Evaluations in Corrosion Testing

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Q-Lab's Winter Webinar Fundamentals Series

Today is the first of a three-part webinar series on key topics in weathering and corrosion testing

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Date	Topic
23 Jan	Evaluations in Corrosion Testing
30 Jan	Essentials of Lab Weathering
06 Feb	Correlation in Accelerated Testing

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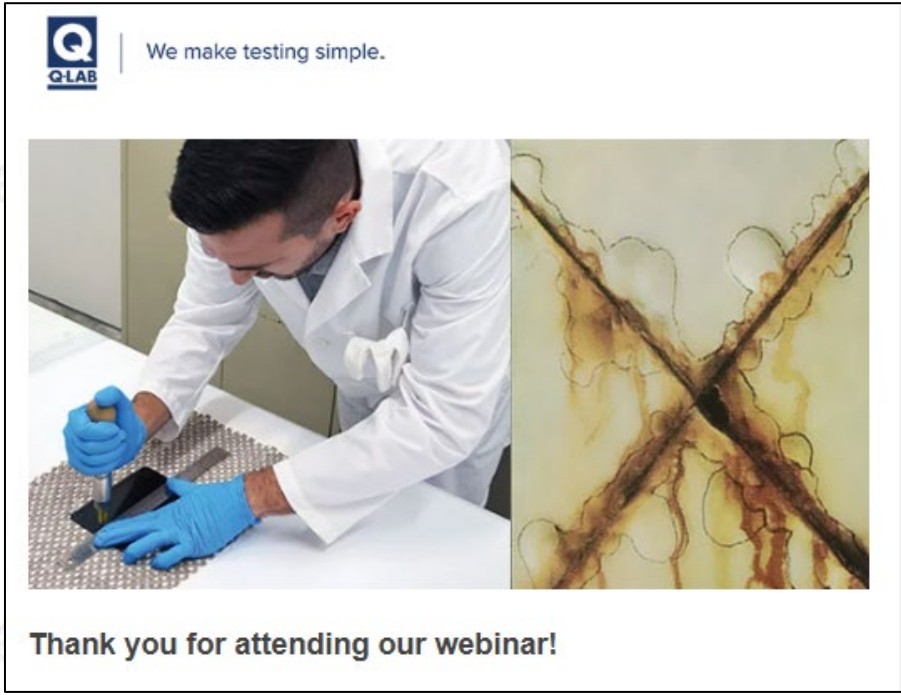

Scope

- This presentation covers the testing of corrosion under a coating
  - Scabbing, Blistering, Rust Spots, Creepage, Pitting
- This presentation does not cover corrosion of bare metals
  - Mass loss
- This presentation does not cover causes of corrosion, or the tests used to create corrosion
- This presentation does not cover filiform corrosion evaluations
- This presentation covers manual and visual methods used for corrosion evaluation

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Corrosion underneath a coating

- Coatings are designed to protect the metal underneath them
- Corrosion tests evaluate how well the coating performs its primary function
- Choose whether coating is pre-damaged
  - Scratched (Scribed), Impacted, Drilled
- Undamaged coatings take longer to show results
  - Undamaged coatings corrosion tests are to check for defects in coating application

Why damage a coating before testing?

- Many coatings perform well if undamaged
  - Unbroken barrier between metal and corrosive environment
- Most surfaces will be damaged at some point
  - Test intended to accelerate this condition
- Illustrates how well the coating performs after imperfection occurs
- Shows how quickly the rust can spread
- Rust stains are not a primary failure result

Standards for corrosion evaluations

- ASTM D1654, ISO 4628-8, GMW15282, SSPC-PA-16
  - Scribe, scrape, measure
- ASTM D610, ISO 4628-3
  - Surface area coverage
- ASTM D2803, ISO 4628-10
  - Filiform corrosion

