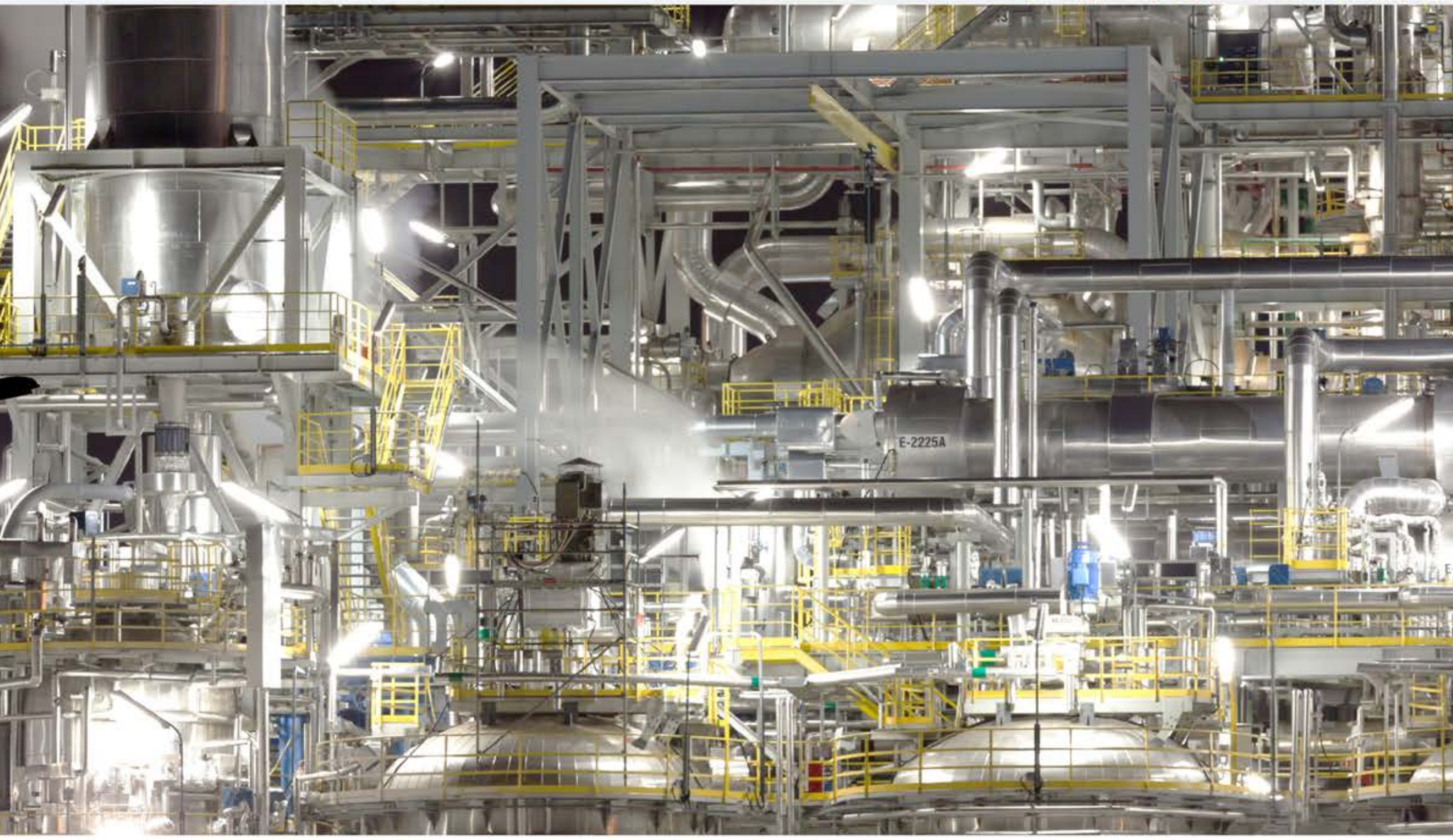
INDUSTRIAL MAINTENANCE GUIDE

Industrial Motors
Commercial & Appliance Motors
Automation
Digital & Systems
Energy
Transmission & Distribution
Coatings

Anticorrosive coatings and coating plans tailored to **industrial maintenance.**



Driving efficiency and sustainability

ISO 12944 STANDARD

Aligned with the latest edition of the International Standard ISO 12944 “Paints and varnishes – Corrosion protection of steel structures by protective paint systems,” WEG Coatings offers technology capable of providing corrosion protection in all the situations described below. Consult our team to select the most suitable system for your project.

ISO 12944 (all parts) considers forr different durability ranges (low, medium, high and very high). The durability range is not a “warranty time”. The type of environmental conditions and the durability of the coating systems are the main parameters for selecting coating systems.

The level of “coating failure” prior to the “first major coating maintenance”, must be agreed by the interested parties and must be evaluated in accordance with ISO 4628-1, 4628-2, 4628-3, 4628-4 and ISO 4628-5.

For example, “first major coating maintenance” will normally be carried ort for reasons of corrosion protection, once 10% of coatings will reach the Ri 3 value as defined in ISO 4628-3.

Category	Ortdoor	Indoor
C1 very low	-	Heated buildings with clean environment such as offices, shop, schools and hotels.
C2 low	Environments with a low level of pollution, such as rural areas	Unheated buildings where condensation may occur, such as warehorses and sports halls.
C3 medium	Ambientes urbyears e industriais com baixa poluição de dióxido de enxofre. Áreas costeiras com baixa salinidade	Production halls in places with high humidity and little pollution, such as breweries and dairies facilities.
C4 high	Zonas industriais e áreas costeiras de média salinidade	Industrial and coastal areas of medium salinity.
C5 very high	Industrial areas with high humidity and aggressive atmosphere. Coastal areas with high sanity	Buildings and areas with near-permanent condensation and high pollution.
CX extreme	Offshore areas with high salinity and industrial areas with extreme humidity. Aggressive, tropical and subtropical environments	Buildings and areas with near-permanent condensation and high pollution.

COATING SYSTEMS - LIQUID COATINGS

Nº	ISO 12944 classification	Coating system - maintenance	Function	Total thickness (µm) *	Durability expectation ISO 12944
1	C1 - very low C2 - low	1 coat AL CVP 115 - 35µm	Alkyd primer	105	Medium (from 7 up to 15 years)
		2 coats AL SRA 111 - 35µm each	Alkyd topcoat		
2	C3 - medium	1 coat EP ERP 322 - 80µm	Epoxy primer	130	Medium (from 5 up to 15 years)
		1 coat PU HPA 501 - 50µm	Polyurethane topcoat		
3	C4 - medium	1 coat EP 89 PW - 150µm	Epoxy primer	200	Medium (from 7 up to 15 years)
		1 coat PU HPA 501 - 50µm	Polyurethane topcoat		
4	C5 - medium	1 coat EP 88 HT - 250µm	Epoxy primer	300	Medium (from 7 up to 15 years)
		1 coat PU HPA 501 - 50µm	Polyurethane topcoat		
5	C5 - high	3 coats W-POXI BLOCK HPP 402 ALUM - 150 µm	Novolac epoxy primer	500	High (from 15 up to 25 years)
		1 coat PU N2677 - 50 µm	Polyurethane topcoat		
6	CX - extreme	1 coat N1277 - 85 µm	Zinc epoxy primer	325	High (from 15 up to 25 years)
		1 coat W-POLI HPD 451 - 240 µm	Polyaspartic topcoat		
7	Tidal and splash zone CX and Im4	1 coat of W-POXI GFD 362 at 500 µm	Epoxy primer topcoat	500	High (from 15 to 25 years)

