

Ship Production Panel Meeting  
Tampa, FL, January 2006



# Digital image processing for rust assessment

Muehlhan Equipment Services GmbH  
Hamburg, Germany

# Rust degrees in standardisation






Rust degree on coated surfaces (ISO 4628-3)

Flash rust degree after surface preparation (ISO/FDIS 8501-4)

# Rust degrees in standardization



Rust degrees at initial condition (before surface preparation) (ISO 8501-1)	Rust degrees on coated surfaces (ISO 4628-3) (SSPC-VIS 2)	Flash rust degree after surface preparation (ISO/FDIS 8501-4) (SSPC-VIS 4 NACE VIS 7)
 <p>© ISO</p>	 <p>© Muehlhan</p>	 <p>© Muehlhan</p>
A, B, C, D	Ri 0 bis Ri 5	L, M, H

# Flash rusting after surface preparation



UHP-waterjetting






Wet blast cleaning



# Flash rust degrees - SSPC-VIS 4 / NACE VIS 7

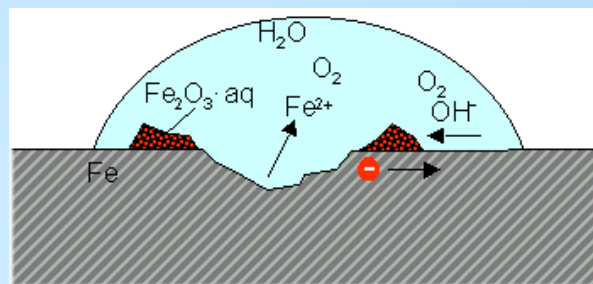


Flash rust degree			Description
light 	L	FR-1	<p>A surface which, when viewed without magnifications, exhibits small quantities of a <i>yellow/brown</i> rust layer <u>through which the steel substrate may be observed</u>.</p> <p>The rust or discoloration may be evenly distributed or present in patches, but will be <b>tightly adherent</b> and not easily removed by light wiping with a cloth.</p>
moderate 	M	FR-2	<p>A surface which, when viewed without magnification, exhibits a layer of <i>yellow/brown</i> rust that <u>obscures the original steel surface</u>.</p> <p>The rust layer can be evenly distributed or present in patches, but it will be <b>reasonably well adherent</b> and lightly marks a cloth that is lightly wiped over the surface.</p>
heavy 	H	FR-3	<p>A surface which, when viewed without magnification, exhibits a layer of <i>heavy red/brown</i> rust that <u>hides the initial surface condition completely</u>.</p> <p>The rust may be evenly distributed or present in patches, but the rust is <b>loosely adherent</b>, easily comes off, and leaves significant marks on a cloth that is lightly wiped over the surface.</p>

# Effects on flash rusting

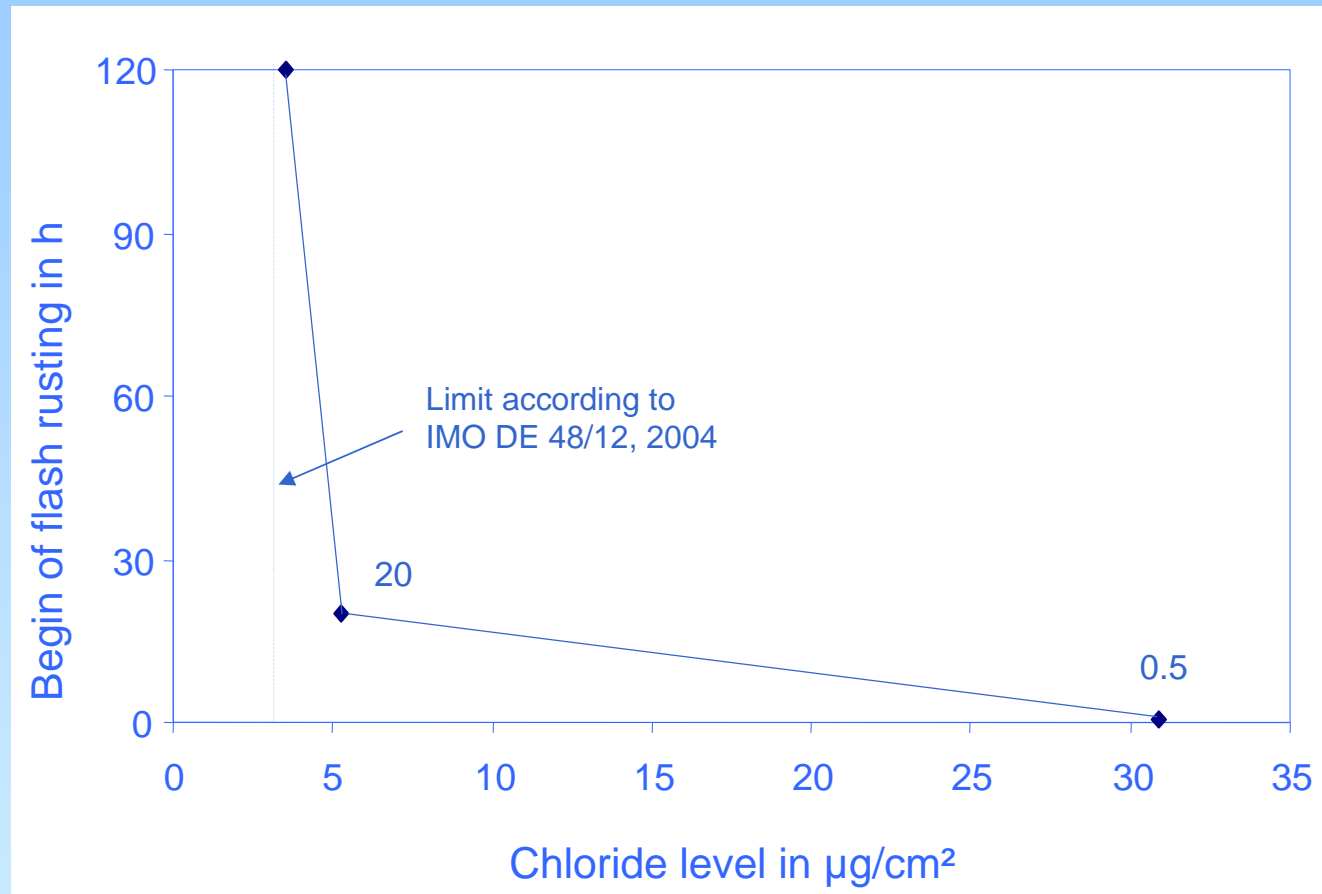


Parameter	Effect on flash rusting
Salt contamination	↑+ ↑+
Relative humidity	↑+ (> 60 %)
Wetting regime	↑+
Temperature	↓- ↓-
Preparation quality	↓-



Flash rust is the result of atmospheric (oxygen) corrosion.

