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SALT FOG TEST OF SAM2X5 COATED STAINLESS STEEL CYLINDER

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ABSTRACT

A salt fog test of an iron-based amorphous metal, SAM2X5, coated Type 316L stainless steel (SS316L) cylinder was made. The cylinder was 30" diameter by 88" long, and 3/8" thick. One end was welded shut with a SS316L end cap before coating. The body of the cylinder and the end cap were both coated. The cylinder was coated with SAM2X5 by the HVOF thermal spray process. The coating thickness was 0.015" to 0.019" thick. The cylinder was tested in a horizontal position. Also included in the test for reference purposes were five coupons (2" x 2" x 1/8") of uncoated Type 1018 carbon steel (1018CS). The test used an abbreviated form of GM 9540P. Each cycle was 6 hours in duration and the cylinder and reference samples were exposed to a total of eight cycles. The cylinder was in relatively good condition after the test. Along the body of the cylinder only two pinpoint spot sized signs of rust were seen. The 1018CS reference specimens were extensively rusted.

INTRODUCTION

Iron based amorphous metal coatings have been developed in a program sponsored by the Defense Advanced Projects Agency (DARPA) and the Department of Energy. The program has been managed by the Lawrence Livermore National Laboratory (LLNL). These coatings when fully amorphous have been found to be resistant to salt fog corrosion. If they are partially amorphous they contain alpha ferrite, which is easily corroded in a salt fog environment. One of these coatings, SAM2X5, is being evaluated on large stainless steel cylinders. The quality of the coating is being evaluated by several means, including salt fog testing.

EXPERIMENTAL PROCEDURE

A SS316L stainless steel cylinder 30" dia. X 88" long, and 3/8" thick has been coated with SAM2X5, an iron based amorphous metal coating. The compositions of SAM2X5 and SS316L alloys are given in Table 1. One end was welded shut with a SS316L end cap before coating. The body of the cylinder and the end cap were both coated. There were no intentionally un-

coated areas on the finished cylinder. The high velocity oxy-fuel thermal (HVOF) spray process was used to apply the coating. The coating was applied to a thickness of 0.015 to 0.019" thick. The cylinder was tested in the horizontal position, as shown in Figure 1. Other images of the cylinder in the as-received condition are given in Figures 2. Also included in the test for reference purposes were five coupons (2" x 2" x 1/8") of uncoated Type 1018 carbon steel. Photographs of the reference specimens in the as-received condition can be seen in Figure 3. The salt fog test used an abbreviated form (Table 3) of the GM 9540P test cycle¹ (Table 4). The full GM cycle is 24 hours long. The abbreviated cycle is 6 hours long and has been found to be adequate in revealing any areas of alpha ferrite in the coating. The cylinder and reference samples were exposed to a total of eight cycles.

RESULTS

Photographs of the cylinder at the end of the test are shown in Figure 4. The cylinder was in relatively good condition after the test. Along the body of the cylinder only two pinpoint spot sized signs of rust were seen. These can be seen in Figures 4e and 4f. There was also some rust that developed during the test on the end cap that appears to be related to the welds. This can be seen in Figures 4c and 4d. The 1018CS reference specimens were extensively rusted, as expected. Close-up photos of the reference specimens at the end of the test are shown in Figure 5.

SUMMARY

A large Type 316L stainless steel cylinder has been coated with an iron-based amorphous metal coating – SAM2X5. A salt fog test has been performed to show that the coating has remained predominately amorphous and has displayed good corrosion resistance.

REFERENCES

1. "Accelerated Corrosion Test", General Motors Engineering Standard GM9540P, Dec. 1997.

