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Preparation of steel substrates before application of paints and related products — Analytical colorimetry method to support visual assessment of surface preparation grades

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 12, *Preparation of steel substrates before application of paints and related products*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The performance of protective coatings of paint and related products applied to steel is significantly affected by the state of the steel surface immediately prior to painting. The principal factors that are known to influence this performance are

a) the presence of rust and mill scale,

b) the presence of surface contaminants, including salts, dust, oils and greases, and

c) the surface profile.

The ISO 8501 series, the ISO 8502 series and the ISO 8503 series provide methods for assessing these factors, while the ISO 8504 series provides guidance on the preparation methods that are available for cleaning steel substrates, indicating the capabilities of each in attaining specified levels of cleanliness.

These International Standards do not contain provisions on the protective coating systems applied to the steel surface. They do not contain provisions related to the surface quality requirements for specific situations even though surface quality can have a direct influence on the choice of protective coating applied and on its performance. Such provisions are given in other documents such as national standards and codes of practice. It would be useful for users of these International Standards to ensure that the qualities specified are

— compatible and appropriate both for the environmental conditions to which the steel will be exposed and for the protective coating system used, and

— within the capability of the cleaning procedure specified.

While these four series of International Standards deal with specific aspects of the preparation of steel substrates, the ISO 8501 series covers the visual assessment of surface cleanliness.

ISO 8501-1 is intended to be a tool for visual assessment of rust grades and of preparation grades. It identifies four levels (designated as “rust grades”) of mill scale and rust that are commonly found on surfaces of uncoated erected steel and steel held in stock. It also identifies certain degrees of visual cleanliness (designated as “preparation grades”) after surface preparation of uncoated steel surfaces and of steel surfaces after overall removal of any previous coating. These levels of visual cleanliness are related to the common methods of surface cleaning that are used prior to painting.

Preparation of steel substrates before application of paints and related products — Analytical colorimetry method to support visual assessment of surface preparation grades

1 Scope

This document provides guidance on the usage of analytical colorimetry to support visual assessment of surface preparation grades described in ISO 8501-1:2007, Clause 4.

This document provides examples of applications where the use of a colorimeter or spectrophotometer can enable a quick and objective assessment of the preparation grade of the substrate.

NOTE The data given in this document was obtained using the methodology described in Annex A.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in in ISO 8501-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
CIELAB colour space
CIE 1976 $L^* a^* b^*$ colour space
three-dimensional L^*, a^*, b^* colour space

3.2
colour difference
difference between two colour stimuli defined as the Euclidean distance between the points representing them in the $L^* a^* b^*$ space and calculated as follows

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

3.3
illuminant
radiation with a relative spectral power distribution defined over the wavelength range that influences object colour perception

3.4
standard illuminant
illuminants (3.3) by the CIE defined in terms of relative spectral power distributions

Note 1 to entry: These illuminants are intended to represent the following:

a) Planckian radiation at a temperature of about 2 856 K;

b) direct solar radiation (obsolete);

c) average daylight;

d) daylight.

The 2-digit number associated to D illuminant denotes the correlated colour temperature.

3.5
observer
CIE 1931 standard colorimetric observer
ideal observer whose colour-matching properties correspond to the CIE colour-matching functions adopted by the CIE in 1931

Note 1 to entry: This standard colorimetric system is applicable to centrally-viewed fields of angular subtending between about 1° and about 4°.

3.6
supplementary standardized observer
CIE 1964 supplementary standard colorimetric observer
ideal observer whose colour-matching properties correspond to the CIE colour-matching functions adopted by the CIE in 1964

Note 1 to entry: This standard colorimetric system is applicable to centrally-viewed fields of angular subtense greater than about 4°.

Note 2 to entry: When this system is used, all symbols that represent colorimetric measures are distinguished by use of the subscript 10.

4 Symbols

L^*	CIELAB lightness
a^*, b^*	CIELAB a^*, b^* coordinates
ΔL^*	CIELAB lightness difference
Δa^*, Δb^*	CIELAB a^*, b^* difference
ΔE^*	CIELAB colour difference
ΔC^*	CIELAB chroma difference
ΔH^*	CIELAB hue difference

5 Principle

The assessment of preparation grade of the surface is done by calculation of the colour difference components, taking as reference the colour components values of a substrate with the targeted surface preparation grade.

