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PREPARED FOR:

Director of Procurement
Volta River Authority
V1CGL332

May 17, 2013

Revised

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May 17, 2013

Director of Procurement
Procurement Department
Volta River Authority
P.O. Box MB77
Accra, Ghana

Re: Physical Testing
P.O. #: W/T
Chemir Job #: V1CGL332

Director of Procurement:

Thank you for choosing Chemir Analytical Services to assist you with your testing needs. The following document summarizes the results of the analyses performed.

EXECUTIVE SUMMARY

The three-component Hemple coating system was compared to two Rust Bullet systems both with and without the Hemple Urethane top coat. The five systems were exposed to four different accelerated test methods for performance. The results of the testing varied with the standard Silver Bullet system performing the best in the Salt Fog testing, but showing the most color change in the QUV test. Cold check testing proved inconclusive as all of the systems performed well. Humidity testing results were also equal except that all of the Hemple Urethane-coated panels had water spots develop between 750 and 1000 hours of exposure. None of the systems showed any signs of peeling or inter-coat failure.

SAMPLE LOG-IN

The samples were logged as follows:

SAMPLE DESCRIPTION	CHEMIR SAMPLE NUMBER
Rust Bullet Silver Inhibitive Protective Coating	S1
Rust Bullet Black Shell Inhibitive Protective Coating	S2
Hemple Urethane Curing Agent 95370	S3
Hemple Zinc Rich Epoxy Curing Agent 97040	S4
Hemple Epoxy Intermediate Coat Curing Agent 97820	S5
Hempadur Epoxy Intermediate Coat 45141 Part A	S6
Hempadur Zinc Rich Epoxy 17360 Part A	S7
Hempathane Urethane Top Coat 55210 Part A	S8

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TESTING RESULTS AND DISCUSSION

The first step before testing involved the panel preparation. After discussions with George Appiah, it was decided to use hot rolled steel panels. These panels were purchased from ACT in Hillsdale, MI. The panels are GM 16-3U and were 4"x6" or 4"x12" X.071 HRS de-burred with a center punched hole at one end. These panels were washed to remove processing oil with Toluene and allowed to dry for 24 hours before being coated. Coatings were applied by brush or drawdown bars to obtain the dry film thicknesses recommended by the manufacturers. Table 1 shows the coating process and the dry film thicknesses achieved.

Table 1

COAT NUMBER AND DRY FILM	HEMPLE 3 COAT CONTROL SYSTEM	RUST BULLET SILVER	RUST BULLET SILVER W/HEMPADUR TOP COAT	RUST BULLET BLACK SHELL	RUST BULLET BLACK SHELL W/HEMPADUR TOP COAT
1	Hempadur Zinc @ 2mil dft.	Silver @ 2.5mil dft.	Rust Bullet Silver @ 2.5mil dft.	Black Shell @ 3mil dft.	Black Shell @ 3mil dft.
2	24hrs-Hempadur 45141@ 3mil dft.	24hrs-Silver @ 2.5mil dft.	48hrs-Rust Bullet Silver @ 2.5mil dft.	24hrs-Black Shell @ 3mil dft.	24hrs-Black Shell @ 3mil dft.
3	72hrs-Hempadur 45141@ 3mil dft.	72hrs-Silver @ 2.5mil dft.	24hrs-Rust Bullet Silver @ 2.5mil dft.	24hrs-Black Shell @ 3mil dft.	48hrs-Black Shell @ 3mil dft.
4	48hrs-Hempathane 55210@ 2mil dft.	24hrs-Silver @ 2.5mil dft.	24hrs-Rust Bullet Silver @ 2.5mil dft.	-----	24hrs-Hempathane 55210@ 2mil dft.
5	------	------	24hrs-Hempathane 55210@ 2mil dft.	-----	-----
Total	**10 mil dft.**	**10 mil dft.**	**12 mil dft.**	**9 mil dft.**	**11 mil dft.**

* Table hours represent the time between coats

Most of the films applied with no problems; however, we did have outgassing problems with the Black Shell material. This problem occurred at various thicknesses and recoat intervals. It should be noted at this point both of the Rust Bullet products are moisture cure systems. The Hempathane top coat had poor opacity and barely hid at the recommended dry film thickness. When the coating process was completed, the panels were placed in the testing apparatuses as soon as possible.

Three 4"x6" panels from each system were placed in the Q-Lab Cleveland Condensing Cabinet ASTM D2247. The temperature was maintained at 38C and 95% Relative Humidity. Panel observations were made at 100, 250, 500, 750 and 1000 hours with gloss readings taken one week after the 1000 hour exposure. The gloss results are reported in Table 2.

Table 2

HUMIDITY							AVG		CHANGE	
	20	60	20	60	20	60	20	60	20	60
Hemple control 1	26.6	71.2	25.6	67.8	20.5	68.7	24.2	69.2	-23.9	-14.7
Hemple control 2	16.9	57.5	24.0	67.8	18.5	59.9	19.8	61.7	-28.3	-22.2
Hemple control 3	23.0	62.2	21.3	61.4	22.9	64.0	22.4	62.5	-25.7	-21.4
Silver bullets TD 1	3.4	17.7	3.7	21.2	4.1	24.4	3.7	21.1	-0.3	-3.0
Silver bullet STD 2	4.0	23.5	4.0	24.5	4.3	26.0	4.1	24.7	0.0	0.6
Silver bullet std 3	5.0	28.8	4.6	27.0	5.0	28.6	4.9	28.1	0.8	4.1
Silver bullet + top coat 1	13.6	51.3	13.2	51.5	16.5	55.5	14.4	52.8	-19.3	-24.0
Silver bullet + top coat 2	14.8	49.3	15.3	50.7	11.4	47.3	13.8	49.1	-19.9	-27.7
Silver bullet + top coat 3	12.2	51.5	13.8	54.5	17.1	57.1	14.4	54.4	-19.4	-22.4
Black shell 1	78.3	86.2	77.9	84.2	83.7	87.5	80.0	86.0	9.7	-6.2
Black shell 2	62.2	85.0	67.4	84.8	66.2	88.0	65.3	85.9	-5.0	-6.2
Black shell 3	79.9	88.9	77.6	88.8	73.8	87.8	77.1	88.5	6.8	-3.7
Black shell + top coat 1	27.2	63.3	26.9	64.2	21.8	62.7	25.3	63.4	-17.4	-16.7
Black shell + top coat 2	30.0	68.6	25.9	63.1	22.0	61.7	26.0	64.5	-16.8	-15.6
Black shell + top coat 3	24.0	62.1	23.3	61.2	21.8	61.8	23.0	61.7	-19.7	-18.4

* Control glosses are listed at the bottom of Table 3.

The gloss readings were compared to control panels that had not been exposed. None of the systems showed any blistering, loss of adhesion, or coat-to-coat delamination during the test cycle. The Silver Bullet did darken to the control but had no other problems. The biggest change seen was in the Hempathane top coat. Not only was there a gloss loss and blush; by 1000 hours the panel had become water spotted/streaked and did not recover after two weeks at 22C and 30% Relative Humidity. The complete observations are in ATTACHMENT 1.

The systems were also tested according to ASTM G154. The cycle consisted of 8 hours of QUV at 60C followed by a 4-hour condensation cycle at 50C. This was repeated for a total of 1000 hours. Two 4"x6" panels from each system were exposed. The panels received visual inspections at the 100-, 250-, 500-, 750- and 1000-hour marks. Panels were compared to control panels for gloss, color change, film defects, etc. at each inspection. The complete observations are noted in ATTACHMENT 2. The actual gloss readings were taken at the end of the test and are compared to the retain readings in Table 3.