Types of Rust

Rust by definition is oxidation of ferrous materials

Red Rust

- Ferrous substrates
- Reddish products
- Easier to see

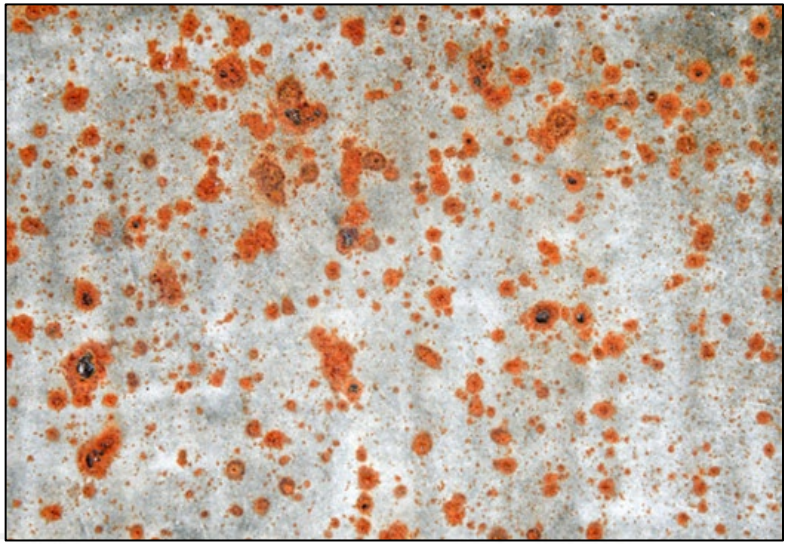
White Rust

- Non ferrous materials
- White products
- Can be difficult to see

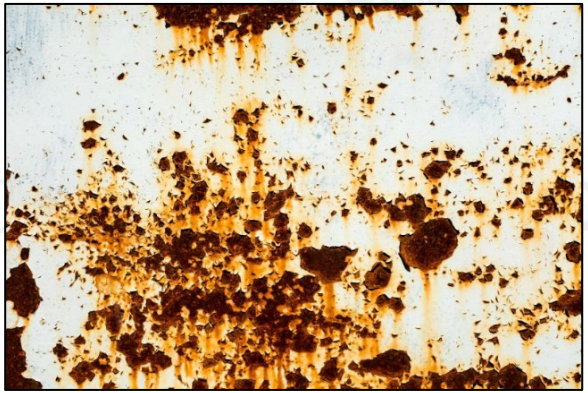
Both types of rust can be tested and evaluated using the same techniques

Surface Rust

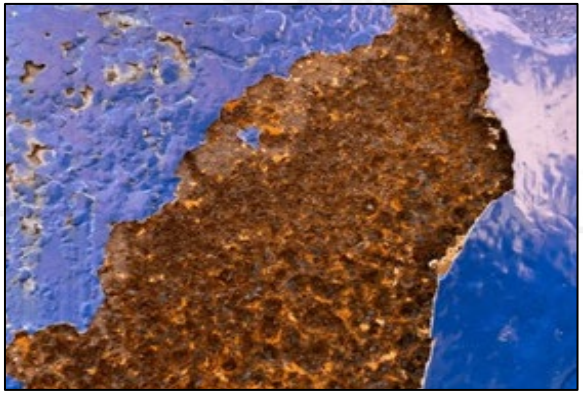
- Simply a measure of the surface area where the rust has emerged
  - Cracks, blisters, pinholes, “holidays”
- Compared to a set of drawings, or measured with computer software
- Ignore the staining
  - Staining does not count



