8. 涂装检查和质量控制

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8. 涂装检查和质量控制

正如在引言中所是到的，人为因素是达到规定涂料系统质量的最为重要的部分。所以进行工作上质量检查是极为重要的。 本章节将描述如何进行，何时进行检查工作，以及工作中所要用的工具。下一章将描述个人可能遇到的涂料弊病和相应的补救措施。

结构物中的建造过程中，检查将贯穿于以下重要阶段：

1. 车间底漆施工时
2. 表面预处理的检查
3. 施工前和施工中的检查
4. 施工后的检查

这里的每一点都将在下面详述。另外，检查员应该检查判断并记录下工作情况：

- 按规格书要求
- 按良好施工工艺的惯例
- 符合涂料生产商对于产品的要求

如果不是这样，进行适当的修正措施，并在工作推进前检查认可。

8.1. 车间底漆检查

近年来一直在讨论车间底漆在进一步涂漆前是否可以保留，或者部分除掉，或者全部除掉。任何保留的车间底漆必须在车间内进行彻底的检查，因为车间底漆将成为结构上长期涂料保护系统中的一部分。车间底漆工厂内检查内容包括：

- 只有锈蚀等级在A或B（ISO8501－1）的钢材能进行车间底漆处理
- 车间底漆只能施工在经喷射喷砂处理至少Sa 2 ½ (ISO 8501-1)钢材表面
- 由于电焊和切割的因素，正确的干膜厚度在15 微米左右(根据厂商建议)
- 令人满意的固化／干燥时间（不会被运输线辊筒所损害）

8.2. 钢结构工作检查（喷砂前处理）

在建结构在建造维修时的工作包括钢材调换或喷砂，钢结构工作应该检查的内容：

- 锐边打磨光滑
- 粗糙焊缝打磨光顺
- 飞溅和焊豆的去除和打磨
- 裂缝和凹坑
- 表面缺陷如迭层

该工作应该按照规格书要求或者ISO 12944-3(设计要求)来进行， 并且要在运送去表面预处理和涂漆前在电焊车间内完成。

图 8.1.表面预处理前，边缘要打磨，飞溅要除掉

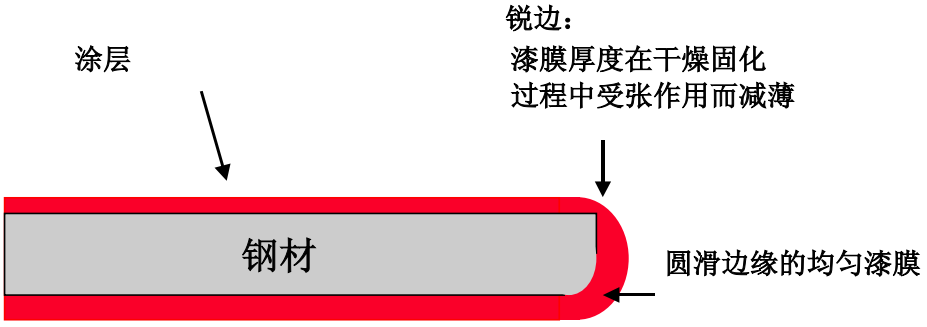
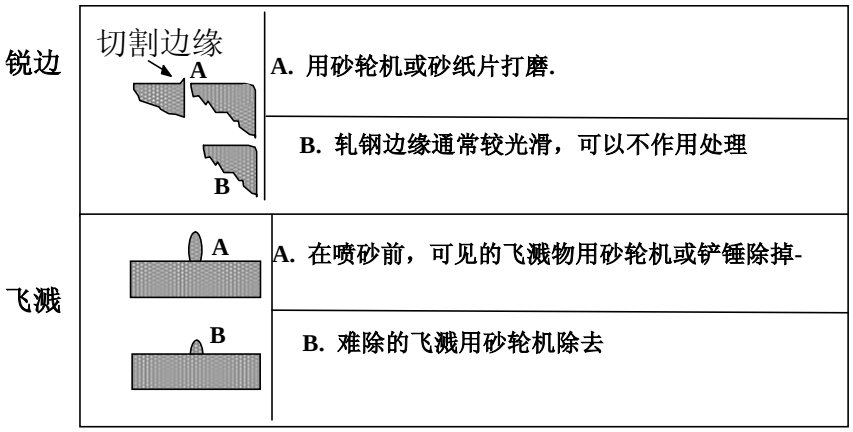


图 8.2.锐边打磨光滑对保证整个表面均匀漆膜是非常重要的



8.3. 表面处理检查

表面处理的检查包括以下内容：

1. 清洁度：溶剂清洗除去盐份、油脂和灰尘污物
2. 原始状态的评定(锈蚀级别)
3. 表面处理（处理级别和粗糙度)
4. 表面处理后的清洁度 (盐份、油脂)
5. 气候条件

从上面可以看出，清洁度要检查两次。第一次是溶剂清洗（根据SSPC－SP1），首先除去油脂灰尘污物。溶剂清洗通常还包括淡水，可以除去可溶性盐。第二次检查是评定施工喷漆前的清洁度。

8.3.1. 溶剂清洗：SSPC-SP1.

根据不同的的标准，在进一步的表面准备和涂漆前，表面或多或少地要没有各种污物。喷射清理和机械处理是不能除去油脂和盐份的。这就有必要介绍一种额外的清理步骤：溶剂清洗。

Table 8.1. 溶剂清洗的方法

清除目的	程序	备注 [1)]
油脂	用水清洗	淡水加入去污剂，压力< 70 MPa，再用淡水漂洗
	蒸汽清洗	淡水，如果加入了去污剂，要用淡水漂洗
	乳液清洗	淡水漂洗
	碱液清洗	铝、锌和某些金属涂层易受强碱腐蚀。用清水漂洗。
	有机溶剂清洗	许多有机溶剂对健康是有害的。如果用抹布清洁，必须多次更换，否则油脂不会清除，反而 在溶剂挥发后在表面留下油膜。
水溶性杂质，如盐份	用水清洗	使用淡水，压力< 70 MPa
	蒸汽清洗	清水漂洗
	碱液清洗	铝、锌和某些金属涂层易受强碱腐蚀。用清水漂洗。

[1)] 备注：有机溶剂清洗不能除去可溶性盐。表面存在的盐份必须另外用淡水清洗。

根据SSPC-SP1，溶剂清洗是除去所有可见油脂、泥污、记号和切割混合物以及其它表面可溶性污物的方法。目的是在涂漆前进行溶剂清洗，结合规定的表面处理方法除去锈蚀、氧化皮和旧油漆。建议先用刮刀除去厚重的油脂，再用上表中方法除去剩下的油脂。

油脂的检测方法

- 最简易的油脂检测方法是在表面洒水的“洒水法”（非标准）。如果没有油脂存在，水滴会在表面很快地扩散开来，如果有油脂存在，则会留存在表面形成水珠状
- Fettrot Test (Din 55 928 Part 4) 使用 0.1%Fettrot B.B. 的在酒中的溶液能在表面很快地进行油脂的目测判别。
- 也可使用紫外线检测表面的油脂，会发出蓝色的萤光。

油脂只有定性没有定量的检测。

盐份的测试方法

当清洗建造时，水溶性盐溶入水中就自动被除去。然而，在厚厚的沉积物下的盐份则不会被溶剂。这些沉积物不能清洗掉，只能用前面所述的方法除去（喷射清理，水喷射等）。These deposits can not be washed off and have to be removed by the surface preparation prescribed (blast cleaning, water jetting etc.). As a consequence of this the amount of salt on the surface is not checked/controlled at this stage of the production, but is a critical part of the inspection prior to application. How to detect and remove them is therefore explained later in this chapter.