Table 3

QUV							AVG		CHANGE	
	20	60	20	60	20	60	20	60	20	60
Hemple control 1	34.1	77.3	33.2	76.6	33.4	76.1	33.6	76.7	-14.6	-7.2
Hemple control 2	27.0	73.4	36.1	78.0	21.8	72.6	28.3	74.7	-19.8	-9.2
Silver bullet std 1	2.3	9.0	2.1	8.5	2.2	8.9	2.2	8.8	-1.9	-15.3
Silver bullet std 2	2.2	8.9	2.3	9.1	2.2	9.2	2.2	9.1	-1.8	-15.0
Silver bullet + top coat 1	19.5	58.6	19.9	59.5	20.6	60.3	20.0	59.5	-13.7	-17.3
Silver bullet + top coat 2	21.6	61.4	19.2	60.7	18.3	59.8	19.7	60.6	-14.0	-16.1
Black shell 1	37.9	76.0	35.5	75.4	27.5	71.3	33.6	74.2	-36.7	-17.9
Black shell 2	15.1	58.6	16.2	59.4	10.8	52.8	14.0	56.9	-56.3	-35.2
Black shell + top coat 1	34.1	75.0	30.6	73.8	29.8	74.3	31.5	74.4	-11.2	-5.7
Black shell + top coat 2	34.0	76.1	29.1	73.1	36.3	74.8	33.1	74.7	-9.6	-5.4
Ref	20	60	20	60	20	60	20	60		
Hemple retain	41.4	80.8	49.5	83.8	53.5	87.1	48.1	83.9		
Silver bullet retain	4.0	23.1	4.2	24.8	4.0	24.3	4.1	24.1		
Silver bullet + TC retain	38.9	80.2	34.3	76.5	28.0	73.6	33.7	76.8		
Black shell retain	73.9	92.7	67.9	92.0	69.1	91.8	70.3	92.2		
Black shell + TC retain	36.6	75.4	43.5	81.0	48.1	83.9	42.7	80.1		

All of the panels show a gloss loss and color change. The Hempathane top coats again showed water spotting/streaking that did not clear up after removing them from the QUV tester. The Silver Bullet panels had whitened considerably and showed signs of chalking.

The third performance test was for cold/hot cycling. The test was conducted from -20C to +65C with a 1-hour ramp up and down. In addition, panels were held at the upper and lower temperatures for 1 hour. The test duration was 20 cycles over a 10-day period. Three 4"x12" panels for each of the five systems were tested. Observations were taken at 5, 10, 15 and 20 cycles. There were no changes to any of the panels exposed.

The last of the performance tests was ASTM B117-11 Salt Spray. This test was run at 35C, racks 15 degrees from vertical, 5% salt solution, PH of 6.8 and a solution collection of 1.3 mL per 80 cmsq. The panels were rated at 100, 250, 500, 750 and 1000 hours using ASTM D1654, ASTM D610 and ASTM D714. These methods are in ATTACHMENT 3. Three 4"x12" panels from each system were tested. The backs and edges of the panels were protected to prevent rust from spreading from unpainted areas. All panels/systems were rated as 10's through the 750-hour inspection. The 1000-hour inspection did start to show some differences in performance. The Silver Bullet had the best overall performance with no blistering or rusting. The Hemple control panels and the Black Shell without top coat were the next best with only slight blistering and very minor rust. The Silver Bullet and Black Shell performed the worst for blistering. They were equal for rust so I would have to believe the top coat (Hempathane) is pulling away from the base coats. The blisters may not be apparent on the panels when you receive them as they tend to dry out when no longer exposed. The full results are in ATTACHMENT 4.

All five systems have good moisture resistance and reasonable corrosion properties. There were no adhesion failures between any of the layers in the systems. I am disappointed by the tendency of the Hempathane top coat to water spot/streak when exposed to humidity and QUV testing. It was the only exposed product to do so. The Hempathane adheres well to both the Rust Bullet products as long as the recoat windows are adhered to. Both systems offer some application advantages/disadvantages.

The Rust Bullet products are moisture cure. Once the cans are opened, the products will form a very thick skin if the can is resealed and not evacuated with nitrogen. It will also react if a brush/roller was contaminated with moisture and that was introduced into the can. The advantages are that both products are one package and require no mixing of parts which can lead to errors. They dry faster and have no pot life like two component systems. Moisture cure systems can also outgas causing blisters or bubbles to be trapped in the dry film. The dft. must be controlled to prevent this.

The Hemple system components can be opened, part of the container removed, and resealed without worrying about skinning. The components must be carefully measured out and thoroughly mixed to ensure system performance. You must use three products to achieve what you get with one or two with the Rust Bullet. The Hemple products are easier to clean up after because of their slower dry and better solvency. You must adhere to the manufacturers recoat schedule as above. They are more forgiving about dft. thickness with no worry about outgassing.

You may reach me by email smoore@eaglabs.com or my direct phone number 00+1+314+227-0852 if you would like to discuss the results of our testing.

ATTACHMENTS

Enclosed please find the following original data generated during the analysis.

ENCLOSURE	DESCRIPTION
ATTACHMENT 1	Humidity Cabinet Observations
ATTACHMENT 2	QUV Observations
ATTACHMENT 3	ASTM Test Methods
ATTACHMENT 4	Salt Spray Observations

An invoice is being sent to your accounts payable department. Samples are disposed of on the first Monday of every month after being retained a minimum of 30 days unless you direct us otherwise in writing. Please review the Terms & Conditions that governs analysis work. Thank you for consulting Chemir Analytical Services. If you have any questions regarding this work, or if we can be of any further assistance, please call us at (314) 291-6620.

Sincerely,
Chemir Analytical Services

Scott E. Moore
Specialist – Paintings and Coatings

SM:td

Enclosures

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ATTACHMENT 1

	100 hrs	250 hrs	500 hrs	750 hrs	1000 hrs
CONTROL 1	Top coat, 2 possible blisters	Gloss Loss	Gloss change, color lighter compared to reference	Gloss loss, looks less smooth but close to reference	Gloss loss, lighter color, water marks
CONTROL 2	No change	Gloss Loss	Gloss change, color lighter compared to reference	Gloss loss, looks less smooth but close to reference	Gloss loss, lighter color, water marks
CONTROL 3	No change	Gloss Loss	Gloss change, color lighter compared to reference	Gloss loss, looks less smooth but close to reference	Gloss loss, lighter color, water marks
SILVER BULLET STD 1	No change	No change	Spots of darker grey	darkening verses reference	Drawdown pattern more accentuated but general darkening reduced
SILVER BULLET STD 2	No change	No change	Spots of darker grey	darkening verses reference	Drawdown pattern more accentuated but general darkening reduced
SILVER BULLET STD 3	No change	No change	No change compared to reference	darkening verses reference	Drawdown pattern more accentuated but general darkening reduced
SILVER BULLET + TOP COAT 1	No change	Gloss Loss	Gloss change, color lighter compared to reference	gloss loss verses reference	Gloss loss, lighter color, water marks
SILVER BULLET + TOP COAT 2	No change	Gloss Loss	Gloss change, color lighter compared to reference	gloss loss verses reference	Gloss loss, lighter color, water marks
SILVER BULLET + TOP COAT 3	No change	Gloss Loss	Gloss change, color lighter compared to reference	gloss loss verses reference	Gloss loss, lighter color, water marks
BLACKSHELL 1	No change	No change	No change compared to reference	pattern of something at bottom, no gloss or color change	Color blush, gloss change
BLACKSHELL 2	No change	No change	No change compared to reference	No change	Color blush, gloss change
BLACKSHELL 3	No change	No change	No change compared to reference	No change	Color blush, gloss change
BLACKSHELL + TOP COAT 1	No change	Gloss Loss, Top coat coating in trough	Gloss change, color lighter compared to reference	gloss loss verses reference	Gloss loss, lighter color, water marks
BLACKSHELL + TOP COAT 2	No change	Gloss Loss	Gloss change, color lighter compared to reference	gloss loss verses reference	Gloss loss, lighter color, water marks
BLACKSHELL + TOP COAT 3	No change	Gloss Loss	Gloss change, color lighter compared to reference	gloss loss verses reference	Gloss loss, lighter color, water marks

	100 hrs	250 hrs	500 hrs	750 hrs	1000 hrs
CONTROL 1	No change	Gloss Change	Gloss loss compared to reference	Gloss loss compared to reference	Gloss loss, color lightening, water spots
CONTROL 2	No change	Gloss Change	Gloss loss compared to reference	Gloss loss compared to reference	Gloss loss, color lightening, water spots
SILVER BULLET STD 1	color change, tan/grey streaks, verticle (7)	Lines of color gone now	No observable change	No observable change	Exposed area considerably whiter, also tan line above grey area leading into unexposed portion
SILVER BULLET STD 2	same streaking as above	rust lines gone from front	No observable change	No observable change	Exposed area considerably whiter, also tan line above grey area leading into unexposed portion
SILVER BULLET + TOP COAT 1	No change	Gloss Change	Gloss loss compared to reference	Gloss loss compared to reference	Gloss loss, color lightening, water spots
SILVER BULLET + TOP COAT 2	No change	Gloss Change	Gloss loss compared to reference	Gloss loss compared to reference	Gloss loss, color lightening, water spots
BLACKSHELL 1	No change	Color Change, greyer	Greyer compared to reference	Greyer, Gloss loss compared to reference	Gloss loss, color changed to lighter
BLACKSHELL 2	No change	Color Change, greyer	Greyer compared to reference	Greyer, Gloss loss compared to reference	Gloss loss, color changed to lighter
BLACKSHELL + TOP COAT 1	No change	Gloss Change	Gloss loss compared to reference	Gloss loss compared to reference	Gloss loss, color lightening, water spots
BLACKSHELL + TOP COAT 2	No change	Gloss Change	Gloss loss compared to reference	Gloss loss compared to reference	Gloss loss, color lightening, water spots

Designation: D 610 – 07

Society for Protective Coatings
SSPC-VIS-2

Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces[1]

This standard is issued under the fixed designation D 610; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the evaluation of the degree of rusting on painted steel surfaces. The visual examples which depict the percentage of rusting given in the written specifications form part of the standard. In the event of a dispute, the written definition prevails. These visual examples were developed in cooperation with SSPC: The Society for Protective Coatings to further standardization of methods. The photographs can be used to estimate the percentage of other coating defects on various substrates. This standard does not include evaluation of rust propagation around an initially prepared scribe, score, or holiday.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Adjunct/SSPC: The Society for Protective Coatings:*

SSPC-VIS 2/ASTM D 610 Standard Method of Evaluating Degrees of Rusting on Painted Steel Surfaces[2]

3. Significance and Use

3.1 The amount of rusting beneath or through a paint film is a significant factor in determining whether a coating system should be repaired or replaced. This test method provides a standardized means for quantifying the amount and distribution of visible surface rust.

