13 Inspection methods and equipment

Objective
When you have gone through this chapter you should

- have an understanding of the importance of checking all work operations, from the steel quality to the finished product
- be able to explain relevant standards and their use for assessing the condition of the steel surface, before and after surface preparation
- be able to determine the roughness of the steel after it has been blast cleaned in accordance with current standards
- be able to use equipment for checking the climatic conditions before and during surface preparation and paint application
- be able to measure the wet and dry film thickness of a paint
- be able to determine the adhesion of paints
- be able to determine discontinuities (holidays, pinholes) in paints
- have some knowledge of how paints are being tested at the paint manufacturer or in the laboratory.

Introduction

When anticorrosion paints or similar coatings are to be applied, surface preparation plays a very important role for the lifetime of the product. It is therefore important to ensure that the work carried out is of a very high quality. It is rarely possible to compensate for poor surface preparation by use of a more expensive paint. It is easy to understand that this has very considerable economic consequences. For example, the quality of the surface preparation may extend the period before any maintenance work is required by several years. This chapter will discuss the inspection instruments, explain their principles and how they work. A major part of this material is of particular importance to coating inspectors.

Inspection routines

Inspection routines cover inspection plans and their implementation in practical tasks of inspection.

The inspection plans comprise several checkpoints, for example

- substrate
- surface preparation

- application
- final control
- documentation

It is important to have inspection plans and schemes for all the inspected areas. It is also important that the person carrying out the inspection has knowledge of and is able to use all necessary equipment including flashlights, magnifying glasses, adhesion test equipment, DFT gauges and holiday detectors.

Inspection of the substrate

If the steel has been damaged, the damage must be repaired before the cleaning of the steel. Such damage is often indentations or laminations. Indentations can be removed by grinding. In the case of deep dents, the remaining material thickness must be measured. Also laminations in the steel can usually be repaired by grinding. After grinding, the object must be checked, for example by X-ray.

It is particularly important to round off all edges and notches. Many specifications include requirements for rounding of edges to a radius of at least 2 mm. Notches should preferably have a radius of 15 mm. If welding work has been carried out on the object, all deposits from weld smoke must be removed by washing, and any rough or uneven weld seams must be smoothened by grinding.

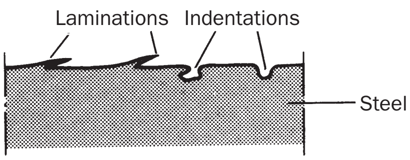

Figure 13.1 Laminations and indentations in the steel surface must be removed by grinding before blast cleaning and paint application

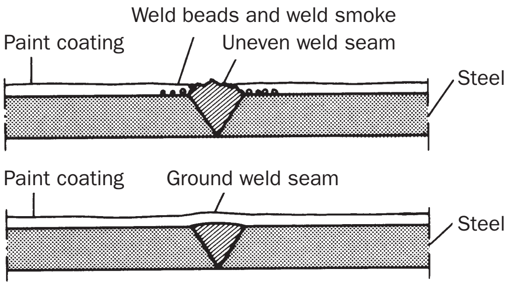

Figure 13.2 Uneven weld seams and residues of weld beads and weld smoke must be removed before paint application

NACE in the USA has published the NACE Standard RP0178-2003 showing graphics of design and fabrication details to be used in tanks [1]. The standard also includes pictorial representations of welds showing various grinding finishes of weld spatter etc. As part of the standard a replica has been made in plastic illustrating preparation grades of welds for any weld slag remaining.

Assessment of rust grades of steel

When the red-hot steel is processed in the steel rolling mill, it reacts with air and forms a layer on the steel surface. This layer is called mill scale. When the steel is stored outdoors, it breaks down – it rusts. Mill scale and rust often create problems and must be removed by mechanical surface preparation.

In order to assess the steel surface prior to surface preparation, the International Standard ISO 8501-1 "Visual assessment of surface cleanliness" is used. The standard is available as a small handbook in A5 format.[2]

This part of ISO 8501 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.

The four rust grades, designated A, B, C and D, respectively, are defined by written descriptions together with representative photographic examples.

- Rust grade A: Steel surface largely covered with adherent mill scale but little, if any, rust.
- Rust grade B: Steel surface which has begun to rust and from which the mill scale has begun to flake.
- Rust grade C: Steel surface on which the mill scale has rusted away or from which it can be scraped, but with slight pitting visible under normal vision.
- Rust grade D: Steel surface on which the mill scale has rusted away and on which general pitting is visible under normal vision.

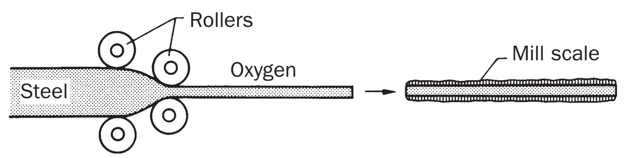

Figure 13.3 When steel is hot-rolled, an oxide film is formed on the surface – mill scale

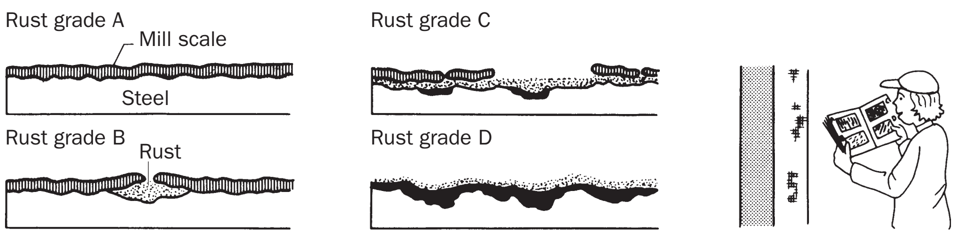

Figure 13.4 When assessing the rust grade of uncoated steel, the standard ISO 8501-1 or a similar standard must be used

When the surfaces are to be compared, it is helpful, initially, for a person having little experience in assessing untreated steel surfaces to use the standard. In time, as the different surfaces have become more familiar, they can be assessed without looking at the photographs in the standard.