The surface preparation will be considered as acceptable if the colour difference is below a certain value agreed between the parties.

NOTE The tolerance associated for each preparation grade described in words in ISO 8501-1 is associated to a dispersion of the colour components values.

6 Recommendations for instruments

6.1 Instrument handling

Two types of instruments can be used for colour measurement: the spectrophotometer and the tristimulus colorimeter. Both types are available as portable instruments and can be used for obtaining the data given in this document.

It is important to ensure a close contact between the instrument and the surface to be controlled, to avoid any foreign light contamination and to keep a constant distance between the surface to analyze and the instrument detection system, as specified by the instrument manufacturer.

The measurement should not be carried out in excessively dusty environments.

6.2 Instrument specifications

Colour measurements of a surface are influenced by the light source (illuminant), the observer and the geometric conditions of observation.

It is important to know these parameters and to keep them constant.

NOTE If one of these factors is modified during the analytical colorimetry measurement, the colour components and the colour difference components will be affected.

6.2.1 Illuminant and observer

The CIE has defined standard illuminants and standard observers that are commonly used by colorimeter and spectrophotometer manufacturers.

6.2.2 Illuminating and viewing conditions

The measured colour values depend on the geometric relationships between the measuring instrument and the sample. These relationships are called geometric conditions. A complete terminology description of geometric conditions can be found in CIE 15.

Several geometric conditions are standardized, and they need to be fixed during the colour measurement. Mainly, two different geometric conditions are used by colorimeter and spectrometer manufacturers:

— 45/0°

  Measurement systems with this measurement geometry observe the sample under conditions similar to those of natural observation by a human. This means that measurements with the angle geometry (45°/0° or 0°/45°) are always taken with the gloss excluded, and therefore result in closer equivalence to the eye’s visual impression. This geometry is predominantly used in colour control for end products.

— d/8°

  Measurement instruments with sphere geometry (d/8°) illuminate the sample diffusely and measure the light reflected by the sample in one direction at an angle of 8° to the vertical position of the sample. When using a sphere instrument, the specular component may be included or excluded from the measurement.

6.2.3 Tolerance of the instrument

Attention should be paid to the colour tolerance of the instrument. It is important that the colour tolerance of the instrument be smaller than the colour tolerance for preparation grade (see Clauses 7 and 8).

In practice, colour tolerance of the instrument is often indicated with a Δ*E* value.

7 Supporting data

7.1 General

Clause 7 provides data to illustrate the possibility of using colorimetry to support visual assessment of surface preparation grade. The data was obtained using the methodology described in Annex A.

7.2 Sample preparation

The test was conducted on a steel sample grade S355K2+N, heat A1/01407932. Samples with three different preparation grades according to ISO 8501-1 were prepared.

— NB = non-blasted area = Rust grade A (see ISO 8501-1:2007, Clause 2).

— Sa 2 1/2 = A Sa 2 1/2 = Very thorough blast–cleaning grade area (see ISO 8501-1:2007, Clause 3).

— Sa 3 = A Sa 3 = Blast-cleaning to visually clean steel grade area (see ISO 8501-1:2007, Clause 3).

The dry abrasive blasting conditions used to prepare the surface are as follow:

— Abrasive: Steel Grit Operating Mix - SR 710;

— Wheel blasting machine Schlick Rotojet (2 wheels of 5,5 KW, flow rate 60 Kg/min per turbine);

— Blasting velocity: 77 m/s;

— Stand – off distance: 500 mm;

— Blasting angle: 45°;

— Running rate: 1,5 m/min.

To obtain the preparation grade Sa 2 1/2, four passes were needed. To obtain the preparation grade Sa 3, eight passes were needed.

7.3 Results

In this example, the sample with preparation grade Sa 2 1/2 represents the targeted preparation grade.

Colour measurements were done with three different instruments to illustrate the impact of the instrument on the method. The results are given in Table 1.