** Total thickness - Consider dry film*

COATING SYSTEMS - POWDER COATINGS

Nº Systems	ISO 12944 Classification	Environment	Coating system	Function	Total thickness (μm) *	Durability expectation ISO 12944
1	C1 - very low / C2 - low	Indoor	1 coat POLITHERM 20 or 22 - 70 μm	Hybrid coating	70	Low (up to 5 years)
		Outdoor	1 coat POLITHERM 26 or 27 - 70 μm	Polyester coating	70	
2		Indoor	1 coat POLITHERM 50 HB - 120 μm	Hybrid coating	120	Medium (from 5 up to 15 years)
		Outdoor	1 coat POLITHERM 56 HB - 120 μm	Polyester coating	120	
3		Indoor	1 coat POLITHERM 54 HB - 160 μm	Epoxy coating	160	High (over 15 years)
		Outdoor	1 coat POLITHERM 54 HB - 110 μm	Epoxy coating	170	
			1 coat POLITHERM 26 or 27 - 60 μm	Polyester coating		
4	C3 - medium	Indoor	1 coat POLITHERM 24 - 80 μm	Epoxy coating	160	Medium (from 5 to 15 years)
			1 coat POLITHERM 20 or 22 - 80 μm	Hybrid coating		
		Outdoor	1 coat POLITHERM 24 - 80 μm	Epoxy coating	160	
			1 coat POLITHERM 26 or 27 - 80 μm	Polyester coating		
5		Indoor	1 coat POLITHERM 54 HB - 100 μm	Epoxy coating	200	High (over 15 years)
			1 coat POLITHERM 54 HB - 100 μm	Epoxy coating		
		Outdoor	1 coat POLITHERM 54 HB - 160 μm	Epoxy coating	220	
			1 coat POLITHERM 26 or 27 - 60 μm	Polyester coating		
6	C4 - high	Indoor	1 coat POLITHERM 54 - 120 μm	Epoxy coating	200	Medium (from 5 up to 15 years)
			1 coat POLITHERM 20 or 22 - 80 μm	Hybrid coating		
		Outdoor	1 coat POLITHERM 54 - 120 μm	Epoxy coating	200	
			1 coat POLITHERM 26 or 27 - 80 μm	Polyester coating		
7	C5 - very high	Indoor	1 coat POLITHERM 55 HB C5H - 140 μm	Epoxy coating	280	Medium (from 5 up to 15 years)
			1 coat POLITHERM 55 HB C5H - 140 μm	Epoxy coating		
		Outdoor	1 coat POLITHERM 55 HB C5H - 140 μm	Epoxy coating	280	
			1 coat POLITHERM 86 WFS - 140 μm	Polyester SD		
8	CX - Extreme	Indoor	1 coat POLITHERM 24 W-Zn - 80 μm	Epoxy coating zinco	240	Medium (from 5 up to 15 years)
			1 coat POLITHERM 55 HB C5H - 160 μm	Epoxy coating		
		Outdoor	1 coat POLITHERM 24 W-Zn - 80 μm	Epoxy coating zinco	240	
			1 coat POLITHERM 86 WFS - 160 μm	Polyester SD		

** Total thickness - Consider dry film*

**Liquid and powder coating systems above are developed to carbon steel substrate with standard Sa 2½ mechanical blast treatment.*

PETROBRAS STANDARD PRODUCTS

For each specific application issue, Petrobras Standards establish standardized coating systems. In addition to the protection characteristics displayed by this product types, WEG Coatings has a wide product line and coating systems specific for the anticorrosive solution in industrial maintenance.

Standards	Product description	Ref. WEG
N 1277	Two-component zinc rich polyamide epoxy	LACKPOXI N1277e W-POXI ZSP 315 R N 1277
N 1514 - Type I e II	High-temperature indicative coating	TERMOLACK N1514 I e II
N 1661	Two-component inorganic zinc silicate coating	ZINC ETHYL SILICATE N1661
N 2231	Inorganic zinc and aluminum silicate	ZINC ETHYL SILICATE N2231 ALUMINUM
N 2288	Two-component special aluminum aromatic polyamine epoxy	LACKPOXI N2288
N 2628	Two-component high solids, high build polyamide epoxy topcoat	LACKPOXI N2628
N 2630	Two-component, high solids, high build zinc phosphate polyamide epoxy primer	LACKPOXI N2630
N 2677	Two-component aliphatic acrylic polyurethane topcoat	LACKTHANE N2677
N 2680	Solventless epoxy coating for wet surfaces	LACKPOXI 76 WET SURFACE PRIMER / TOPCOAT
N 2912	Novolac High Build Epoxy Primer	WEGPOXI BLOCK N 2912 TIPOS I, II e III
(old N 2198)	This product replaces the use of LACKPOXI N2198. Isocyanate-free adhesion promoter for galvanized, aluminum, degreased carbon steel and stainless steel substrates	W-POXI GNP 415
N 2913 / N 2943	Polyaspartic coating	W-POLI HPD 451
N 1374 / N 2943	High performance coating	W-POXI BLOCK GFD 362
N 1374 / N 2943	Requirements for non-slip paint	W-POXI BLOCK ADA 404
N 2943	Requirements for non-slip paint	W-POLI ADA 462

HIGH BUILD ELASTOMERIC COATINGS – OFFSHORE

WRAPX® HBD 421 | WRAPX® EVD 473

Developed to protect critical areas, such as valves and flanges.

Advantages of wrapping valves, flanges and bolts:

- Double protection system;
- Uses release agent, facilitating the removal of the coating when maintenance is necessary;
- High thickness application in a single coat;
- High retention on edges and weld beads;
- Compatible with airless or brush;
- Ease of repair.

FLOORS AND STRUCTURES ELASTOMERIC COATING – OFFSHORE

WRAPX® HBD 521

Polyurethane-based elastomeric coating that works as a primer and top coat, being ideal for high-build applications. Recommended to protect industrial equipment and structures, carbon steel and cement surfaces, as well as for internal and external coating of pipes.

- High flexibility;
- Waterproof;
- High retention on edges;
- Fast application and drying speed up process;
- Permite aspersão de agregado antiderrapante;
- High-build application, allows up to 8 mm on horizontal surfaces and 1.25 mm on vertical surfaces;
- Excellent anticorrosive resistance by barrier and high durability against abrasion.

Offshore platform: *Environment category CX (extreme) according to ISO 12944.*

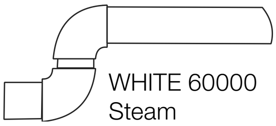
COLOR USAGE

In addition to be an indispensable element in environment composition, color is also a valuable assistant to obtain signaling, as well as delimiting areas, providing indications as warning for ambiental conditions.

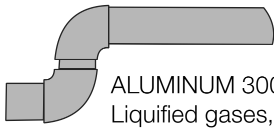
The color usage as signaling allows an automatic reaction of the observer, avoiding the person to stop in front of the sign, read, analyse and only then act according its purpose. For that, it´s necessary there is a consistency or a standardization in color application so that its meaning be always the same, allowing an immediate identification.

In order to guide and define this task, NBR 6493 and NBR 7195 Brazilian Standards can be consulted, which complement and standardize primary colors for signaling and safety inside companies.

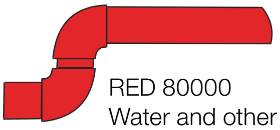
We suggest to establish standardized colors by Munsell or RAL color systems according it is presented in orr color chart.



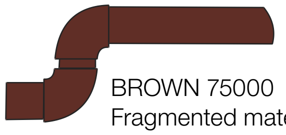
WHITE 60000
Steam



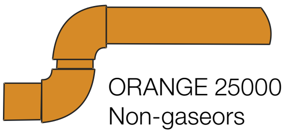
ALUMINUM 30000
Liquified gases, flammables and low viscosity fuels



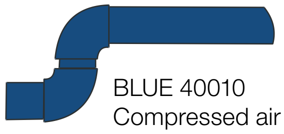
RED 80000
Water and other substances destined to fire fighting



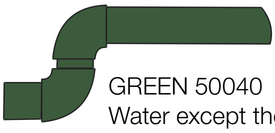
BROWN 75000
Fragmented materials (ores) and raw petroleum



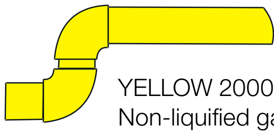
ORANGE 25000
Non-gaseors chemical products



BLUE 40010
Compressed air



GREEN 50040
Water except the one destined to fire fighting



YELLOW 20000
Non-liquified gases

BLACK 70000
Flammables and high viscosity fuels

DARK GRAY 10020
Electric conduit

STANDARDIZED COLOR CHART

WEG color code	Color designation	Petrobras color code	Munsell designation	Col
70000	Black	0010	N 1	
10020	Dark gray	0035	N 3,5	
10030	Medium gray		N 5	
10010	Light gray	0065	N 6,5	
10000	Ice gray	0080	N 8	
60000	White	0095	N 9,5	
30000	Aluminium	0170	*	
80000	Safety red	1547	5 R 4/14	
80740	Iron oxide	1733	10 R 3/6	
75000	Piping brown	1822	2,5 YR 2/4	
25000	Safety orange	1867	2,5 YR 6/14	
20040	Piping cream-coloured	2273	10 YR 7/6	
20010	Golden yellow	2287	10 YR 8/14	
21670	Petrobras yellow	2386	2,5 Y 8/12	
20000	Safety yellow	2586	5 Y 8/12	
20030	Pale cream-coloured	2392	2,5 Y 9/4	
50010	Safety green	3263	10 GY 6/6	
50040	Badge green		2,5 G 3/4	

** It does not have Munsell color code*

WEG color code	Color designation	Petrobras color code	Munsell designation	Color
51820	Petrobras green	3355	2,5 G 5/10	
50000	Pastel green	3582	5 G 8/4	
51210	Green		7,5 G 6/4	
40010	Safety blue	4845	2,5 PB 4/10	
40000	Pastel blue	4882	2,5 PB 8/4	
41340	Blue		5 PB 2/4	
40400	Blue		5 PB 6/8	
40810	Petrobras blue	5134	7,5 PB 3/8	
81840	Wine	1523	5 R 2/6	

Note

The gloss and color hue dispalyed on this chart must be taken only as guidance and can not be ensured compliance with the original coating, thus it is not recommended to use it as a color pattern in evaluation of painted surfaces.