ISO 8501-1 applies to not previously treated surfaces. However, an area from which a coating system has broken down completely will show a rust pattern resembling that of rust grade C or D. It has therefore become common practice to refer to such areas as being of rust grade C or D.

Assessment of visual cleanliness

In addition to the four pictures of the rust grades A, B, C and D, the standard also contains a total of 24 pictures showing the visual cleanliness after preparation of the steel.

Each preparation grade is designated by the appropriate letters, “Sa”, “St” or “Fl” to indicate the type of cleaning method used. The number following, if any, indicates the degree of cleaning from mill scale, rust and previous coatings.

The standard includes three preparation grades:

- Blast cleaning, Sa
- Hand and power tool cleaning, St
- Flame cleaning, Fl

Blast cleaning

Four levels of cleanliness are defined which have the following designations: Sa 1, Sa 2, Sa 2½ and Sa 3. Only very light blast cleaning is required to achieve a cleanliness of Sa 1 or Sa 2. In order to achieve a cleanliness of Sa 2½ and Sa 3 very thorough blast cleaning is required.

Sa 1 *Light blast cleaning*
When viewed without magnification, the surface shall be free from visible oil, grease and dirt, and from poorly adhering mill scale, rust, paint coatings and foreign matter. See photographs B Sa 1, C Sa 1 and D Sa 1.

Sa 2 *Thorough blast cleaning*
When viewed without magnification, the surface shall be free from visible oil, grease and dirt, and from most of the mill scale, rust, paint coatings and foreign matter. Any residual contamination shall be firmly adhering. See photographs B Sa 2, C Sa 2 and D Sa 2.

Sa 2½ *Very thorough blast cleaning*
When viewed without magnification, the surface shall be free from visible oil, grease and dirt, and from mill scale, rust, paint coatings and foreign matter. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes. See photographs A Sa 2½, B Sa 2½, C Sa 2½ and D Sa 2½.

Sa 3 *Blast cleaning to visually clean steel*
When viewed without magnification, the surface shall be free from visible oil, grease and dirt, and shall be free from mill scale, rust, paint coatings and foreign matter. It shall have a uniform metallic colour. See photographs A Sa 3, B Sa 3, C Sa 3 and D Sa 3.

Surface preparation by hand and power tool cleaning, such as scraping, wirebrushing, machine brushing and grinding, is designated by the letters “St”. Two preparation grades, designated St 2 and St 3, can be achieved using hand and power tool cleaning. Preparation grade St 1 is not included as it would correspond to a surface unsuitable for painting.

Hand and power tool cleaning, St

Surface preparation by hand and power tool cleaning, such as scraping, wirebrushing, machine brushing and grinding, is designated by the letters “St”. Two preparation grades, designated St 2 and St 3, can be achieved using hand and power tool cleaning. Preparation grade St 1 is not included as it would correspond to a surface unsuitable for painting.

St 2 *Thorough hand and power tool cleaning*
When viewed without magnification, the surface shall be free from visible oil, grease and dirt, and from poorly adhering mill scale, rust, paint coatings and foreign matter. See photographs B St2, C St 2 and D St 2.

St 3 *Very thorough hand and power tool cleaning*
As for St 2, but the surface shall be treated much more thoroughly to give a metallic sheen arising from the metallic substrate. See photographs B St 3, C St 3 and D St 3.

Flame cleaning, Fl

Surface preparation by flame cleaning is indicated by the letters Fl. Before flame cleaning, thick rust layers must be removed by chipping and afterwards the surface must be cleaned by power tool wirebrushing.

Fl When viewed without magnification, the surface shall be free from mill scale, rust, paint coatings and foreign matter. Any remaining residues shall show only as a discoloration of the surface (shades of different colours). See photographs A Fl, B Fl, C Fl and D Fl.

The standard lists in detail the appearance of the surfaces after the different surface preparation methods. The various grades are defined by written descriptions together with photographs that are representative examples within the tolerance for each grade as described in words.

In addition, the standard lists several conditions to be considered when inspection is carried out, including removal of dust from the surface after blast cleaning, for example by vacuum cleaning or by blowing with compressed air. Furthermore, the standard indicates that the prepared surface may have a different appearance than the photograph in the book. There may also be various degrees of corrosion on the surface, tool marks, different lighting conditions, shadows due to the blasting angle and embedded abrasives.

The blasted steel surfaces depicted in ISO 8501-1 have been blast cleaned using an abrasive called silica sand (quartz sand). Today, due to the silicosis hazard, the use of silica sand is prohibited in many countries. The use of silica sand gives the steel surface a somewhat lighter shade than when dark slags are used.

The shade of the steel after blasting has caused extensive problems in connection with the approval of blasted steel surfaces before paint application. In 1994 a supplement to ISO 8501-1 was issued, showing the appearance of steel with rust grade C before and after blast cleaning with six different abrasives (metallic and non-metallic) [3]. When this supplement is used, this may simplify matters both for the operator doing the blast cleaning of the steel and the inspector who is to approve it before painting or themal spraying.

In many countries wirebrushing and blast cleaning are the most widely used mechanical methods of surface preparation. Flame cleaning finds limited use, but was previously widely used on board ships.

Before flame cleaning of a steel surface is started, all thick rust layers must be removed. After the steel surface has been flame cleaned, it must be free of mill scale, rust, paint residues and other contamination. Afterwards the steel surface is cleaned with power tool wirebrushing.

For newbuilding, for example within the offshore industry, a steel quality equal to rust grade B is required. In certain cases rust grade C may be considered. Rust grade D is out of the question for new constructions. In specifications requirements for a surface preparation degree of B Sa 2½ can be seen.

The designation B Sa 2½ corresponds to very thorough blast cleaning of steel with rust grade B, i.e. a steel surface which has begun to rust and from which the mill scale has begun to flake. When examining the surface without magnification, it must be free from visible contamination of oil, grease and dirt, and largely free of mill scale, paint and other foreign matter. Remaining traces of contamination may only show as slight stains in the form of spots.