8.3.2. 现状评判 (锈蚀级别和可见清洁度)

Before starting work on larger or smaller jobs the surface to be protected has to be inspected so that the initial condition of the steel surface is determined. Such an inspection is important, as the assessment of the steel will be decisive for the pre-treatment to prescribe and to some extent also for the coating system to be used.

The inspector’s tool is the international standard: **ISO 8501-1** from 1988. The standard gives four rust grades which are used to assess the steel surfaces. These are given the designations A, B, C and D (See section 3 “Pre-treatment”). Photographs are used to illustrate the four rust grades of the steel. The present ISO standard, with a few changes, is based on the former Swedish Standard 05 5900-1967 which has been used for a number of years.

For personnel with little experience in assessing steel surfaces it may seem difficult. Thus, it is an advantage to use the standard to compare the photos with the surfaces. However, the inspector will gradually learn to know the surfaces, which eventually can then be judged without the use of the standard. An experienced inspector will be able to identify the rust grade of a steel surface very easily.

The above mentioned part of the standard is for assessing bare (unpainted) steel. For evaluation of shop-primed steel or steel with an old paint system where localised pre-treatment is to be carried out, **ISO 8501-2** should be used.

8.3.3 Inspection of surface preparation

8.3.3.1. Uncoated steel

A paint specification will give the pre-treatment method to use and the standard to be achieved (e.g. wire brushing to St.3). It is the inspector’s job to verify that the work has been done in accordance with the specification and that the given pre-treatment standard has been obtained. As

well as photographs of dissimilar rust grades A, B, C and D (see above), **ISO 8501-1** also contains 24 pictures which show the visual cleanliness after mechanical pre-treatment by wire-brushing, blast-cleaning and flame cleaning on steel substrates originating from the four different rust grades. Furthermore, the standard lists a number of important factors to consider during the control.

A typical example is the appearance of the pre-treated substrate: The colour of the steel can vary from the pictures in the book. This is due to; Inclusion of blasting abrasives, dissimilar corrosion on the surface, shadows caused by the blasting angel, type of lighting used at inspection and marks after equipment.

To overcome some of these problems **Supplement 1** to ISO 8501-1 was issued in 1989. Here, representative photographic examples of the change of appearance of the steel blast cleaned with different abrasives are given.

The dissimilar grades of cleanliness are characterised as follows:

- Wirebrushing: St 2 and St. 3
- Blast-cleaning Sa 1, Sa 2, Sa 2 ½ and Sa 3.
- Flame cleaning: F1

On assessing and comparing the steel surfaces after pre-treatment, the characters A, B, C and D are often used in front of the cleanliness grades in order to emphasise the original condition of the steel prior to pre-treatment.

Example: B Sa 2 ½ implies:
Very thorough blast-cleaning (2 ½) of a surface which had started to rust (grade B)

8.3.3.2. 先前涂漆的钢板

很多情况况下，要进行评估的钢板早就涂过漆了。这种表面外观与没有涂漆的钢板稍有不同，有一个相对较新的标准用来评估这些表面：**ISO 8501-2**“先前涂漆的钢板在局部除漆后的准备级别”。

ISO 8501中的这一部分的基本要点是经验显示没有必须总是完全除去旧油漆。在定期间隔维进行维修工作时尤其是真实的。在局部清理首先满足后，还要达到以下要求：

- 剩下的完好涂层须要有助于且使新的防腐蚀系统持久，并且完全与之相兼容。
- 在局部处理锈蚀部位至底材的时候，在周边部位不能搞得无法修补或太过于明显地被损害
- 尽可能节约维修工作的费用。

This standard is built up in the same way as **ISO 8501-1**: The various preparation grades are defined by written description accompanied by representative photographic examples, given in ISO 8501-1. In addition, photographs showing some typical examples of steel prior to and after preparation are given. A written description follows each example.

ISO 8501-2 is applicable to surfaces prepared for painting by methods such as blast cleaning, hand- and power-tool cleaning, and machine abrading. The appropriate letters designates each preparation grade. “Sa, St or Ma “ to indicate the type of cleaning method used. Ma means, “Machine abrading”, for example by disc with abrasive paper or by special rotating wire brushes or non-woven abrasive tools. The letter P before Sa. St. and Ma indicate that only localised removal of previous paint has been done.

例：
P Sa 2 ½: 非常彻底的局部的喷砂清理

P St 2 : 彻底的局部的手工和动力工具清理
P Ma: 局部机械打磨

不要忘记在喷砂清理、钢丝刷清理或机械打磨前，任何厚锈应该先铲除之。可见的油脂和污物以及可溶性盐份和焊剂应该除。.

8.3.3.3. 粗糙度 (钢板表面轮廓)

When a surface is blast cleaned a certain surface profile or roughness is obtained. The roughness can be characterised by both shape and size. What is the advantage for a paint system to be applied to a surface of a certain roughness, and how rough should the surface be?

This question has been discussed for many years. After blast cleaning the surface area will be significantly increased and many points of anchorage for the coating system will be gained. It is, however, important that the roughness profile of the steel is not unnecessarily high, as the paint system must cover the peaks of the roughness. Too great a degree of roughness will require increased paint consumption. In specifications a required surface profile is often stipulated with a maximum roughness of approx. 35 - 75 microns. (See also section 6 “Surface preparation”).

In order to determine the surface roughness different equipment can be used and the roughness is measured in microns. The most usual method, at least for corrosion protective coatings, is to use a comparison test. For a number of years **Rugotest No. 3** has been used. This comprises a number of segments, which have been blast-cleaned with grit (rough edges) or shot (round) of varying size. In this way it has been possible to obtain different degree of roughness on the segments. However, the roughness, which is defined by using Rugotest No. 3, is not the maximum roughness, but a more average roughness. We shall return to this later in this section.

In recent years comprehensive research has been carried out on this subject. There is now an international standard, split into four sections, to determine the surface profile/roughness, **ISO 8503 1 - 4**. The methods used to determine the roughness are as follows:

ISO 8503-1 Comparison tests/comparators, the first for a grit and the other for a shot-blasted surface. (Description of method)
ISO 8503-2 The use of comparison tests/comparators.
ISO 8503-3 The use of a microscope
ISO 8503-4 The use of stylus instruments

The defined roughness can be interpreted in different ways. To avoid any misunderstanding we will therefore define these methods in more details.

h_y : Maximum peak to valley height within a given area. (By microscope) ISO 8503-3
R_y Maximum peak-to-valley height within a given area. (By stylus) ISO 8503-4
R_a : Average distance from imaginary centre line. ISO 3274

There is no direct transfer / connection between R_a and R_y, but a rule of thumb is that R_a is equivalent to approx. 5-6 times R_y.