3.2 The degree of rusting is evaluated using a zero to ten scale based on the percentage of visible surface rust.

3.3 The distribution of the rust is classified as spot rust, general rust, pinpoint rust or hybrid rust.

4. Interferences

4.1 The visual examples that are part of this test method and the associated rust-grade scale cover only rusting evidenced by visible surface rust.

4.2 The use of the visual examples requires the following cautions:

4.2.1 Some finishes are stained by rust. This staining must not be confused with the actual rusting involved.

4.2.2 Accumulated dirt or other material may make accurate determination of the degree of rusting difficult.

4.2.3 Certain types of deposited dirt that contain iron or iron compounds may cause surface discoloration that should not be mistaken for corrosion.

4.2.4 Failure may vary over a given area. Discretion must therefore be used when selecting a single rust grade or rust distribution that is to be representative of a large area or structure, or in subdividing a structure for evaluation.

4.2.5 The color of the finish coating should be taken into account in evaluating surfaces as failures will be more apparent on a finish that shows color contrast with rust, such as used in these reference standards, than on a similar color, such as an iron oxide finish.

5. Procedure

5.1 Select an area to be evaluated.

5.2 Determine the type of rust distribution using definitions in Table 1 and visual examples in Fig. 1, Fig. 2, and Fig. 3.

5.3 Estimate percentage of surface area rusted using the visual examples in Fig. 1, Fig. 2, and Fig. 3 or SSPC-VIS 2, or both, by electronic scanning techniques or other method agreed upon by contracting parties.

5.4 Do not consider flow of corrosion products onto the surface of intact coating (that is, "rust bleed" or staining) as part of the surface area rust. It may be helpful to wipe the surface with a damp cloth to remove the rust bleed before evaluating.

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[1] This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

This test method has been jointly approved by ASTM and SSPC: The Society for Protective Coatings.

Current edition approved July 1, 2007. Published July 2007. Originally approved in 1941. Last previous edition approved in 2001 as D 610 – 01.

[2] Colored visual examples are available at a nominal cost from ASTM International Headquarters (request Adjunct ADJD0610A), SSPC Publication No. 00-08 from The Society for Protective Coatings (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656, http://www.sspc.org.

TABLE 1 Scale and Description of Rust Ratings

Rust Grade	Percent of Surface Rusted	Visual Examples		
		Spot(s)	General (G)	Pinpoint (P)
10	Less than or equal to 0.01 percent		None	
9	Greater than 0.01 percent and up to 0.03 percent	9–S	9–G	9–P
8	Greater than 0.03 percent and up to 0.1 percent	8–S	8–G	8–P
7	Greater than 0.1 percent and up to 0.3 percent	7–S	7–G	7–P
6	Greater than 0.3 percent and up to 1.0 percent	6–S	6–G	6–P
5	Greater than 1.0 percent and up to 3.0 percent	5–S	5–G	5–P
4	Greater than 3.0 percent and up to 10.0 percent	4–S	4–G	4–P
3	Greater than 10.0 percent and up to 16.0 percent	3–S	3–G	3–P
2	Greater than 16.0 percent and up to 33.0 percent	2–S	2–G	2–P
1	Greater than 33.0 percent and up to 50.0 percent	1–S	1–G	1–P
0	Greater than 50 percent		None	

Rust Distribution Types:

S: Spot Rusting—Spot rusting occurs when the bulk of the rusting is concentrated in a few localized areas of the painted surface. The visual examples depicting this type of rusting are labeled 9-S through 1-S (See Fig. 1, Fig. 2, and Fig. 3).

G: General Rusting—General rusting occurs when various size rust spots are randomly distributed across the surface. The visual examples depicting this type of rusting are labeled 9-G through 1-G. (See Fig. 1, Fig. 2, and Fig. 3).

P: Pinpoint Rusting—Pinpoint rusting occurs when the rust is distributed across the surface as very small individual specks of rust. The visual examples depicting this type of rusting are labeled 9-P through 1-P. (See Fig. 1, Fig. 2, and Fig. 3).

H: Hybrid Rusting—An actual rusting surface may be a hybrid of the types of rust distribution depicted in the visual examples. In this case, report the total percent of rust to classify the surface. 9-H through 1-H.

5.5 Use percentage of surface area rusted to identify rust grade (see Table 1). Assign rust rating using rust grade of 0-10 followed by the type of rust distribution identified by *S* for spot, *G* for general, *P* for pinpoint or *H* for Hybrid.

NOTE 1—The numerical rust grade scale is an exponential function of the area of rust. Plotting the rust grade versus area of rust results in a straight line in semilogarithmic coordinates. The slope of the line changes at 10 % of the area rusted to allow it to resolve differences below 10 % across rust grades from 10 to 4 while including 10 to 100 % in rust grades 3 through 0.

5.6 The visual examples are not required for use of the rust-grade scale since the scale is based upon the percent of the area rusted and any method of assessing area rust may be used to determine the rust grade.