3 Different Types of Surface Rust



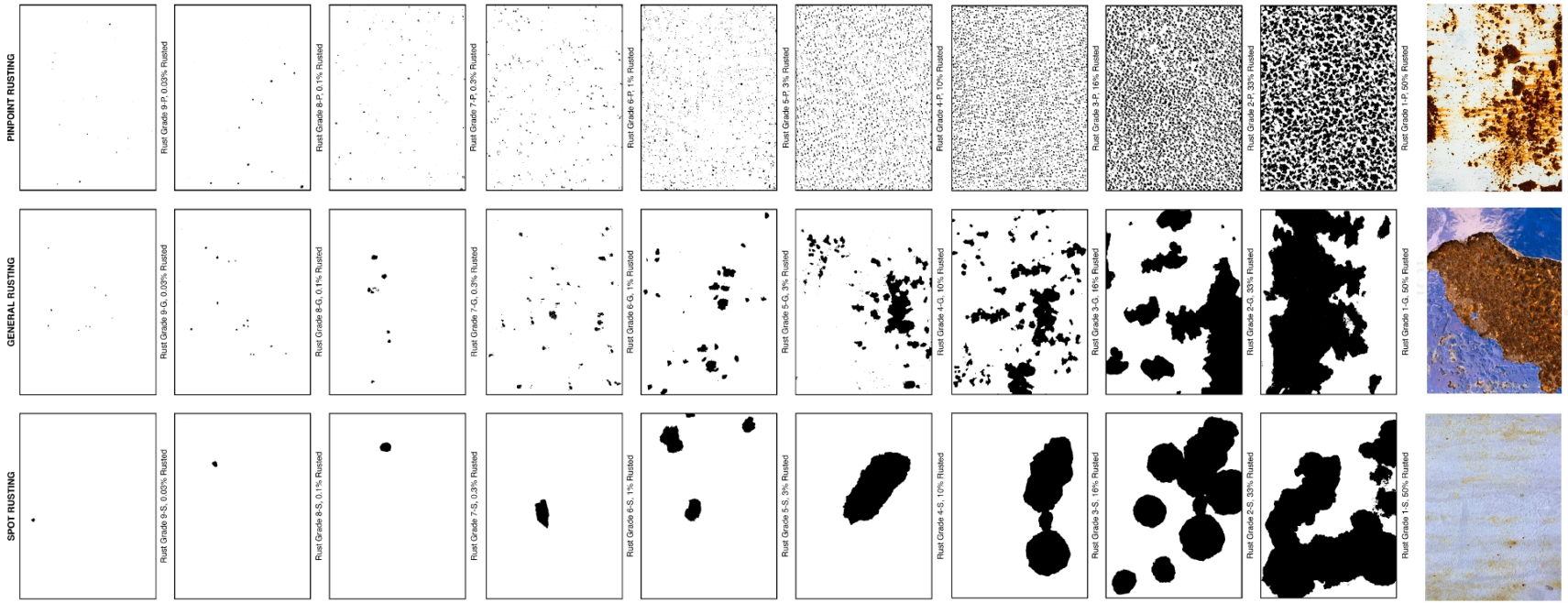
General



Spot

Pinpoint

Pictorial Reference (ASTM D610)



Pictorial Reference (ISO 4628-3)

Figure 1 — Degree of rusting Ri 1

Figure 2 — Degree of rusting Ri 2

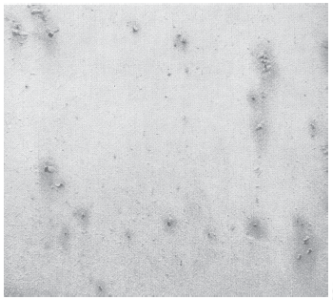


Figure 3 — Degree of rusting Ri 3

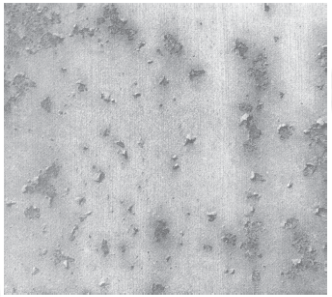


Figure 4 — Degree of rusting Ri 4

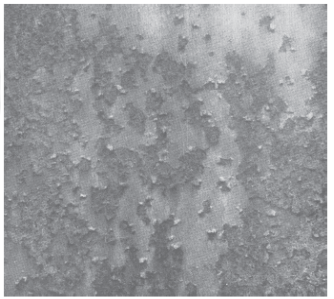
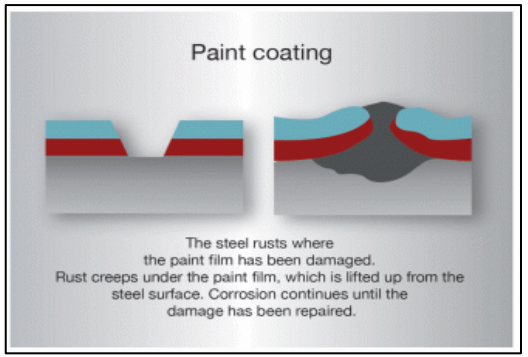


Figure 5 — Degree of rusting Ri 5

Figure 4 — Degree of rusting Ri 4

Scab Rust

- Major problem in automotive and with industrial equipment
- Aesthetic and structural problem
- Once initiated, will not stop by itself
- Expensive to fix …
- … but easy to test for



Outdoor Corrosion Tests

- Outdoor direct exposure; adds manual 5% salt spray
- ASTM D6675

- Seaside exposure; no additional spray
- ASTM G50

ASTM B117

- The single most popular corrosion test on the planet
  - Also the most denigrated test in corrosion
- First introduced in 1914 and published in 1939 - it's been around a long time
- 5% continuous salt spray at 35 °C (95 °F)
- Quick test for quality control, or simple pass/fail decision
- Usually a ferrous panel with a scribe line
- Same test found in ISO 9227

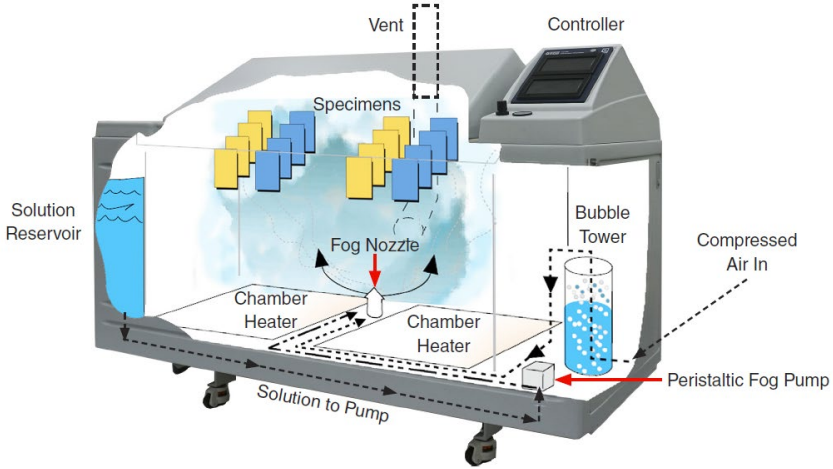


Fig. 1 *Scribed regions of panels after 2,000 hours' salt spray testing (1,000 hours for latex)*