There are several methods for measuring the roughness of blast-cleaned steel. Some of the methods can be used in laboratories:

- Electron microscope
- Opticam microscope
- Metallographic section
- Electronic roughness gauge (stylus instruments)

These are extremely advanced instruments, which can give a transcript of the profile of the steel surface. Instruments of this type are, however, expensive and the user needs a great deal of instruction and training on how to use them. Even though they are becoming available in smaller, portable versions, they are too advanced for use as roughness gauges on site.

Others are more suited for field operations:

- Comparators: ISO 8503-1 (Rugotest No. 3, Keane-tator, Clemtex)
- Elcometer 123
- Testex imprint tape

Here is a brief description of how the various instruments function:

Comparators:

In **ISO 8503**, two comparators are specified; one with profiles corresponding to blast-cleaned surfaces using grit abrasive (reference comparator G) and one corresponding to blast-cleaned surfaces using metallic shot abrasives (reference comparator S).

The nominal values for these profiles, identify the limits of the three grades “fine”, “medium”, and “coarse”. (See table 8.X). When a mixture of shot and grit abrasive is used to blast-clean a substrate, the grit-abrasive reference comparator G should be used.

Table 8.2.
Nominal value of surface profiles.

Fine	Profiles equal to segment 1 and up to but excluding segment 2
Medium	Profiles equal to segment 2 and up to but excluding segment 3
Coarse	Profiles equal to segment 3 and up to but excluding segment 4

In the USA both Clemtex and Keane-Tator surface profile comparators are available.

Elcometer 123:

This is a solid roughness gauge, which rests on a round plate and has a spring-loaded point, which registers the difference between peak and valley for the roughness profile at a given point. The instrument is placed at several locations of the blast-cleaned surface. The point has a diameter of approximately 50 microns, which means that it can not measure the deepest and narrowest “valleys”. The instrument is capable of measuring h_y values of up to 600 microns.

Testex imprint tape:

This method is considered to be a suitable test for use in the field, for measuring the surface profile/roughness of blast-cleaned steel with roughness in the range from 40 to 120 microns. The tape is placed on the blast-cleaned steel surface and compressed with a roller so that the tape retains a print of the surface. A micrometer screw gauge can later measure this replica. The tape is available for two levels of roughness, coarse and extra coarse.

8.3.3.4. Abrasives for blast cleaning.

The blast-cleaning material should be checked for:

- Grain size, size distribution
- Hardness (by a glass slide test)
- Water-soluble contaminants by conductivity measurement
- Moisture
- Water soluble chlorides

The metallic abrasives are checked in accordance to **ISO 11125** and the non-metallic abrasives in accordance to **ISO 11127**. See also section 6 "Surface preparation" regarding characterisation for the various types of abrasives.

8.3.3.5. Water jetting

For water jetting, as well as for hosing, contaminated water may impose impurities on the surface to be painted. The quality of the water must be checked:

- Drinking water quality is recommended.
- Check salt level (Fresh water is often produced from seawater).
- Foreign matter / impurities / calcareousity (Hard/soft water).
- Contaminants on surface to be painted.

Assessment of the cleaning degree by water jetting is made immediately after the cleaning, i.e. before formation of flash rust. While assessing the degree of cleaning it must be recognised that these in general will not look the same as surfaces cleaned by methods employing abrasives. Water jetting will remove paint and / or rust and reveal the substrate with scars from corrosion giving the surface a non-uniform appearance.

Methods which make use of abrasives will in addition to removal of paint and / or rust re-model the substrate and leave the surface with a uniform appearance. Assessment of the degree of flash rust must be carried out immediately prior to the start of application.

Also in the assessment of flash rusted conditions it must be recognised that these may have a different appearance on different steel surfaces. This is certainly the case for the two lowest degrees of flash rust, whereas the highest degree will appear very much the same regardless of the initial condition. The time it takes to reach a certain degree of flash rust depends on the micro-climate, the original condition of the surface, the cleaning degree (remaining salt and contaminants) and on the way the cleaning is organised. The less affected the original surface and the more thoroughly it is cleaned, the longer it will take to develop flash-rust - all other factors being equal.

The very high pressure employed by water jetting results in substantial heating of the substrate, giving a faster evaporation of the humidity and therefore virtually no formation of flash rust. However, if the heated surface is subsequently exposed to water - e.g. from cleaning an adjacent area - flash rust will appear very fast. To secure minimum formation of flash rust at the time of paint application, the cleaning may be programmed to allow for drying without subsequent exposure to water, followed by application of a hold coat immediately after drying.

8.3.4. Cleanliness after surface preparation.

The surface preparation will remove rust, scale, old paint etc.. Nevertheless, the substrate may not be sufficiently clean for painting. Soluble iron corrosion products may still contaminate rusted steel, particularly of rust grades C and D, even when blast-cleaned to Sa 3. Iron corrosion products are almost colourless and are localised at the lowest point of the rust pits. At

preparation grades lower than Sa 2 ½ it is likely that soluble iron corrosion products will be concealed under layers of iron oxide, and will not be detectable until further blast cleaning is carried out. These iron corrosion products (mostly ferrous chloride and ferrous sulphate) are water-soluble and will cause blistering of the paint film. Therefore they have to be removed, or at least be below a given acceptance level, before the paint is applied.

Visual cleanliness is checked according to ISO 8501-1 or -2 and the non-visual cleanliness according to different sub-standards of ISO 8502 (Iron salts, chlorides, dust and condensation).

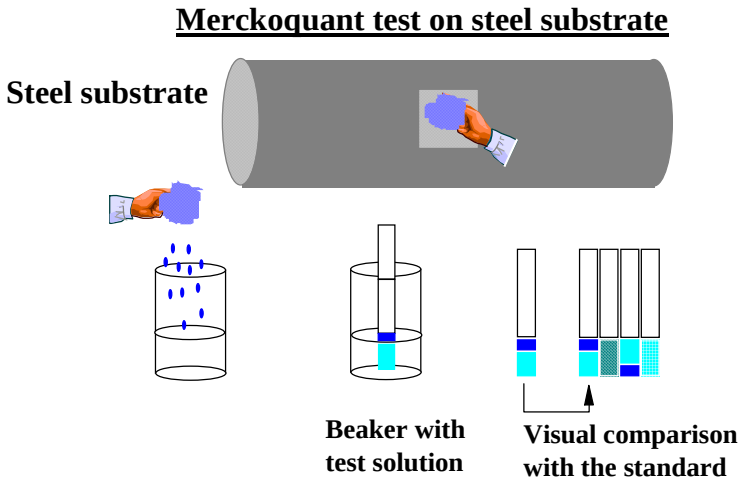
8.3.4.1. Detection of ferrous salts.

There are several methods for detection of ferrous salts as described in the standard **ISO 8502-1**. The most commonly used methods are:

1. The Potassium Hexocyano-ferrate test papers. This test must be considered as a qualitative analysis, which only indicates whether or not such salts are present. Depending on the specification, these blue spots could indicate the need for high pressure washing, steaming or wet-blasting of the surface before re-blasting, to remove of all iron salts. This is the simplest method. An area on the blast-cleaned steel is moistened with distilled water by spraying. (If you use too much water the test is spoiled). When the water has just about evaporated, the filter paper (impregnated with potassium Hexacyano-ferrate) is pressed gently on to the damp surface for 10-15 seconds (use plastic gloves). The filter paper is examined for blue spots, which indicate the presence of soluble iron salts.