6. Report

6.1 Identify sample or area evaluated.

6.2 Report rust grade using rating of 0-10.

6.3 Report rust distribution using *S* for Spot, *G* for General, *P* for Pinpoint and *H* for Hybrid.

7. Precision and Bias

7.1 No precision or bias statement can be made for this test method.

8. Keywords

8.1 corrosion; rusting

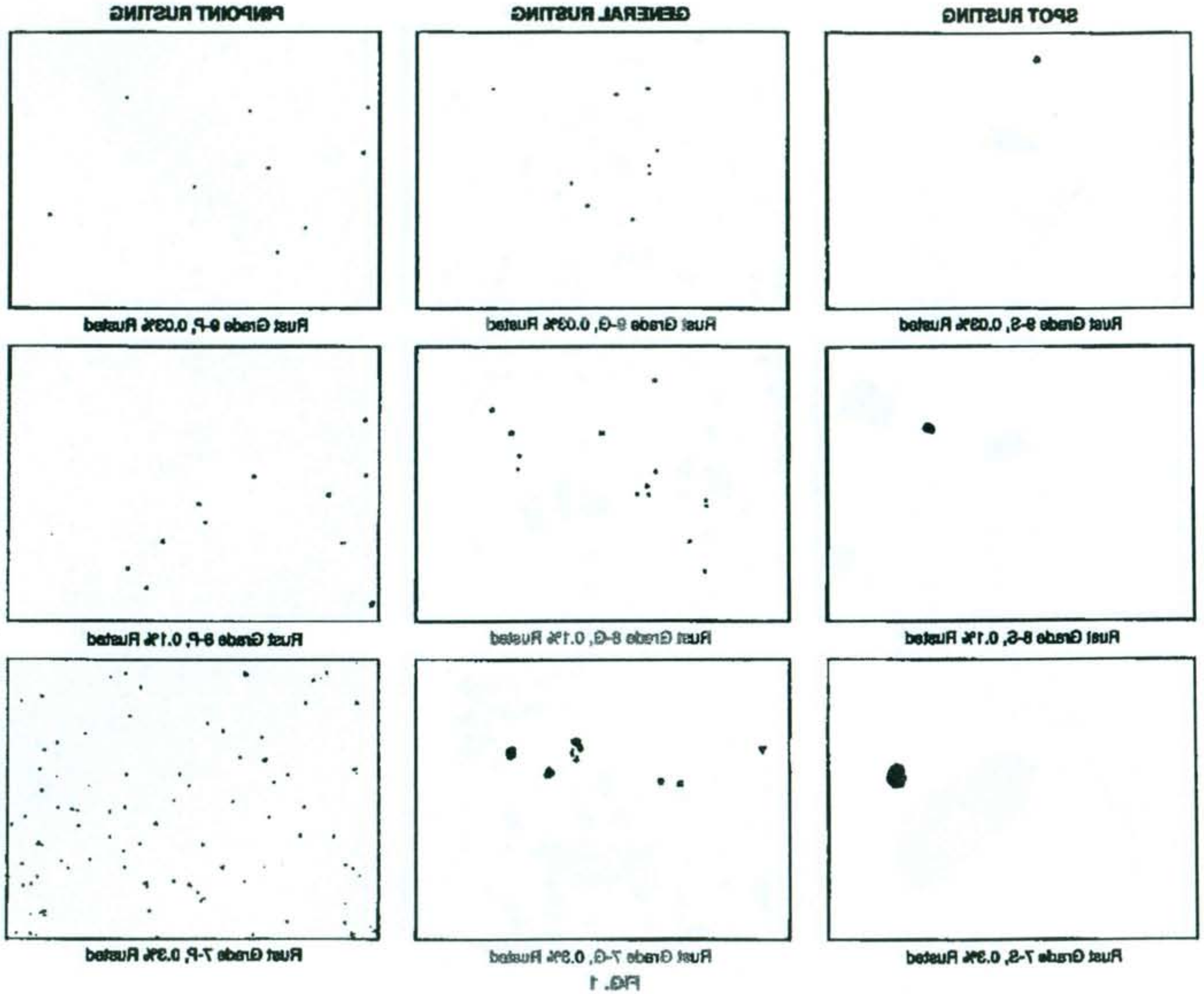

FIG. 1 Examples of Area Percentages

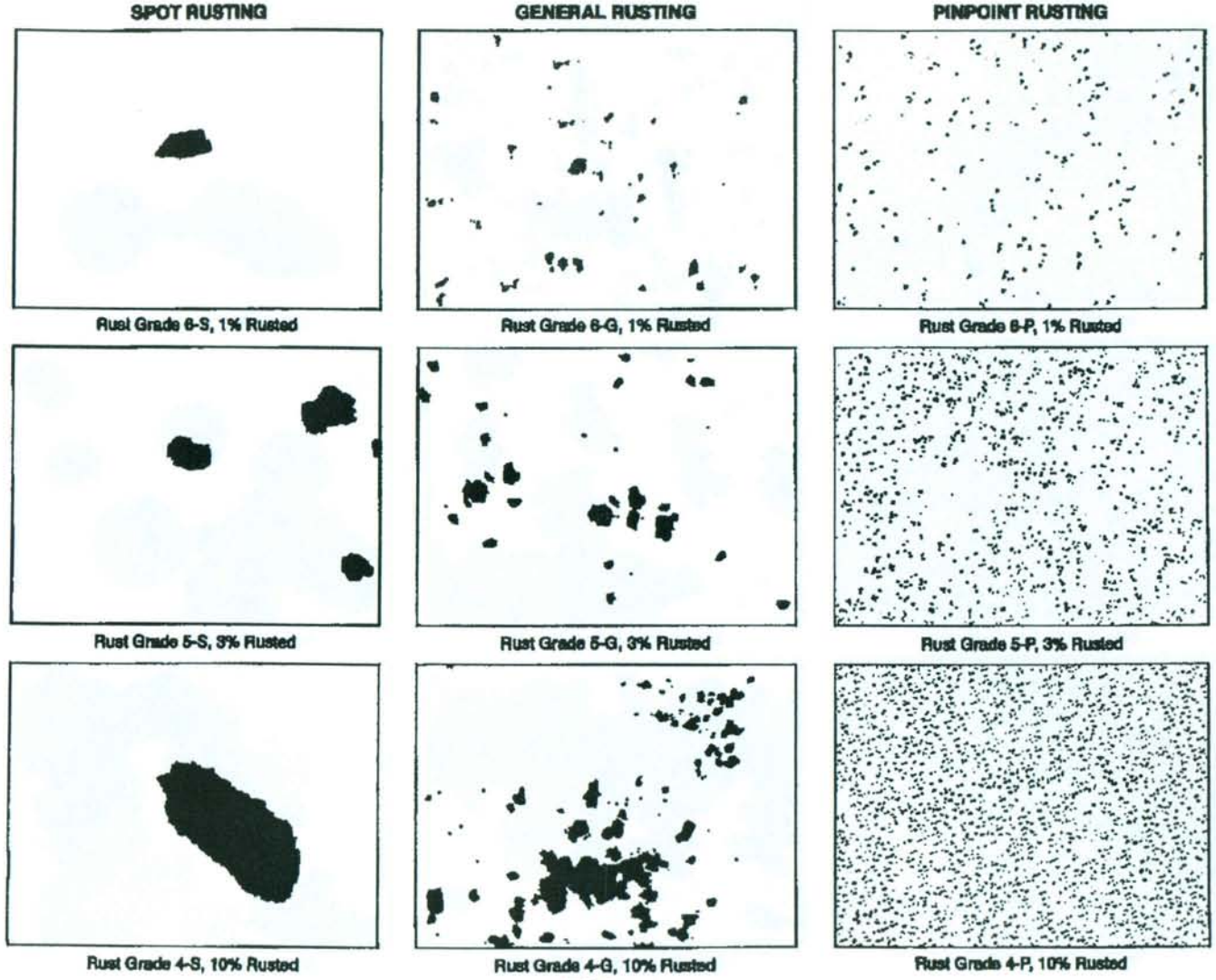

FIG. 2 Examples of Area Percentages

FIG. 2

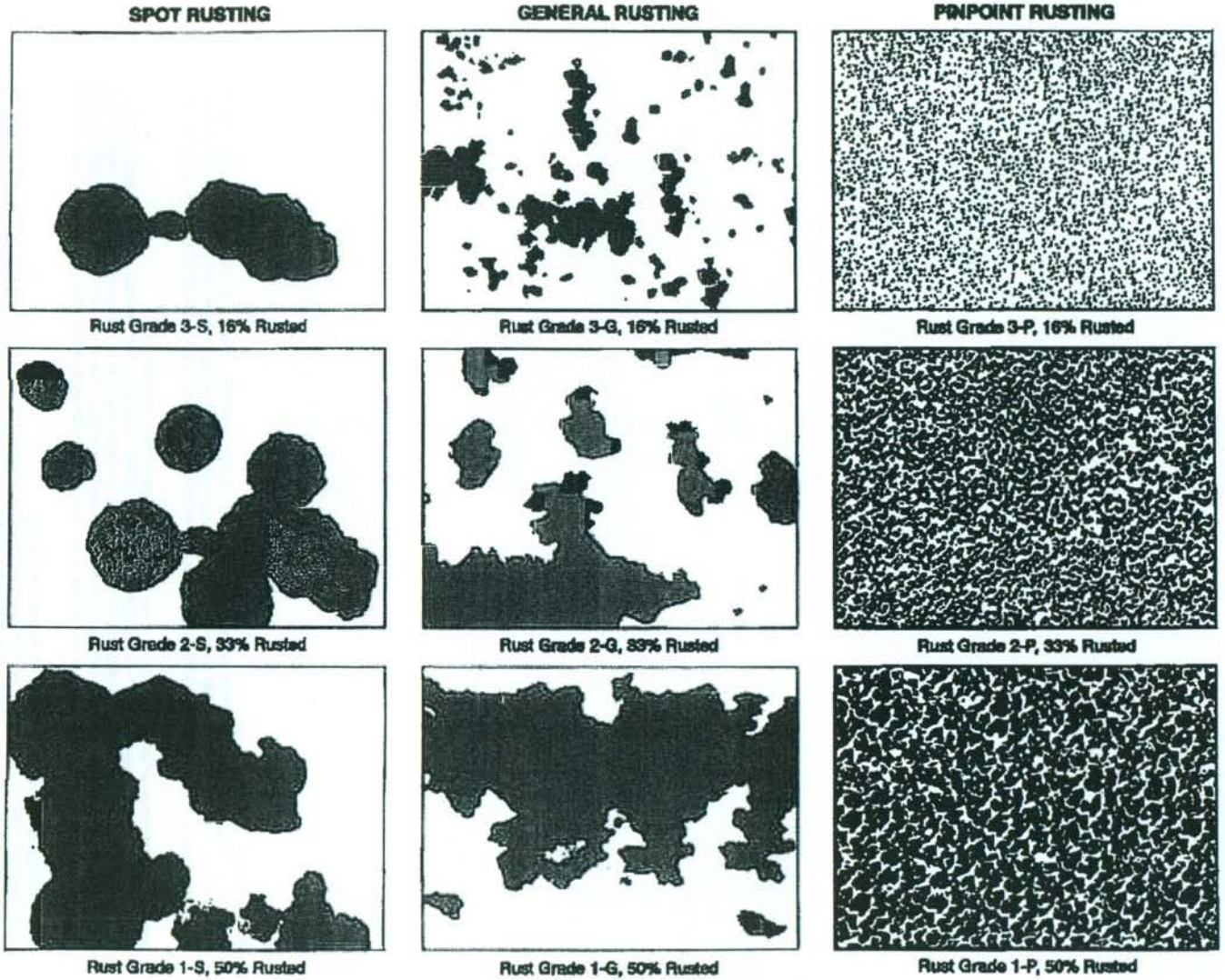

FIG. 3 Examples of Area Percentages

FIG. 3

Designation: D 714 – 87 (Reapproved 2000)