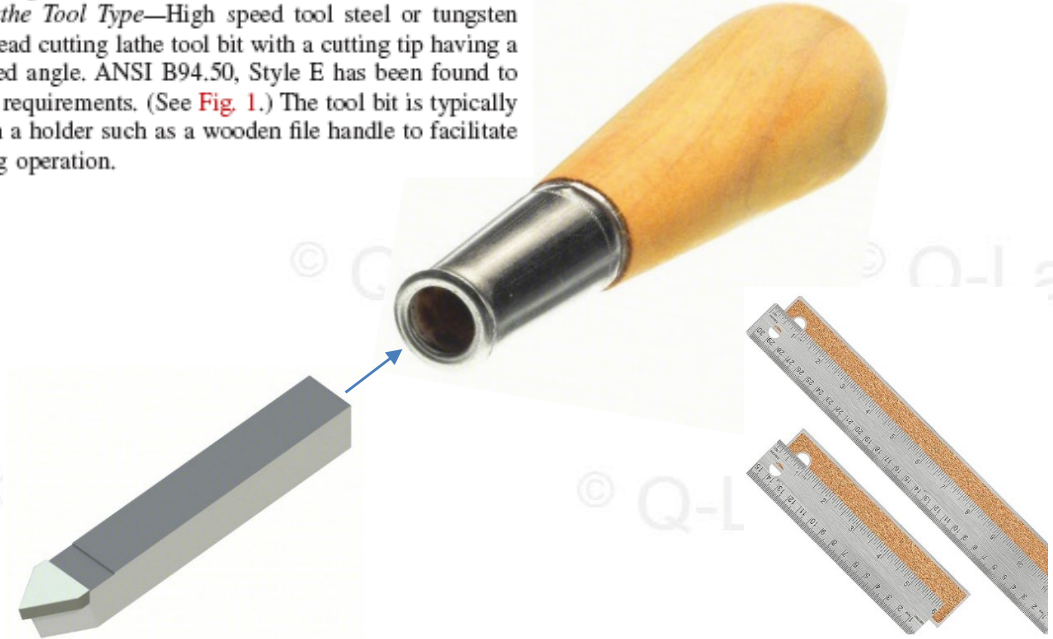
Scribing

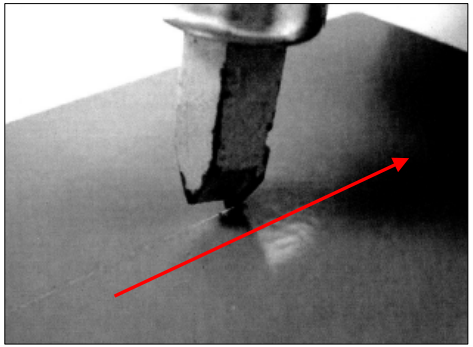
- Most common technique for creating weakness
- Repeatable and Reproducible with only minor training
- Provides a uniform cut of predictable depth and width
- Always use a straight edge
- Mechanical apparatus can be used to hold and guide cutter
- Powered cutters (rotary blades) should not be used
- Width of scribe more important than depth
  - But must penetrate to metal surface

Scribing Tool

5.1 *Scribing Tools:*

5.1.1 *Lathe Tool Type*—High speed tool steel or tungsten carbide thread cutting lathe tool bit with a cutting tip having a 60° included angle. ANSI B94.50, Style E has been found to meet these requirements. (See Fig. 1.) The tool bit is typically mounted in a holder such as a wooden file handle to facilitate the scribing operation.