2. The second test is a quantitative test, the "Merckoquant test", which is sensitive within the range of 10 to 500 mg/$m^{2.}$ Here a volume of 50 ml distilled water is used to wash / dissolve the salts on a test area of 25 x 10 cm.

Figure 8.3.
Detection of Ferrous salts. "Merckoquant test": ISO 8502-1, Part 1.



8.3.4.2. Detection of chlorides

ISO 8502-2 清洁表面的氯化物实验室测试法。水银离子与自由氯离子反应的滴定法。

目前还没有一个经认可的实地测试方法。现场使用的方法还在制作之中。

8.3.4.3. 所有可溶性盐的检测

实地试验方法必须很简单地使用，包括取样、分析和设备的使用。现今较友好的测试方法是溶解表面存在的盐份在水中测量其样品的传导率。传导率是溶液的导电性的指示，用 (µS)来测量。传导率可以通过计算转换成相应的表面盐份含量。可溶性盐份总量的检测方法在两个标准中有讲述：

- 取样法**ISO 8502-6,** “Extraction soluble contaminants for analysis” the Bresle sampler.
- 分析法**ISO 8502-9,** “Field method for soluble salts by conductometric measurement”.

记住：使用这种方法所有的水溶性盐，如氯化物、硫酸盐、铁盐等，将成为最后测量的传导率。这样，计算的盐份水平将是保守值，因为盐份是最为危险的，会促使产生渗透性起泡。也要记住，使用蒸馏水来取样。

从传导率到盐份含量的计算(ISO 8502-9)

可溶性盐的表面密度， S （mg/m^2，）可以用很简单的方法计算出来，按下列公式：

$S = 6 \times (L_{样品} - L_0)$

S = 可溶性盐表面浓度 mg/m^2

6 = 常量，水样在15 ml时

$L_{样品}$ = 水样测量的传导率, µS

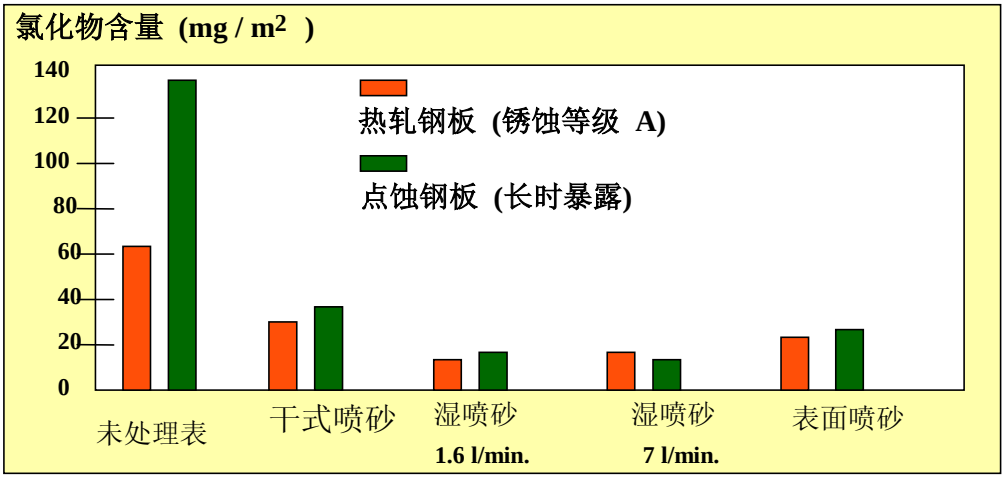
L_0 = 取样前蒸馏水所测量的传导率

例：$6 \times (8\mu S - 3\mu S) = 30$ mg salt/m^2

含盐量直接分析法(SCM 400).

对以上取样和计算的替代方法是便携式传导仪。取样很方便，滤纸用蒸馏水润湿。滤纸压在钢材表面溶解可溶性盐后放在便携装置中测量其传导率。这不是ISO标准，但却是常用的一种方法。

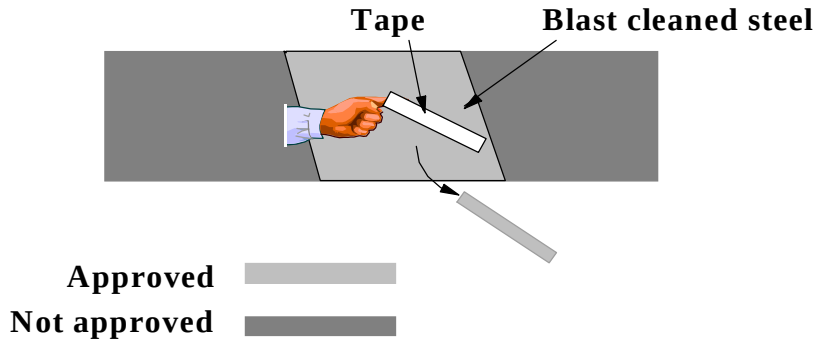
图 8 4.氯化物浓度随暴露状态和表面处理方法不同而不同



8.3.4.4. Dust.

The presence of dust on a steel surface may first of all give adhesion problems and blisters for under water surfaces. A commonly used standard for quantifying the amount of dust present on a surface is given by **ISO 8502-3** “Assessment of dust on steel surfaces prepared for painting”. This test is done by pressing a pressure-sensitive tape onto the surface. The tape is rubbed into the steel surface and then removed. The assessment is done by placing the tape against a white background, and the amount of dust present is compared with pictorial ratings for both quality and size.

Figure 8.5.
Assessment of dust on steel surfaces prepared for painting. ISO 8502-3



The ratings go from 0-5, where "0" means that the particles are not visible under 10 x magnification and "5" means that the particles are larger than 2.5 mm in diameter. The pictorial references show the dust quality ratings of 1 to 5.

It should be noted that research work has shown that the method is not a very accurate one as large amounts of dust can remain on the surface even if the above method give a low rating.

The acceptance value of dust may vary significantly both with respect to area of use and among different specifications. For example:

- Jotun Tankcoating: The quality of dust shall be less than Rating 1 according to ISO 8502-3.
- NORSOK specification: Maximum quantity and size Rating 2.

8.3.4.5. Welding fumes

Welds are likely to be one of the areas where the first failures of a paint system occur. The cleaning of the weld seams and the adjacent areas are often overlooked. The use of manual welding will leave welding smoke or welding flux on both sides of the welding seems. This welding smoke can either be alkaline or acidic deposits, depending on the welding pins and welding method used. These deposits are water-soluble and will promote osmotic blistering. Water-soluble deposits on the steel must be removed by fresh water cleaning prior to final pre-treatment (blast cleaning or mechanical).

A helpful tool for determining the degree of cleanliness are the pH strips. If the steel is free from these deposits the pH strips should show values of around 7.