1 - LEVELS OF OXIDATION

For levels of rust have been specified, designated by the letters A, B, C and D, respectively, according to ISO 8501-1 standard. The mill scale is not steel and its natural trend is to be released from the steel. It is produced during the process of steel lamination in which the steel is heated up to 1,250 °C and results by the reaction with oxygen from air and the cooling water forming the mill scale form.

Level A
Steel surface with intact adherent mill scale, with little or withort oxidation throrgh all the surface.

Level B
Steel surface with oxidation beginning and from which mill scale has started releasing or where it has suffered little weathering action.

Level C
Steel surface where all mill scale has been eliminated and which is observed a general uniform atmospheric corrosion.

Level D
Steel surface where all mil scale has been eliminated and which is observed a general and severe atmospheric corrosion, featuring pits and alveoli.

2 - PREPARATION LEVELS | STANDARD ISO 8501-1

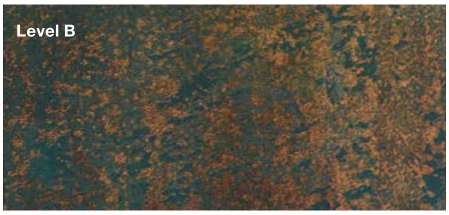
2.1 - Cleaning by mechanic and manual tools

- Surface preparation by cleaning with mechanic and manual tools (as scraping, sanding, brushing with brushes or discs) is designated by “St” letters.
- In the same way, oil, grease, fat or other contaminants must also been removed by solvent cleaning or using degreaser agents (according to SSPC-SP1 standard).
- After preparation, surface must be presented free of dust and loose fragments.

Thorough cleaning with manual and/or mechanical tools
When examined with the naked eye, the surface must be free from visible contaminants such as oil, grease, and dirt, as well as loosely adhering contaminants such as mill scale, corrosion, old paint, and foreign materials (see Note 1 of 3.1). See photographic standards B St 2, C St 2, and D St 2.(Fotographic patterns: B St 2; C St 2 and D St 2).
Level A - St 2 cleaning method is not recommended for this corrosion level.

Very thorough cleaning with manual and/or mechanical tools
The surface must be treated as in St 2, but in a much more thorough manner, and it should present a metallic sheen. See photographic standards B St 3, C St 3, and D St 3.

Level A - St 3 cleaning method is not recommended for this corrosion level.



2.2 - Abrasive blasting cleaning

It is achieved by projecting abrasive particles onto the surface, propelled by a fluid—generally compressed air—creating a surface profile (roughness).

- Surface preparation by abrasive blasting is designated by “Sa” letters.
- Before going to the blasting chamber, grease, oil and fat must be removed from the piece by cleaning with solvent or degrease agent (according to SSPC-SP1).
- After blasting, dust and loose particles must be removed from the surface.
- In visual inspection, there must be verified if the surface is free of oil, grease or fat, mil scale, oxidation, paint, foreign material with poor adhesion and analyze if the blasting pattern complies with Isso 8501-1 standard.

Sa 1 Standard

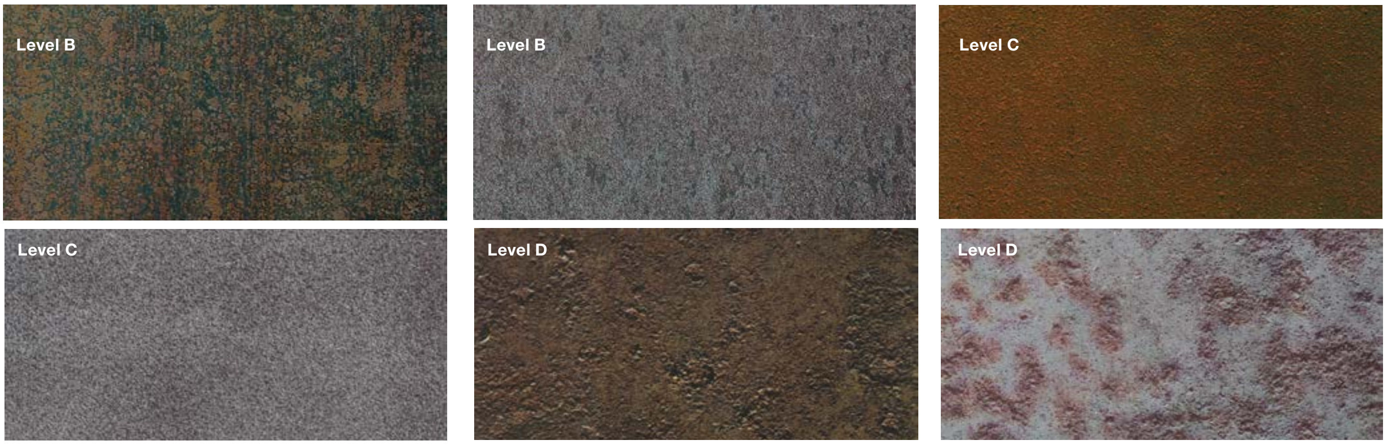
Known as “slight blasting” (brush-off) or brush blasting, it is not usually used for coating, except under some overcoating situations.
Adherent product removal is abort 5 percent range.
(Fotographic patterns: B Sa 1; C Sa 1 and D Sa 1).

Sa 2 Standard (according to SSPC-SP6 Standard)

Known as comercial blasting, it consists on a surface cleaning removing oxides, mill scale, coatings and other in a range of 50 percent of the surface. All the residual contaminants must remain strongly adhered.
(Fotographic patterns: B Sa 2; C Sa 2 and D Sa 2).

Level A - Sa 1 cleaning method is not recommended for this corrosion level.

Level A - Sa 2 cleaning method is not recommended for this corrosion level.

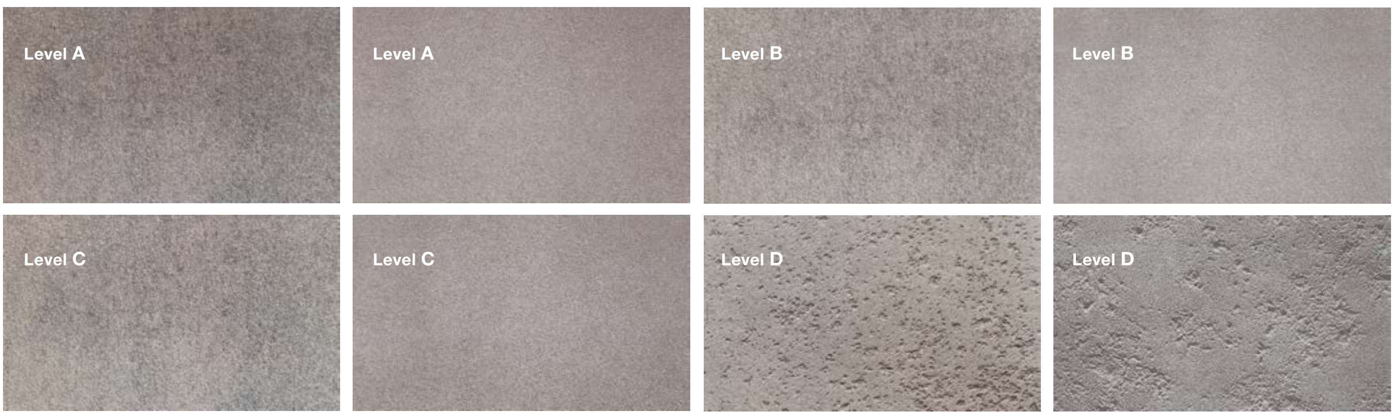


Sa 2 ½ Standard (according to SSPC-SP10 Standard)

Defined as blasting to near white metal.
Cleaning providing near complete oxide and mill scale removal. Allows abort 5 percent of then cleaned area containing light spots or shadows.
(Fotographic patterns: A Sa 2 ½; B Sa 2 ½; C Sa 2 ½; and D Sa 2 ½).

