product. Note that six scans were performed on each area using a cut length of 0.030-inch x 5 (total stroke 0.150 inch). The average R_a (roughness average, microinches) values obtained for Type V acrylic, PolyMedia Lite 75, and ENVIRO**Strip**® **XL** are presented in Tables 3, 4, and 5.

Table 3. **Summary of Surface Roughness (R_a) obtained for Type V Acrylic on Panels A, B, and C.**

	Surface Roughness R_a (μinches)		
Nozzle Distance (inches)	**Series A**	**Series B**	**Series C**
6	164	144	168
12	183	167	196
18	189	166	204

Table 4. **Summary of Surface Roughness (R_a) obtained for PolyMedia Lite 75 on Panels A, B, and C.**

	Surface Roughness R_a (μinches)		
Nozzle Distance (inches)	**Series A**	**Series B**	**Series C**
4	121	105	129
8	128	125	143
12	126	109	116

Table 5. **Summary of Surface Roughness (R_a) obtained for ENVIRO**Strip**® XL on Panels A, B, and C.**

	SURFACE ROUGHNESS R_a (µINCHES)		
NOZZLE DISTANCE (INCHES)	SERIES A	SERIES B	SERIES C
4	103	89	109
8	93	83	98
12	101	83	106

7. Visual Examination of Stripped Surface

The most apparent visual difference between the panels was the degree to which the chemical conversion film was left intact. For all panels stripped with ENVIRO**Strip**® **XL**, considerable chemical conversion coating appeared to remain on the clad surface. On the other hand, it was found that panels stripped with Type V acrylic and PolyMedia Lite 75 showed little to no chemical conversion coating was left behind. Since most of the chemical conversion coating was retained, this indicates that a minimum of clad was removed with ENVIRO**Strip**® **XL**.

8. Strip Rates

To conduct strip rate tests and provide a representative performance comparison, all three media types were used for several cycles as would be experienced in a production situation. Thus the relative mesh size distributions for ENVIRO**Strip**® **XL** and PolyMedia Lite 75 were similar using a 16/20 to 100 mesh size (US Std.) range. Type V acrylic was used in the 30/40 mesh size and screened out at 60 to 80 mesh.

The strip rate tests were performed manually using the process parameters listed on page 3. The distance to the test panel was varied, while the nozzle pressure, media flow, and blast angles were kept constant for each respective media type. Distance ranges for Type V acrylic were 6, 12, and 18 inches, while that for ENVIRO**Strip**® **XL** and PolyMedia Lite 75 were closer at 4, 8, and 12 inches. If longer distances had been used for ENVIRO**Strip**® **XL** and PolyMedia Lite 75, it is likely that strip rates would have been below the 0.5 ft^2/min threshold preferred by the industry. In order to maintain approximate distances, a small rod was attached to the nozzle to serve as a guide during each strip rate test. Figures 4, 5 and 6 present the strip rate results obtained for Panel Types “A”, “B”, and “C” respectively. These are plots of strip rate versus nozzle distance.

These charts illustrate how the productivity of the different media types can be compared. Mil-spec guidelines call for using Type V acrylic at a minimum nozzle distance of 12 inches, and preferably at 18-inch standoff (with a ½-inch nozzle). Limiting the distance for Type V acrylic helps to limit the potential aggressiveness of the process and the mechanical effects on aluminum alloys. It has been found that both ENVIRO**Strip**® **XL** and PolyMedia Lite 75 are less aggressive than Type V Acrylic, and can be applied at shorter distances to the surface being stripped. Thus for a proper comparison of the productivity of the three media types, the strip rates results achieved for Type V acrylic at 18 inches should be compared to ENVIRO**Strip**® **XL** and PolyMedia Lite 75 at a nozzle distance of 8 inches.

Some interesting observations can be drawn from studying Figures 4, 5 and 6. If the use of Type V acrylic is kept at an 18-inch nozzle standoff, the strip rates would be very similar to ENVIRO**Strip**® **XL** and PolyMedia Lite 75 at 8 inches. However coat weight can have a strong influence on the strip rates achieved with each media type.