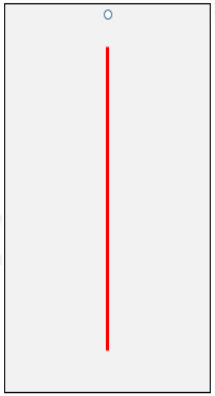




Most Common Scribe Lines

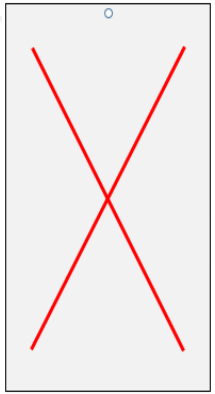
Straight Line

- Vertical
- Center of Panel
- Away from edges



X Mark

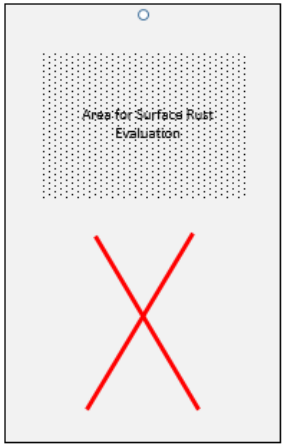
- "St Andrew's Cross"
- Corner to corner, or
- Angle ~ 60°
- Away from edges



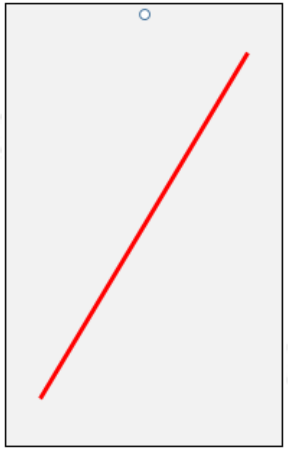
Make sure your scribing tool is clean and free of damage before using it to cut the coating

Alternate Optional Methods

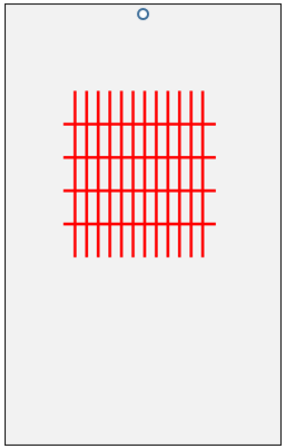
Surface rust and scribe rust evaluation on the same panel



A single diagonal scribe



Cross-hatch scribes not recommended



How to Make a Perfect Scribe

- Measure where each line will go and mark the ends of the scribe line with a pencil
- Use a metal ruler with cork backing as a straight edge
- Hold the scribing tool as shown in this photo

  - Do not use a knife, or box-cutter
- Scribe once in a single continuous stroke pulled towards you
- Press down **hard;** enough to cut through to the substrate
  - You will see shiny bright metal behind the tool tip
- Check the scribe, make sure the cut is through to the metal all the way
- Wipe the scribe with a clean lint-free cloth to remove burrs and flakes

Review the Scribe Line

- The scribe must be evenly wide and deep
  - Cuts all the way down to the metal
- *Minor* paint flaking along the edge will not affect performance
- Measure the width of the scribe
  - Should be 0.5 mm wide if using the ASTM D1654 Lathe Tip
  - This width will be used later in the calculations
- Start the exposure

Exposure Care

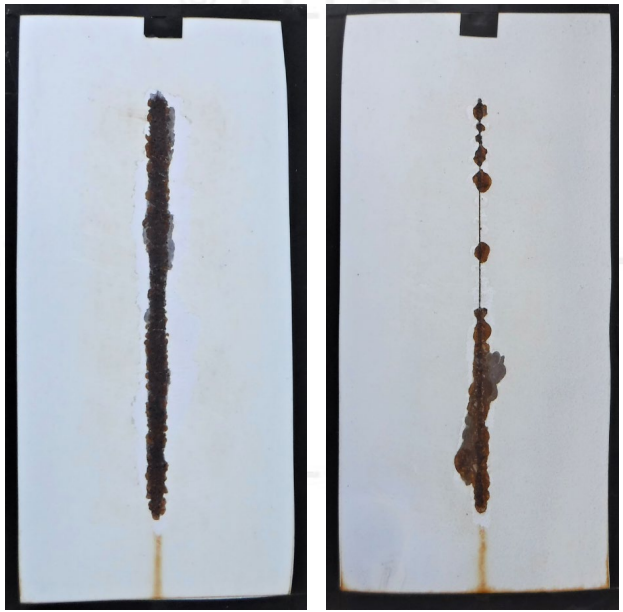
- After exposure has begun, keep interruptions to a minimum
  - Do not let the panels get dry
  - Do not let panels sit out of the test
  - Do not interrupt the continuity of exposure unless specified
- Make sure the scribe surface is face up to receive the salt droplets
- Make sure the scribe is vertical
  - Horizontal scribes have uneven two-sided results

Cleaning

- Immediately after exposure, wash the panel but leave the surface wet
- Removing the paint is only way to determine rust rating
- Scrape is the most common and simplest method
  - Sand blasting, chemical immersion, and air-blow are also found in some specifications
- Use a rigid metal scraper with a blunt edge like this one
- Be brutal! Don't be afraid to scrape vigorously
- Rinse the loose paint chips off