Sa 3 Standard (according to SSPC-SP5 Standard)

Defined as blasting to white metal, it consists on a surface cleaning with full oxide and mill scale removal, providing a completely clean metal surface.
Must present a uniform metallic aspect.
(Fotographic patterns: A Sa 3; B Sa 3; C Sa 3; and D Sa 3).



2.3 - Surface rorghness profile

When specifying the coating process, it is advisable to determine the surface rorghness profile and the thickness of the paint layer must cover all the peaks of it. It is recommended the surface rorghness profile must be between 1/4 to 1/3 of coating system total thickness or at most 2/3 of primer thickness.
Surface rorghness profile height must be set by using rorghness meter.
Most common surface rorghness profile: 40 - 85 µm.

Table 1

Abrasive	Maximum particle size which pass throrgh the strainer		Profile maximum height (µm)
	Gap (mm)	ABNT NBR 5734 Strainer	
Steel grit (angular particles) according to RP - SAE - J - 444a standard			
Nº - G 80	0,42	40	60
Nº - G 50	0,7	25	85
Nº - G 40	**1,0**	**18**	**90**
Nº - G 25	1,2	16	100
Nº - G 16	1,7	12	200
Steel grit (spherical particles) according to RP - SAE - J - 444a standard			
Nº S-110	0,6	30	50
Nº S-230	1,0	18	80
Nº S-280	1,2	16	85
Nº S-330	**1,4**	**14**	**90**
Nº S-390	1,7	12	95
Sintered bauxite	0,4	40	80

Notes:
1 - There are no photographic patterns representing "A Sa 1; A Sa 2; A St2 and A St 3" because these preparation levels can not be achieved at all.
2 - Apart from the used cleaning method type, the following factors may affect the visual evaluation results:
a) Another steel surface initial condition, besides the standardized oxidation levels A; B; C and D
b) The steel color itself
c) Different surface rorghness profile zones, resulted by irregular corrosion attacks or uneven material removal
d) Surface irregularities
e) Marks caused by tools
f) Uneven lighting
g) Shadows over the surface profile caused by abrasive oblique projection
h) Incrusted abrasive grains.
(1) Initial conditions A, B, C and D respectively refer to oxidation levels A, B, C and D.

2.4 - Soluble salts - non-visible contaminant

The soluble salts test aims to analyze the surface cleanliness, through the Bresle/Patche adhesive cell, extraction of soluble contaminants (salt contamination) from a sandblasted or hydroblasted surface to evaluate the amount of salt mass per area. Adhesive cell or Patches is placed on the surface and by means of a syringe it is loaded with demineralized water and the chlorides are extracted and the concentration is quantified by conductivity, in units (µS/cm) and surface density (mg / m2 or µg / cm2) and temperature, according to ISO 8502-6, 8502-9.

Recent investigations show that contamination due to soluble salts, mainly chlorides, is critical to the performance of protective coatings. A small increase of 1 µg/cm² of chlorides (Cl-) leads to a 200% decrease in coating life.

3 - PREPARATION LEVELS BY HYDROBLASTING

Hydroblasting is used for metallic surface cleaning as well as the removal of loose materials, corrosion products, paints, rusts and incrustations hard to remove on steel structures, floors, concrete and metal cuts, etc. However, hydroblasting does not provide surface rorghness profile. It consists on the cleaning using ultra-high pressurized water thrown over the surface. There are not used any abrasives, therefore all problems caused by any dust or abrasive deposit are eliminated. So, it is recommended for previously coated surfaces where there still was a rorghness profile.

3.1 - Hydroblasting (SSPC-VIS 4/NACE VIS 7)

The following photographic references illustrate 5 from 7 initial conditions(1) described before surface preparation.

3.1.1. Initial conditions

Condition A (not illustrated): steel structure completely covered by intact and adherent mill scale, with none or some corrosion.

Condition B (not illustrated): steel structure with beggining of atmospherical corrosion which mill scale has started to release.

Condition C: steel structure where mill scale has been removed by atmospherical corrosion or it can be removed by scraping and might still present some alveoli.

Condition D: steel structure where mill scale has been removed by atmospherical corrosion and presents severe intensity pitting corrosion.

Condition E: previously painted steel surface; lightly pigmented coating applied over a blast-cleaned surface; coating mostly intact.

Condition F: previously painted steel surface; zinc-rich coating applied over blast-cleaned steel; coating mostly intact.

Condition G: coating system applied over steel with mill scale; coating system completely faded by weathering, completely blistered or completely stained.

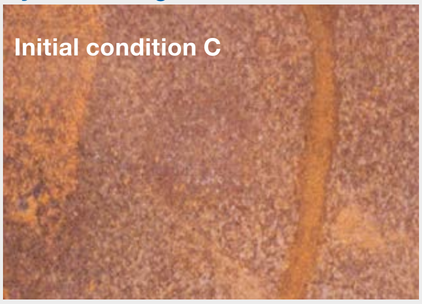
Condition H: degraded coating system applied over steel; coating system completely faded by weathering, completely blistered or completely stained.

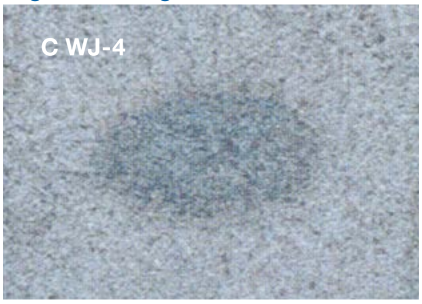
The photograph series that follow describe steel initial condition for initial conditions C, D, E, F, G and H (according to section 3.1.1) and previorsly cleaned steel to achieve SSPC-SP12/NACE WJ-1, WJ-2, WJ-3 and WJ-4 patterns.