# Chlorides and flash rusting

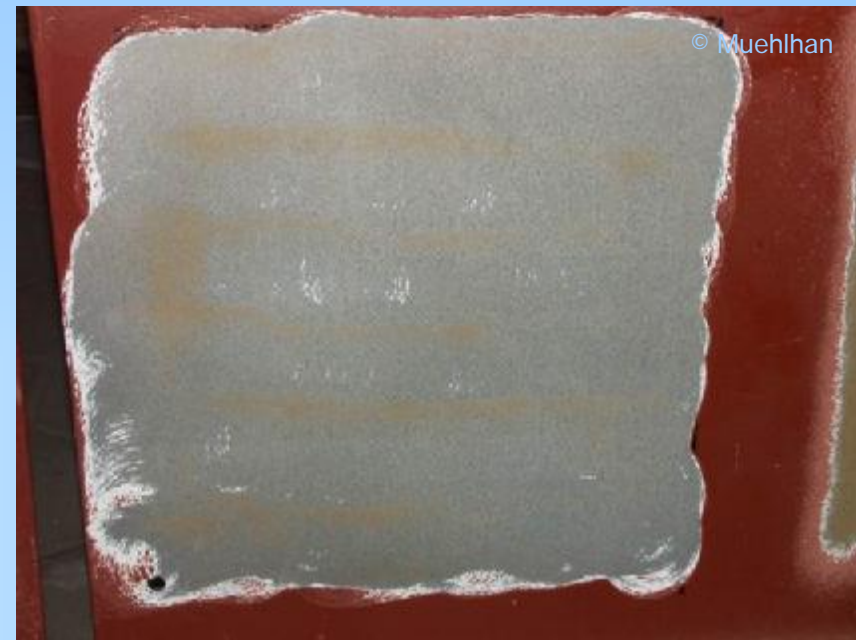


Reference: Dept. of Transport and Urban Planning, Adelaide, Australia

# Wetting regime and flash rusting

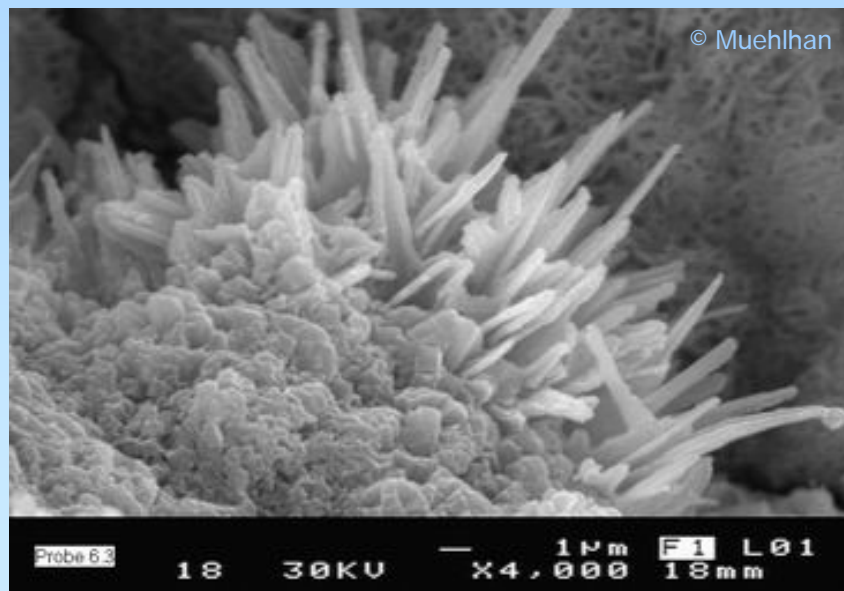
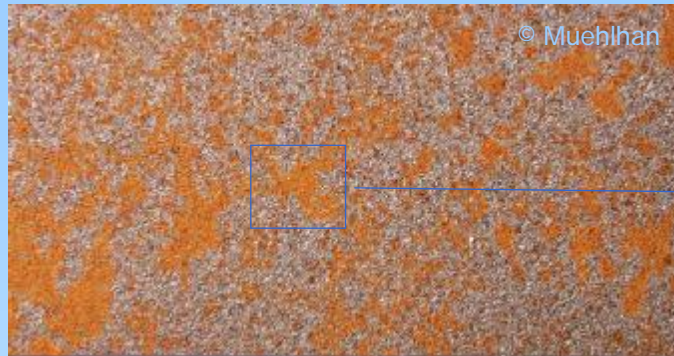


Wet blasting at high relative humidity (70%)

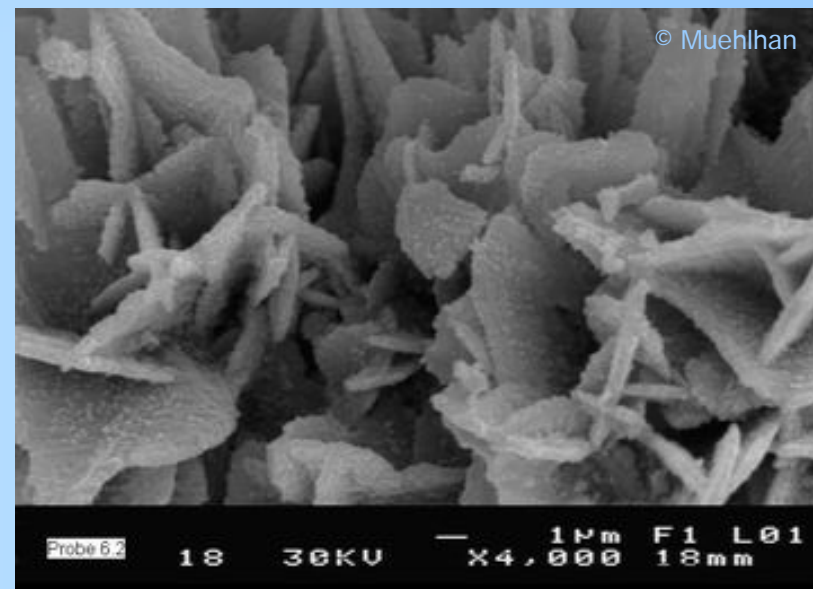


UHP-jetting with rotating nozzle carrier

# Flash rust morphology

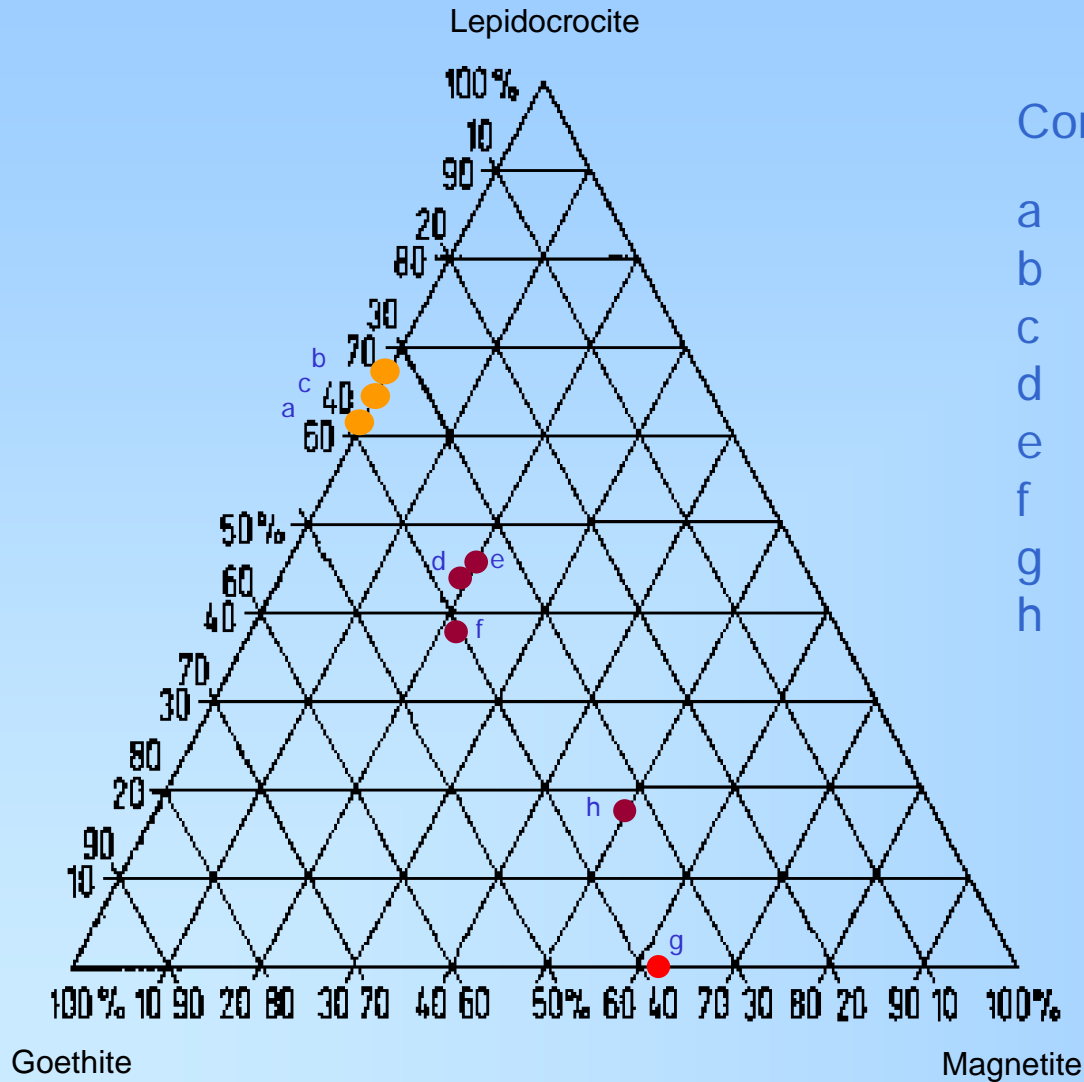


Goethite-crystals ( $\alpha$ -FeOOH)



Lepidocrocite-crystals ( $\gamma$ -FeOOH)

# Phase composition of rust

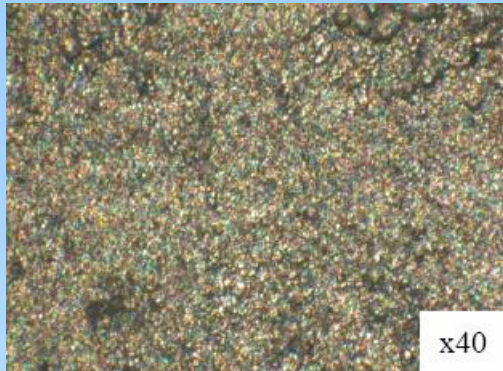


Condition:

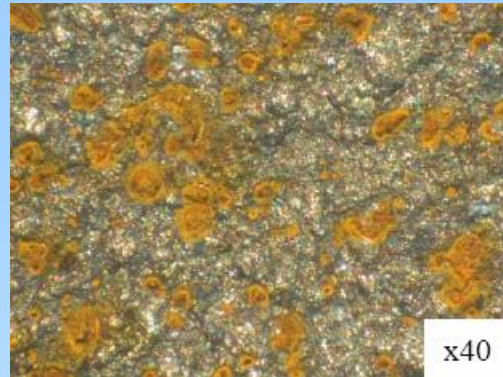
- a after blast cleaning
- b after blast cleaning
- c after blast cleaning
- d old rust, St 33
- e old rust, St 50
- f old rust, St 37
- g old rust, Brücke
- h Industry rust, scale

Measurements from: Keller (1967), Hiller (1966) – crystalline phases only.