8.3.4.6. Climatic conditions, ISO 8502-4

Climatic conditions must be controlled during pre-treatment, application and drying/curing. Air temperature and humidity as well as surface temperature affect the results obtained. In general, the steel temperature should be minimum 3 °C above dew point temperature. Inspection of climatic conditions includes:

1. Ambient air temperature
2. Relative humidity, %
3. Steel surface temperature

4. The dew point temperature

Most paints (not all) require a substrate that is dry before application of the paint. It is definitely not good enough to verify that humidity is not present on the surface only by visual inspection. A thin film of condensation is more or less invisible. This necessitates the use of technical equipment. Luckily, the equipment needed to define the relative humidity is cheap and simple and comprises a sling-phsychrometer and steel thermometer with a precision of 0.5 ^{o}C. The sling-phsychrometer consists of two thermometers, one dry and one wet (wet cotton wool wrapped around the sensor). On rotation, the water in the cotton wool will evaporate, thus cooling the thermometer in ratio to the dry one, which measures the temperature of the air. From the temperature readings, the relative humidity can be calculated.

More expensive types of humidity gauges are available; electronic types from which the humidity and air temperature can be read immediately. These are often expensive and often need to be carefully calibrated.

The calculation can be done from tables or by a so-called “dew-point calculator”. There are two slightly different types available today. They are based on similar principles and consist of two seals, which are set against each other, so that the required information can be read. Correctly used, the following information can be read:

Marintek disc:
Known: Relative humidity and air temperature.
Reading: Dew point and required steel temperature for painting.

Elcometer disc:
Known: “Dry and wet bulb” temperature.
Reading: Dew point and relative humidity.

Remember: *The steel temperature should always be 3 ^{o}C above the dew point*, unless otherwise agreed. The dew point is the highest temperature at which moisture will condense from the atmosphere.

表 8.3. 预处理和清理控制概要，所有表面的检查

内容	喷射清理	机械工具清理
检查和记录	1. 锈蚀级别 2. 准备级别 3. 锚固样式 4. 磨料 5. 清理 ●铁盐 ●氯化物 ●灰尘 6. 气候条件	1. 锈蚀级别 2. 准备级别 3. 清理 ●铁盐 ●氯化物 ●灰尘 4. 气候条件

方法	1.目测法 ISO 8501-1和2 2.目测法 ISO 8501-1和2 3. 目测法ISO 8503- 或 Elcometer 123 和Testex 压印带 4. ISO 11125 和 ISO 1127 5. ISO 8502 - 1, 8502-2, 8502-3, 8502-6 和 8502-9 6. ISO 8502-4	1 目测法ISO 8501 – 1和 2 2. 目测法ISO 8501-1 和 2 3. ISO 8502-1, -2, -3, -6 和 9 4. ISO 8502-4
仪器	1. 照相机 2. 参考部位? 3. 标准 4. 比较仪 5. 胶粘带 6. 摇式干湿球湿度计 7. 温度计 8. 露点计算表	1.照相机 2. 标准 3. 胶粘带 4. 摇式干湿球湿度计 5. 温度计 6. 露点计算表

8.4. Inspection before and during application.

Inspection during application includes the following activities:

- Technical Data Sheet must be available and followed
- Ensure correct mixing and thinning (Normally not required)
- Measuring the wet film thickness (WFT)
- Number of coats as given in the specification
- Cleanliness between coats (salts, dust, oil etc.)
- Drying time between coats, minimum and maximum
- The workmanship
- Controlling the equipment and methods used
- Climatic conditions

8.4.1. Technical Data Sheet, TDS

The Technical Data Sheet (TDS) contains important information on how the paint should be used. It is important to get the valid version of the TDS for all paints to be used. It is the responsibility of the inspector to ensure that the correct paint is used and that the mixing ratios given in the TDS is followed. If thinning of the paint is required the thinner to be used is given in the TDS. Wrong thinner may change the properties of the paint completely. Other important information is the surface preparation required, the drying periods and the re-coating interval. It is also frequently experienced that the equipment used by the contractor is either not that specified for the product or that the equipment is worn out. This will of course result in a poor paint film. Finally, the shelf life of the coating should be noted and also the storage requirement.

8.4.2. Correct mixing and thinning

One-component paints can be stirred up by hand, but mechanical agitators are better. Check the bottom of the original container for unmixed solids.

Two-component material, such as epoxies and urethanes are normally provided in kits comprised of a Component A and Component B. The two components are proportionate to one another in the kit. Each component should be mixed separately before the two components are combined and mixed together. Use always a mechanical stirrer. Good mixing of the two components is very important. The fully mixed coating should have a uniform colour and consistency. If the two components are not proper mixed the mixing ratio will vary from place to place in the container. A coating, not properly mixed will have fewer properties (less chemical resistance, water resistance etc.) than a properly mixed coating.

Sometimes it is necessary to decrease the viscosity of the coating with the addition of thinner, so that it can be effectively applied.

The Application Data Sheet will specify the thinner and the maximum amount to use. Remember: The Application Data Sheet give the maximum amount of thinner that can be used. It is not always necessary to add the maximum amount. Just add enough so that the coating can be applied. Do not substitute another thinner for the one specified unless consulting the Paint Manufacturer. Wrong thinner can create a number of negative results as gelling, bad adhesion etc.

Some two-component materials will have a specified induction time (See Application Data Sheet). This is the time required for the two components to react chemically with one another before the coating can be applied. Remember that the temperature affects the induction time.
Data sheets also give an estimate of pot life, but pot life will also be affected by temperature.

8.4.3. Wet film thickness (WFT)

The wet film thickness must be checked at regular intervals during application. The correct film thickness is given in the specification. Here, also acceptable deviations from the specified film thickness should be found. If the specification only state the Dry Film Thickness (DFT), calculate the WFT as explained in section 16 “Calculations”. Remember to adjust for any thinner added.

<u>WFT measured by a comb</u>
A paint specification will give requirements related to minimum, maximum as well as mean values of the film thickness. Thus, control of the film thickness must be carried out.

The wet film thickness has to be measured immediately after application and is usually only measured by the coating applicator. It is important that the responsible applicator can use suitable control methods to determine the paint-film thickness applied. Usually a comb or a roller device are used. When conducting a measurement the comb is placed firmly onto the substrate in the wet film. Then the gauge is removed, and the teeth are examined to determine which is the shortest one to touch the wet paint film. The film thickness to be recorded is found as the value between the last “touching” tooth and the first “non-touching” tooth. At least two or three further readings should be done to obtain a representative result over the painted surface. After use the comb should be properly cleaned.

The wet film gauge can be used for the all kinds of paints. However, it can be difficult to measure the WFT of Zinc-ethylsilicate paints where the solvents evaporate very quickly. Also problems will arise when the wet film gauge is used on the second coat of physical drying paints as they re-dissolve the previous coat. The combs are usually made of stainless steel, but some paint manufacturers will also supply them in a plastic material.

<u>WFT measured by a wheel gauge</u>

The wet film thickness can also be determined using a *wheel gauge*. The gauge consists of a wheel of which the perimeter has three equally spaced rims, the central one of which is smaller than and eccentric to the outer ones. When the wheel gauge is rolled over a wet film the eccentric central rim shows a position at which it just touches the wet paint surface, and a calibrated scale engraved on the outer wheel enables the wet paint thickness at this point to be noted. Several readings are taken in a similar manner to obtain representative results over the painted area.