Table 1 — Colour difference between Sa 2 1/2 and Sa 3 steel substrates measured with three different instruments

Instrument type	Geometric conditions	Illuminant/observer	Sample Sa 2 1/2 $L^*; a^*; b^*$	Sample Sa 3 $L^*; a^*; b^*$	Colour difference ΔE^*
Spectrophotometer Tungsten lamp	d/8°	D65 / 10	48,5 ; 0,6 ; 1,9 dE < 0,1	53,1 ; 0,9 ; 4,3 dE = 0,3	$[(53,1 - 48,5)^2 + (0,9 - 0,6)^2 + (4,3 - 1,9)^2]^{1/2}$ = 5,2
	d/8°	D50 / 10	48,7 ; 0,8 ; 2,0 dE < 0,1	53,1 ; 1,5 ; 4,6 dE = 0,1	$[(53,1 - 48,7)^2 + (1,5 - 0,8)^2 + (4,6 - 2,0)^2]^{1/2}$ = 5,2
	d/8°	A / 10	48,8 ; 1,2 ; 2,2 dE < 0,1	53,8 ; 2,0 ; 4,4 dE < 0,1	$[(53,8 - 48,8)^2 + (2,0 - 1,2)^2 + (4,4 - 2,2)^2]^{1/2}$ = 5,4
Colorimeter 3 colour LED source	45°/0°	D65 / 10	41,3 ; 1,2 ; −3,0 dE = 0,4	45,6 ; 2,6 ; −1,7 dE = 1,6	$[(45,6 - 41,3)^2 + (2,6 - 1,2)^2 + (3,0 - 1,7)^2]^{1/2}$ = 4,6
Colorimeter White LED source	45°/0°	D65 / 10	54,3 ; 1,2 ; 3,9 dE = 1,3	59,6 ; 2,4 ; 7,2 dE = 3	$[(59,6 - 54,3)^2 + (2,4 - 1,2)^2 + (7,2 - 3,9)^2]^{1/2}$ = 6,1

$L^* a^* b^*$ values reported are the average of 10 measurements.

dE values reported is the maximum colour difference calculated with the $L^* a^* b^*$ average values measured for each preparation grade. These values represent the colour tolerance of the preparation grades (see 7.2).

The L^*, a^*, b^* values measured by the three instruments tested and reported in Table 1 are different. It confirms the impact of the instrument specification.

The colour differences ΔE^* reported in the last column of Table 1 are in all cases higher than the sum of the colour tolerance dE of each preparation grades.

EXAMPLE Colour difference measured with a 3 colour LED source colorimeter.

ΔE^* = 4,6 is higher than 0,4 + 1,6 = 2

The measurements reported in Table 1 give in all cases significant results.

8 Examples of application

8.1 General

In Clause 8, user feedback has been gathered to illustrate the benefits of analytical colorimetry to support surface preparation grades assessment. The instrument used was 3 LED colour colorimeter with 45°/0° geometric conditions, illuminant D65 with supplementary standardized observer.

8.2 Steel pipes producer for oil and gas industry

8.2.1 Application: control quality of blasting operation prior to anticorrosion coating

The parts controlled were internal and external surfaces of steel pipes, with initial rust grade B and targeted preparation grade Sa 2 1/2 according to ISO 8501-1. The colorimetry analyses were done to ensure adequate cleanliness of the steel substrates after blasting. The results from colorimetry were compared with visual assessment.

8.2.2 Reference substrate

A third-party inspector was present to assess the cleanliness grade of the blasted parts and to agree on the colour component values of the targeted preparation grade.

8.2.3 Quality control

The colorimeter was used on a daily basis to control the surface preparation grade, by an operator of the blasting unit qualified for cleanliness inspection.

The colorimeter was used to quickly identify process deviation under conditions of lighting deficiency or to get reliable data when the assessment of cleanliness grade was debated.

8.3 Cast iron foundry

8.3.1 Application: control quality of desanding operation of cast iron automotive parts

The quality control was done by colorimetry method before sending the parts to other plants for machining.

8.3.2 Reference substrate

For one given part, the surface preparation grade targeted was agreed between the final customer, production and quality departments. At least 30 colour measurements were done on this reference to define the colour components values and the tolerance level associated to the surface preparation targeted.

The stability of the colour components values of the reference substrate were regularly controlled on parts considered as “acceptable”.

8.3.3 Quality control

The colour components values determined for the reference substrate were used to define a minimum level of cleanliness to reach on the desanding line. The operator had to measure the colour components on 3 points specified by agreement between production and quality departments. The colorimeter was calculating each time the corresponding colour components differences. All parts getting out of the desanding line should be above the cleanliness level targeted.