Ready to Measure

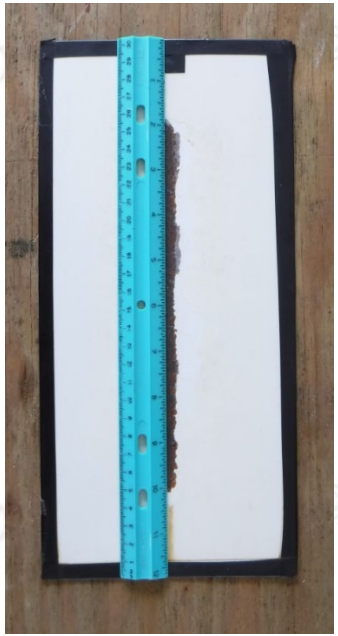
- When the scraping is complete, you might have a wide area or a narrow area
- Most likely you will see two areas with different colors
- The larger and lighter metal color area is the paint delamination
- The darker and browner colored area is the rust creepage
- ASTM D1654 is the best all-around method for taking the measurements

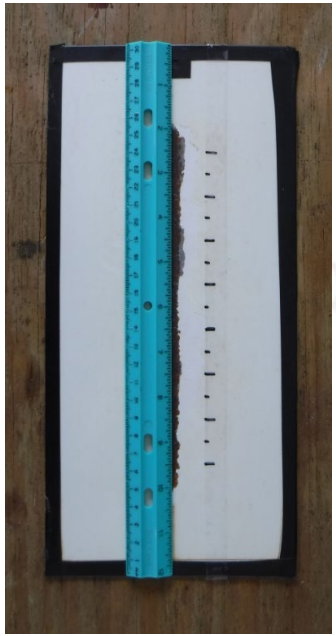


Step 1: Mark the Panel

- Place the ruler on the scribe aligning to the top and bottom of the panel
- Make the first mark at a point below the top of the scribe
- Add a mark every predetermined interval
  - Every 25 mm for 300 mm panel*
  - Every 12 mm for a 150 mm panel*
- Use a permanent marker to indicate directly on the panel each mark on the template

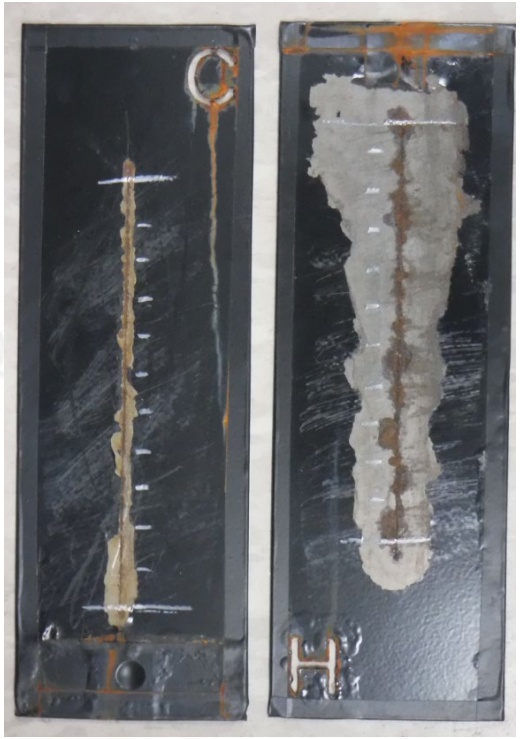
** ½ inch or 1 inch for 6" or 12" panels*





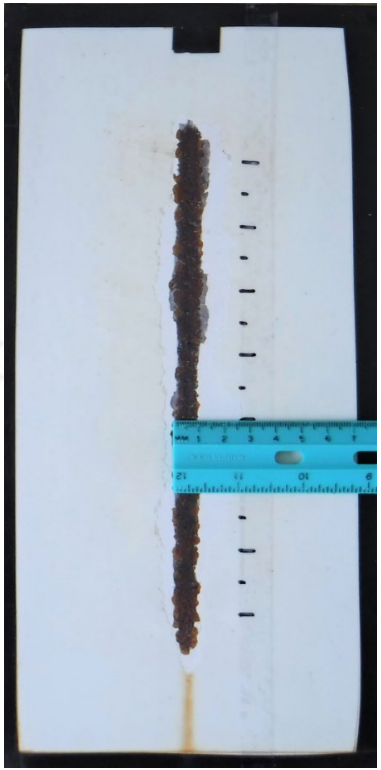
How many Marks are needed?