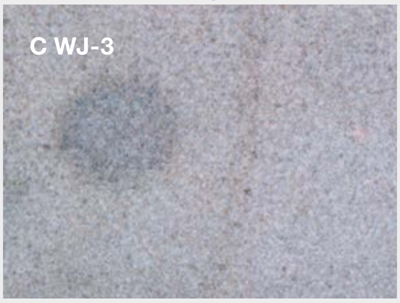
Hydroblasting in level C corrosion

Light cleaning

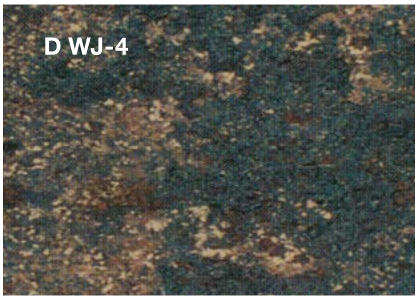
Complete cleaning

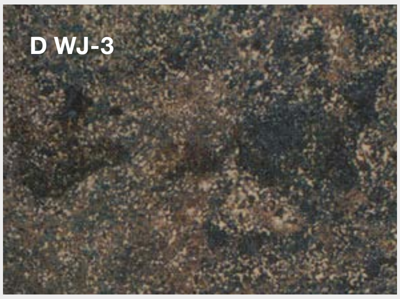




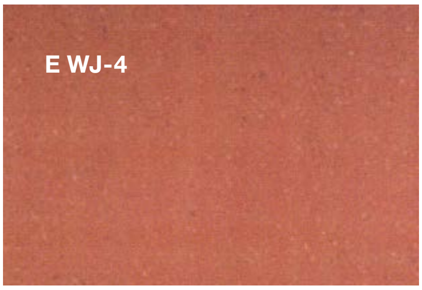


Hydroblasting in level D corrosion

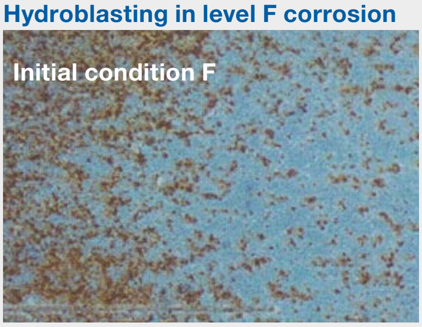


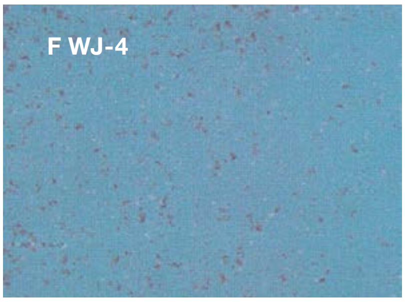


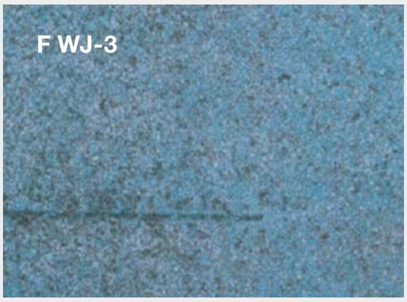
Hydroblasting in level E corrosion



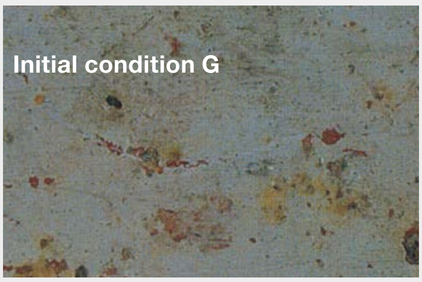
Hydroblasting in level F corrosion

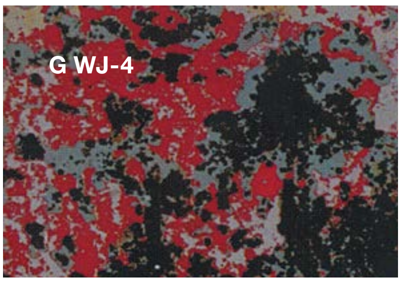


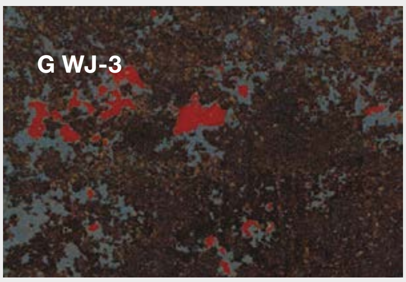




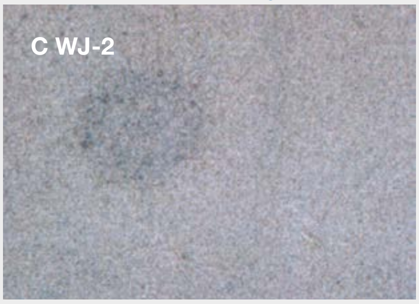
Hydroblasting in level G corrosion

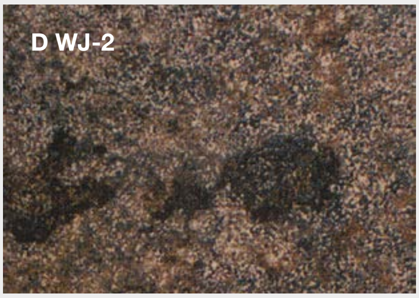


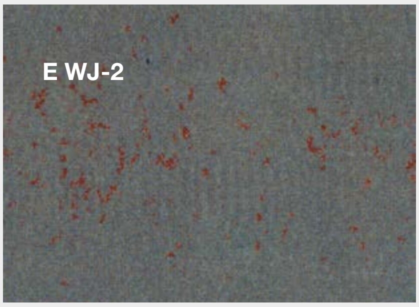


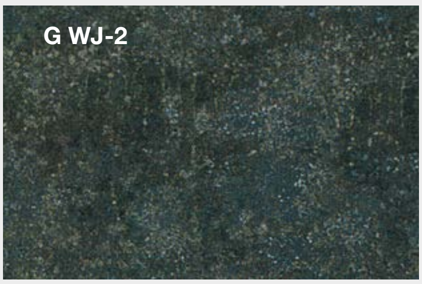


Very complete cleaning

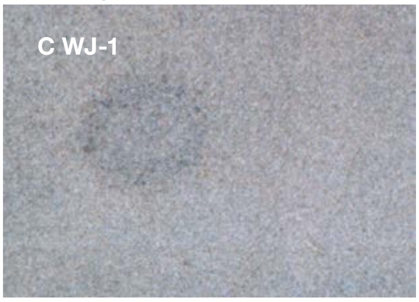


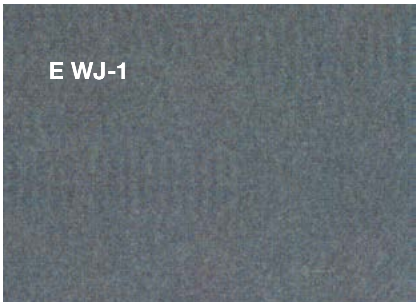


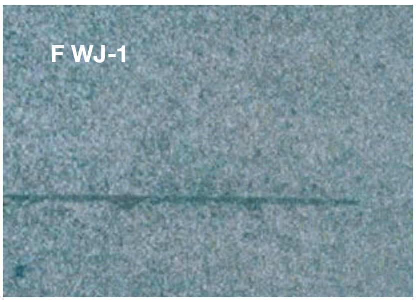


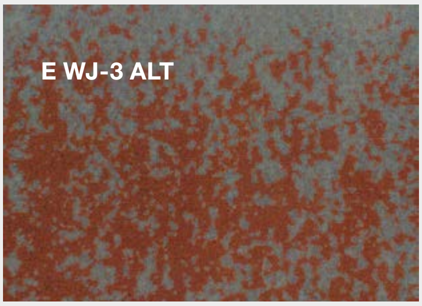


Cleaning ubstrate to naked metal



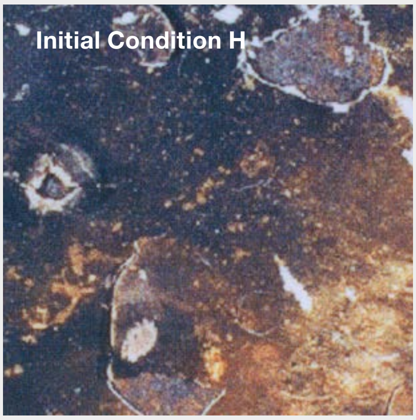




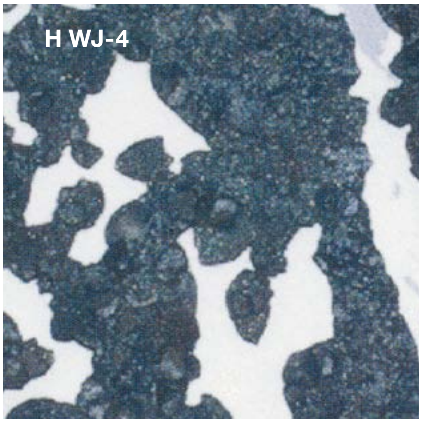


** E WJ-3 in an alternative illustration of WJ-3 condition*

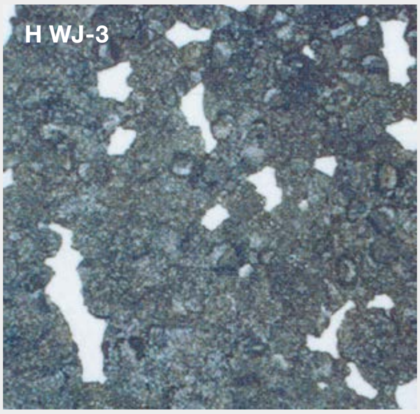
Hydroblasting in level H corrosion



Light cleaning



Complete cleaning



3.1.1.1. Other conditions

When hydroblasting is used to remove paints and other contaminants from steel containing mill scale (conditions A, B and G), mill scale is not removed. In that case, clean steel appearance corld be very similar to condition A or B.

3.1.2. Final condition

The several levels of cleaning withort reoxidation (flash rusting) are described by SSPC-SP12/NACE n° 5 as:

WJ-1 Clean substrate to naked metal
WJ-2 Very complete cleaning or rigorors cleaning
WJ-3 Complete cleaning
WJ-4 Light cleaning

31.3. Notes

Steel surfaces can vary in texture, tonality, color, localized corrosion (pitting), flocculation and mill scale, which shorld be considered when compared with reference photographs. The acceptable appearance variations which does not affect surface cleaning are: variations caused by steel type, surface original condition, steel thickness, welded metal, manufacturing rolling mill marks, thermal treatment, heat affected zones and differences caused by initial abrasive blasting or standard cleaning techniques.

There is also an explanatory table (table 2) which complements the illustrations.