The standard also mentions that the surface must be free of foreign matter. This includes water-soluble salts, residues from weld smoke and weld spatter. It can be difficult to remove such contaminants completely by mechanical surface preparation. In such cases it may be appropriate to hose down the surfaces before they are blast cleaned, or they can be wet blasted.

In the USA and within American shipping companies building ships in Europe or in other parts of the world, the American standards from Steel Structures Painting Council (SSPC), VIS-1 (Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning) and VIS-3 (Visual Standard for Power- and Hand-Tool Cleaned Steel) are much more widely used than ISO 8501-1. Like ISO 8501-1 also these standards are pictorial standards.

VIS-1 is a visual standard showing colour photographs of different surfaces before and after surface preparation by blast cleaning. The surface preparation grades in the standard are designated as SP 5 (Sa 3), SP 6 (Sa 2), SP 7 (Sa 1), and SP 10 (Sa 2½).[4]

VIS-3 is a visual standard for hand and power tool cleaning of steel [5]. This standard differs slightly from VIS-1 by containing seven conditions, which are the rust degrees A, B, C and D for new constructions and E, F and G for maintenance of constructions. The latter three conditions are previously coated surfaces.

The seven conditions are then prepared by five different methods:

- Manual wirebrushing
- Power wirebrushing
- Power grinding
- Power needle hammering
- Power tool surface preparation to bare metal by equipment producing minimum 25 µm roughness on the steel.

The pictures show the condition of welds prior to and after surface preparation.

SSPC has also issued the standard VIS-4 "Guide and Reference Photographs for Steel Surfaces Prepared by Waterjetting". This standard deals with different surface preparation degrees on steel after high and ultra-high pressure water jetting. In the case of ultra high pressure water jetting (UHPWJ) pressures above 1700 bar are used.

The standard shows a total of 6 pictures (two uncoated and four previously coated steel surfaces before and after water jetting. Photographs show four different degrees of cleaning (WJ 1, WJ 2, WJ 3 and WJ 4) for each condition. The standard also contains photographs showing slight, moderate and heavy re-rusting, "flash rust", on the surface. The standard is provided with a description for the photographs as well as a guide to the use of the standard.

Preparation of previously coated steel substrates after localized removal of previous coatings

When steel constructions are to be maintained, complete removal of previous paint coatings is not always necessary. This is especially true where maintenance work is carried out at regular intervals. In the cases where only a localized area is to undergo surface preparation, it is important to ensure that

- The paint remaining on the surface is compatible with the new paint, and together the system must provide durable protection.
- During cleaning of locally corroded areas down to steel care must be taken not to damage adjacent areas unnecessarily.

Work is also in progress concerning recommendations and guidelines for maximum acceptable chloride and sulphate contents on surfaces in various service exposures.

The standard ISO 8501-2 deals with preparation grades of previously coated steel substrates after localized removal of previous coatings [6]. Like the ISO 8501-1 also this standard contains several photographs.

The standard specifies several surface preparation grades, indicating the preparation method and the degree of cleaning. The surface preparation grades are defined by written descriptions of how the surface must appear after it has been cleaned.

Surface preparation by localized blast cleaning of previously coated surfaces is designated by the letters P Sa.

Surface preparation by localized hand and power tool cleaning of previously coated surfaces, such as scraping, wirebrushing and grinding of surfaces, is designated by the letters P St.

Surface preparation by localized machine abrading of previously coated surfaces is designated by the letters P Ma. It comprises cleaning by very thorough machine abrading (for example abrasive discs) or by special rotary wirebrushes used in conjunction with needle guns.

Local blast cleaning of previously coated surfaces, P Sa, comprises a total of three surface preparation grades:
P Sa 2 *Thorough localized blast cleaning*
P Sa 2½ *Very thorough localized blast cleaning*
P Sa 3 *Localized blast cleaning to visually clean steel*

Localized hand or power tool cleaning (not machine grinding) of previously coated surfaces, P St, comprises two surface preparation grades:
P St 2 *Thorough localized hand or power tool cleaning*
P St 3 *Very thorough localized hand or power tool cleaning*

Localized power tool grinding of previously coated surfaces, P Ma, only contains one surface preparation grade:
P Ma *Localized machine abrading*

The pictorial reference examples in this part of ISO 8501 show typical appearance of surfaces before and after they have been locally cleaned before repainting. (Magnifications are between five and six times). The photographs show examples of very thorough localized blast cleaning (P Sa 2½) and localized machine abrading (P Ma).

Preparation of welds, cut edges and other areas with surface imperfections
When welding and cutting steel, edges are often left in a condition unsuitable for painting. Such imperfections are generally not dealt with by blast cleaning alone and require other preparation methods.

ISO 8501-3 "Preparation grades of welds, cut edges and other areas with surface imperfections" describes the various types of imperfections by illustrations.

The areas with imperfections related to this standard are:
- Welds
- Cut edges
- Steel surfaces generally

There are three preparation grades for making the steel surfaces suitable for the application of paints:
P1 *Light preparation*
Minimum preparation considered necessary before application of paint
P2 *Thorough preparation*
Most imperfections are remedied and surface prepared for painting
P3 *Very thorough preparation*
Surface is free of visible imperfections

The choice of the preparation grade can be correlated on a broad basis with the corrosivity categories in ISO 12944-2. A general correlation is given in the table below.

Preparation grade	Corrosivity category
P1	C1 and C2
P2	C3 and C4
P3	C5I and C5M

Surface preparation standards for water jetting

Within European and International Standardization work is in progress concerning the preparation of an international standard for the area of “water jetting”. The work is in its final phase and the standard will be found as a part standard under ISO 8501 with the title ISO 8501-4 ”Preparation grades of coated and uncoated steel substrates after removal of rust and previous coatings by high-pressure water jetting”.

Six initial surface conditions are defined.

Five initial surface conditions of surfaces degraded after previously having been blast cleaned and painted with a protective paint system.

One initial surface condition, specified for a steel surface after previously having been blast cleaned and painted with an iron oxide prefabrication primer.

The initial surface conditions are defined both by written descriptions and by representative photographs.