Standard Test Method for Evaluating Degree of Blistering of Paints[1]

This standard is issued under the fixed designation D 714; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method employs photographic reference standards to evaluate the degree of blistering that may develop when paint systems are subjected to conditions which will cause blistering. While primarily intended for use on metal and other nonporous surfaces, this test method may be used to evaluate blisters on porous surfaces, such as wood, if the size of blisters falls within the scope of these reference standards. When the reference standards are used as a specification of performance, the permissible degree of blistering of the paint system shall be agreed upon by the purchaser and the seller.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Significance and Use

2.1 A phenomenon peculiar to painted surfaces is the formation of blisters relative to some system weakness. This test method provides a standard procedure of describing the size and density of the blisters so that comparisons of severity can be made.

3. Reference Standards

3.1 The photographic reference standards are glossy prints.[2] Figs. 1-4 are reproductions of these standards and are included to illustrate two characteristics of blistering: size and frequency.

3.2 *Size*—Reference standards have been selected for four steps as to size on a numerical scale from 10 to 0, in which No. 10 represents no blistering. Blistering standard No. 8 represents the smallest size blister easily seen by the unaided eye. Blistering standards Nos. 6, 4, and 2 represent progressively larger sizes.

3.3 *Frequency*—Reference standards have been selected for four steps in frequency at each step in size, designated as follows:

Dense, *D*,
Medium dense, *MD*,
Medium, *M*, and
Few, *F*.

NOTE 1—A quantitative physical description of blistering would include the following characteristics determined by actual count:
Size distribution in terms of mensuration units,
Frequency of occurrence per unit area,
Pattern of distribution over the surface, and
Shape of blister
For the usual tests, an actual count is more elaborate than is necessary.

4. Procedure

4.1 Subject the paint film to the test conditions agreed upon by the purchaser and the seller. Then evaluate the paint film for the degree of blistering by comparison with the photographic reference standards in Figs. 1-4.

5. Report

5.1 Report blistering as a number (Note 2) designating the size of the blisters and a qualitative term or symbol indicating the frequency.

5.2 Intermediate steps in size or frequency of blisters may be judged by interpolation.

5.3 When the distribution of blisters over the area has a nonuniform pattern, use an additional phrase to describe the distribution, such as "small clusters," or "large patches."

NOTE 2—The number refers to the largest size blister that is numerous enough to be representative of the specimen. For example, photographic standard No. 4, "Dense," has blisters ranging in size from about No. 7 to No. 4, inclusive.

6. Keywords

6.1 blistering; corrosion; evaluations; reference standards

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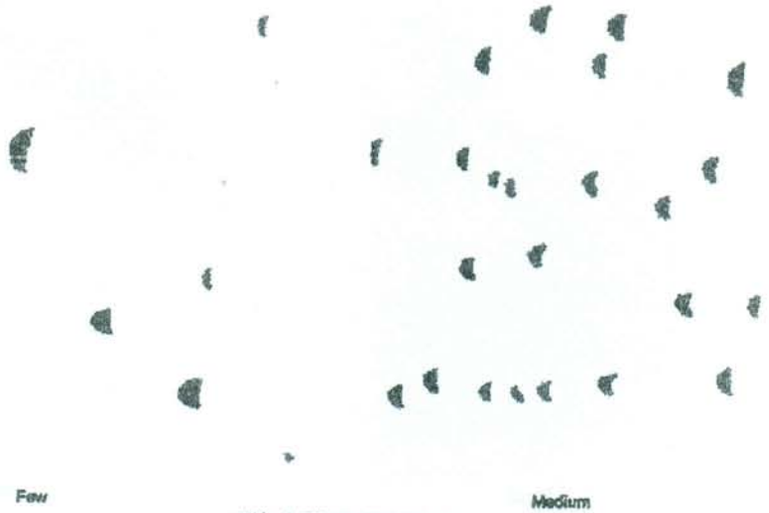
[1] This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.25 on Pictorial Standards of Coating Defects.

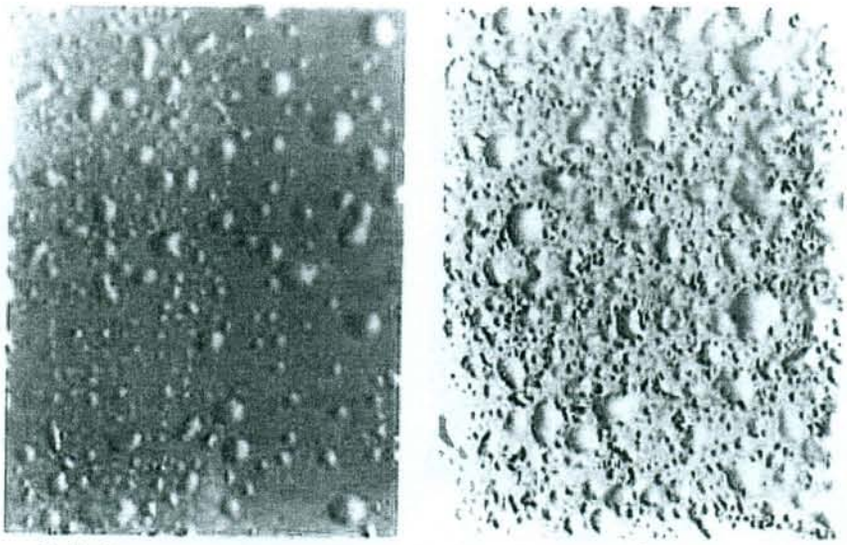
Current edition approved May 29, 1987. Published July 1987. Originally published as D 714 – 43 T. Last previous edition D 714 – 56 (1981).

[2] Glossy prints of the photographic reference standards showing types of blistering are available at a nominal charge from ASTM Headquarters. Order Adjunct ADJD0714.