With Panel Type "B", which has a coat weight of 1.1 - 1.6 mil, well below the mil-spec requirement, Type V acrylic strips at a higher rate than the other two media types. The reverse seems to hold true at the high coat weights of Panel Type "C" (7.3 - 10.6 mil), where ENVIRO**Strip**® **XL** and PolyMedia Lite 75 at 8 inches seem to strip either at the same rate or perhaps faster than Type V acrylic (at 18 inches). In a production situation, the coat weights of Panel "C" are much more likely to be encountered, as "scuff sand and paint" tends to build excessively high coat weights. Scuff sand and paint is often used as a repaint method, a common practice that postpones complete stripping of aircraft.

The faster strip rates for Type V acrylic on thin coatings could be attributable to several factors. A "brittle erosion mechanism" or impacting action of the acrylic media to remove paint is one possible reason. The higher impact angles that are preferred for Type V support this view. This would help to explain why Type V removal rates are much quicker on thin coatings versus thick coatings. Another factor is apparent coating hardness. Due to its higher media hardness level, Type V acrylic probably penetrates harder coatings better than ENVIRO**Strip**® **XL** and PolyMedia Lite 75.

However, on tenacious, well-adhered aerospace coatings, it is believed that ENVIRO**Strip**® **XL** and PolyMedia Lite 75 use a "ductile erosion mechanism" or gradual eroding action to remove paint. The difference in apparent coating removal mechanisms explains why the removal rate of these two products improves on thicker coatings relative to Type V acrylic.

It was found that the production rates for ENVIRO**Strip**® **XL** and PolyMedia Lite 75 are comparable to Type V acrylic, if Type V is limited to a minimum standoff distance due to its more aggressive nature.

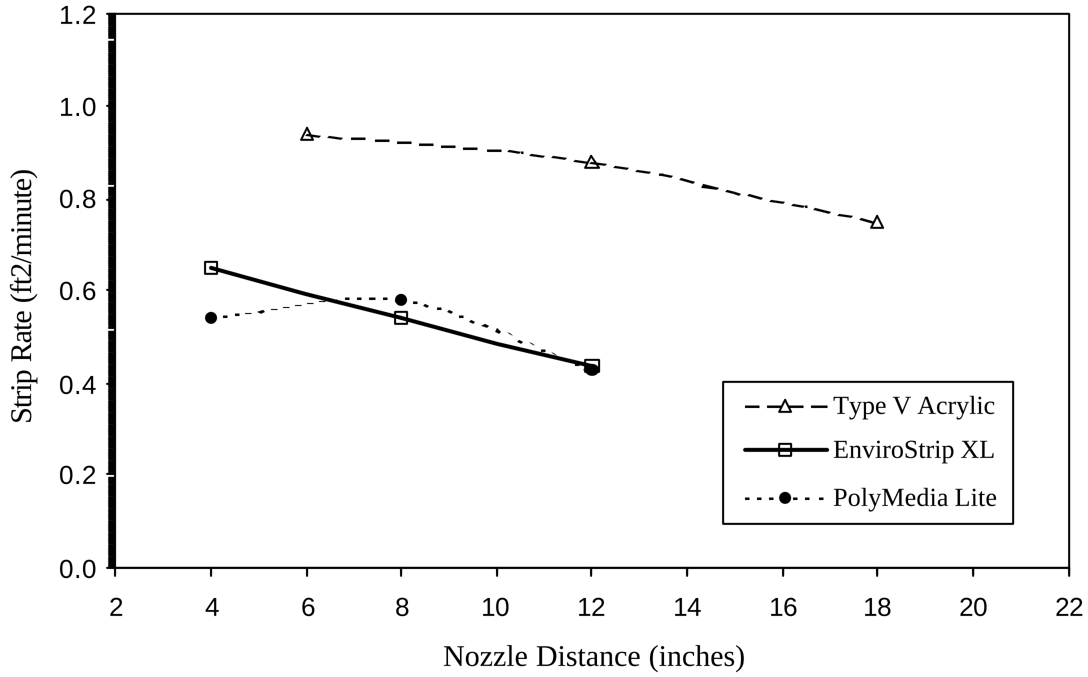

Figure 4. **Plot of Strip Rate versus Nozzle Distance on Panel Type "A" for Type V Acrylic, ENVIRO**Strip**® XL, and PolyMedia Lite 75**