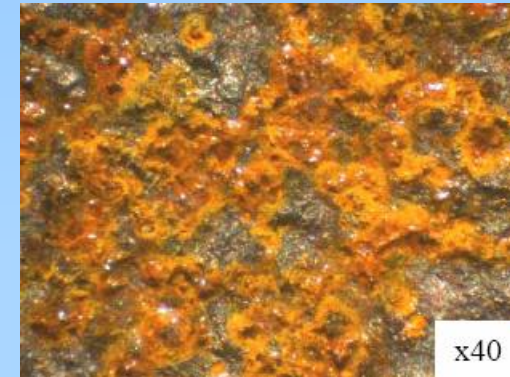
# Kinetics of flash rusting



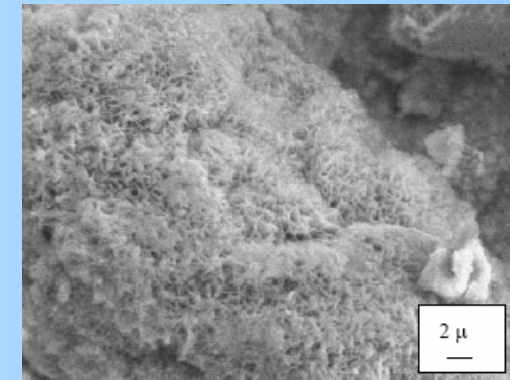
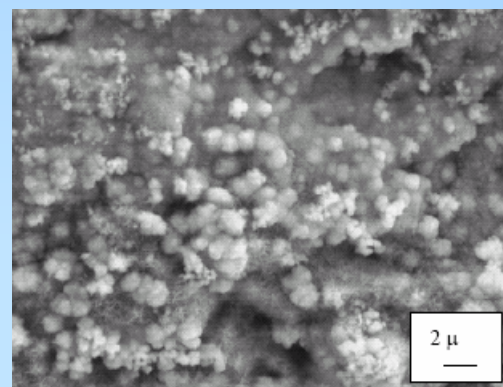
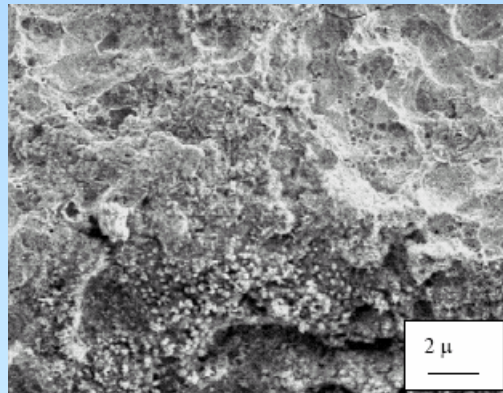
no flash rust