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Table 1 - Alloy and Coating Nominal Compositions

Alloy Designation	HPCRM Designation	Nominal Compositions in Weight Percent
SS316L	SS316L	C – 0.03, Mn - 2.00, Si – 1.00, Cr – 16.0 to 18.0, Ni -10.0 to 14.0, Mo 2.0 to 3.0, Fe – balance
SAM2X5	SAM2X5	Cr – 18.5, Mn – 2.0, Mo – 14.0, W – 5.8, B – 3.2, C – 1.0, Si – 1.3, Fe – balance
1018 Carbon Steel	None	C – 0.14 to 0.2, Mn - 0.6 to 0.9, P – 0.04 max., S – 0.05 max., Fe - balance

Table 2 - Summary 2” x 2” x 1/8” Reference Samples

Coating:	Substrate:	Sample Type	Sample ID:
Uncoated	1018 Carbon Steel	Reference sample	A25
Uncoated	1018 Carbon Steel	Reference sample	A26
Uncoated	1018 Carbon Steel	Reference sample	A27
Uncoated	1018 Carbon Steel	Reference sample	A28
Uncoated	1018 Carbon Steel	Reference sample	A29

Table 3 - Abbreviated GM Salt Fog Test Cycle

Cycle Segment	Elapsed Time	Event
Soaking with Salt Solution	2 minutes	Soak samples with a salt solution mist* for 2 minutes at ambient temperature: 13 – 28°C (55 - 82°F).
High Humidity Exposure	4 hours	Expose samples to 100% relative humidity at 49 ±0.5°C (120 ±1°F), including a 55 minute ramp to wet conditions
Sample Drying	1 hours and 58 minutes	Heat sample to 60 ±0.5°C (140 ±1°F) and reduce humidity to 30% or less. Hold until dry and then reduce temperature to ambient conditions.
Repeat Cycle		

- A distilled water solution of 0.9% sodium chloride, 0.1% calcium chloride, and 0.25% sodium bicarbonate will be used for the salt solution mist.

Table 4. 24 Hour Test Cycle for GM9540P¹ Accelerated Corrosion Test.

<i>Shift</i>	<i>Elapsed Time (hrs)</i>	<i>Event</i>
Ambient Soak	0	*Salt solution mist for 30 seconds, followed by ambient exposure (13-28 °C (55-82 °F))
	1.5	*Salt solution mist for 30 seconds, followed by ambient exposure (13-28 °C (55-82 °F))
	3	*Salt solution mist for 30 seconds, followed by ambient exposure (13-28 °C (55-82 °F))
	4.5	*Salt solution mist for 30 seconds, followed by ambient exposure (13-28 °C (55-82 °F))
Wet Soak	8-16	8 hour high humidity exposure (49 ± 0.5 °C (120 ± 1 °F), 100% RH) including 55 minute ramp to wet conditions
Dry Soak	16-24	8 hour elevated dry exposure (60 ± 0.5 °C (140 ± 1 °F), <30% RH) including 175 minute ramp to dry conditions

*Salt solution mist consists of 1.25% solution containing 0.9% sodium chloride, 0.1% calcium chloride, and 0.25% sodium bicarbonate.

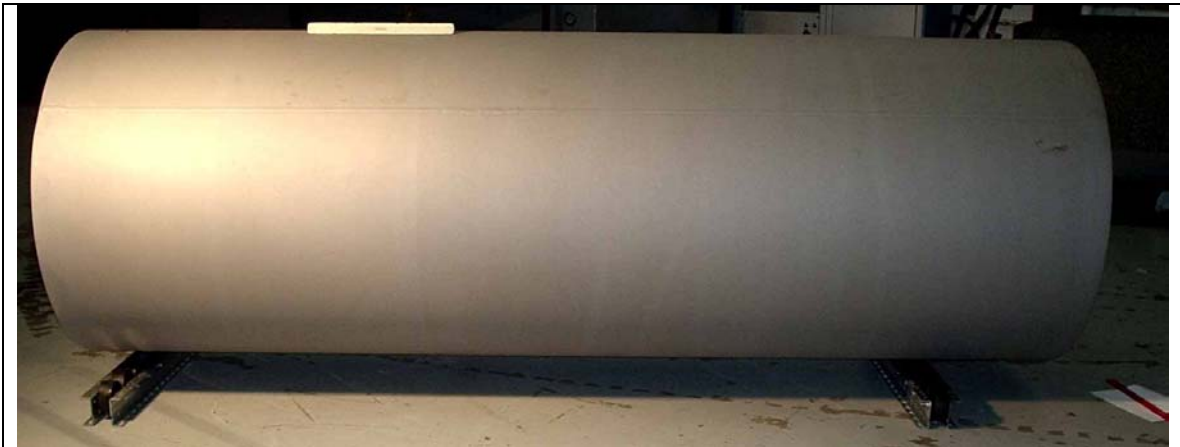


Figure 1 –Side View of Cylinder Before Salt Fog Testing.