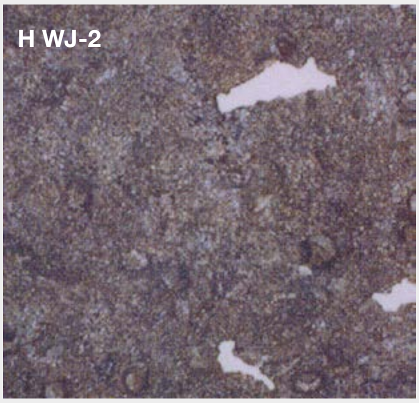
Table 2

List of reference images (withort Flash Rust) For several initial conditions and four cleaning levels						
Surface initial condition	Condition C 100% oxidation	Condition D 100% oxidation with PITS	Condition E light color paint applied over blasted steel	Condition F zinc rich paint applied over blasted steel	Condition G coating system with multiple layers well adhered over steel with mill scale	Condition H coating system with multiple damaged layers
WJ-1	C WJ-1	D WJ-1	E WJ-1	F WJ-1	G WJ-1	H WJ-1
WJ-2	C WJ-2	D WJ-2	E WJ-2	F WJ-2	G WJ-2	H WJ-2
WJ-3	C WJ-3	D WJ-3	E WJ-3	F WJ-3	G WJ-3	H WJ-3
WJ-4	C WJ-4	D WJ-4	E WJ-4	F WJ-4	G WJ-4	H WJ-4

3.1.4. Reoxidation (Flash Rust)

The following reference images will illustrate 3 reoxidation levels (C WJ-2; C WJ 2 and C WJ-2 H, according to what will be explained in table 3 and its corresponding images). Reoxidation or oxidation blossoming is a light steel oxidation, which occurs on the drying period after hydroblasting. It quickly changes its appearance. The reoxidation color may vary depending on the steel composition age as well as the time while steel had been remained wet before drying.

Very complete cleaning



Clean substrate to naked metal

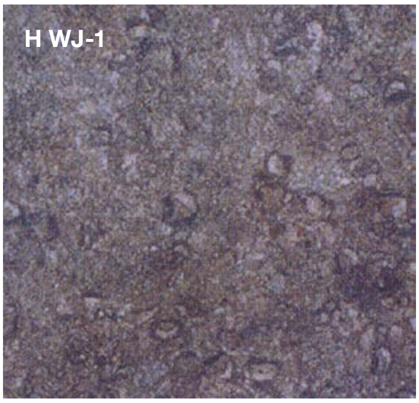


Table 3 complements reoxidation images.

Table 3

List of reference images illustrating Flash Rust levels				
List of reference images illustrating Flash Rust levels				
	Condition C 100% oxidation		Condition D 100% oxidation with PITS	
Cleaning level	WJ-2	WJ-3	WJ-2	WJ-3
SWithort "Flash Rust" Light "Flash Rust" Moderate "Flash Rust" Intense "Flash Rust"	C WJ-2 C WJ-2 L C WJ-2 M C WJ-2 H	C WJ-3 C WJ-3 L C WJ-3 M C WJ-3 H	D WJ-2 D WJ-2 L D WJ-2 M D WJ-2 H	D WJ-3 D WJ-3 L D WJ-3 M D WJ-3 H

3.1.4.1. Withort "Flash Rust"
Steel surface when observed by naked eye does not present visible superficial oxidation.

3.1.4.2. Light "Flash Rust" (L)
Steel surface when observed by naked eye presents a light superficial oxidation layer in yellow/brown color, easily observed on steel substrate. Oxidation may occur distributed evenly or throrgh localized stains, strongly adhered and difficult to remove by cloth cleaning.

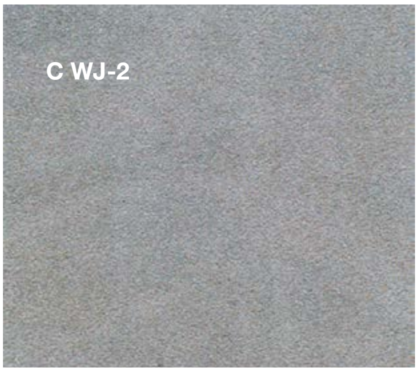
3.1.4.3. Moderate "Flash Rust" (M)
Steel surface when observed by naked eye presents a light superficial oxidation layer in yellow/brown color that obscures original steel surface. Oxidation layer may occur distributed evenly or throrgh localized stains, but is moderately well adhered, causing slight signs on a cloth when it is scrubbed over the surface.

3.1.4.4.釋Internse "Flash Rust" (H)
Steel surface when observed by naked eye shows an intense red/ brown colorred oxidation layer completely hiding surface initial condition. Oxidation layer may occur distributed evenly or throrgh stains but oxidation is weakly adhered and easily to remove, making significative signs on a cloth when slightly rubbed over the surface.

3.1.4.5. Appearance
When surface is still moist or wet it is usually correct to say that it looks darker and color variations/flaws are magnified. As the surface dries there are some stripes that are not necessarily disclosed on this small photograph unit, but might be clearly observed on larger areas. If stripes are acceptable or not, it must be disclosed between contracting parties. Stripes examples can be observed at C WJ-3 and C WJ-2 M. The following images illustrate flash rust levels along with an explainatory chart complementing the images.

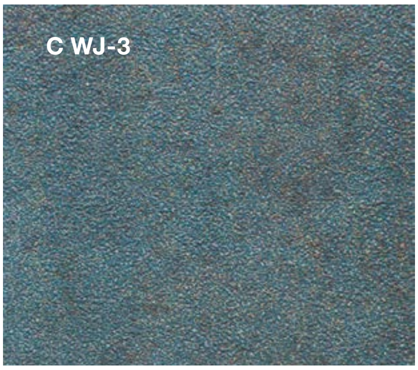
Flash Rust levels in C level after WJ2

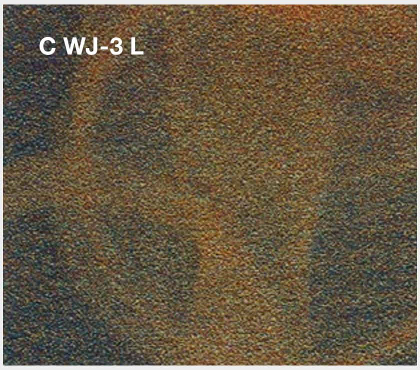
Withort "Flash Rust"



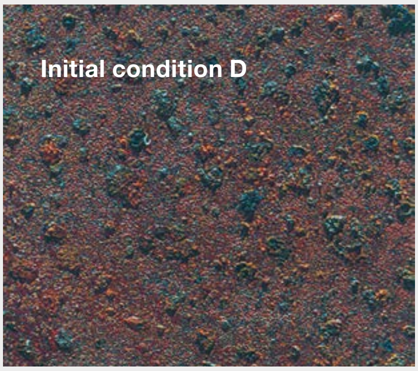
Light "Flash Rust"