light flash rust

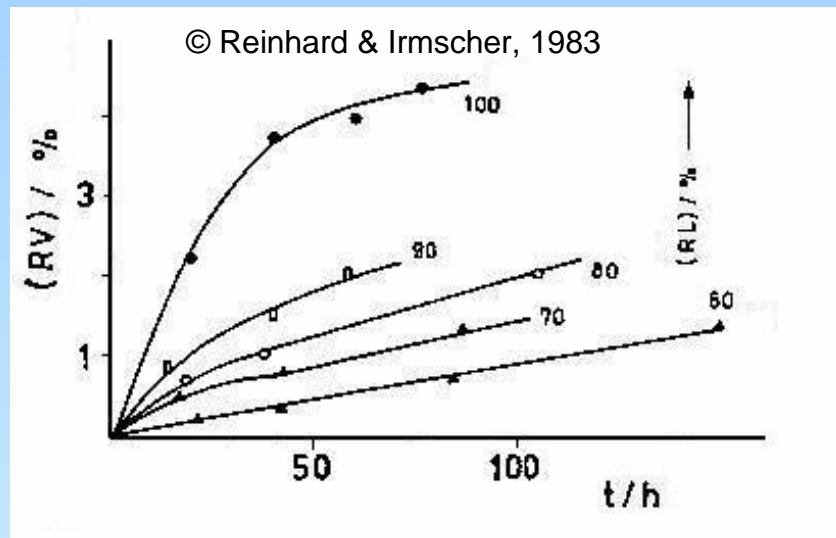


moderate flash rust

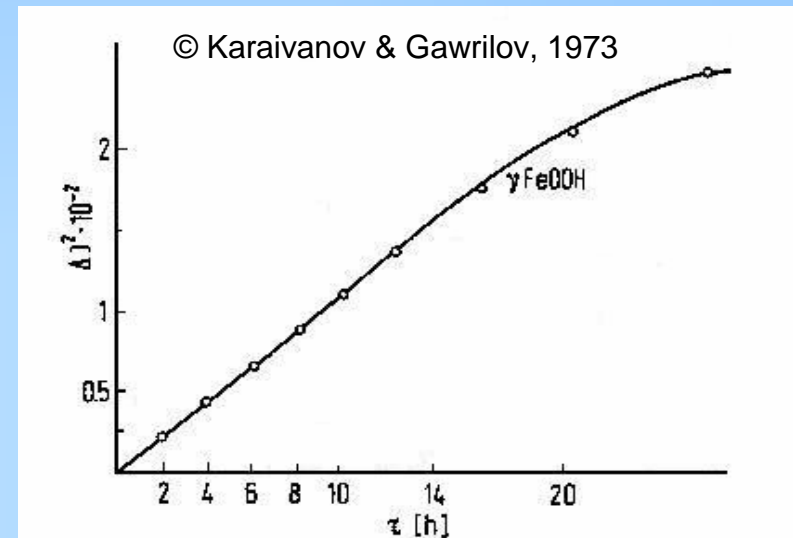


Reference: CorrPro, Washington

# Kinetics of rusting

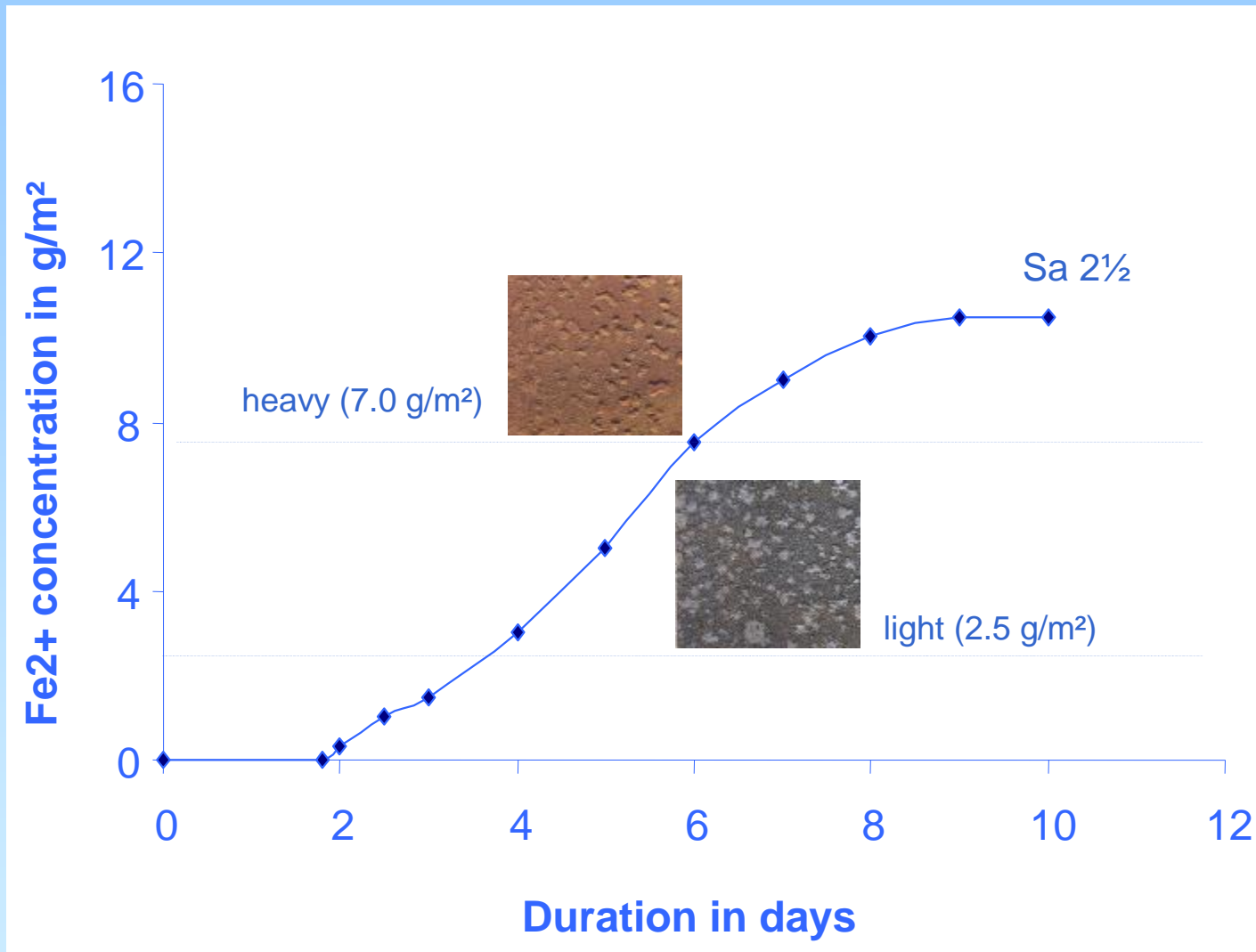


Loss in reflectance due to rusting



Diffraction intensity Lepidocrocite

# Kinetics of flash rusting



Reference: SNCF, Paris

# Kinetics of flash rusting



Steel condition	Fe <sup>2+</sup> -concentration in g/m <sup>2</sup>		
	No visible flash rust	Light / Moderate	Heavy (powdery)
Sa 2½	0 - 2	2 - 7	> 7
Rust Degree C	1.5 - 4	4 - 8	> 8
Deteriorated Shop Primer	0 - 3	3 - 6	> 6

Reference: SNCF, Paris

Flash rust degree	No visible flash rust	Light	Moderate
Thickness in μm	0.5	2.4	18.2

Reference: CorrPro, Washington

# How harmful is flash rust



Coating	Epoxy, solvent-free			Epoxy, with glass flakes			Epoxy, with gf, low cure temperature			Epoxy, modified			Tar-coal epoxy			Epoxy, tank lining		
	K	S	A	K	S	A	K	S	A	K	S	A	K	S	A	K	S	A
Dw2	0	1	Y	0	1	Y	0	2	Y	0	0	B	0	1	B	1	1	Y
Dw2 + FR	0	3	B	0	2	Y	0	2	Y	0	2	B	0	2	B	0	1	Y
Dw3	0	1	Y	0	1	B	0	1	Y	0	1	B	0	1	Y	0	2	Y
Dw3 + FR	0	1	B	0	1	B	0	1	Y	0	0	B	0	2	Y	1	1	Y

Dry film thickness: 2 x 150 μm

Tests:

K = cross cut (numbers in mm)

S = impact test (0 – no damage, 1 – very slight debonding, 2 – slight debonding)

A = pull-off test (Y – failure in glue;

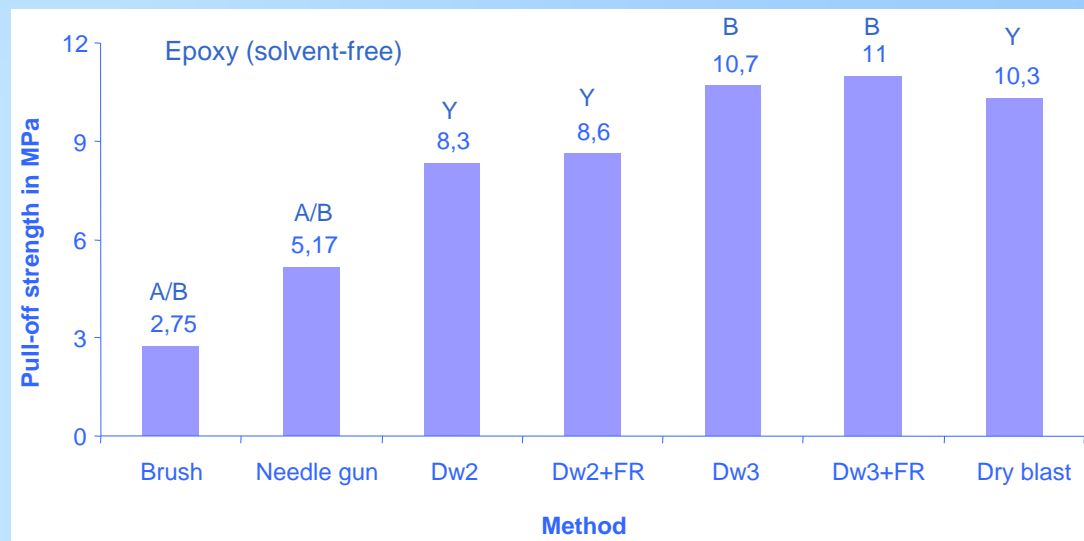
A/B – adhesive failure; B – failure in coating)

Dw2 / Dw3 = UHP jetting according to STG 2222

FR = Flash rust (L/M)

Test duration: 36 months

Reference: Morris (2000)



## Certain coating systems tolerate flash rusting



**Repair and maintenance:** Remove oil and grease, etc. with suitable detergent. Remove salt and other contaminants by (high pressure) fresh water cleaning. Clean damaged areas thoroughly by abrasive blasting or power tool cleaning. As an alternative to dry cleaning, water jetting to sound, well adhering coat and/or to steel. Intact coat must appear with roughened surface after the water jetting. By water jetting to steel, cleanliness shall be minimum WJ-2 (NACE No. 5/SSPC-SP 12). A flash-rust degree of FR-2, preferably FR-1 (Hempel standard) is acceptable before application. Feather edges to sound and intact areas. Dust off residues. Touch up to full film thickness.

## Many coating systems do not tolerate flash rusting

### **NEWBUILDING**

Abrasive blast clean to Sa2½ (ISO 8501-1:1988). If oxidation has occurred between blasting and application of Intershield 163 Inerta 160, the surface should be reblasted to the specified visual standard. A blast profile of 75 microns minimum is required.

### **MAJOR REFURBISHMENT**

Abrasive blast clean to Sa2½ (ISO 8501-1:1988). If oxidation has occurred between blasting and application of Intershield 163 Inerta 160, the surface should be reblasted to the specified visual standard. Surface defects revealed by the blast cleaning process, should be ground, filled, or treated in the appropriate manner. A blast profile of 75 microns minimum is required.

# Certain coating systems do tolerate flash rust



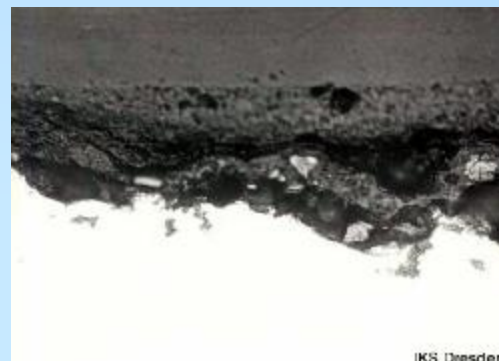
# When better not overcoat flashrust?



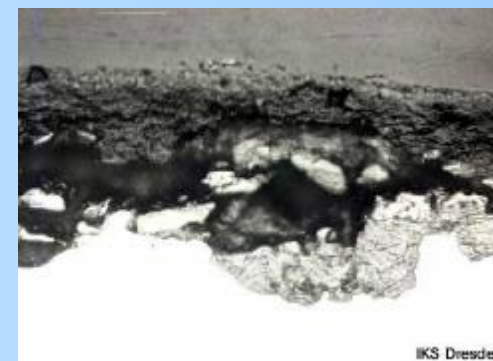
1. If the flash rust is only loosely adherent (designation „H“), or, respectively, if the flash rust layer is rather thick.