8.4.4. 气候条件

方法和程序在 8.3.4.6.中有描述。

表8.4. 施工控制：涂漆工作前和进行中的检查

内容	施工中检查所有的表面
Check and record:	• 使用了正确的油漆？ • 油漆生产 • 正确的混合 • 使用正确的稀释剂（如果有必要） • 湿膜厚度 • 重涂间隔 • 干燥 / 固化时间 • 重涂前的清洁 • 施工设备 • 安全 • 卫生 • 气候条件
方法	• 目测 • 技术参数说明书 • 安全参数说明书 • ISO 8502-4
仪器	• 参照或测试部位可以作为“校准” • 梳式湿膜仪 • 干膜仪 • 标准

8.5. 施工后的检查

紧接着的另一个重要阶段是施工结束后。施工结束后的检查包括：

- 干膜
- 固化 / 干燥
- 附着力
- 针孔探测

8.5.1. 干膜厚度

Two different principles/methods are generally used to determine a dry film thickness. These are usually referred to as:

- Destructive test methods
- Non-destructive test methods (NDT)

The non-destructive methods do not entail any damage to the paint film. Instruments based on the following principles are usually employed:

8.5.1.1. Non - destructive test methods.

The magnetic pull off instruments (banana)

These instruments are usually quite simple and very easy to use. They are often known as the "banana" gauge and they can only operate on magnetic substrates. On the sensor tip they have a small round permanent magnet which is placed onto the paintfilm on the steel. A small wheel on the "banana gauge" is then turned towards the operator until the magnetic forces are overcome and the magnet lifts from the paint film. At this point we have reached the DFT of the paint. The accuracy of the instrument is approximately ± 5 %.

Electromagnetic instruments

These instruments have been available for a long time and are equipped with either a twinpole probe or a single probe and have an accuracy of ± 3%. The instrument measures the magnetic flux between the probe and the steel substrate. It is battery operated and needs frequent calibration.

Many of the instruments available today are digital instruments, but there are also logical instruments available, which are preferred by many inspectors. Here the display of the results are not "as conclusive" as other digital ones. It is not possible on a logical instrument to distinguish between 10 - 20 microns of accuracy. We could say the instrument makes the inspector somewhat more "tolerant" in his readings.

When using the instrument skill and common sense in interpreting the results are required. The readings on the instruments are very accurate and can give the result in 0.1 microns. A good inspector should know the practical range of film-thickness that can be accepted when painting. We have, unfortunately, heard of inspectors who have rejected areas with a thickness that in some places were 6 microns below that specified.

The eddy-current principle

Such instruments are used in connection with the measuring of paint film in *non-magnetic surfaces* e.g. aluminium, some stainless steels etc. From a probe, a small amount of eddy-current is transmitted through the paint film down to the metallic surface. This is interpreted by the instrument as thickness, and can be read either analogically or as a digital signal.

Calibration.
A reading on a digital instrument may be as erroneous as a reading on a logical instrument. The important thing is to calibrate the instrument correctly. If this is not done the readings are of no use. In case of dispute, it is very important that all instruments involved are calibrated the same way. Problems are likely to occur if one instrument is calibrated over smooth steel and the other one on blast-cleaned steel. The difference in roughness when calibrating on a blast-cleaned surface will result in an increase of the DFT, compared with one calibrated on a smooth surface.

In many specifications today you will find a reference to the SSPC standard SP-2. This standard does not take into account the blast-cleaned steel for calibration, only smooth steel. In the offshore industry or shipping industry we will often be inspecting DFT's of 250 - 500 microns, so the influence of the surface roughness actually plays an insignificant part.

ISO 2808 (Third edition 1997-09-15), " Determination of dry-film thickness on blast-cleaned steel substrates (method 10)", specifies that calibration shall be done on a smooth steel surface.

Quotation from the standard:
"If a coating is applied to a blast-cleaned steel substrate, the measurement of its thickness is more complicated than for smooth surfaces. The object of this method is to minimise variability and achieve a uniformity of practice in the measurement of film thickness on coated blast-cleaned surfaces. The method entails the measurements of film thickness using an instrument of the magnetic induction type after calibrating it on a smooth steel surface.

The method will determine the coating thickness over a magnetic plane in the rough surface at which the thickness is greater than the thickness over the peaks. This thickness corresponds to about 25 micrometers (which corresponds to about half of the surface roughness, expressed as the height from the bottom to the top of the peaks, of the blast-cleaned surface) except for surfaces prepared to ISO 8503-1, grade "fine".

Calibrating the instrument on a blast-cleaned surface introduces problems in addition to the normal variation of results with the type of probe and instrument, such as:

a) Poor repeatability

b) Variability in the measured thickness of a shim over such a surface (the thicker the shim the greater the apparent increase in shim thickness);

c) A coated steel surface whose surface roughness is unknown

The procedure describes the determination of a parameter related to the thickness of a dried paint film applied to a blast-cleaned steel substrate. The actual film thickness as measured by a reference method shall not be less than 25 microns and preferably above 50 microns for meaningful results.

Film thickness measuring instrument, magnetic induction principle type, as used in method No 6A.

The use of equipment additionally fitted with facilities for converting measurements into mean standard deviation and other statistical values should be treated with caution and preferably only used by those trained in statistical techniques.

Calibration shims, of the foil type, with assigned values traceable to nationally recognised standards, of thickness near to the expected film thickness. The use of uncertified shims is permitted provided they are verified on site using a micrometer.

Smooth piece of steel, free of mill scale and rust, similar in magnetic nature to the painted steel and at least 1,2 mm thick, for use in calibration.

There are many errors that will influence the results when you are taking measurements on painted steel. These are things that the inspector should be aware of.

- Soft films
- Distance to edges (approx. 15 mm)

- Distance to shoulders (approx. 30 mm)
- Surface roughness
- Curved surfaces
- Residual magnetism
- Position and pressure of the probe
- Temperature
- Magnetic leaking fields

How to adjust your DFT gauge.
You need a piece of smooth / polished steel and calibration foils to adjust your DFT gauge.

1. Place the probe onto the smooth / polished steel and adjust to zero
2. Select a foil close to the thickness you plan to measure
3. Place the foil onto the smooth / polished steel and adjust the instrument so that the DFT of the foil is read on the instrument.
4. Recheck step 1 and 3

8.5.1.2. Destructive test methods.

The dial gauge.
On a small area the paint film is scraped off down to the substrate. The difference in height is then measured between the area from which the paint has been removed (bare metal), and the surrounding, intact painted area. The two outer legs are firm, while the legs in the centre are connected to an indicator and scale. The instrument, which can be used for this, is called a dial gauge. This method is often used in shop priming plants for DFT measurements on flat steel or glass plates.

The paint inspection gauge, P.I.G..
Another method for determining the film-thickness is with a paint inspection instrument, also known as the P.I.G., which is an abbreviation for Paint Inspection Gauge. This instrument is equipped for a number of different functions, including three knives, which can be used to bevel the paint film. By this method and with help of a scale in a little microscope at the end of the apparatus, the film thickness of one or several coats of paint can easily be determined.