Three preparation grades, designated:

Wa 1 *Light high pressure water jetting*
Wa 2 *Thorough high pressure water jetting*
Wa 2½ *Very thorough high pressure water jetting*

These preparation grades indicate the degree of cleaning. These are defined by written descriptions of the surface appearance after the cleaning operation along with representative photographs.

When cleaned with water, steel will flash rust (definition: oxidation of steel that occurs as water jetted steel dries). Three flash rust grades are specified; L (low), M (medium) and H(high). They are defined by written descriptions of the surface appearance before subsequent painting along with representative photographs.

The standard contains a procedure for the visual assessment of steel substrates where the substrate is examined with the appropriate photograph.

Chemical cleanliness

As previously mentioned, an important factor for the lifetime of a coating system is that the steel surface is as free of contamination as possible before the paint is applied.

An international standardization committee is working on control methods for detecting the presence of contaminants remaining on metal surfaces after they have been prepared. The methods established by the committee must be suitable for field use.

The international standard ISO 8502, which deals with chemical cleanliness, will most likely comprise a total of 13 parts when finished. Some of the parts have been in use since 1992, whereas considerable work is still outstanding in the case of others before they are ready.

ISO 8502 is listed below, as it is intended today. The number in brackets indicates the year the standard was accepted.

Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness

ISO 8502 Part 1:	Field test for soluble iron corrosion products (1991)
ISO 8502 Part 2:	Laboratory determination of chloride on cleaned surfaces (1992)
ISO 8502 Part 3:	Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method) (1992)
ISO 8502 Part 4:	Guidance on the estimation of the probability of condensation prior to paint application (1993)
ISO 8502 Part 5:	Measurement of chloride on steel surfaces prepared for painting (ion detection tube method) (1998)
ISO 8502 Part 6:	Extraction of soluble contaminants for analysis – The Bresle method (1995)
ISO 8502 Part 7:	Field method for the determination of oil and grease (in progress)
ISO 8502 Part 8:	Field method for the refractometric determination of moisture (2001)
ISO 8502 Part 9:	Field method for the conductometric determination of water-soluble salts (1998)
ISO 8502 Part 10:	Field method for the titrimetric determination of water-soluble chloride (1999)
ISO 8502 Part 12:	Field method for the titrimetric determination of water-soluble ferrous ions (2003)
ISO 8502 Part 13:	Field method for the determination of soluble salts by conductometric measurement (in progress)

Field test for soluble iron corrosion products (ISO/TR 8502-1)

Even if a surface has been blast cleaned to a cleanliness degree of Sa 2½, it may still be contaminated with salts from the corrosion process. Such salts are usually iron sulphate and iron chloride.

These salts are often found in pits on the blast cleaned steel and are colourless. Consequently, they are difficult to spot, also using a magnifying glass. However, after a certain period of time a colour change can be seen on such areas in the form of re-rusting of the steel. It can be difficult to distinguish between re-rusting due to high humidity and re-rusting due to the presence of iron salts on the surface. However, blasted steel with such salts re-rust locally at low humidity. In the case of high humidity, the whole surface will re-rust.

If the salts are not removed before repainting, this may result in extensive corrosion, and the paint system may be destroyed. ISO has worked out a Technical Report, ISO/TR 8502-1, intended as a guideline for determining the presence of such contamination.

When carrying out the test, plastic gloves should be used in order not to contaminate the surface and water with salt from the hands. In order to determine the presence of water-soluble iron corrosion products a marked out area of 100 x 250 mm is swabbed with a certain amount of distilled water and a cotton pad. It is important to carry out the swabbing in such a way that water does not run from the marked out area. The wash water is swabbed up with cotton and all the water is kept in a small glass flask for subsequent analysis.

The water is then analysed with commercially available indicator strips, for example of the Merckoquant-type, determining Fe^{2+}. The analysis range of this type of indicator strips is from 0 to 500 mg/l or ppm Fe^{2+}. If this method is chosen, solutions of known iron concentration must be prepared in order to calibrate the indicator strips in solutions of known concentrations of Fe^{2+}.

The method for determining the amount of water-soluble iron corrosion products on steel surfaces is quite comprehensive. It can also be difficult to use the method on curved surfaces. Alternative methods for determination are mentioned in the Technical Report.

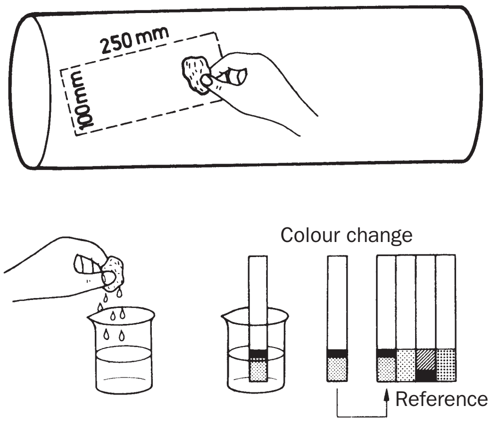

Figure 13.5 Soluble iron salts on the blasted steel surface result in a colour change on the indicator paper

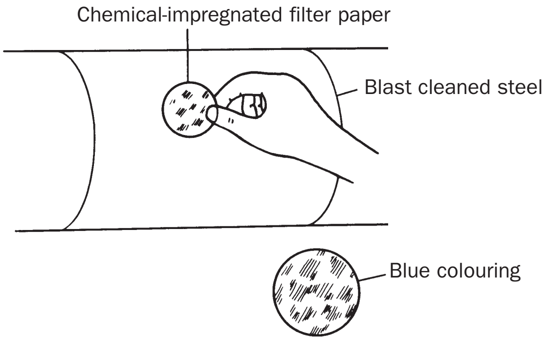

Figure 13.6 Soluble iron salts on the blast cleaned surface produce blue stains (spots) on the impregnated filter paper (potassium hexacyanoferrate)

Water-soluble iron corrosion products on the surface can also be determined by a chemical-impregnated filter paper producing a colour change. A solution of 4% of the chemical potassium hexacyanoferrate(III) in distilled water is prepared, the filter paper soaked in the solution and allowed to dry. Before carrying out the test, put on plastic gloves to prevent the chemical from penetrating the skin and prevent salt on the filter paper from the hands. A spray bottle with fine atomization is used for moistening the surface slightly with distilled water. The water must evaporate a little before the impregnated filter paper is pressed onto the surface and held there for about 15 seconds. The presence of water-soluble iron corrosion products appears as dark blue spots on the yellowish filter paper. If considerable amounts of water-soluble iron corrosion products can be determined, it may be necessary to wash and re-blast. The extent of the contamination can be seen more clearly if the blast cleaned steel is left for a few hours after having been blast cleaned. The contaminated areas will then usually be visible as darker blotches on the steel surface.