To ensure good setting of the desanding operation at the beginning of a new series, 10 measurements were done. When desanding operation was well tuned, quality controls were done every three hours.

8.4 Trailers manufacturer

8.4.1 Application: control quality of blasting operation prior to painting

The parts controlled were small parts of trailers and welded steel flatbed, with initial rust grade A or B and targeted preparation grade Sa 2 1/2 according to ISO 8501-1. The colorimetry analyses were done to ensure adequate cleanliness after blasting. The results from colorimetry were compared with visual assessment.

8.4.2 Reference substrate

A third-party inspector was present to assess the cleanliness grade of the blasted parts and to agree on the colour component values of the targeted preparation grade.

8.4.3 Quality control

The colorimeter was used on a daily basis to control the surface preparation grade, by a quality inspector qualified for cleanliness inspection.

The colorimeter was used to get reliable and objective measurement of cleanliness grade.

8.5 Production of freight wagons

8.5.1 Application: control quality of blasting operation prior to anticorrosion coating

The parts controlled were frames and bogies of wagons, with initial rust grade B or C and targeted preparation grade Sa 2 1/2 according to ISO 8501-1. The colorimetry analyses were done to ensure adequate cleanliness of the steel substrates after blasting. The results from colorimetry were compared with visual assessment.

8.5.2 Reference substrate

A third-party inspector was present to assess the cleanliness grade of the blasted parts and to agree on the colour component values of the targeted preparation grade.

8.5.3 Quality control

The colorimeter was used on a daily basis to control the surface preparation grade, by a quality inspector.

The colorimeter was used to quickly identify process deviation or to get reliable and objective measurements when the assessment of cleanliness grade was debated.

8.6 Cold drawn bars producer

8.6.1 Application: optimisation of descaling operation

The parts controlled were hot rolled steel bars, with initial rust grade C and targeted preparation grade Sa 3 according to ISO 8501-1. The colorimetry analyses were done to ensure adequate cleanliness of the steel substrates after blasting. The results from colorimetry were compared with visual assessment. No painting or coating operation was done after blasting.

8.6.2 Reference substrate

The assessment of the preparation grade of the blasted bars was done by an operator qualified for cleanliness inspection but no third-party inspector was present to agree on the surface cleanliness grade.

8.6.3 Quality control

The colorimeter was used on a daily basis to control the surface preparation grade, by an operator.

The colorimeter was used to get reliable and objective measurements and to optimize blasting cost operations by avoiding over blasting. This had enabled an optimization of the speed of the line.

Annex A
(informative)

Methodology

A.1 General

The methodology described in this Annex is the methodology used to obtain the data given in Clause 7.

A.2 Field of application

This procedure is suitable for centrifugal abrasive blast-cleaning method.

Any change of the blasting media, the blasting operating conditions, the rust grade of the substrate to prepare, the colour measurement instrument are parameters that could affect the result of colour measurements.

If one of these parameters is changed, it is recommended to redo the procedure from the beginning.

At the time of preparation of this document, no sufficient data were available to reject the possibility to apply the procedure to other types of surface preparation methods.

A.3 Reference substrates

Prepare reference substrates corresponding to the range of preparation grades achievable according to the original rust grade and the type of cleaning method used (see ISO 8501-1:2007, Clause 5). The substrate used to prepare these reference substrates has to be similar to the substrate to be prepared afterwards. The blasting parameters such as blasting media and blasting operating conditions has to be similar to those under operation.

EXAMPLE Blast-cleaning of steel substrates rust grade A.

The preparation grades achievable are non-blasted, Sa 2 1/2 and Sa 3. The number of reference substrates for colorimetry analyses recommended is three.

The preparation grade of each reference substrates should be controlled according to procedure detailed in ISO 8501-1. Once the visual assessments are complete, gather the samples for colour measurement. Place the colour measurement instrument on each reference substrates, measure and report the L^*, a^*, b^* values. Repeat the measurement on different areas of the substrate and report the average $\overline{L^*}, \overline{a^*}, \overline{b^*}$ values and standard deviation σ_L, σ_a, σ_b for each reference substrate (Figure A.1).