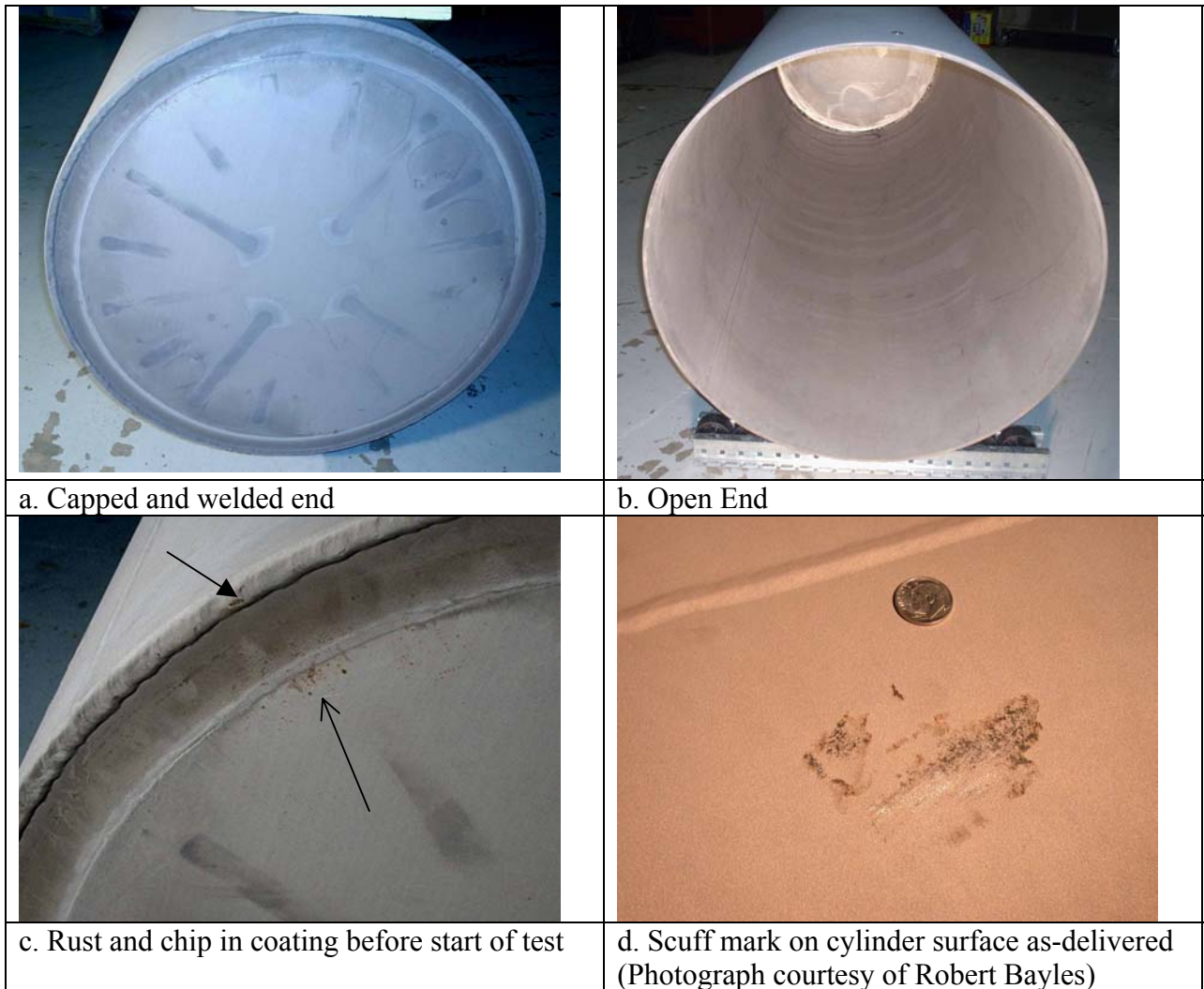


Figure 2. Additional Photographs of Cylinder in As-received Condition.