8.5.1.3. Calculation of Dry-film Thickness (DFT)

It is important not to exceed the minimum and maximum DFT given by the paint specification. Also, the manufacturer's recommendations should always be followed.

The specification of the average thickness should be sufficiently high to obtain a minimum target DFT. This means that a minimum of 80 % of all thickness measurements ought to be $\geq$ the specified mean DFT. Of the remaining 20 % of the measurements, none should be below 80 % of the specified DFT (this is called the 80/20 practise). Example: To obtain a minimum DFT of 200 µm the average or nominal DFT should be specified to be at about 250 µm.

DFT can be estimated from the WFT. A volume per cent solid is found in the technical data sheet.

$$\text{DFT} = \frac{\text{WFT x (Volume \% solids)}}{100}$$

See also section 16 "Calculations" regarding coating related calculations.

8.5.2. Curing / drying.

An inspector might be required to determine whether or not a coating is sufficiently cured. Often the inspector will be relying on the data sheets and the daily logs concerning the coating application.

Pencil hardness test can be used for the control of curing. A butt-ended pencil is held at an angle of 45^{o} to the substrate and is pushed into the coating. Start with the softest pencil and then increase the hardness until you find one that scratches the paint film.

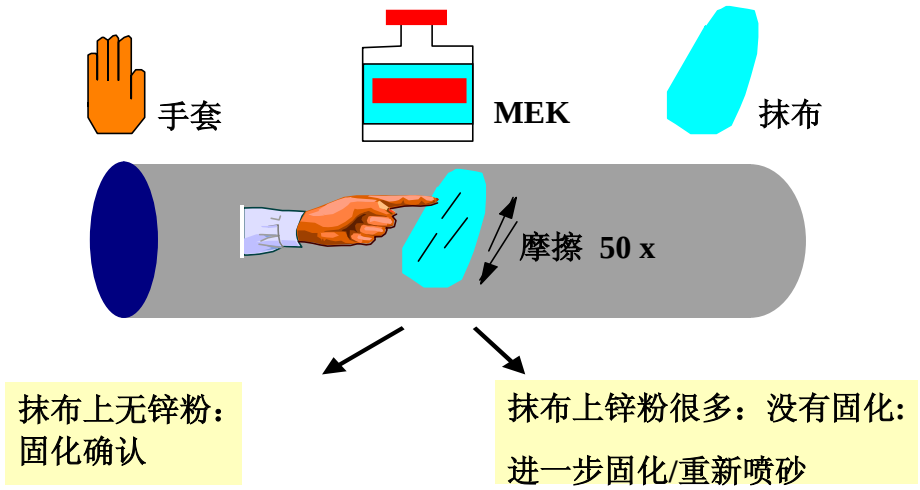
Another test can be the use of special hardness testers that are held to the surface and a *spring-loaded plunger* is driven into the coating.

Sometimes for two pack paints such as epoxy and polyurethane coatings a solvent resistivity test is used. There are different methods. One method is to saturate a *cloth/rag with solvent*. The cloth/rag is wiped across the surface of the coating for a specified number if times. After completion of the rubbing the cloth or rag is inspected visually. Very little, if anything at all, shall be visible if the paint is cured.

Curing of zinc ethylsilicate paints.

The test method for testing the curing of zinc ethylsilicate paints is standardised as *ASTM D 4752 - the MEK test*. The surface is cleaned with freshwater prior to the test to remove all loose zinc dust. A white cloth/rag is saturated with the solvent Methyl-Ethyl-Kethone (MEK) and rubbed over a selected area of at least 50 mm. Use the thumb and perform up to 50 double rubs across the zinc ethylsilicate. If the solvent has very little or no effect on the surface, then the coating will be rated as 4 or 5 according to the standard. At this level one assumes the coating to be cured.

图 8.6. 硅酸锌漆的固化测验MEK. ASTM. D4752-87）



8.5.3. Adhesion control by “Pull-off test”.

One of the most important single factors in connection with paints and coatings is the adhesion. Sufficient adhesion between the paint and the substrate will greatly improve the lifetime of the paint system. To achieve good adhesion a suitable coating must of course be selected. However, of even greater importance to avoid early breakdown of the paint system is to ensure a good surface preparation. When the surface is properly cleaned the adhesion between the primer and the steel will also be better.

The pull off strength of a coating often depends on the paint itself. The breaks will in general be of two kinds: Adhesion failure or cohesion failure. An adhesion failure occurs as a break between two different coats of the paint system or as a break between the substrate and the first coat. However, in many cases the paint is found to break within the coating. This is known as a cohesive break. Thus, the cohesive properties of the paint are very important.

On a well prepared surface with an epoxy coating you might achieve pull off strength values of 5 - 10 MPa, maybe even higher.

Procedure for the pull off testing.
In some specifications requirements are given for the pull off strength of the coating system to be used. When you carry out the tests it is important to follow a standard. E.g. ISO 4624.

Step 1: Cleaning.
The dollies used have to be cleaned just prior to the gluing operation. The dollies should be free of old paint and shall be rubbed gently on sanding paper to remove residues. The dolly is then dried, using a dry paper towel, and set aside. Also the surface of the coating to be tested should be abraded by sanding paper. Dust formed at the surface is then removed by a paper towel.

Step 2: Gluing.
It is strongly recommended to use a two-pack epoxy glue. It is important that correct amounts of the two components are mixed thoroughly. After mixing, a small amount of glue is applied onto the dolly, and the dolly is then placed on the abraded painted surface. It is very important both on horizontal and vertical surfaces that the dollies are kept steadily in place by cross-taping the dollies. If this is not done the dollies may slide away. For an epoxy two-pack glue the curing time at 20 ^{o}C is approximately 24 hours. (Please follow instructions given by the glue manufacturer).

Also Cyanoacrylate glue ("super glue") can be used for adhesion testing. Put the glue on the dolly and hold the dolly onto the abraded surface for 10 - 15 seconds. This glue sticks immediately to the abraded surface. Using this type of glue you may pull-off the dollies after only half an hour of curing.

Step 3: Cutting around the dolly.
In the standard it is emphasised that you shall cut through the coating around the dolly down to the substrate. When this is done the breaking strength will be measured over an exact area, the area of the dolly. If you don't cut around the dolly sometimes the area of the dolly will increase due to extra paint be pulled of. A similar effect may be caused by surplus glue around the edges. This will give erroneous results.

Step 4: The pull off.
Checking the adhesion properties involves special equipment and instruments. The most commonly used instruments in many European countries today are:

- PAT Model GM 01
- Elcometer Hate 108
- Säberg IS 90
- Elcometer 106

These instruments are briefly described below.

The PAT GM 01.
This is a fairly new instrument on the market, but it is also one of the most used instruments for adhesion testing in Norway and many other countries. The instrument is equipped with a special probe with four hydraulic cylinders (legs) that appear when pressure is placed on the hydraulic

power unit. The probe is equipped with a quick release coupling and for practical measurements on steel normally two dolly sizes are used. Using the smaller of two dollies (1.57 cm^2) it is possible to measure values up to 40 MPa. Using dollies of 3.14 cm^2 is possible to measure values up to 20 MPa.