Control method for determination of chloride on cleaned surfaces (ISO 8502-2)

The adopted method has been developed for laboratory use. The sample-taking in the standard is very similar to the procedure explained in ISO/TR 8502-1 for determination of soluble iron corrosion products.

In order not to contaminate the surface plastic gloves are worn. The method basically consists of swabbing a marked out area of 100 x 250 mm with a cotton pad with a certain quantity of distilled water. The used wash water is collected and the solution titrated in the laboratory with a solution of mercury nitrate. The chloride content is recorded in mg/m².

The standard provides recommended concentrations of chemicals and special formulas for calculating the concentration of chloride in mg/m². With the recommended chemicals it may be difficult to determine concentrations of chlorides less than 10-20 mg/m².

Assessment of dust on steel surfaces prepared for painting (ISO 8502-3)

The method is suitable for determining the quantity of dust after having blast cleaned steel with rust grades A, B or C, and removed the dust either by vacuum cleaning or blowing with compressed air. The method, employing tape, cannot be used on highly corroded areas, rust grade D, because the tape is not elastic enough to get down into the pittings in the steel.

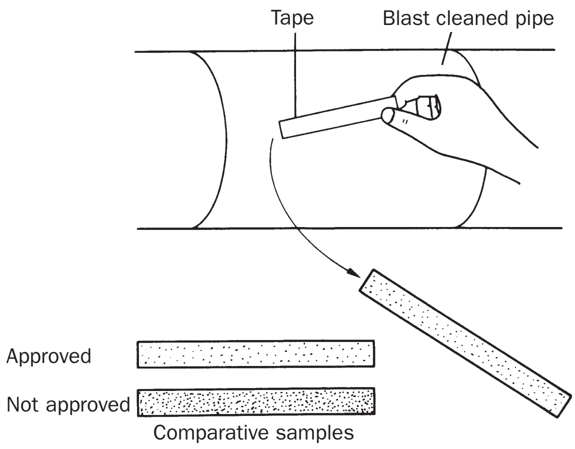

Figure 13.7 Assessment of the quantity of dust present after blast cleaning according to a standard may be relevant

A 25 mm wide and approximately 150 mm long piece of tape is applied on the blast cleaned steel and worked thoroughly into the surface by rubbing with a thumb or using a soft roller. The tape is carefully removed and attached on a display board of contrasting colour in relation to the dust. The background can be glass, black or white tiles, or paper. The tape is rubbed well and compared to the photographs in the standard.
Both quantity as well as particle size of the dust are assessed and rated from 0 to 5. In order to be able to view the particle size of the dust, the use of a magnifying glass with up to 10 times magnification may be relevant.

Estimation of the probability of condensation (8502-4)
This part standard touches upon the equipment and the requirements which the equipment used for checking the climatic conditions at the work site must be able to fulfil in connection with blast cleaning and paint application.

Detailed information on the probability of the formation of condensation is required. In order to assess this, we can compare the steel temperature with the dew point of the ambient air.

The steel temperature can be measured with a magnetic steel thermometer which is attached to the steel surface and allowed to remain there long enough to stabilize. This may perhaps take half an hour. Also electronic steel thermometers can be used on which readings can be taken directly when in contact with the steel.

The standard ISO 8502-4 also contains several tables showing the dew point temperature as a function of the temperature and relative humidity of the air. When the air temperature and the relative humidity have been measured, the dew point temperature can be determined.

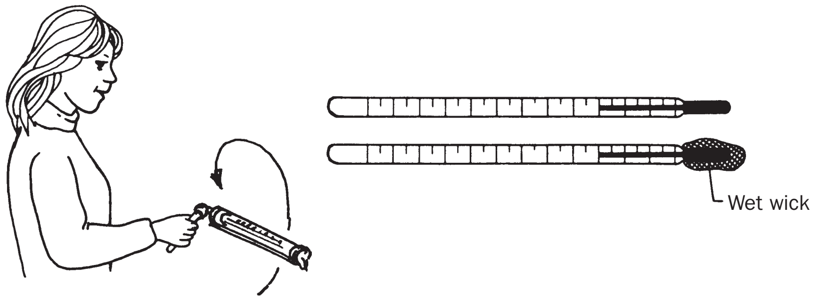

Figure 13.8 Principle and operation of a sling psychrometer

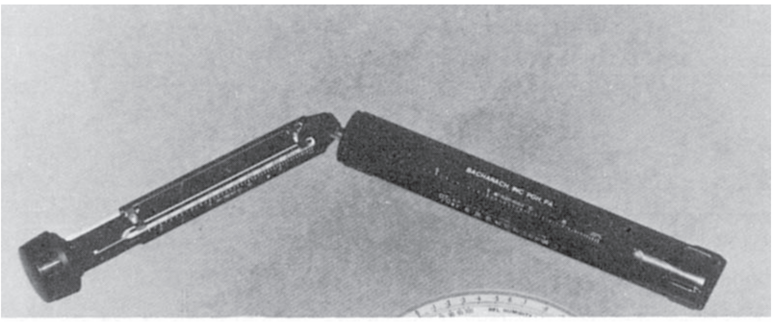

Figure 13.9 Sling psychrometer

Sample-taking according to the Bresle-method (ISO 8502-6)
We would like to be able to use most of the part standards of ISO 8502 in the field. This requires sample-taking methods which are simple and accurate when used. In 1995 the ISO 8502-6 *Sampling according to the Bresle method* was adopted. This standard is intended for use in connection with the determination of several types of contaminants on the steel surface. So far the standard has been used for determining conductivity and chloride concentrations on blast cleaned steel surface before paint application.