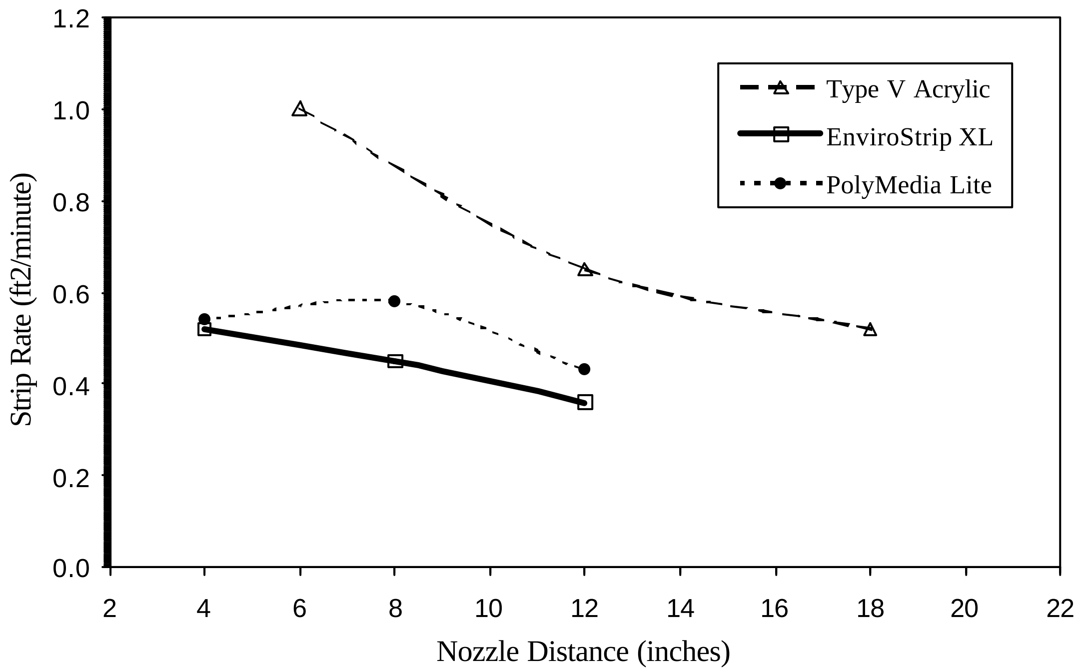

Figure 5. **Plot of Strip Rate versus Nozzle Distance on Panel Type "B" for Type V Acrylic, ENVIRO**Strip**® XL, and PolyMedia Lite 75**