The Elcometer Hate 108.
该仪器配置的压力表读数高达25MPa。随仪器提供的The dollies supplied with the instrument are not pulled off the substrate in the same manner as for other instruments, but they are *pushed* off. A piston in a centre hole, which lies in the instrument, achieves the push-off principle.

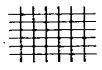
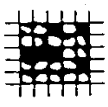
When gluing the dollies on to the substrate it is important that a small Teflon plug is fitted in the centre hole to avoid glue from entering. This sometimes proves to be difficult so all glue shall be removed prior to pull off using a small drill. The drill will remove the glue and the deposits of paint.

The Säberg IS 90 instrument.
The instrument is a pneumatic pull off instrument operated on nitrogen gas. There are three dolly sizes for the instrument. The two most commonly used for measurements on steel substrates are the dollies of 1.13 cm^2 and 3.14 cm^2. The instrument is capable of taking readings up to 21 MPa using the smallest dolly. Since the instrument is operated on nitrogen gas, you are not allowed to bring a full gas cylinder on board planes. In such cases the inspector needs to insure that gas is available on site.

8.5.3.3. Cross-cut test.
An alternative method for checking the adhesion properties of a paint film is to conduct a "Cross-cut" test **ISO 2409**. Here, lines are cut into the paint, all the way down to the substrate material, with a single-blase cutting tool or a multi-blade cutting tool (spaced 1 mm or 2 mm apart) at angles of 90^o to each other (cross hatch). The space between the lines varies with the film thickness. The thinner the film the shorter the distance between the lines. A cross-cut test can be used on paints with a DFT up to 250 µm.

After cutting the lines the surface should be brushed lightly with a soft brush to remove all loose particles and an adhesive tape is fixed on the test area. After rubbing the tape firmly with a fingertip, the tape is removed by pulling it off. Classification of test results is compared with a table in the standard. Other standards for Cross-cut test are **ASTM D 3359** (also with X-cut test) and **BS 3900 F6**.

Figure 8.7.
Classification of cross-cut test.

Classi-fication	Description	Appearance of surface Six parallel cuts
0	Completely smooth: none of the squares detached	
1	Small flakes at the Intersections. Area affected 5 %	
2	Flaked along the edges and/or at the Intersections. Area affected: 5-15%	
3	Flaked along the edges, wholly in large ribbons, and/or partly or wholly on different parts of the squares. Area affected: 15-35%	
4	Flaked along the edges in large ribbons and/or some squares have detached partly or wholly. Area affected: 35-65%	
5	Any degree of flaking that cannot even be classified by 4.	

8.5.4. Holiday detector

A holiday detector is an instrument used to identify painted areas with insufficient film thicknesses or areas with pores in the film. The instrument is especially used in tanks where it is crucial to avoid corrosion. For such areas it is important that the coating system is completely free from pores or holidays. This particularly refers to paints and coatings which are to form a barrier against humidity in the atmosphere or the liquids (cargo, ballast water etc.). If the barrier effect is reduced (read: thickness too low) the risk of starting corrosion increases.

Which method of holiday detection to choose depends on several factors, including the thickness of the coating.

Low voltage holiday detector (ASTM G 62 - 85 Method A. Non-destructive method).
For thinner coats - by which we mean film thicknesses below approx. 500 microns - a low-voltage pore finder, or holiday detector, is often used. First, the instrument is earthen to the object. Then a wet sponge is fastened to the detector and brushed in even passes over the object. Whenever there is a signal (sound), an area with a failure is identified and should be clearly marked. In connection with low voltage pore finding it is important that the sponge is not passed over too large an area at a time. The reason being that water may lead the electrical current from an area with defects to the area currently being tested. Even if the test area is perfect the instrument may give a sound indicating a defect. The consequence being that a greater number of areas with pores than actually exist will be registered.

High voltage holiday detector (ASTM G 62 – 85 Method B. Destructive method).
High voltage holiday detectors are usually used on thicker paint films. As this type of detector uses a very high voltage (approximately 20 kV), there is a danger of burning through the paint film. This is particularly the case at low film thicknesses. Therefore, the film thickness of the coating must be measured in the area in which pore finding is to take place. The output voltage must be adjusted in accordance with the film thickness. Furthermore, it is important to note that a conductive primer will influence on the voltage to apply. The film thickness of these must be subtracted from the total film thickness when the voltage is adjusted.

Contrary to the low voltage holiday detector, which only registers pores going all the way down to the substrate, the high voltage pore finder also registers defects like cavities in the paint film. Such cavities can of course contain moisture, which will reduce the lifetime of the paint.

Table 8.5.
Inspection after application.

Content:	Checking of all surfaces during application.
Check and record:	1. Dry film thickness 2. Curing / drying 3. Adhesion 4. Holiday detection

Cont. next page.

Table 8.5. (cont.)
Inspection after application.

Method:	1. ISO 2808, SSPC PA – 2 2. Pencil hardness test. Cloth / rag with solvent. ASTM D 4752. 3. ISO 4624, ISO 2409, ASTM D 3359 and BS 3900 F6 4. ASTM G 62 – 85 Method A and B.
Equipment:	1. Magnetic pull-off instrument (banana). Electromagnetic paint inspection gauge (PIG). 2. White rag, MEK (Methyl Ethyl Ketone)

	3. Pull-off adhesion instrument. Instrument for cross-cut test. 4. Low voltage holiday detector and high voltage holiday detector.

8.6. Records of work and working conditions.

As you work, it is necessary to follow specification requirements. It is good practice to document that you have met these requirements for two main reasons. First, the documentation can help you make your case in a dispute, but more important, documentation is your quality control check of the work carried out. You must keep the records of work and working conditions to guard against unwarranted claims, and to ensure that all steps are in compliance with the specification.

Records can be kept in the format of a daily diary, or they can be kept on pre-printed forms. Pre-printed forms will be preferable because they are more organised.

The following documentation shall be done:

Environmental conditions.
You should record environmental conditions before you begin work to determine if they are within parameters established by the specification. If there are substantial changes in weather once the work begins, the time and nature of the changes should also be recorded.

Blasting equipment
Reading the pressure at the nozzle with a needle gage. Blotter tests for cleanliness of compressed air, moisture checks on the air supply and contaminant tests for abrasives.

Surface preparation.
Check and record that the cleanliness is within parameters established by the specification. Check and record rust grade before blasting and cleanliness after blasting according to ISO 8501-1 or 2. In addition check for compliance with surface profile requirements (ISO 8503) in the specification (such as with surface profile comparator or replica tape).

Cleanliness after surface preparation.
Check and record for dust (ISO 8502-) and chemical cleanliness (ISO 8502 - see table 8.3.) if this is required.

Mixing and thinning
Batch numbers of paint material, as well as generic kind, proprietary name and amount used should always be recorded.
Check that the right thinner and right amount of thinner is used and the induction time allowed for two-component materials.
The shelf life of the paint material should also be noted, and storage requirements as described in application data sheets should be observed.

Application
Check that the applicator makes wet film thickness readings as required to assure that dry film thickness will be in compliance with the specification.

Once the coating has dried sufficiently, the dry film thickness should be measured and recorded. Areas with filmthickness below that specified should be re-coated or touch up immediately to meet the specification.