When a sample is to be taken according to this standard, a small self-adhesive plastic patch (Bresle patch) with a latex membrane is used where the area and volume are known. First we remove the protective tape from the adhesive back of the patch and the cut-out in the patch, and then we attach it to the blast cleaned steel. When doing this, make sure that as little air as possible is trapped in the analysis compartment of the patch.

15 ml of distilled or deionized water is poured into a graduated measuring tube. The conductivity of the distilled water is measured using a calibrated conductivity meter. Note the value. From the graduated measuring tube 3 ml of the distilled water is drawn using the needle of a syringe. The 3 ml of water is injected into the analysis compartment through the edge of the Bresle patch. The water is pumped back and forth between the patch and the syringe 2-4 times per minute for about five minutes. All the water is finally drawn into the syringe and transferred back into the graduated tube with the 12 ml of water. The meter probe is inserted and the conductivity measured. In order to calculate the salt concentration in mg/m^2 the actual increase in conductivity (in µS/cm) is multiplied by a factor of 6.

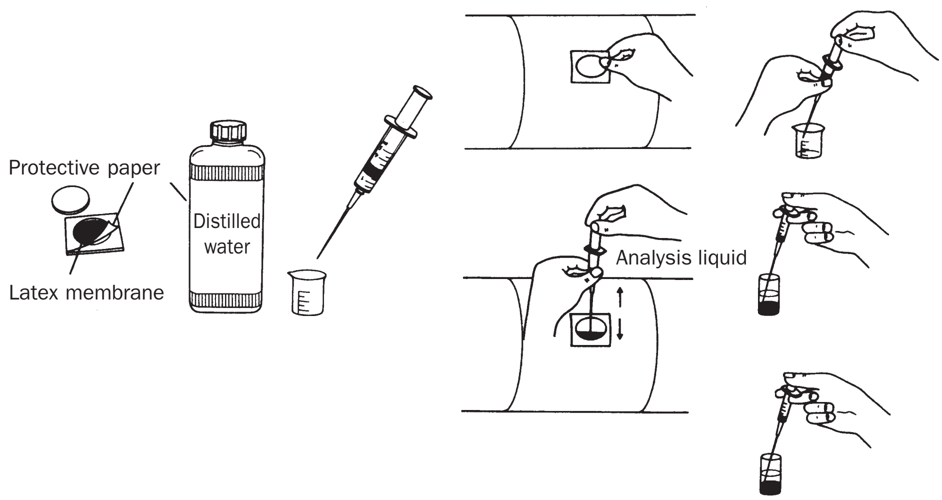

Figure 13.10 Using self-adhesive plastic patches for sample-taking

Another analysis method for chloride also commercially available is marketed under the name of Salt Concentration Meter – SCM 400. A filter paper is soaked with a known volume of distilled water and applied to the blast cleaned surface. After this, the paper is placed in the small, portable instrument SCM 400 which determines the resistivity in the solution across two electrodes. The method enables us to determine soluble salts (such as sodium chloride) within the range of 0.1-20 µg per cm^2 (1-200 mg/m^2).

The NORSOK standard M-501 Rev. 4 from December 1999 "Surface Preparation and Protective Coating" includes requirements for maximum conductivity of the water corresponding to 20 mg/m^2 NaCl.

Substrate roughness

After mechanical surface preparation like blast cleaning the surface obtains a certain surface profile or roughness. Both the area and shape of the surface vary with the abrasive used. In order to obtain a high-quality and fast cleaning of the surface the particle size distribution should contain both small and large particles. Small particles provide fast removal of rust and other foreign matter, while the larger particles increase the surface roughness of the steel.

What is the purpose of the surface roughness and how rough should the surface be?

This has been the subject of much discussion in recent years. Blast cleaning produces a clean surface as well as an anchor pattern for the paint, but it also increases the surface area of the steel. Avoid using an abrasive mix which produces a higher roughness than specified, since this will result in a higher consumption of primer.

There is no direct correlation between the surface profile and the surface cleanliness. Consequently, if the steel has been assessed as having been blast cleaned to Sa 2½ according to ISO 8501-1, this does not tell us anything about the roughness of the surface.

Comparators

Comparators made of stainless steel have been used for a number of years. Previously, within the shipping and offshore industries, the comparator Rugotest No. 3 was used in many European countries, while in the USA comparators from Clemtex and Keane-Tator were used.

Even though comparators used in Europe and in the USA look different, they are used more or less in the same way. The comparators consist of small areas or segments which have been blast cleaned using an abrasive. This produces two types of comparators, one for grit and one for shot, with increasing roughnesses.

In 1988 the international standard ISO 8503 for determining surface roughness was adopted.

The standard has four parts and is designated EN ISO 8503 "Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast cleaned steel substrates".

Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast cleaned surfaces

Part 2: Method for the grading of surface profile of abrasive blast cleaned steel – Comparator procedure

Part 3: Method for the calibration of ISO surface profile comparators and for the determination of surface profile – Focusing microscope procedure

Part 4: Method for the calibration of ISO surface profile comparators and for the determination of surface profile – Stylus instrument procedure

Determination of roughness

In the specification requirements to the surface roughness will be listed. For most paints a common requirement is a surface roughness "medium" in accordance with ISO 8503-1. This indicates a surface roughness of R_{y5}= 50-85 µm.

Two types of roughness will be discussed. Sophisticated equipment (electronic stylus instruments) is used for determining the roughness.

The maximum height of the profile is called R_y. This is the distance between the top line and the bottom line of the profile within a reference length. Normally, several measurements are taken. Sometimes you may encounter R_{y5} or R_z. R_{y5} is the average of R_y on 5 adjoining reference lengths. R_z is the ten-point height of profile irregularities and the mean value of the heights of the five highest peaks and depths of the deepest valleys within one reference length. R_{y5} and R_z are approximately equal.