Few Medium

FIG. 1 Blister Size No. 2



Medium Dense Dense

FIG. 1 *(continued)*

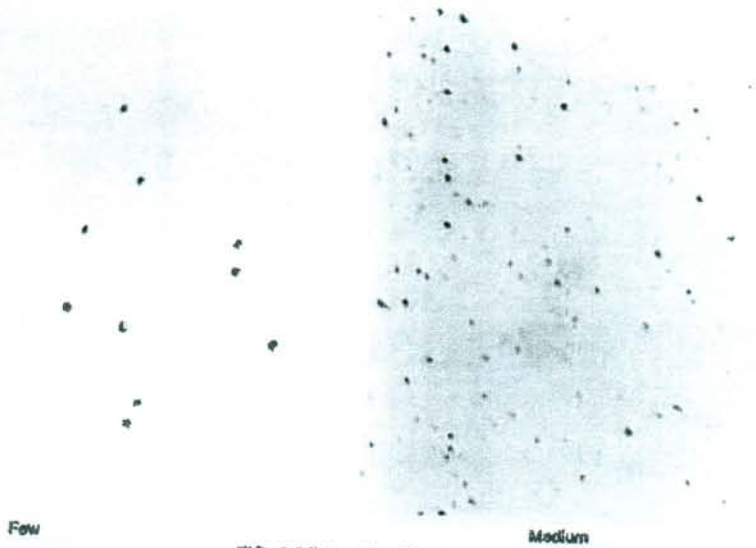


FIG. 2 Blister Size No. 4

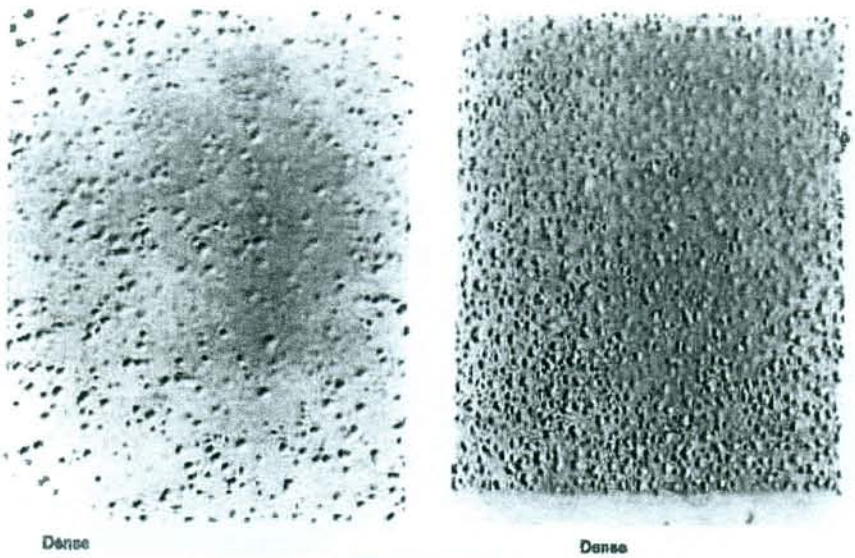
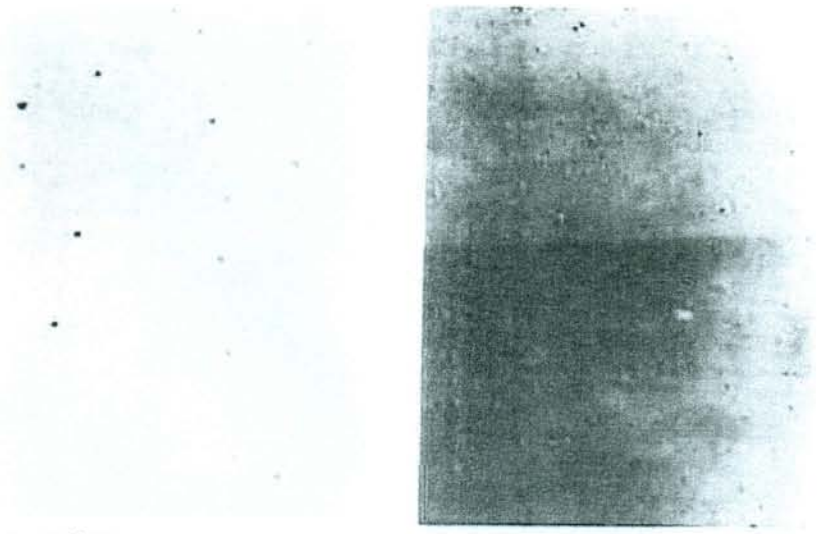
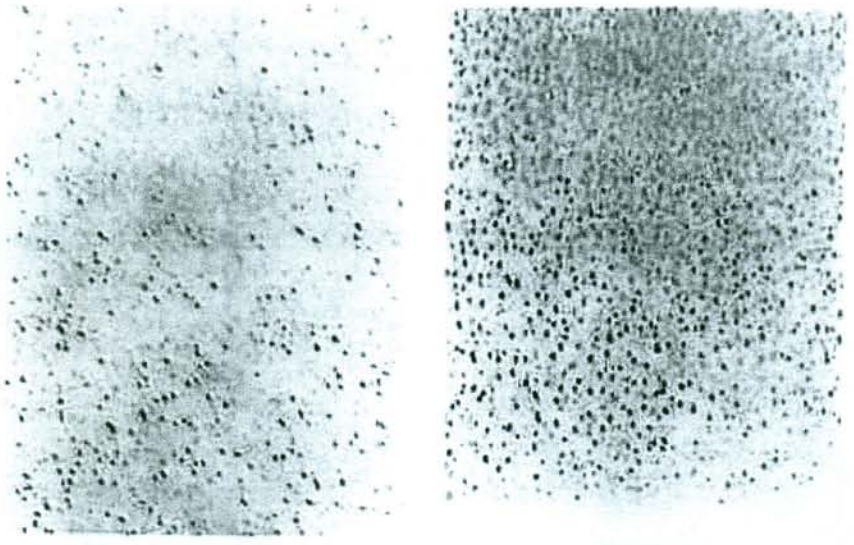


FIG. 2 *(continued)*



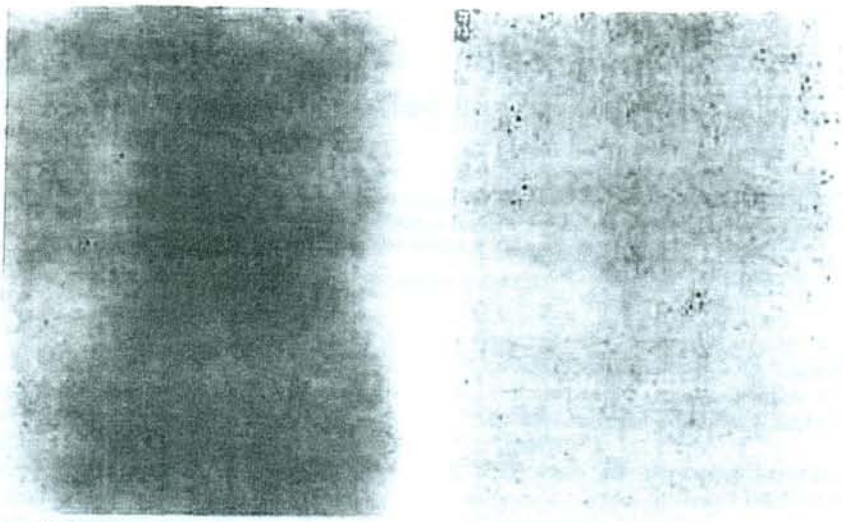
Few Medium

FIG. 3 Blister Size No. 8



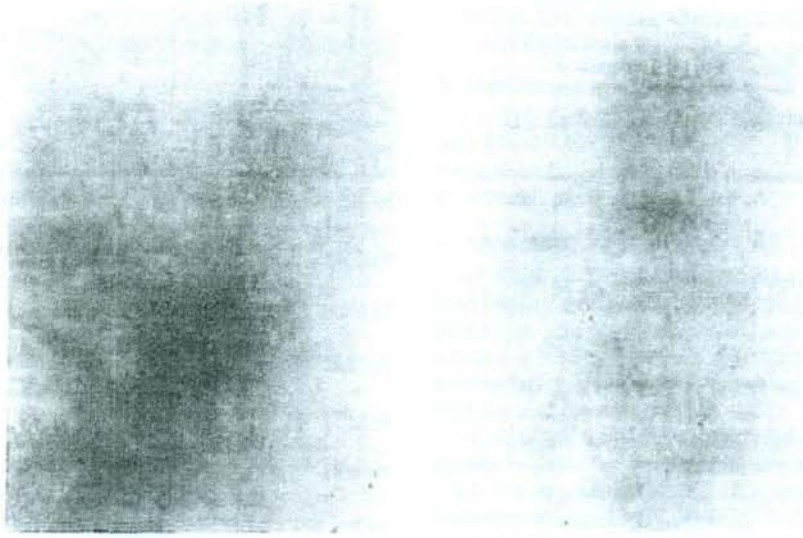
Medium Dense Dense

FIG. 3 *(continued)*



Medium Dense Dense

FIG. 4 *(continued)*



Few Medium

FIG. 4 Blister size No. 8

Designation: D 1654 – 92 (Reapproved 2000)

Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments[1]

This standard is issued under the fixed designation D 1654; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the treatment of previously painted or coated specimens for accelerated and atmospheric exposure tests and their subsequent evaluation in respect to corrosion, blistering associated with corrosion, loss of adhesion at a scribe mark, or other film failure.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

B 117 Practice for Operating Salt Spray (Fog) Testing Apparatus[2]

D 610 Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces[3]

D 714 Test Method for Evaluating Degree of Blistering of Paints[4]

D 870 Practice for Testing Water Resistance of Coatings Using Water Immersion[4]

D 1014 Practice for Conducting Exterior Exposure Tests of Paints on Steel[4]

D 1735 Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus[4]

D 2247 Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity[4]

D 2803 Guide for Filiform Corrosion Resistance of Organic Coatings on Metal[4]

D 4141 Practice for Conducting Accelerated Outdoor Exposure Tests of Coatings[4]

D 4585 Practice for Testing Water Resistance of Coatings Using Controlled Condensation[4]

D 4587 Practice for Conducting Tests on Paint and Related Coatings and Materials Using a Fluorescent UV-Condensation Light- and Water-Exposure Apparatus[4]

G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[5]

G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[5]

G 85 Practice for Modified Salt Spray (Fog) Testing[6]

G 87 Practice for Conducting Moist SO_2 Tests[6]

2.2 *ANSI Standard:*

B94.50 Single-Point Cutting Tools, Basic Nomenclature and Definitions for[7]

3. Significance and Use

3.1 This method provides a means of evaluating and comparing basic corrosion performance of the substrate, pretreatment, or coating system, or combination thereof, after exposure to corrosive environments.