2. If the flash rust is not clean (e.g. salt contaminated).



clean rust



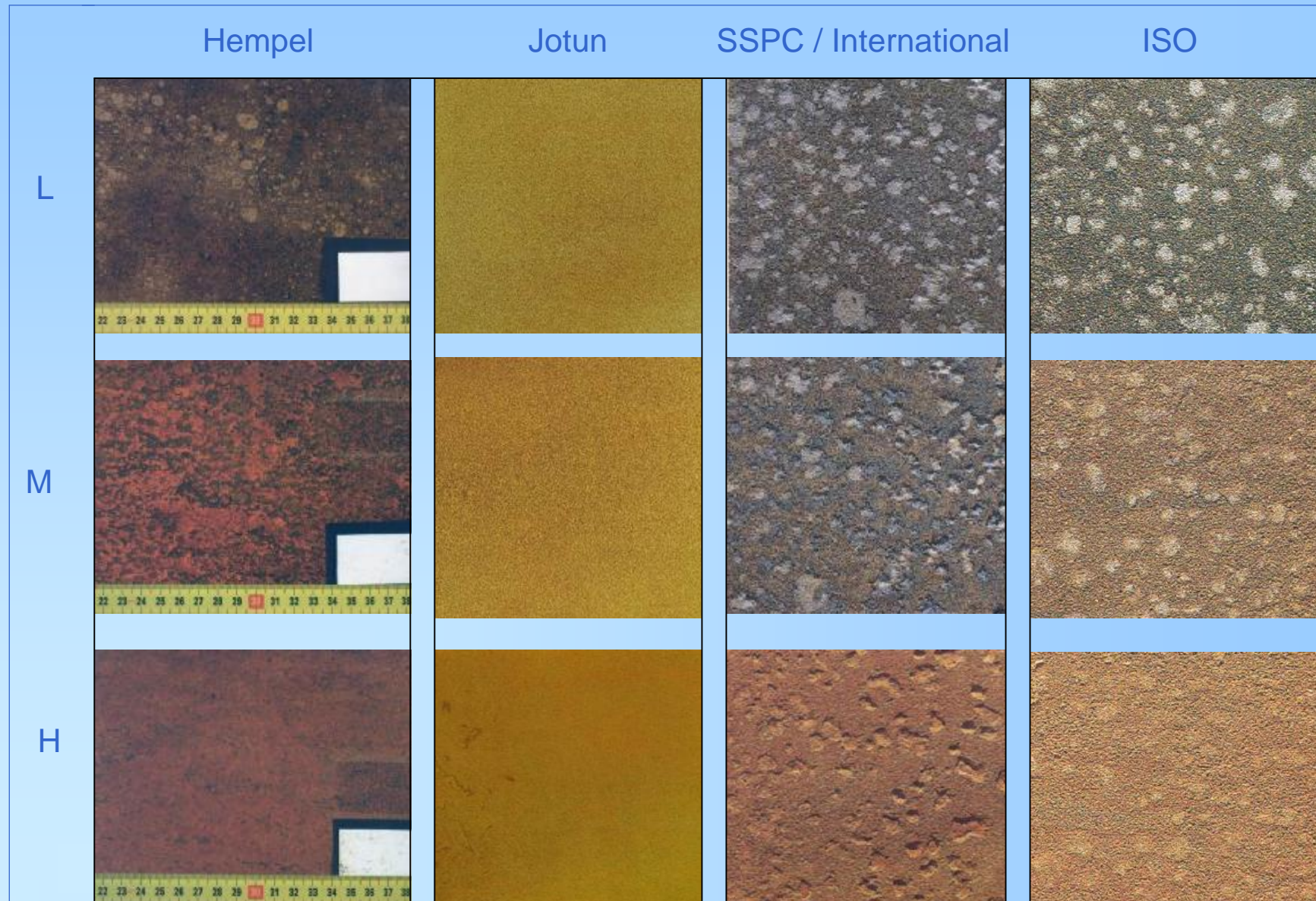
chloride contaminated rust

# Visual flash rusting references

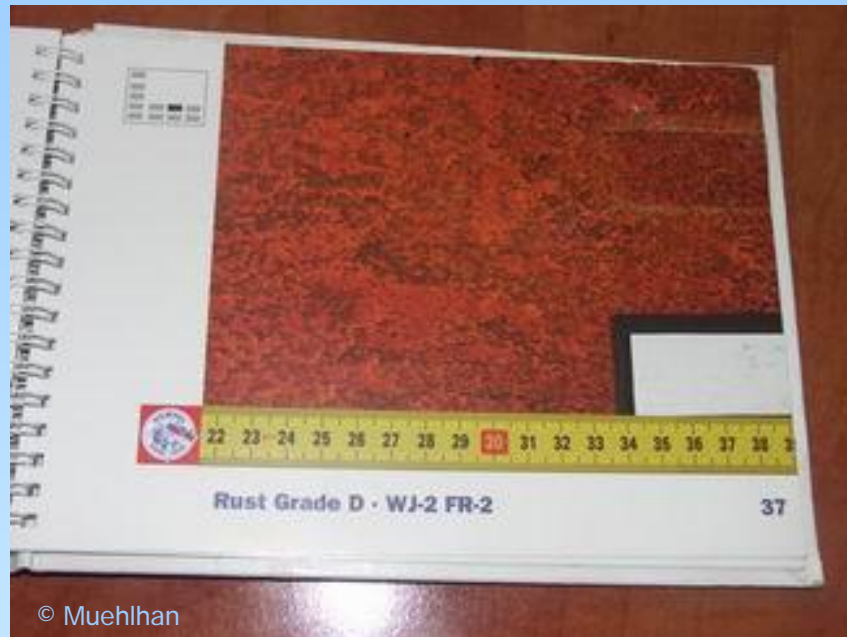


Standard / Reference	Method	Flash rust degree		
		Light (slight)	Moderate (medium)	Heavy (considerable)
ISO 8501-4	Water washing	L	M	H
SSPC-VIS 5	WAB cleaning	L	M	H
SSPC-VIS 4	Waterjetting	L	M	H
NFT 35 520	Cleaning	OF1	-	OF2
International	Slurryblasting	L	M	H
International	Hydroblasting	L	M	H
Hempel	Waterjetting	FR-1	FR-2	FR-3
Jotun	-	JG-2	JG-3	JG-4