Previously, roughness was usually indicated as R_a, which is the arithmetic mean deviation of the profile. When the instrument stylus passes across the profile, the instrument stores an imaginary centre line in its memory. This centre line intersects the profile in such a way that the total areas on both sides are equal. R_a is then defined as the average distance of all points on the profile relative to the centre line.

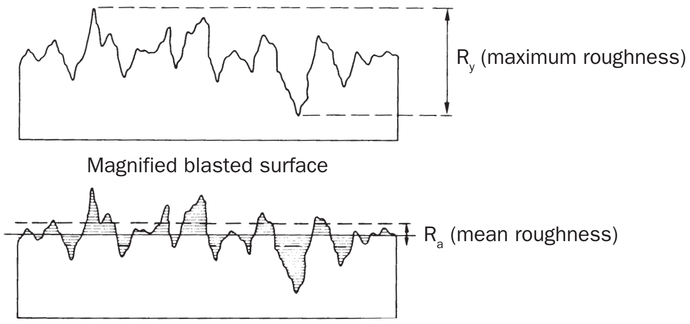

Figure 13.11 Roughness given as R_a and R_y

ISO 8503-1 asseses the average maximum profile height, R_{y5}, while Rugotest No. 3 assesses the arithmetic mean deviation of the profile, R_a. The average maximum roughness, R_{y5}, is usually four-eight times higher than R_a.

In connection with thermally sprayed coatings it is today common practice to specify a roughness Grit-medium according to ISO 8503-1.

When checking the roughness, a number of measurements are taken within a reference area of for example 10 m^2. If the readings taken are either too low or too high, additional blasting may be required.

If the roughness is too high in relation to the thickness of the paint film applied, the peaks may penetrate through the paint film. This may cause premature breakdown of the paint system on such areas.

Table 13.1

Laboratory examinations	Field use at work site
Electron microscope Metallographic crosscut Optic microscope (ISO 8503-3) Electronic roughness meter (ISO 8503-4) Stylus instrument	ISO 8503-1 Other comparators Pull-off tape – Testex tape Dial gauge method Stylus instrument

A brief explanation will be give below of the operating principles of various instruments, comparators and stylus instruments and how they are used.

Dial gauge method
The dial gauge method was among the first to be used for field measurements.

The instrument is a small, durable roughness gauge. It comprises a number dial, which can be adjusted, and a spring-loaded tip. This instrument records the difference in height between a reference point and the surface at a certain location.

When calibrating, the instrument is placed on top of a glass plate and a small screw is loosened so that the number dial can be set to zero.

The instrument is placed on several spots on the blasted surface. The tip size is approximately 50 µm. As a result of this, measurements of the deepest and narrowest valleys may not be adequate. The instrument can show R_y-values of up to 600 µm.

Figure 13.12 Roughness gauge of the type Elcometer 123

The number of measurements should be specified in advance. If this is not done, 10-15 measurements per square metre should be taken. The average value can then be calculated.

Replica tape

In our opinion this method is very suitable in the field where the surface profile or roughness of blast cleaned steel is to be measured and documented. In the USA the corrosion organisation NACE has issued a standard for the use of replica tape, NACE RP 0287-2002.

The method consists of a small, compressible plastic film which is applied onto the blasted steel. A roller is then taken across a small area of the surface so that a replica of the roughness will be made in the plastic film. The thickness of the film with the replica of the roughness is measured with a micrometer. Adjustment must be made for the thickness of the film itself by subtracting 50 µm from the values measured. The surface roughness for this area has now been determined.

The tape is available in two measurement ranges, coarse and extra coarse. The roughness can be determined within the range of 1.5-4.5 mils (thousandths of an inch), i.e. approximately 40-120 µm. With this method the maximum roughness R_y is found.

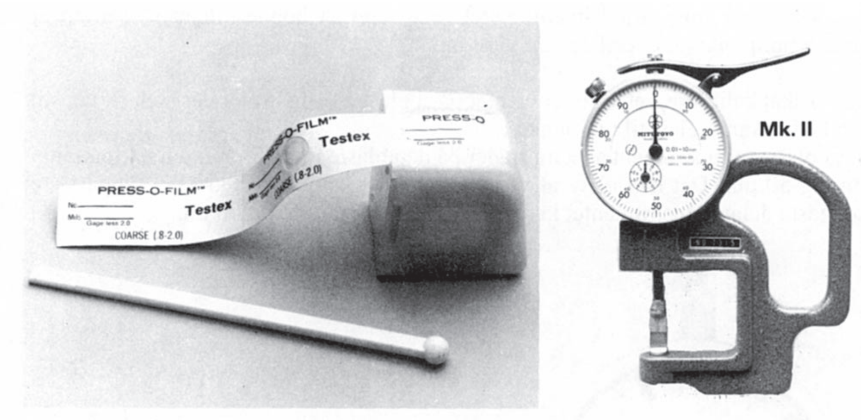

Figure 13.13 Special tape and equipment for measuring roughness

ISO 8503-1

The comparators have four segments and have been blasted with shot or grit abrasives. The reverse side of the comparator is labelled either S or G, indicating whether the comparator is to be used on shot blasted steel or grit blasted steel.

These designations apply to measurement of roughness in accordance with ISO 8503:

Fine	Roughness lies between segments 1 and 2
Medium	Roughness lies between segments 2 and 3
Coarse	Roughness lies between segments 3 and 4

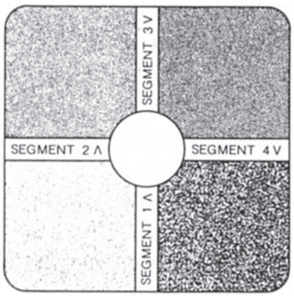

Figure 13.14 ISO 8503 comparator samples

Using 8503-1 for determining roughness

The comparator is placed onto the surface of the blast cleaned steel. The surface profile is seen through the centre of the comparator and in turn compared with the segments of the comparator. In accordance with ISO 8503-1 the roughness is characterized as fine, medium or coarse. If you find it difficult to make the comparison, a 7 x magnifying glass can be used.