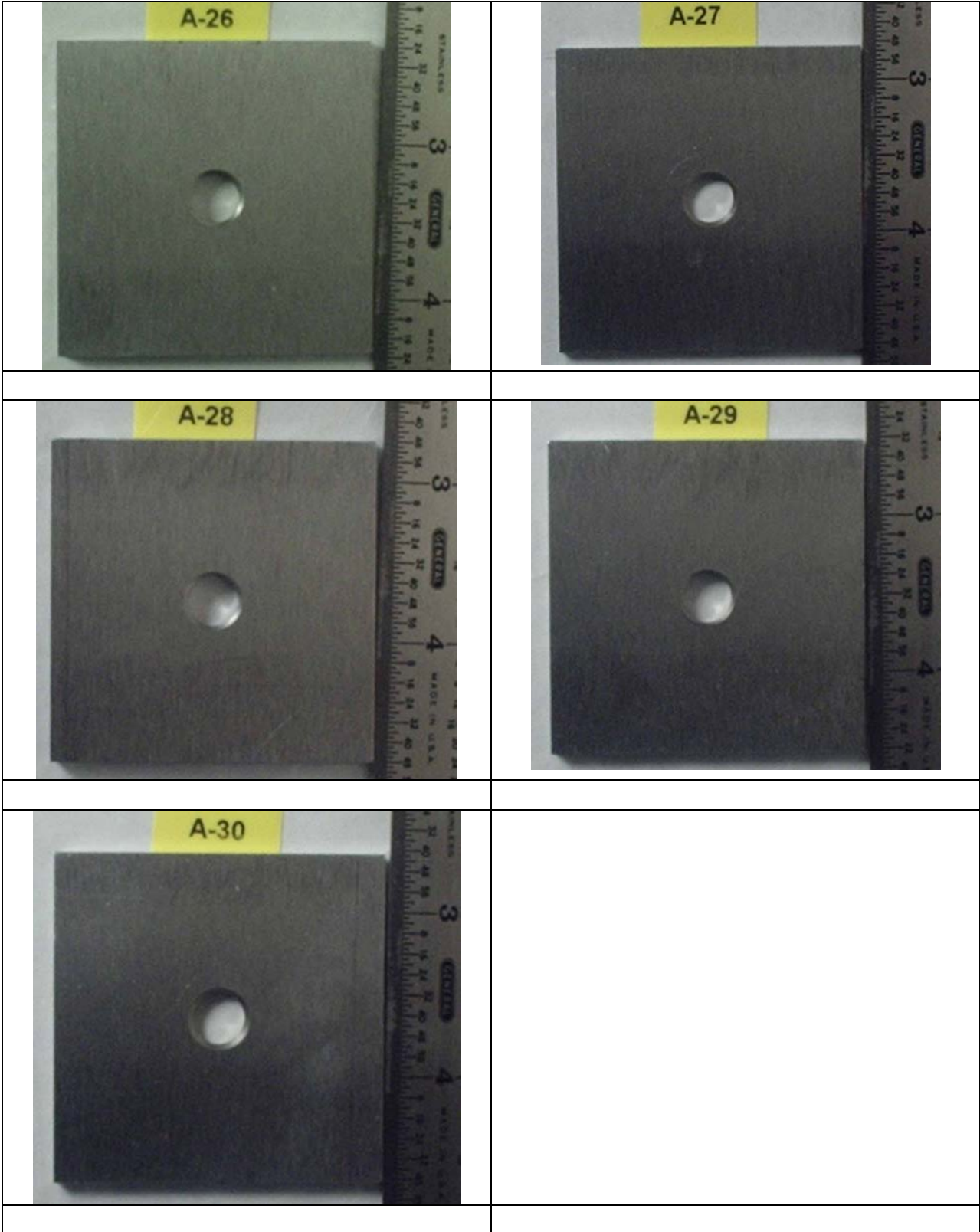


Figure 3. 1018CS Reference Specimens Before Test Exposure