4. Apparatus

4.1 *Scribing Tool*—A straight-shank tungsten carbide tip, lathe cutting tool (ANSI B94.50, Style E) or carbide-tipped pencil-type tool is recommended. Any other type of scribing instrument such as a scalpel, razor blade, knife, or other sharp pointed tool is unacceptable unless agreed upon between the producer and the user.

4.2 *Straightedge*—Any straightedge of sufficient length and rigidity to guide the scribing tool in a straight line.

4.3 *Air Source*—A source of compressed air capable of delivering at least 10 ft^3/min (4.72 L/s) at 80 psi (552 kPa).

4.4 *Air Gun*—An air dusting gun and nozzle combination[8] to meet the following specification:

Air Consumption, ft^3/min (m^3/min)	Pressure, psi (kPa)	Nozzle Diameter, in. (mm)

[1] This method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.25 on Evaluation of Weathering Effects.

Current edition approved Oct. 15, 1992. Published December 1992. Originally published as D 1654 – 59. Last previous edition D 1654 – 79a (1984) ε1.

[2] *Annual Book of ASTM Standards*, Vol 03.02.

[3] *Annual Book of ASTM Standards*, Vol 06.02.

[4] *Annual Book of ASTM Standards*, Vol 06.01.

[5] Discontinued; G 23 replaced by G 152 and G 153; G 26 replaced by G 155. See 2000 *Annual Book of ASTM Standards*, Vol 14.04.

[6] *Annual Book of ASTM Standards*, Vol 03.02.

[7] Available from American National Standards Institute, 13th Floor, 11 W. 42nd St., New York, NY 10036.

[8] Spray gun and nozzles, Model No. AA23LTP0020 have been found satisfactory and may be obtained from Spray Systems Co., North Avenue at Schmale Road, Wheaton, IL 60187. Equivalents may be used.

8.4 (0.24)	80 (550)	0.12 (3.0)

4.4.1 A guard consisting of barriers, baffles, or screens is required to protect the operator and other individuals near the area where the air is being used. The guard must be placed between the air nozzle and the operator. A device such as a sand-blasting cabinet has been found to be acceptable.

NOTE 1—The use of an air gun without a guard is in violation of the U. S. Occupational Safety and Health Administration regulation.

4.5 *Scraping Tool*—A rigid spatula, knife, or similar instrument with no sharp edges or sharp corners.

4.6 *Scale*—Any rule with 1-mm divisions.

5. Preliminary Treatment of Test Specimens

5.1 *Scribed Specimens*:

5.1.1 Where specified or agreed upon, prepare each specimen for testing by scribing it in such a manner that the scribe can be exposed lengthwise when positioned in the test cabinet. This position will allow solution droplets to run lengthwise along the scribe.

5.1.2 Scribe the specimen by holding the tool at approximately a 45° angle to the surface. Position the tool so that only the carbide tip is in contact with the surface. Pull the scribing tool to obtain a uniform V-cut through the coating that is being tested. Inspect the tool frequently for dulling, chipping or wear and replace or repair as needed. The scribe should be of sufficient length to cover the significant test area, but should not contact the edge of the specimen. The scribe must penetrate all organic coating layers on the metal, leaving a uniformly bright line of burrs. The extent of scribe penetration through metallic coatings should be agreed upon between the producer and user. Quality of the scribe may be observed with the aid of low-power magnification. Note, mark, and describe defects, coding, and flaws that may affect results.

5.1.3 Scribe lines other than those of a single, straight nature may be used if agreed upon between the producer and the user.

5.1.4 Expose scribed specimens in accordance with 6.1 and rate in accordance with Section 7.

5.2 *Unscribed Specimens*—Specimens coated with paint undercoats, oils, or waxes may be evaluated without a scribe. Expose such specimens in accordance with Section 6 and rate for corrosion of the general surface in accordance with Section 8.

5.3 *Cut Edges*—Cut edges of panels may be exposed during testing, or protected by wax, tape, or other means as agreed upon between the producer and the user. If left unprotected, method of shearing panel edges should be agreed upon between the producer and user, noting whether edges are oriented in the "burr up" or "burr down" configuration.

5.4 *Deformation*—Deformation of test panels prior to exposure, if desired, should be agreed upon between the producer and user.

6. Exposure of Test Specimens

6.1 Expose test specimens in accordance with one or more of the following test methods or practices: B 117, D 610, D 714, D 870, D 1014, D 1735, D 2247, D 2803, D 4141, D 4585, D 4587, G 23, G 26, G 85, G 87, or any other applicable test method, as agreed upon between the producer and the user. The length of test and evaluation intervals should be agreed upon prior to exposure of specimens.

7. Procedure A—Evaluation of Scribed Specimens

7.1 *Method 1 (Air Blow-Off)*—Rinse each specimen after completion of the exposure period, using a gentle stream of water at a temperature up to 110°F (45°C). Holding the nozzle at approximately a 45° angle, blow along the entire scribe line, disturbing the surface adjacent to the scribe mechanically by the air nozzle to ensure an opening for the air blast. Complete the air blasting within 15 min of specimen removal from the exposure cabinet. If the air blasting cannot be completed within the prescribed time, immerse the specimens in water at room temperature or store in a plastic bag to avoid any drying effect.

7.2 *Method 2 (Scraping)*—Rinse the specimen after completion of the exposure period, using a gentle stream of water at a temperature up to 110°F (45°C). Scrape the specimen vigorously with an instrument described in 4.5 while under the gentle stream of the rinse water. Hold the scraper with its face perpendicular to the specimen surface and parallel to the scribe, moving it back and forth across the scribe to remove the coating that has been undercut and has suffered loss of adhesion only, not to remove the coating that still has adhesion. Complete the scraping within 15 min of specimen removal from the exposure cabinet. If scraping cannot be completed within the prescribed time, immerse the specimens in water at room temperature or store in a plastic bag to avoid any drying effect.

NOTE 2—Rinsing, scraping, or air blow off may not be appropriate in all cases, such as for interim ratings in coatinning tests. Alternative methods may be used if agreed upon between the producer and the user.

7.3 *Rating*—Rate the corrosion or loss of paint extending from a scribe mark as prescribed in Table 1. Record the representative mean, maximum, and minimum creepage from the scribe, and note whether or not the maximum is an isolated spot. Record creep values in millimeters, inches, or rating numbers, as agreed upon between producer and user.

7.3.1 Unless otherwise agreed upon by the producer and user, scribe creepage is defined as "one sided", that is, from the original scribe line to the creepage front. Also, rate in accordance with Table 2 the prevalence of corrosion on areas removed from the scribe.

8. Procedure B—Evaluation of Unscribed Areas

8.1 Rinse the specimen after completion of the exposure

TABLE 1 Rating of Failure at Scribe (Procedure A)

Representative Mean Creepage From Scribe		
Millimetres	Inches (Approximate)	Rating Number
Zero	0	10
Over 0 to 0.5	0 to 1/64	9
Over 0.5 to 1.0	1/64 to 1/32	8
Over 1.0 to 2.0	1/32 to 1/16	7
Over 2.0 to 3.0	1/16 to 1/8	6
Over 3.0 to 5.0	1/8 to 3/16	5
Over 5.0 to 7.0	3/16 to 1/4	4
Over 7.0 to 10.0	1/4 to 3/8	3
Over 10.0 to 13.0	3/8 to 1/2	2
Over 13.0 to 16.0	1/2 to 5/8	1
Over 16.0 to more	5/8 to more	0

TABLE 2 Rating of Unscribed Areas (Procedure B)

Area Failed, %	Rating Number
No failure	10
0 to 1	9
2 to 3	8
4 to 6	7
7 to 10	6
11 to 20	5
21 to 30	4
31 to 40	3
41 to 55	2
56 to 75	1
Over 75	0

period (Section 6), using a gentle stream of water at a temperature up to 100°F (40°C). Dry the surface of the specimen with paper towels or compressed air. Drying should be done in such a manner that the corrosion on the specimen surface is not disturbed.

8.2 Evaluate unscribed specimens for corrosion spots, blisters, and any other types of failure that may occur. Where the character of the failure permits, the photographic blister standards given in Test Method D 714 may be used to describe the results of the exposure test, with respect to size of blisters or corroded areas, while Method D 610 may serve to describe the frequency and distribution of rusting. Record the size, frequency, or area affected. Discount corrosion within ⅛in. (12.7 mm) of edges.