Avoid using the finger tip for control, as it may leave traces of grease and salts on the surface.

The ISO comparators are widely used. But also other methods for checking the roughness are available.

Other comparators

Rugotest no. 3

This comparator has a rectangular shape and the blasted specimens are grouped vertically according to the shape of the abrasives with which they have been blasted.

The specimens on the left side, denoted A, are shot blasted, while those on the right side, denoted B, are grit blasted.

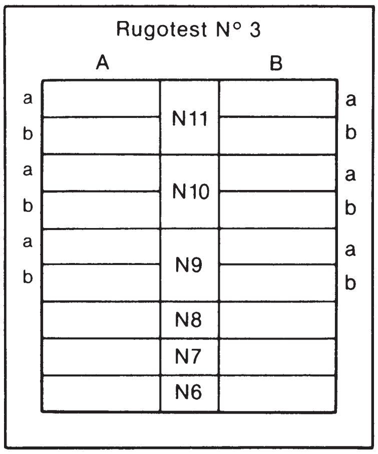

Figure 13.15 Rugotest no. 3 comparator

Each half is divided into six roughness areas, from N 6 to N 11. N 11 indicates the highest and N 6 the lowest roughness. The average roughness R_a ranges from 0.8 µm to 25 µm on the specimens from N 6 to N 11 on Rugotest no. 3. Some of the specimens, N 6-N 11, have been subdivided into two specimens. These specimens are designated a or b. a indicates that blasting has been carried out with coarse abrasive grains, b with fine abrasive grains.

In the offshore industry a roughness within the range B N9a-B N10a is usually required.

Some years back this comparator was widely used all over the world to determine roughness on blast cleaned steel. But after the adoption of the ISO-comparators, a decreasing number of specifications refers to this method.

Clemtex and Keane-Tator

The Clemtex comparator contains individual, small, rectangular coupons blasted to different roughnesses on stainless steel.

Each of the three comparators from Keane-Tator contains five projections from a central hole. One comparator has been blasted with a mineral abrasive, the other two blasted with metallic grit and shot abrasives.

The comparators from Clemtex and Keane-Tator provide the average maximum roughness, R_z. Rugotest no. 3, on the other hand, gives the average arithmetic roughness, R_a. When a figure is given for a roughness with Rugotest no. 3, the result is a much lower value than in the case of 8503-1 or any of the other comparators mentioned.

Other methods for determining roughness

In the international standard ISO 8503, in addition to the comparators, an appendix also mentions other methods for controlling the roughness. This includes microscope (ISO 8503-3) and electronic roughness instruments (ISO 8503-4). These methods are mostly intended for laboratory use.

Electronic roughness instruments and stylus instruments

These instruments are highly advanced. They can provide a printout of the profiling of the surface, with an indication of both R_a, R_z, R_{y5} and R_y.

The instruments have a small diamond stylus being moved over a reference length of approximately 5 mm. The instruments record the variations in the substrate. They can be connected to a printer so that a printout of the substrate roughness can be produced. On the printouts the measurement values registered by the instrument are magnified both horizontally and vertically.

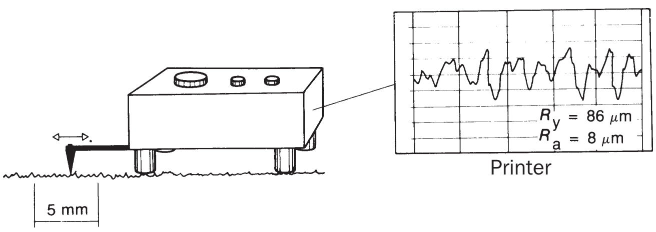

Figure 13.16 Electronic roughness instrument connected to a printer

However, these types of instruments are expensive to buy and require a certain amount of training before they can be used. Today they are available as small, portable types, but they are probably too advanced to measure the roughness of blast cleaned steel. Such instruments have been used for a few major projects in Norway, but the comparators are the most common tools.

Determination of the climatic conditions

Both when surface preparation and paint application are carried out, it is important to work under the optimum ambient conditions. If the conditions are unfavourable, high relative humidity may cause condensation on the steel, and if this happens while blast cleaning or shortly afterwards, the steel will flash rust. A thin rust film is formed on the surface. Most paints are sensitive to condensation on the surface. If paint application is carried out under such conditions, adhesion problems may occur. Consequently, it is important to check the climatic conditions both before work is started and while work is in progress, for example air temperature, steel temperature, relative humidity of the air and dew point.

Relative humidity of the air and dew point may be unfamiliar terms. From our daily life situations involving condensation or dew formation will be known. After a shower, the bath-room mirror will often be completely steamed up. If something is taken from the refrigerator, it may be dewy. Perhaps you may even have seen it in practice at your place of work. Steel having been stored outside is taken into the blasting hall, and then suddenly water starts running from it. The condensation having taken place is due to the material being colder than the air, which contains so much humidity that it condenses on the steel and water is precipitated.

Condensation also occurs at small temperature differences when the relative humidity of the air is high. In order to avoid such problems it is important to heat the steel in order to obtain a higher steel temperature than the dew point temperature. Condensation will then no longer be formed on the steel. Alternatively, an attempt can of course also be made to remove the humidity from the air, but this is not common practice in places like blasting halls. In other places where it is necessary that the steel keeps its cleanliness degree over an extended period of time before it is painted, it may be an important point to remove the humidity. During blast cleaning and painting of penstocks (water transporting pipes) in the mountains, dehumidifying units are often used.

The air contains various gases and water vapour. The volume of water vapour in the air varies. When the temperature is high, the air can hold more water vapour than at lower temperatures.

At a certain temperature the air is no longer able to contain the water vapour. This temperature is called the *dew point temperature*. At the dew point the relative humidity is 100%. The air is saturated with humidity (moisture). Condensation occurs.

If there is no precipitation in the air, there is usually too little humidity in the air to say that it is saturated. Consequently, the *relative humidity* is usually given. The relative humidity (RH) is the ratio between the actual content of water vapour in the air and the maximum content of water vapour to be found at the same tempera-