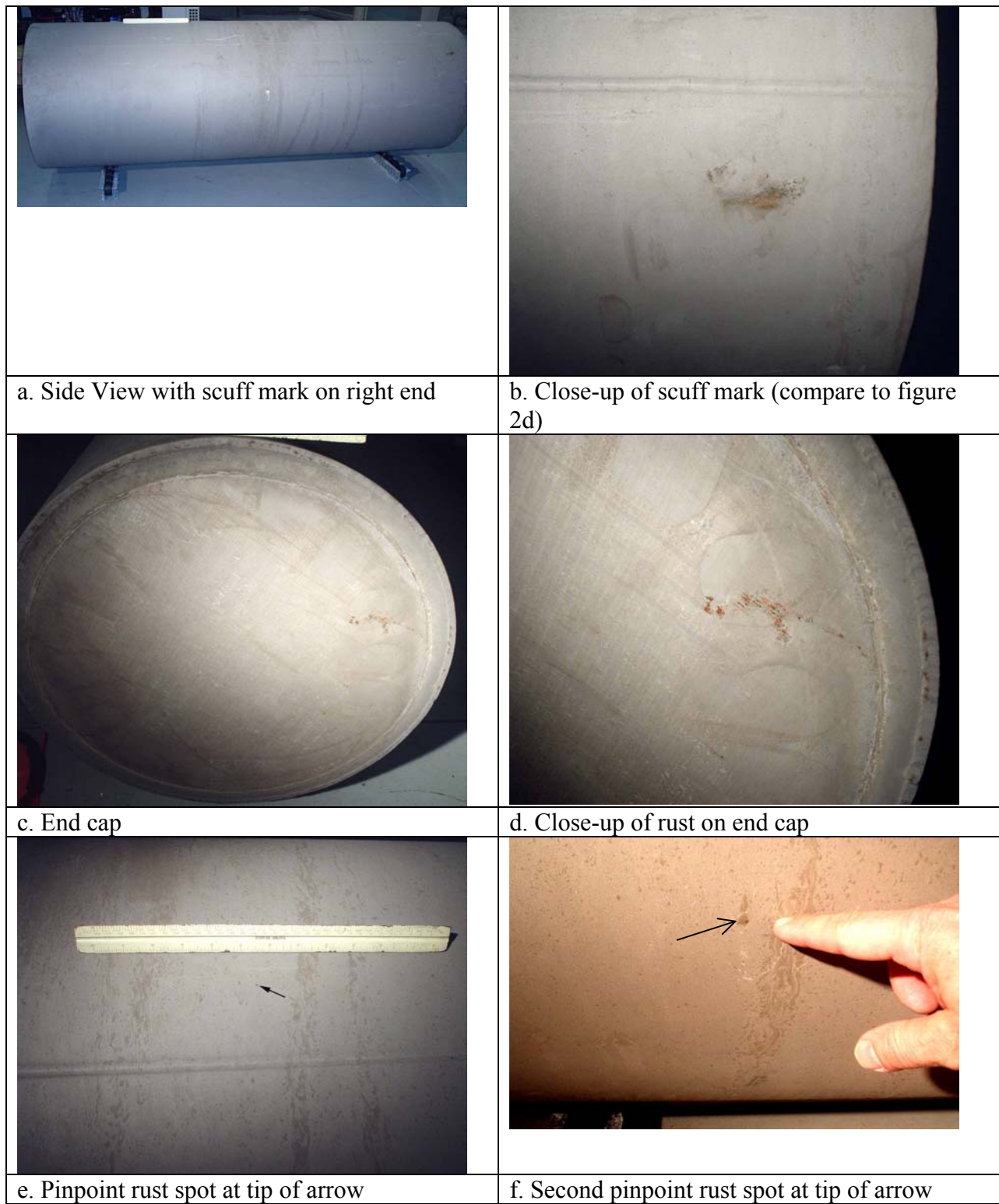


Figure 4. Cylinder After 8 Abbreviated GM cycles.