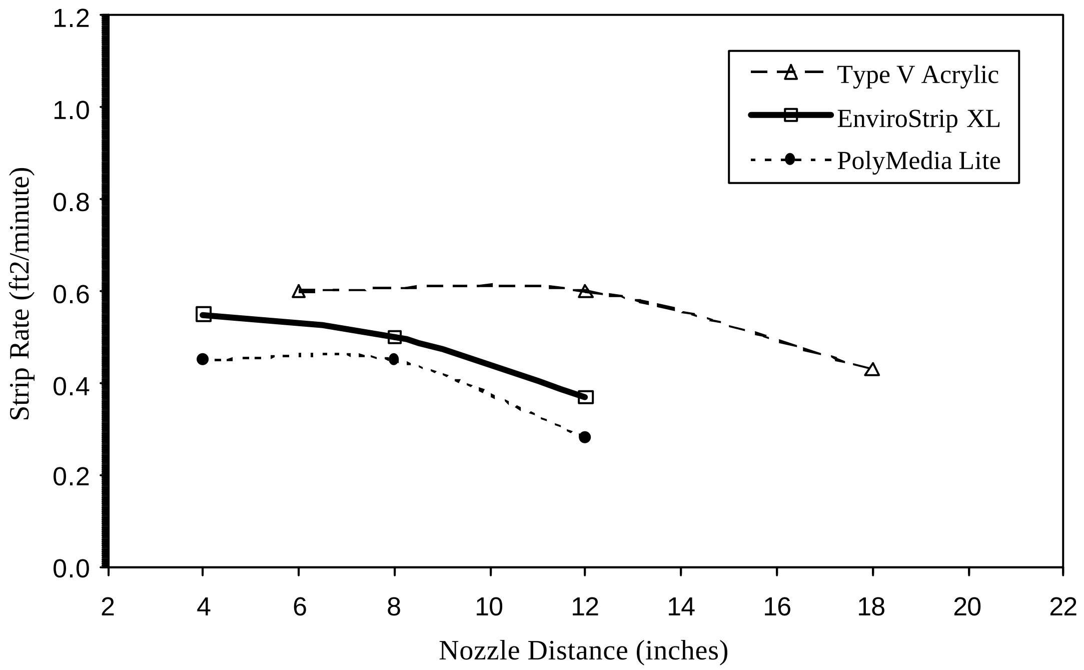

Figure 6. **Plot of Strip Rate versus Nozzle Distance on Panel Type "C" for Type V Acrylic, ENVIROStrip® XL, and PolyMedia Lite 75**

CONCLUSION

ENVIRO**Strip**® **XL** offers the aerospace industry an effective alternative to Type V acrylic blast media. ADM/Ogilvie has created a new media that delivers comparable productivity economics to Type V media, yet induces much lower mechanical effects on thin aluminum alloys.

From this study we can conclude the following:

1. The Almen Arc Height saturation levels obtained with ENVIRO**Strip**® **XL** are the lowest of the three products tested.

2. Type V acrylic demonstrates the highest potential for surface damage, particularly if minimum nozzle distances to the work surface are not respected.

3. Type V acrylic offers the highest strip rates of the products tested at a given nozzle distance.

4. Both Type V acrylic and ENVIRO**Strip**® **XL** can withstand the formation of condensation within pressurized blast equipment.

5. ENVIRO**Strip**® **XL** combines acceptable production and consumption rates with the lowest potential for surface damage.

REFERENCES

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APPENDIX A

Table A. **Mesh Size Analysis of ENVIRO**Strip® **XL and PolyMedia Lite 75 tested as new, and after six blast cycles.***

Product	Mesh Size (US Std.)							
	20	30	40	50	60	80	100	<100
ADM/Ogilvie XL lot # 0359-009K	27.5	28.0	19.6	13.1	3.3	3.9	1.3	1.7
After 6 Blast Cycles	1.1	7.7	14.8	23.7	8.3	15.6	8.0	20.1
ADM/Ogilvie XL lot # 2528-012E	48.0	26.4	13.5	6.9	1.5	1.5	0.4	0.6
After 6 Blast Cycles	1.6	8.4	14.5	24.1	8.5	15.2	7.9	19.1
UST PML 75 lot # UST-014	0.3	24.7	30.8	28.2	7.8	6.5	0.4	0.2
After 6 Blast Cycles	0.2	0.1	0.5	5.3	4.7	15.4	9.6	64.8
UST PML 75 lot # K-38	9.2	42.5	23.3	15.4	3.6	4.2	0.8	0.3
After 6 Blast Cycles	0.0	0.2	0.8	6.8	5.2	16.3	12.1	57.4

Table B. **Calculation of Total Dust recovered for ENVIRO**Strip® **XL and PolyMedia Lite 75 after six blast cycles.***

	Media recovered (lb)	Dust in Media Recovered (%)	Dust in Media Recovered (lb)	Dust Removed by cyclone (lb)	Total Dust Recovered (<100 mesh) (lb)
ADM/Ogilvie XL # 0359-009K	24.8	20.1	5.0	5.2	10.2
ADM/Ogilvie XL # 2528-012E	26.8	19.1	5.1	3.2	8.3
Average – XL					9.3
UST PML 75 # UST-014	23.8	64.8	15.4	6.2	21.6
UST PML 75 # K-38	25.8	57.4	14.8	4.2	19.0
Average – PML 75					20.3

* - Start weight 30 lbs/ parameters 35 psi nozzle pressure, 45° angle, 6-inch distance