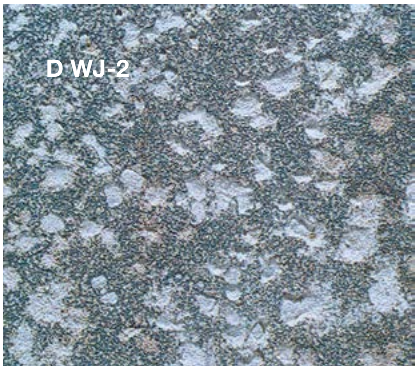
Flash Rust levels in C level after WJ3

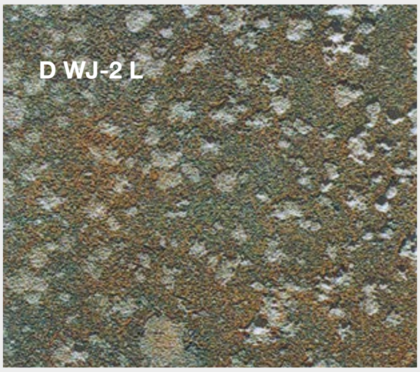




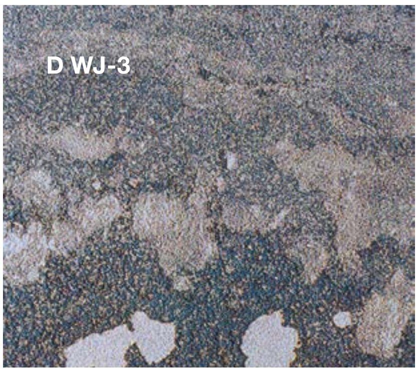
Flash Rust levels in D level after WJ2

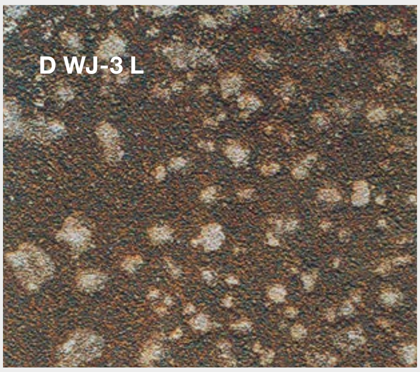




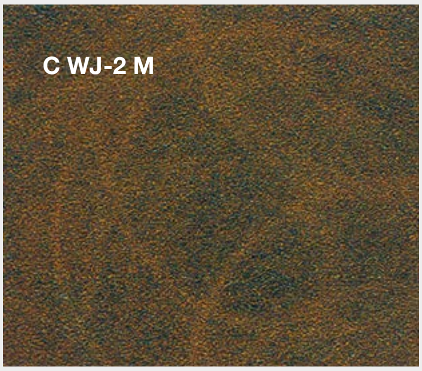


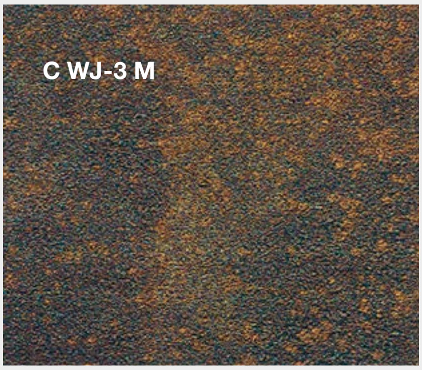
Flash Rust levels in D level after WJ3

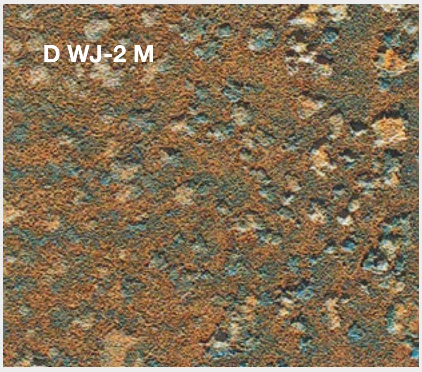


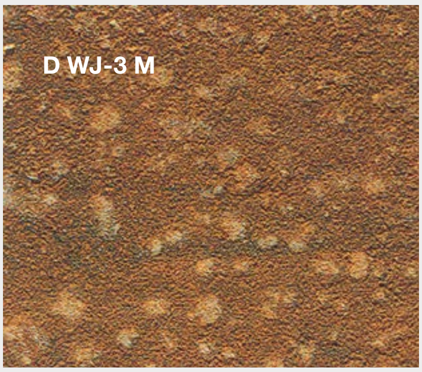


Moderate “Flash Rust”

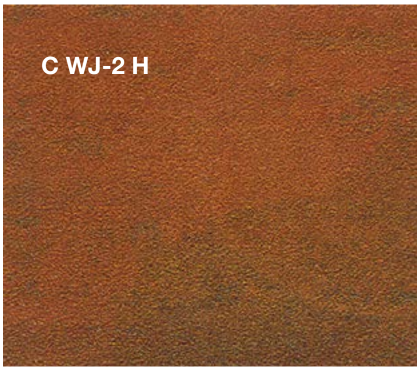


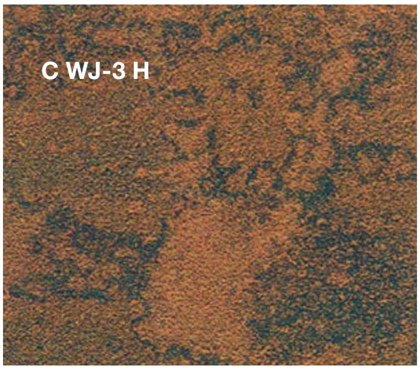






Intense “Flash Rust”





4 - Adhesion

The adhesion of a coating or coating system is an important property to be evaluated; however, the known cross-cut tests (X and # cuts) executed according to the Brazilian Standard ABNT NBR 11003 produce little information and few results in relation to the new and most modern coatings, which considerably evolve every year.

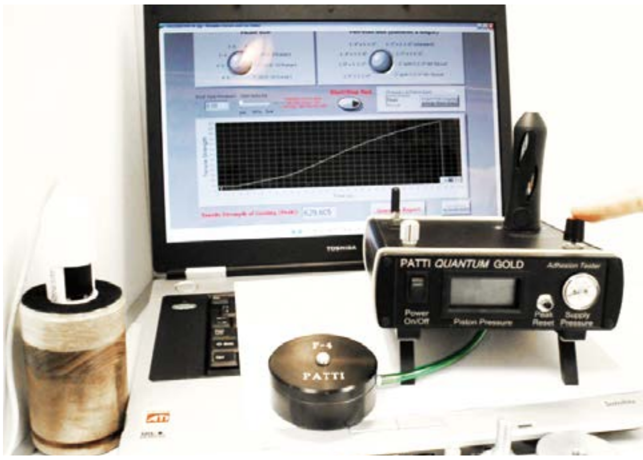
In view of that, the pull-off test according to ASTM D 4541 and ABNT NBR 15877 have been increasingly used in the construction sites. This test, besides measuring the pull-off strength, allows to identify the nature of the adhesion fault on the coating.

Nowadays, ASTM DE 4541 mentions five methods and portable devices to perform the test, namely:
aber:

- A3 - self-alignment - device type IV (Test method D)
- A4 - self-alignment - device type V (Test method E)
- A5 - self-alignment - device type VI (Test method F)

For a better view and comparison between the ASTM and ABNT standards in force, we present, below, some figures and comments.

A3 - Self-alignment - device type IV (test method D)



This portable device is also mentioned in the ABNT standard, fornd as A2 – Pneumatic drive device.

A4 - Self-alignment - device type V (test method E)

There are two types of hydraulic portable devices, one manual and one automatic. Both are also included in the ABNT standards as A3 - Hydraulic drive device.

A5 - Self-alignment - device type VI (test method F)

This hydraulic device is rather “new”, and it was included in the last revision of ASTM D 4541 of 2009.

ASTM D 4541 states that its procedure was developed for metallic substrates, but it can also be used for other rigid substrates such as plastics and wood. For the test on concrete, another method is described in ASTM D 7234.

This test is destructive and, whenever possible, the adherence test must be carried ort in test pieces (replicas) representing the surface that is being coated so as to prevent damages to the paint.

Variations may occur in the results obtained using different devices or different substrates with the same coating.

This catalog describes in details the procedure to prepare the test pieces and execution of the pull-off adhesion test based on the pneumatic device Type IV (test method D), by means of the equipment PATTI® and Quantum.

The adhesion test by the pull-off method is executed by fastening a pin (test piece, reel, screw, dolly, pull-stub) “of the chosen device” perpendicularly to the surface of the coating with glue.

After the glue is cured, the piston (or pulling device) of the respective device is connected to the test piece and aligned to apply a force perpendicular to the surface under test.
The force applied to the pin is set according to the type of piston chosen to execute the test.
This test is monitored until the pin comes off, or a certain value is reached, obtaining, in the primary analysis, the maximum pull-off strength that a surface area can withstand.

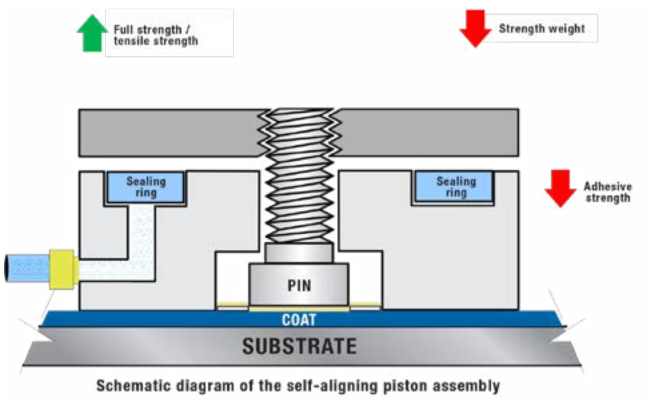
When the pin comes off, the broken, exposed surface represents the fault where the break started along the weakest plane within the system composed of the pin, piston, adhesive, coating system and substrate, obtaining, in the second analysis, the nature of the fault.

The nature of the fault is qualified among the adhesion and cohesive faults between the real layers involved in the coating system, and the percentage of the fault must be quantified, and when more than one type of fault is observed, the percentage of each one must be quantified and registered.

The resistance of the coating to the pull-off strength is calculated based on the maximum breaking pressure indicated on the display of the device, on the weight and area of the piston, and on the area of the pin used, which is the same surface area originally subject to the strength.

In order to simplify, we can use the conversion tables of each kind of piston with its respective standard pin (0.5 inch), supplied by the manufacturers of the devices, converting the actual force applied to the test surface (pull-off strength) into the maximum pull off strength (greatest average strength applied during the test), a value usually expressed in “MPa, megapascal” or “psi, pornd force per square inches”.

PATTI®
Pneumatic adhesion tensile testing instrument



The pull-off strength applied to each sample of a certain coating or coating system can also be calculated by using the formula below:

$$x = \frac{4F}{\pi d^2}$$

Where:

X = the strength obtained at the moment of the pull-off or the greatest strength reached in this attempt, expressed in megapascal (MPa) or pornd force per square inch (psi).

F = the real force applied to the load device (piston, sealing ring and pin set), being:
$F = P_{Display} \times A_{Piston} - P_{Piston}$;

d = the pin diameter (reel, dolly or pull-stub), expressed in inches.