- Must use specific pre-determined gradations
- Regular steps such as
  - Every inch, or 25 mm
  - Every ½ inch, or 10 mm
  - At least 6 points (more is not always better)
  - Evenly spaced throughout
- Start and stop at least 3 mm (1/8 inch) from the ends of scribe
- Selective random locations ensure more objective measurements
- Some marks will be less rust; some will be more
- Highs and lows will even out



Step 2: Measure the Total Width

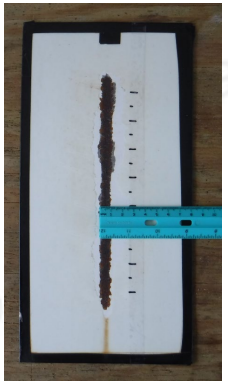
- Measure the total width of the creepage (seen as the darker area near the scribe) at each pre-marked position along the scribe
- Measure the total width at every mark within the scribe length to the nearest 0.5 mm
  - Record each individual width measurement
- Subjectively find, measure, and record the maximum and the minimum creepage
- Calculate the arithmetic mean (average) of the width measurements



Data Analysis

Using panel from previous slide

	Large marks (25 mm)	All marks (12 mm)
# Values recorded	8	15
Values (mm)	10, 8, 7, 8, 10, 9, 10	10, 12, 8, 9, 11, 9, 7, 6, 8, 10, 10, 10, 9, 9, 10
Average (mm)	9.13	9.20
Max	13.0	13.0
Min	6.0	6.0



Step 3: Calculate the Creepage Value

- Calculate the rust creepage value c
- Take the average creepage measurement w_c and subtract the width of the scribe w
  - Measured earlier ~ 0.5 mm
- Divide by 2 to get a one-sided value

$$c = \frac{w_c - w}{2}$$

where:

w_c = mean overall width of the corrosion zone and
w = width of the original scribe.

Large Marks
w_c = 9.13 mm
w = 0.5 mm
c = (9.13-0.5) / 2 = 4.32 mm

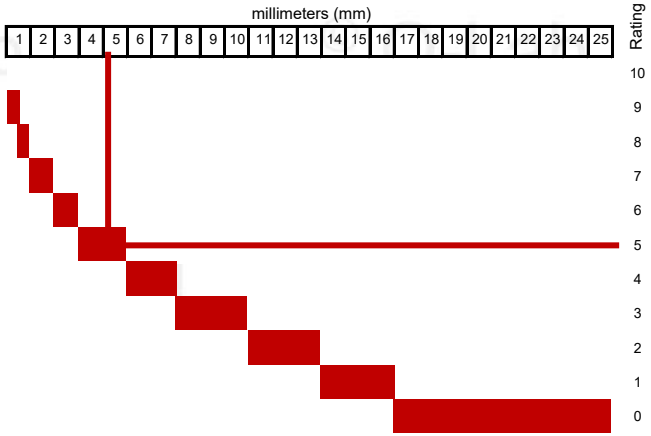
All Marks
w_c = 9.20 mm
w = 0.5 mm
c = (9.20-0.5) / 2 = 4.35 mm

Step 4: Assign a Rating Value

- Determine the creep rating
- Use the table here to apply a rating number to the creep measurements

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



Rating when w_c = 4.32 mm is 5

Rating when w_c = 4.35 mm is 5

ISO 4628-8 Method

6.2 Corrosion by measurement and calculation

Determine, to the nearest 0,5 mm, the mean overall width of corrosion, w_c, using Formula (5):

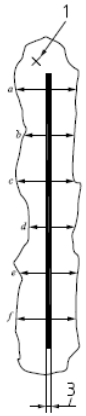
$$w_c = \frac{a+b+c+d+e+f}{6} \quad (5)$$

Calculate the corrosion, c, in millimetres, using Formula (6):

$$c = \frac{w_c - w}{2} \quad (6)$$

where

w_c	is the mean overall width of corrosion, in millimetres;
w	is the width of the original scribe or other artificial defect, in millimetres;
a, b, c, d, e, f	are individual corrosion measurements — see Figure 1.