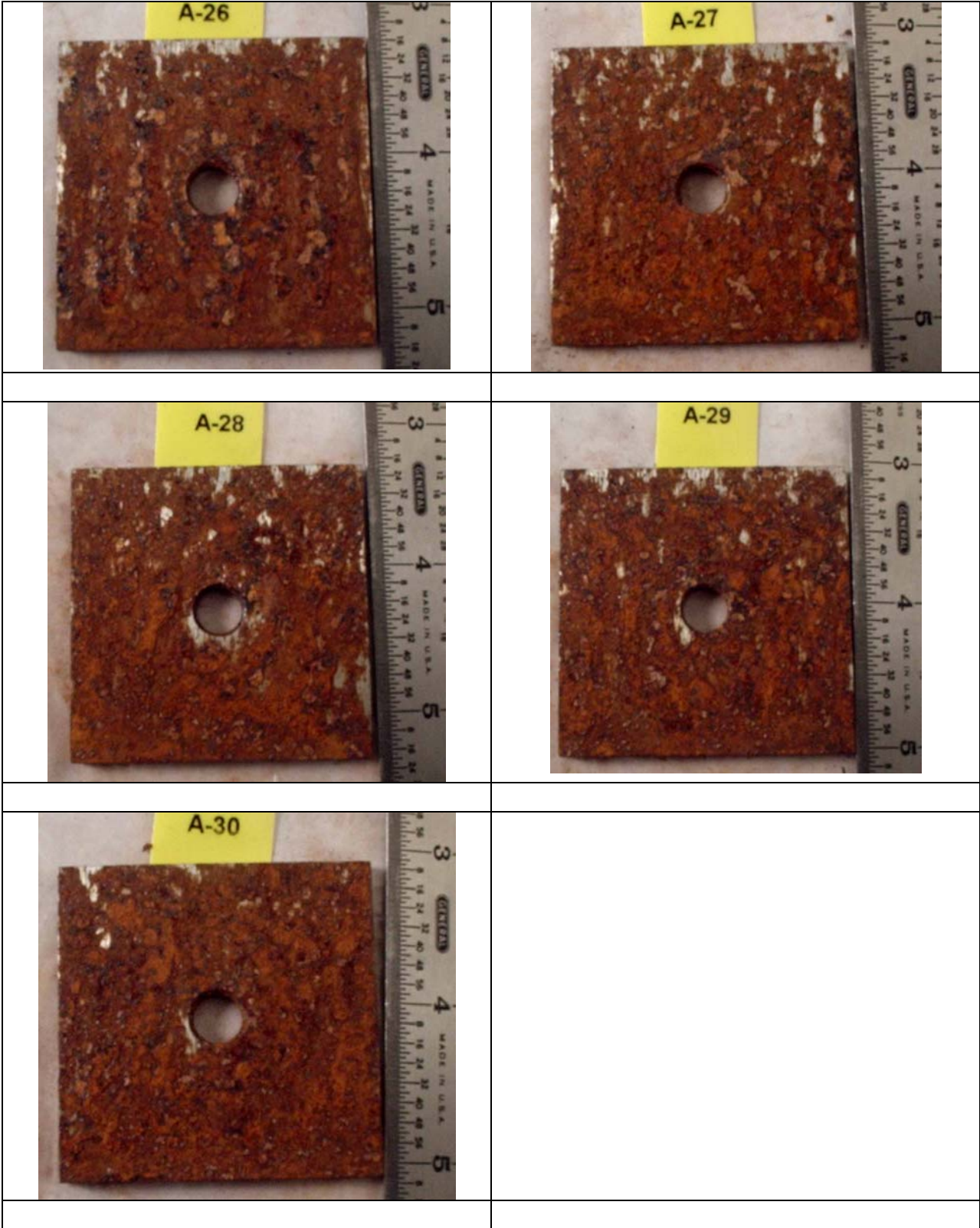


Figure 5. Reference Specimens Used in Cylinder Salt Fog Test After 8 Abbreviated GM Cycles.