# Reference images for flash rust



# Visual flash rust assessment

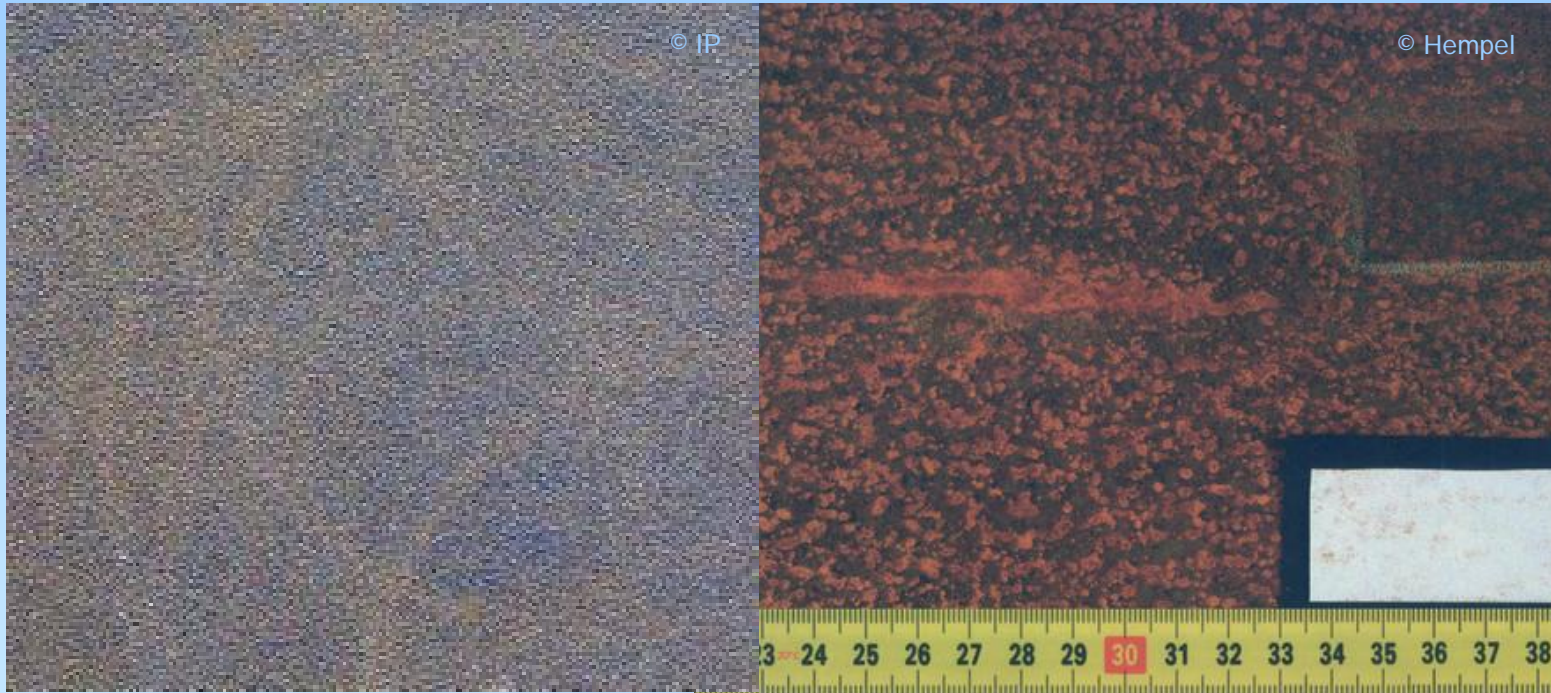


Moderate (FR-2 = M) - Hempel



Light (L) – International / SSPC / NACE

# Visual flash rust assessment (?)



C HB2.5 M

C WJ2-FR2

# Adhesion „test“ for flash rust assessment



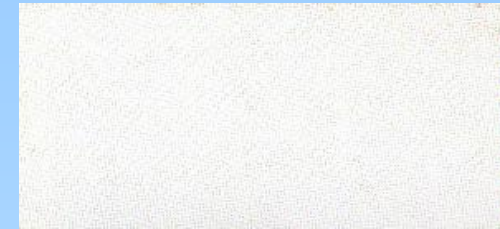
Degree	Adhesion (SSPC-VIS 4 / NACE VIS 7)
L	tightly adherent
M	reasonably well adherent
H	loosely adherent



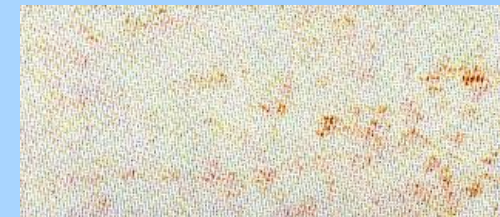
# Assessment with Hempels „Tape-Test“



Tape-Test after WAB cleaning



FR-1 (L)



FR-2 (M)



FR-3 (H)

Assessment scheme  
acc. to Hempel

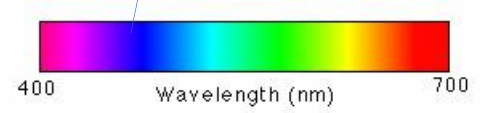
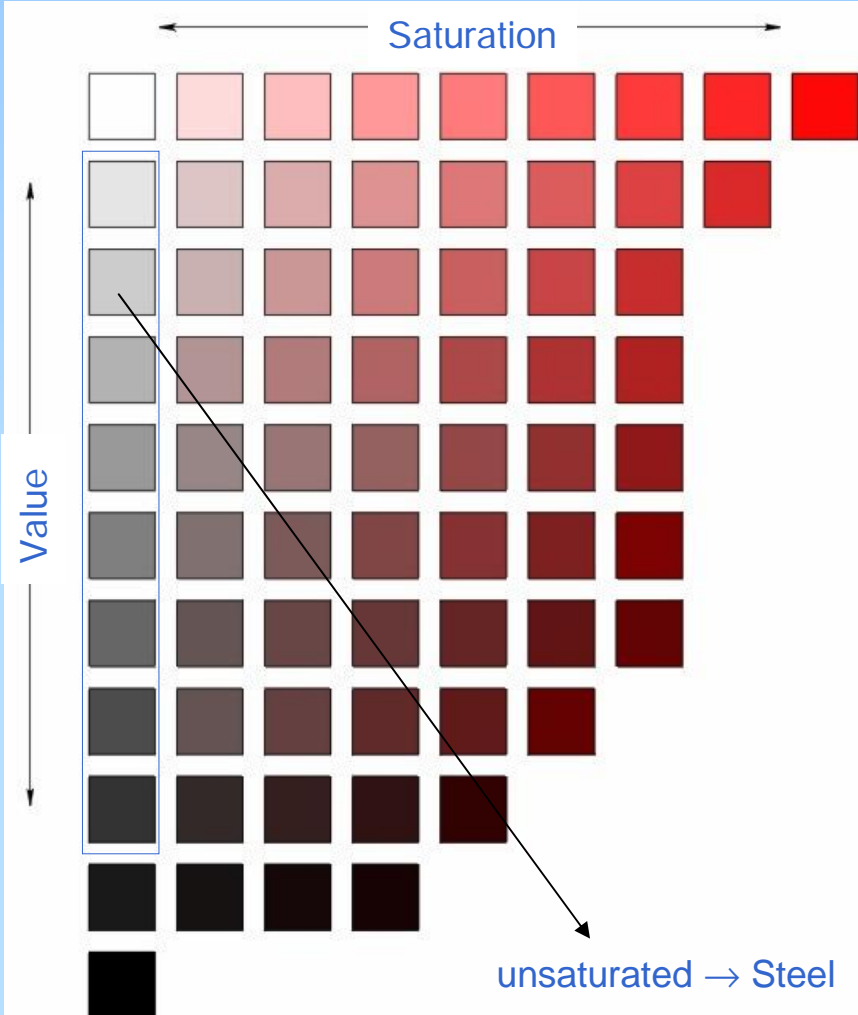
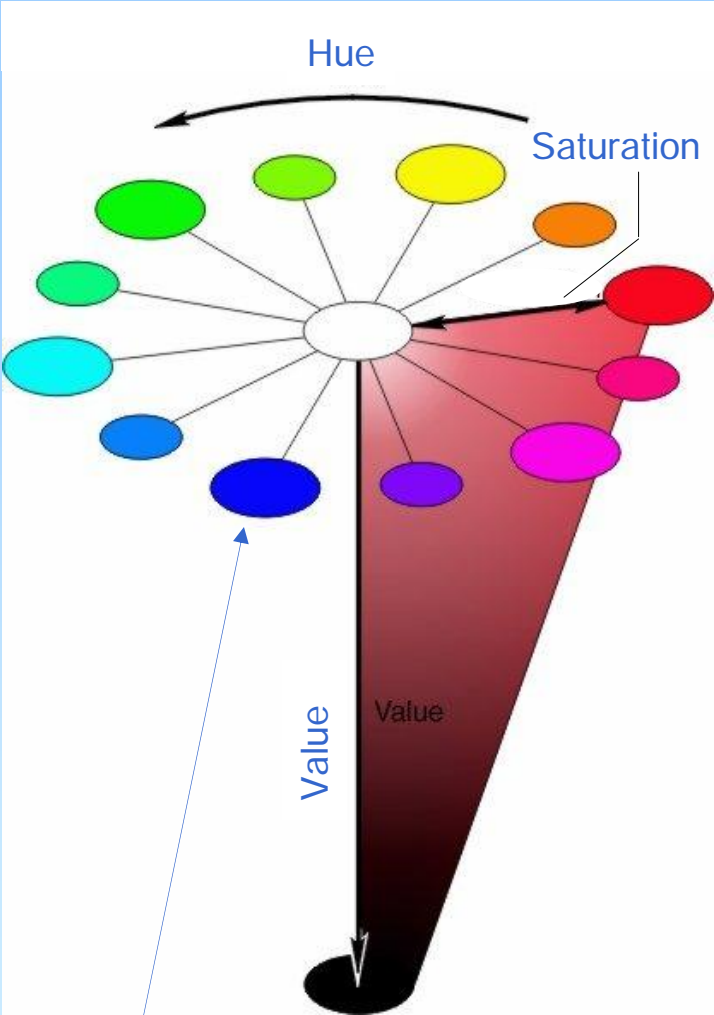
# Image processing