a) Scribe

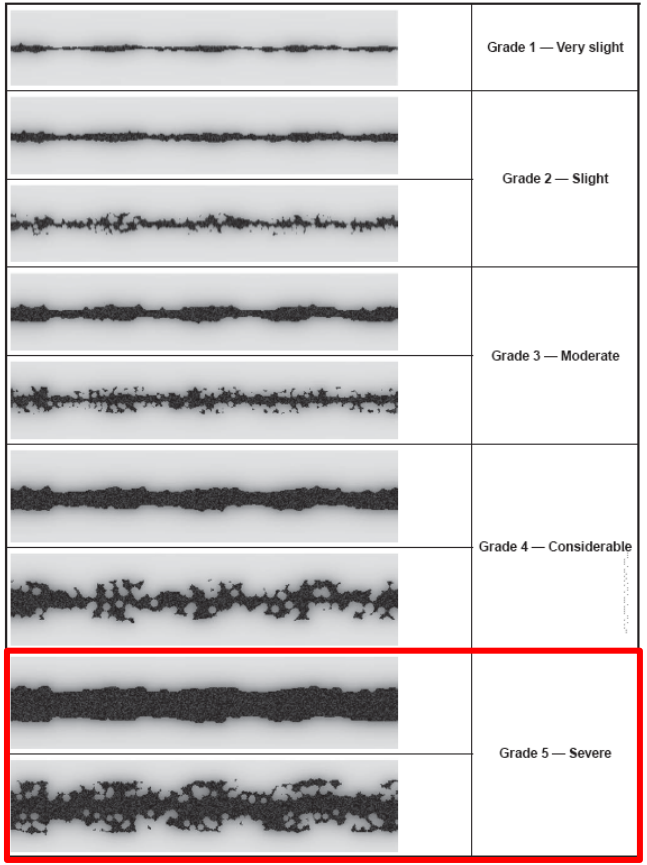


Figure 2 — Pictorial standards for assessment of delamination and corrosion around a scribe (approximate scale 1:1)

The value for **c** will be the same as for ASTM D1654 but our Panel would be Grade 5 according to this photo reference

GMW 15282 Method

- GM method different in three requirements
  - Report the C_{Max}
  - Scab corrosion width is total (both sides)
  - 10 mm spacing mandated

GM WORLDWIDE ENGINEERING STANDARDS **GMW15282**

Appendix D: Example Scribe Creepback Evaluation & Documentation

Example: A scribe line 50 mm in length after material specification test exposure.

1. First, scribe should be measured in millimeters using the "zero to peak + zero to peak" technique as illustrated (refer to red line and text) in Figure D1.
   $C_{Max} = C_{Left\ Max} + C_{Right\ Max}$
2. Second, scribe creepback should be measured across the scribe line in 10 millimeters increments from the top of the scribe line as illustrated (refer to blue lines and text) in Figure D1
   $C_{Average} = (C_{10\ mm} + C_{20\ mm} + C_{30\ mm} + C_{40\ mm})/4$

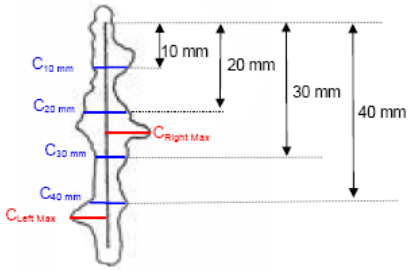


Figure D1: Scribe Creepback Measurement Illustration

What if you did not want to scrape?

Cleaning a corrosion panel permanently prevents the panel from being exposed again

- For example > interim evaluations
- ASTM D7087 traces a pattern around the scabbing and blistering

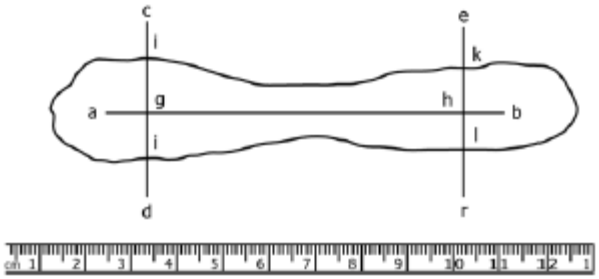


FIG. 1 The Scanned Trace and Markings for Area Integration of Creepage Area Around the Scribe Line.

7.4 *Calculating the Net Mean Creepage (Excluding Area of Original Scribe Line)*—Calculate the net mean creepage as follows:

$$C_{net} = (A_{ijlk} - A_o)/(2L) \quad (2)$$

where:

C_{net} = net mean creepage in mm,
A_{ijlk} = integrated area inside the boundary of ijlk by tracing and imaging,
A_o = integrated area of scribe line before exposure, and
L = length of scribe line from which creepage (or undercutting) is extended and area is integrated.

Final thoughts

- Scribing and scribe rust evaluation are easier than you might think
- ASTM D1654 has very good repeatability and reproducibility
  - Recent P&B study finds great R and r values
- The main source of variability is scribe width inconsistency
  - Scribe depth not as important (ISO study)
- Main error is using an old tool with defects
- Do not improvise over choice of measurement intervals

Thank you for your time.

Questions?

info@q-lab.com

My appreciations to Thomas Allie, Q-Lab Florida Lab Manager, for his expert input and review

We make testing simple.

Q-LAB