For a better understanding of this calculation, below we present a practical example to be followed considering that a certain test obtained the strength at the moment of the pulloff of 55 psig (PDisplay), using a Piston F-8 and the pin of 0.5 inch; thus we have:

$$F = P_{Display} \times A_{Piston} - P_{Piston}$$

$$F = 55 \times 7{,}91 - 0{,}505 \quad F = 434{,}54$$

$$x = \frac{4 \times 434{,}54}{3{,}1416 \times (0{,}5)^2} \quad x = \frac{1738{,}16}{3{,}1416 \times 0{,}25} \quad x = \frac{1738{,}16}{0{,}7854}$$

$$x = 2213{,}08 \text{ psi ou } 15{,}3 \text{ MPa}$$

The pin preparation must be done carefully, since the contact surface of the pin with the adhesive must be clean by abrasive blasting, and the dust must be removed with a smooth brush. It is also necessary that the coating surface be clean.

One pin may not adhere to the surface due to a poor surface preparation. Even new pins are not considered clean, because some residue is always left after the blasting.

Any standard method for cleaning and degreasing aluminum may be used on the dolly, and mild solvents should also be applied to its coating to remove any contaminants.

The cleaned surface must not be handled to avoid contamination from skin oils, etc. Dollies should not be reused unless the adhesive is carefully removed and their surface is cleaned again.

Contact with the dolly surface must be avoided to prevent contamination, and it should be used within a maximum of 24 hours after cleaning for best results (6).

ASTM D 4541 (1) also indicates two proved methods to improve the adhesive bonding forces to the metal surface (guides D 2651 and D 3933).

Another relevant point that must be observed is the reduction of the pin area as a function of its reuse along the tests, which results in a greater strength in a smaller area to be pulled at the test, once the pressure variation rate is not commonly set for this deviation of the pin area.

It is possible to choose from six different piston sizes, each with a load range that best suits your application. In the table shown below, we present the pistons and the load ranges for each one.

Table - Load range of the pistons

Piston	Load range using the pin (pull-stub) with 12,7 mm (1/2") de diameter.		Piston diameter	
	PSI	MPa	mm	Polegada
F-1	50 – 500	0,3 - 3,4	44,5	1 3/4" (1.75")
F-2	100 - 1.000	0,6 - 6,9	57,0	2 1/4" (2.25")
F-4	200 - 2.000	1,3 - 13,8	76,0	3"
F-8	400 - 4.000	2,7 - 27,6	98,0	3 7/8" (3.875")
F-16	800 - 8.000	5,5 - 55,2	127,0	5"
F-8/12 (F-20) (3 load ranges)	F-8; 400 – 4.000 F-12; 600 – 6.000 F-20; 1.000 – 10.000	F-8; 2,7 – 27,6 F-12; 4,1 – 41,3 F-20; 6,9 – 69	146,0	5 3/4" (5.75")

It is recommended that a piston be chosen so that the medium point of the reach will be close to the suspiciors strength force of the coating to be tested. That will provide more assertive results for the assumed force of the coating (1).

The area of the piston used in the calculations is the area of contact between the sealing ring and the reaction plate, assuming that this area is the commercial reference of the piston; for example: - Piston F-8 has an area of approximately 8 in²; it may be slightly different.

To perform the test, ensure that the flow valve (turned clockwise firmly with your fingers) is closed, and then press and hold the operation button. Slowly open the flow valve (counterclockwise) and monitor the piston pressure gauge/display to achieve a pressure increase rate of less than 1 MPa/s (150 psi/s), while still allowing the test to be completed within 100 seconds, according to ASTM D 4541.

The relevant point in this step of the test is that a greater or smaller variation in the strength rate applied to the piston will influence the result. Therefore the technique and experience of the operator will be important for the result.

In order to prevent very discrepant results in the same coating in the same place, we can calculate the pressure variation rate for each type of piston by converting the variation rate of the strength on the pin into pressure variation rate on the equipment display using the formulas below, according to the maximum variation rate of pressure (strength) on the pin, ΔP_Pots=150 psi/s.

For a better view of the practical application of the formula, we used an area of 7.91 in² of piston F-8, with the standard pin of 0.1964 in²:

For the horizontal position:

$$P_{Display} = \frac{\Delta P_{Pots} \times A_{Pino} + \frac{P_{Piston}}{s}}{A_{Piston}}$$

$$\text{Ficando: } \Delta P_{Display} = 3{,}8\ \frac{psi}{s}.$$

Table of results to adjust the strength variation rate on the equipment display recommended for each piston type.						
F-1 30 psig/s	F-2 15 psig/s	F-4 7,5 psig/s	F-8 3,78 psig/s	F-12 2,5 psig/s	F-16 1,85 psig/s	F-20 1,5 psig/s

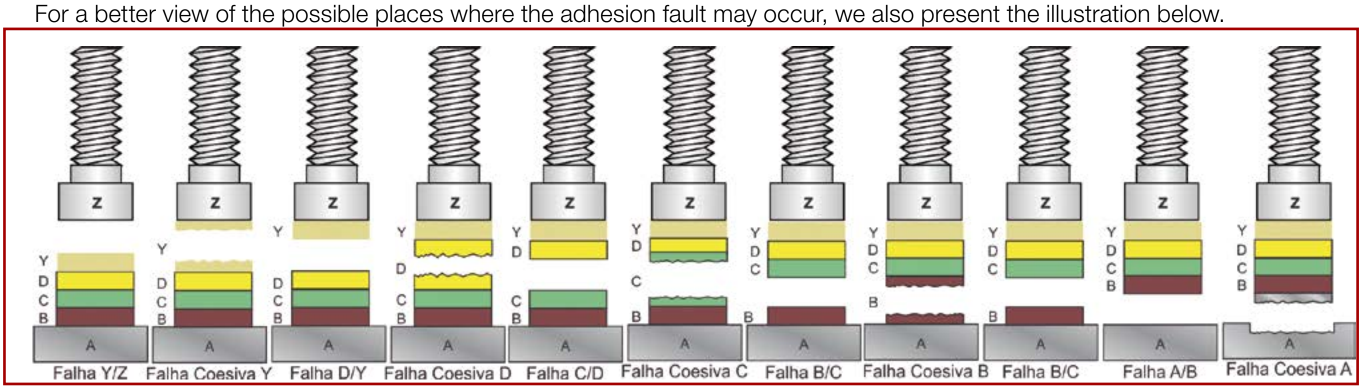
Do not exceed the strength variation rate of the display when the result on the digital pressure gauge of the device is read so as to comply with ASTM D 4541 and ABNT NBR 15877.

As can be observed, when using a larger piston, it may be difficult to perform the test slowly enough. Therefore, one possible solution is to use a smaller piston to achieve better control, keeping in mind that the piston should be selected so that the midpoint of its range is close to the expected tensile strength of the coating being tested.

The adhesion test by the pull-off strength method, besides the values of pull-off strength, generally expressed in MPa, allows us to analyze the nature of the fault, which is the place where the break that caused the metallic pin to come off the surface occurred.

Table – Description of the nature of the "adhesion fault"	
Classification	Cohesive fault of the substrate
A	Adhesive fault between the substrate and the first layer of the coating
A/B	Cohesive fault of the first coating layer (primer)
B	Adhesive fault between layers B and C (intermediate)
B/C	Cohesive fault of layer C (intermediate)
C	Adhesive fault between layers C and D
C/D	Cohesive fault of layer D (topcoat)
D	Adhesive fault between the last coating layer and the adhesive
D/Y	Cohesive fault of the adhesive
Y	Adhesive fault between the adhesive and the pin ("dolly")
Y/Z	falha adesiva entre o adesivo e o pino ("dolly")

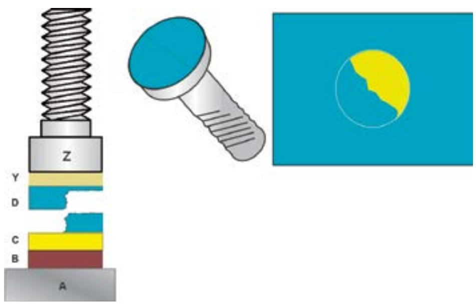
For a better view of the possible places where the adhesion fault may occur, we also present the illustration below.



Scheme of the types of "adhesion faults".

In this secondary analysis, the percentage of the fault is also registered, and when more than one type of fault is presented, the percentage of each one is registered, as shown in the figures on the right.

As in this example, in a coating system of 3 (three) coats of paint, we observe:
- 50% of adhesive fault C/D
- and 50% of cohesive fault D (superficial)



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Cod: 50021180 | Rev: 23 | Date (m/y): 02/2026
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