**colour is essential!**



# Rust designation in a colour space



Colour correlation

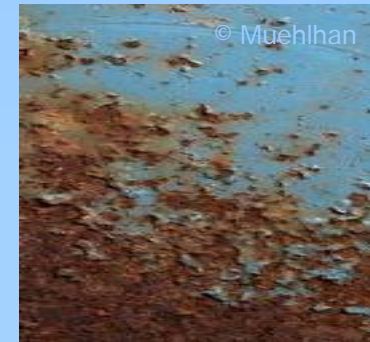
# Colour as a rating criterion



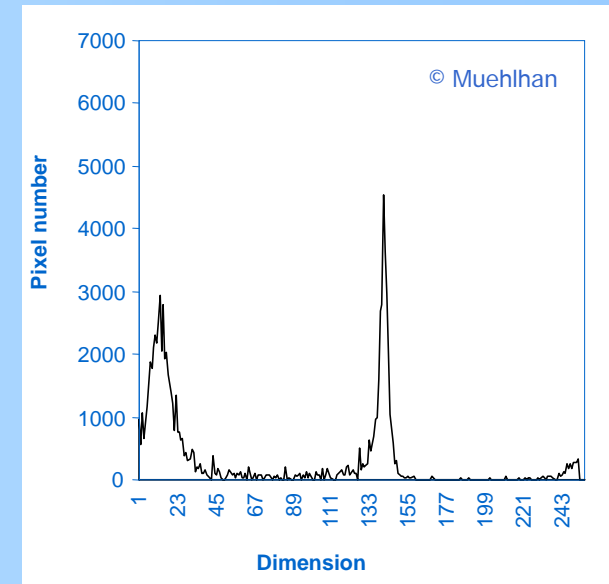
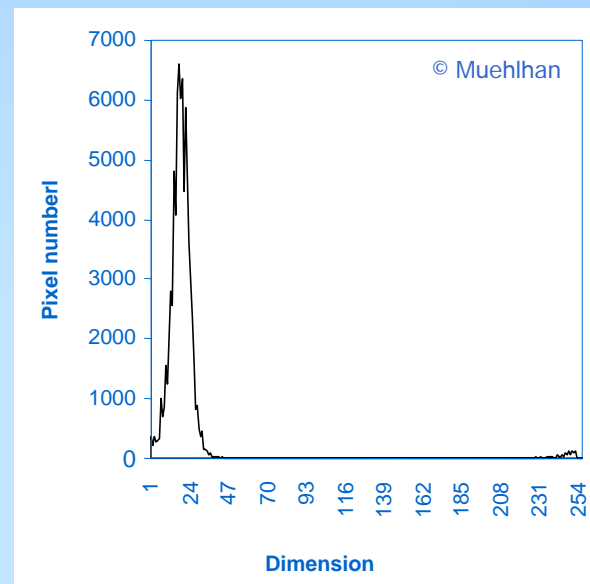
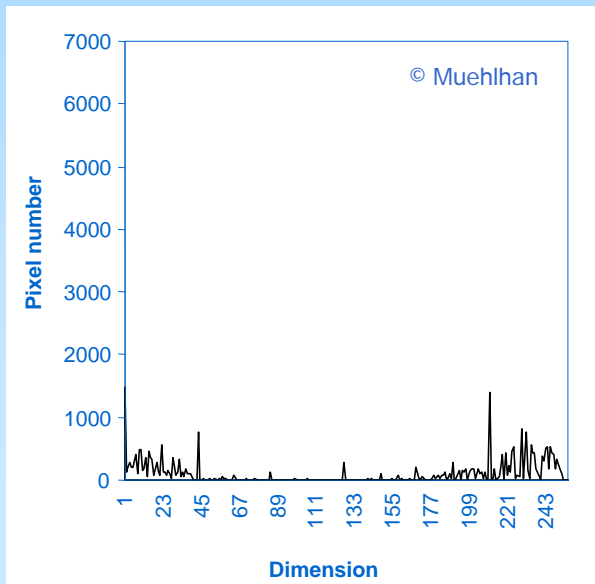
Shot blasting, Sa 2½



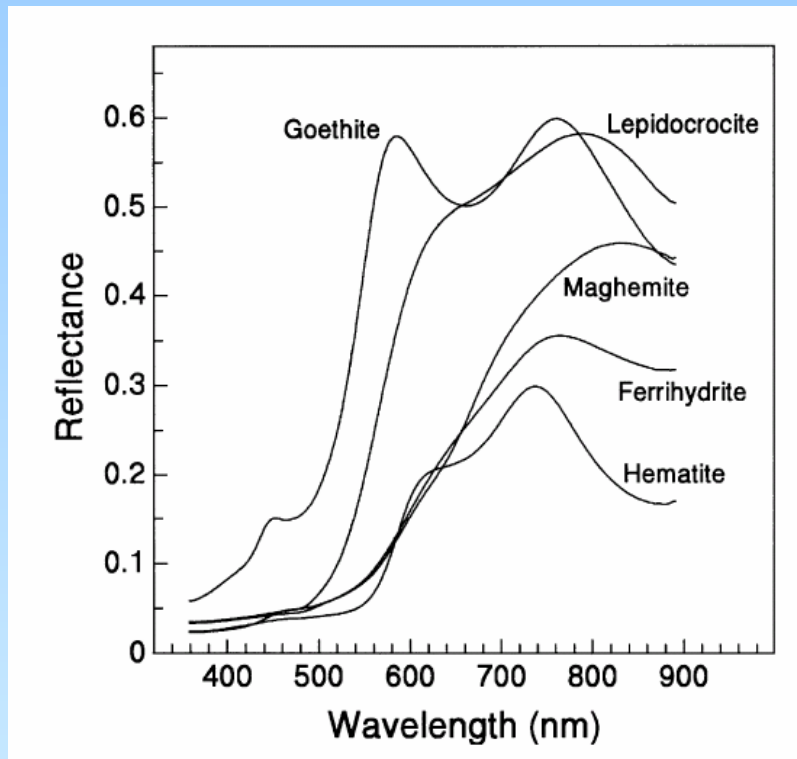
WAB cleaning + flash rust



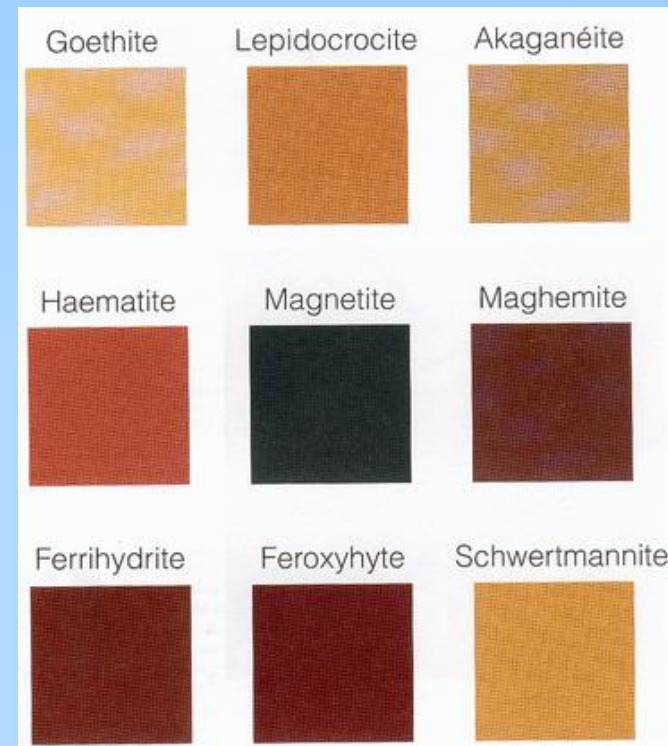
Coating with underrustings



# Colours of iron(hydr)oxides

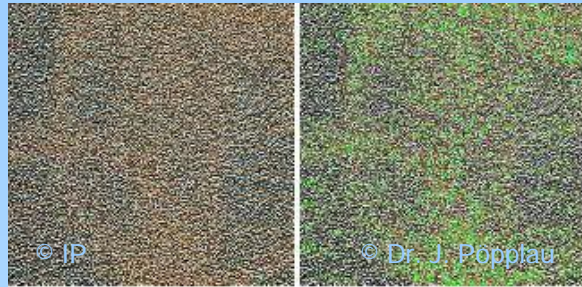


© Torrent & Barron, 2002



© VCH, Weinheim

# „Occupation level“ - image processing



light flash rust  
(6%)

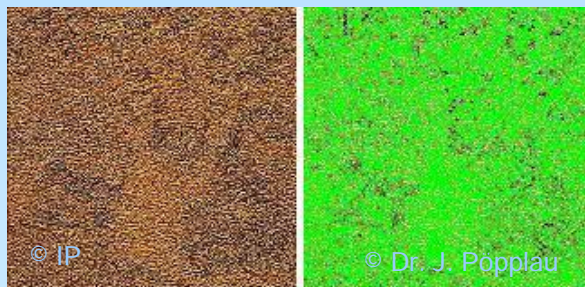
SSPC/NACE-Definitions:

„Layer through which the steel surface may be observed.“



moderate flash rust  
(30%)