8.3 *Rating*—Record percent failed area or convert percent failure to rating numbers in accordance with Table 2 as agreed upon between the producer and user.

NOTE 3—Formation of under-film corrosion may be evaluated and reported in accordance with Table 2 if the film is first carefully stripped with a neutral stripper. Exercise care to avoid alteration of the corrosion pattern or pretreatment.

NOTE 4—Where the character of the failure permits, the photographic blister standards given in Test Method D 714 may be used to describe the results of the exposure test, in respect to size of blisters or corroded areas, while Method D 610 may serve to describe the frequency and distribution, if desired.

9. Procedure C—Evaluation of Unprotected Edges

9.1 If paint creepage from cut edges is tested, rate the corrosion or loss of paint extending from a cut edge in the same manner described for scribes in Procedure A.

10. Procedure D—Evaluation of Formed Areas

10.1 If tested samples contain bends, dimples, or other formed areas of interest, rate the extent of failure at these areas separately in the same manner described in Procedure B, or as agreed upon between the producer and user.

11. Report

11.1 The report shall include the following information, unless otherwise agreed upon between the producer and user:

11.1.1 All pertinent information regarding the conduct of each corrosion test, as prescribed in the specifications for each test,

11.1.2 Methods of scribing, shearing, or forming, or combination thereof, or test specimens.

11.1.3 Ratings of test specimens, including procedure(s) employed.

12. Precision and Bias

12.1 *Precision*—Since this is a method of evaluation based on measurements after various tests, the statement of precision applicable to each specific method of exposure to corrosive environments applies.

13. Keywords

13.1 blistering; corrosion; paints/related coatings/materials; creepage; edge/scribe; rust

Sample	Hours	D1654-08	D610-08(2012)	D714-02(2009)
Black Shell #1	100 03/17/13	10	10	No Blisters
Black Shell #2		10	10	No Blisters
Black Shell #3		10	10	No Blisters
Black Shell + T.C. #1		10	10	No Blisters
Black Shell + T.C. #2		10	10	No Blisters
Black Shell + T.C. #3		10	10	No Blisters
Silver Bullet #1		10	10	No Blisters
Silver Bullet #2		10	10	No Blisters
Silver Bullet #3		10	10	No Blisters
Silver Bullet + T.C. #1		10	10	No Blisters
Silver Bullet + T.C. #2		10	10	No Blisters
Silver Bullet + T.C. #3		10	10	No Blisters
Control #1		10	10	No Blisters
Control #2		10	10	No Blisters
Control #3		10	10	No Blisters

Sample	Hours	D1654-08	D610-08(2012)	D714-02(2009)
Black Shell #1	250 03/23/13	10	10	No Blisters
Black Shell #2		10	10	No Blisters
Black Shell #3		10	10	No Blisters
Black Shell + T.C. #1		10	10	No Blisters
Black Shell + T.C. #2		10	10	No Blisters
Black Shell + T.C. #3		10	10	No Blisters
Silver Bullet #1		10	10	No Blisters
Silver Bullet #2		10	10	No Blisters
Silver Bullet #3		10	10	No Blisters
Silver Bullet + T.C. #1		10	10	No Blisters
Silver Bullet + T.C. #2		10	10	No Blisters
Silver Bullet + T.C. #3		10	10	No Blisters
Control #1		10	10	No Blisters
Control #2		10	10	No Blisters
Control #3		10	10	No Blisters
Black Shell #1	500 04/03/13	10	10	No Blisters
Black Shell #2		10	10	No Blisters
Black Shell #3		10	10	No Blisters
Black Shell + T.C. #1		10	10	No Blisters
Black Shell + T.C. #2		10	10	No Blisters
Black Shell + T.C. #3		10	10	No Blisters
Silver Bullet #1		10	10	No Blisters
Silver Bullet #2		10	10	No Blisters
Silver Bullet #3		10	10	No Blisters
Silver Bullet + T.C. #1		10	10	No Blisters
Silver Bullet + T.C. #2		10	10	No Blisters
Silver Bullet + T.C. #3		10	10	No Blisters
Control #1		10	10	No Blisters
Control #2		10	10	No Blisters
Control #3		10	10	No Blisters
Black Shell #1	750 04/13/13	10	10	No Blisters
Black Shell #2		10	10	No Blisters
Black Shell #3		10	10	No Blisters
Black Shell + T.C. #1		10	10	No Blisters
Black Shell + T.C. #2		10	10	No Blisters
Black Shell + T.C. #3		10	10	No Blisters
Silver Bullet #1		10	10	No Blisters
Silver Bullet #2		10	10	No Blisters
Silver Bullet #3		10	10	No Blisters
Silver Bullet + T.C. #1		10	10	No Blisters
Silver Bullet + T.C. #2		10	10	No Blisters
Silver Bullet + T.C. #3		10	10	No Blisters
Control #1		10	10	No Blisters
Control #2		10	10	No Blisters
Control #3		10	10	No Blisters

Sample	Hours	D1654-08	D610-08(2012)	D714-02(2009)
Black Shell #1	1008 04/24/13	9	10	Few Size 6
Black Shell #2		8	10	Few Size 6
Black Shell #3		10	10	Few Size 6
Black Shell + T.C. #1		8	10	Medium Dense 6
Black Shell + T.C. #2		9	10	Medium Dense 6
Black Shell + T.C. #3		10	10	Medium Dense 6
Silver Bullet #1		10	10	No Blisters
Silver Bullet #2		10	10	No Blisters
Silver Bullet #3		10	10	No Blisters
Silver Bullet + T.C. #1		9	10	Medium Dense 6
Silver Bullet + T.C. #2		9	10	Medium Dense 6
Silver Bullet + T.C. #3		9	10	Medium Dense 6
Control #1		9	10	Few Size 6
Control #2		9	10	Few Size 6
Control #3		9	10	Few Size 6

TERMS & CONDITIONS

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5. Whenever performance by either party is delayed or prevented by war, insurrection, fire or other casualty, strikes or embargoes, shortage of transportation facilities or any other similar or dissimilar causes, beyond the control of such party, such delay or prevention shall be excused and the time of performance hereunder extended for the duration of the causative factor.

COSTS AND PAYMENT

1. Sponsor agrees to pay all invoices within 30 days of invoice date.

2. In the event that payment is not received within 30 days of invoice date, Sponsor agrees to pay a late payment charge on the unpaid balance equal to 1-1/2% per month.

3. All costs associated with compliance with any subpoena(s) for documents, testimony in court of law, or for any other purpose relating to Services performed by EAG for Sponsor, shall be paid by Sponsor. Sponsor shall also pay EAG's then existing standard fees for consulting, deposition and trial testimony and all expenses related thereto.

4. Project specific supplies including, but not limited to, standards, raw materials, shipping, columns and/or specialty chemicals and supplies required for execution of a Sponsor's project will be purchased by EAG and billed to Sponsor as pass-through costs. If necessary, EAG may bill a waste disposal fee of up to 5% of total project cost or $500.00, whichever is lower, to cover proper sample and chemical disposal.

5. EAG reserves the right to request a prepayment from Sponsor prior to initiating project work.

6. Should Sponsor cancel all or a portion of the project after the project has been initiated, Sponsor will be liable to EAG for all hours expended on the project up to the time of cancellation, at a rate of $400.00 per hour, plus all project specific supplies at cost, or a minimum of 25% of the estimated project cost as a fee for EAG's mobilization on the project, whichever is greater. This cancellation charge is a fee for work performed and is not regarded as liquidated damages.

MISCELLANEOUS

1. This agreement and any and all claims and disputes hereunder or related thereto shall be governed by the internal laws of the State of California. EAG and Sponsor agree that exclusive jurisdiction and venue for any and all such claims and disputes shall be in Santa Clara County, California.

2. In the event that EAG prevails in any dispute or claim, including the collection of monies from Sponsor, Sponsor agrees that Sponsor will pay any and all expenses, including collection costs and attorney's fees, reasonably incurred in the prosecution or defense of such claim, dispute or collection.

3. The terms and conditions contained herein, together with EAG's quotation and offer of Services to Sponsor, and Sponsor's acceptance of such offer, shall constitute the entire agreement between EAG and Sponsor. Any conflicting terms contained in any order or acceptance submitted by Sponsor shall be null and void.

4. Due to the aggressive timelines associated with expedited analyses, a graduated surcharge would apply if the target completion date were not met. The graduated surcharge would be pro-rated and based on the date when verbal analysis results were provided. If an expedited analysis is cancelled after the start date, up to 50% of the surcharge may be applied and due since mobilization of resources is performed immediately for rush projects.