„Layer that obscures the original steel surface.“

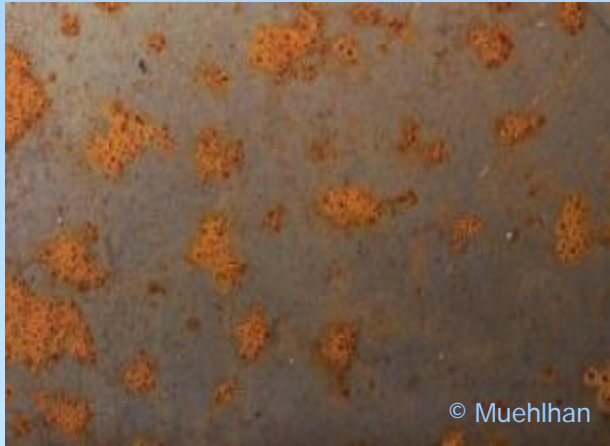
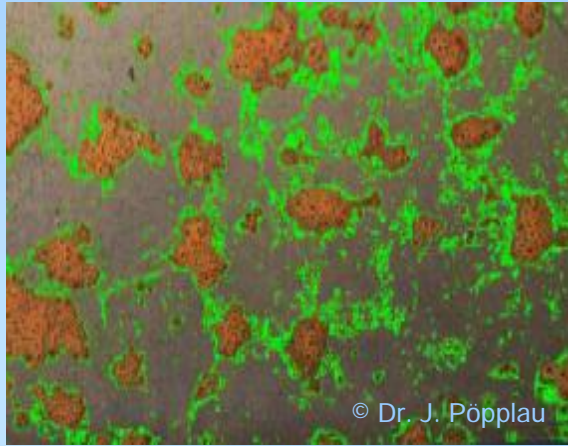
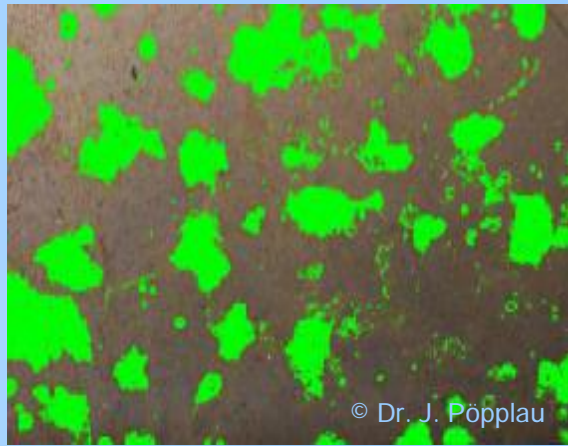


heavy flash rust  
(60%)

„Layer that hides the initial surface condition completely.“

# „Colour parameters“ - Image processing



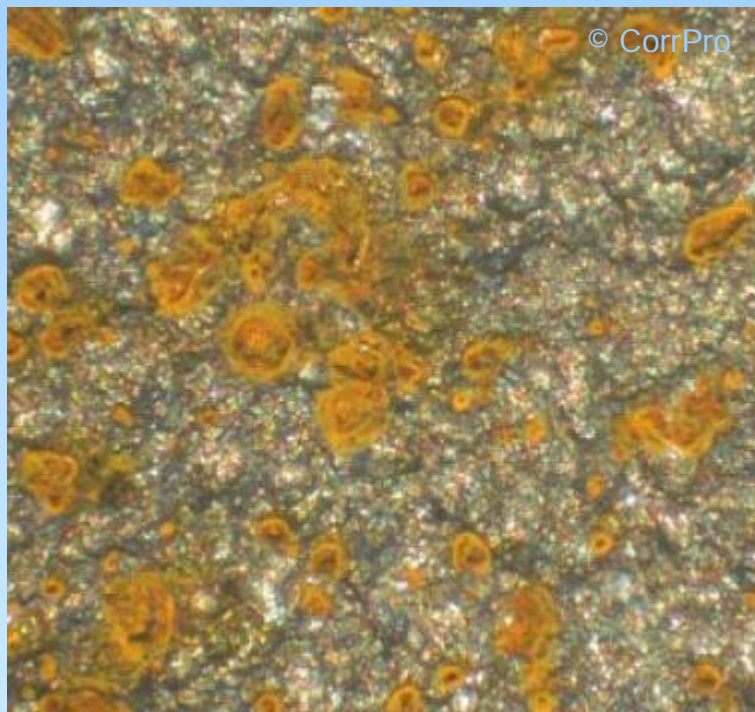
Initial image	Low intensity („Rustfinder“)	High intensity („Rustfinder“)
 <p>© Muehlhan</p>	 <p>© Dr. J. Pöplau</p>	 <p>© Dr. J. Pöplau</p>

Calculation programme: „Rustfinder“, © Dr. Jens Pöplau, Hamburg

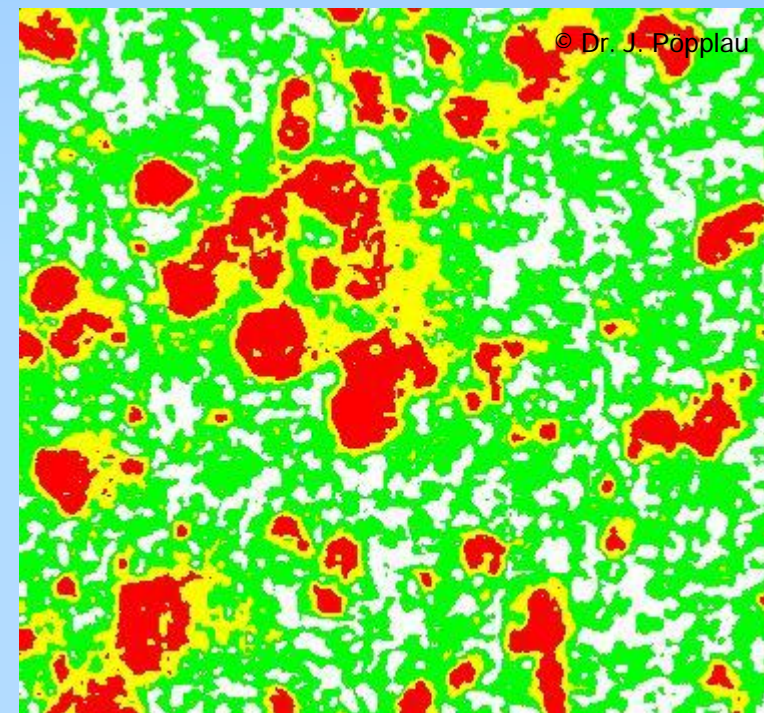
# Classification of rust intensities



## Results of non-calibrated measurements



Initial image



After image processing

Calculation programme: „Rustfinder“, © Dr. Jens Pöpplau, Hamburg

## Next steps



- Calibration of flash rusting degrees based on coating manufacturers' specifications.
- Installation of a test version of the software.
- Transition from macro images (cm<sup>2</sup>-range) to longshot images (range of tenth of m<sup>2</sup>).
- Use of “standard” imaging technique, e.g. cellular phone cameras.
- Standardization of the procedure and its implementation into a Surface Quality Monitoring System (SQMS).

# How to avoid flash rusting?



- Use of very clean water; e.g. water from reverse osmosis processes, distilled water.
- Use of mobile water cleaning / desalination devices.  
Muehlhan: *μ-water* = two-step reverse osmosis plant.



# How to avoid flah rusting?



- Immediate drying after blast cleaning / washing / jetting

Muehlhan: *μ-switch* + *μ-select*: Control switch for the selection of:  
- Dry blast cleaning; Wet blast cleaning; Washing; Drying

Assessment method	Test 1 (after 5 h)	Test 2 (after 5 h)
Tape test		
<i>μ-pix</i> ® image		
Magnified <i>μ-pix</i> ® image		

No drying

Drying



UHPAB-nozzle mit *μ-switch* + *μ-select*

# How to avoid flash rusting?

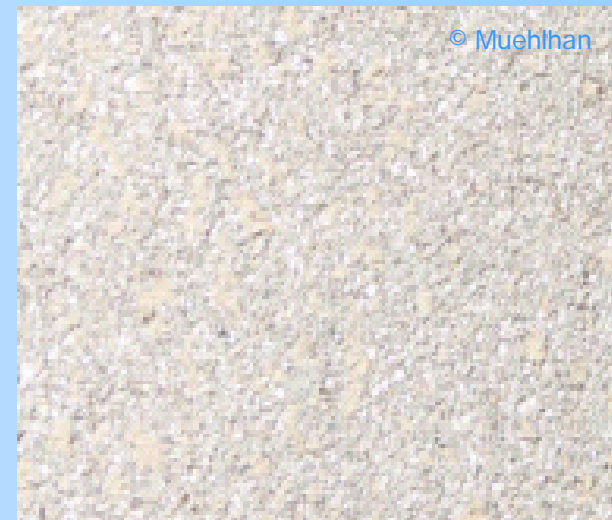


Addition of inhibitors, etc.

- Flash rust formation can be avoided over a longer period even in areas with high humidity.
- Acceptance? Coating manufacturers must be consulted, and they should approve the product.



after 24 h



after 48 h



Many Thanks.

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