**Title**
Inspection and testing of coatings
Surface preparation and organic coating related inspections.

**Prepared for**
Institute of Corrosion

**Our Reference**
ICorr/CED/CT01

**Confidentiality, copyright and reproduction**
This report was prepared by members of the Institute of Corrosion.
© Institute of Corrosion 2017. It should not be copied without the permission of the Institute of Corrosion.

The Institute of Corrosion accepts no responsibility for any loss of information, materials or equipment arising from actions taken as a result of any of the information provided in this report either by the Customer or by any third party who has obtained any of the said information directly or indirectly from the Customer. Neither party shall be liable to the other for any indirect consequential or special loss whatsoever including but not limited to loss of revenue or profit.

**Contact Details**
Institute of Corrosion
ICorr Head Office
Barratt House
Kingsthorpe Road
Northampton
NN2 6EZ
Tel 01604 438222

E: admin@icorr.org

http://www.icorr.org

<table>
<thead>
<tr>
<th>Name</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrew Patterson</td>
<td></td>
<td>23 June 2017</td>
</tr>
<tr>
<td>John Fletcher</td>
<td></td>
<td>20 June 2017</td>
</tr>
<tr>
<td>Douglas Mills (Appendix)</td>
<td></td>
<td>19 June 2017</td>
</tr>
</tbody>
</table>

**Author(s)**

**Reviewed by**
David Horrocks MICorr (Chairman CED Coatings group) and Working Group members 21 June 2017

**Approved by**
Nick Smart, Chair of Corrosion Engineering Division 30 November 2017
Executive Summary

This report was prepared as an outcome of discussions within the Coatings Working Group, where it was agreed to produce a number of technical guidance documents and make them available through the CED technical area of the Institute of Corrosion website. This document (CT01) is intended to give a brief insight into Coatings Inspection and Testing, highlighting the aims and requirements of the procedures and containing information regarding the specific areas that a paint inspector might check. It includes the reasons for inspection and testing, describes the methods and equipment used, and provides relevant industry standards. It does not aim to cover all the possible tests available in each of the specific areas, but it briefly summarises the techniques considered by the Coatings Working Group to be the best or most commonly used. The areas were divided into the following main categories: Pre-coating (visual inspection, surface profile checks, extraction of soluble salts, surface cleanliness checks, ambient monitoring) and Post-coating (coating thickness checks, adhesion testing, holiday detection). An emerging test in the latter category for monitoring corrosion protection, which has not been commonly used to date, but with the potential to become so, is included here as an Appendix. For ease of identification of the various areas of application, a tabular form of presentation has been employed.
# Contents

1 Introduction 5

2 Pre-coating inspection 5
   2.1 Visual inspection 5
   2.2 Surface profile checks 5
   2.3 Extraction of soluble salts 6
   2.4 Surface cleanliness checks 6
   2.5 Ambient monitoring 6

3 Post-coating inspection 8
   3.1 Coating thickness checks 8
   3.2 Adhesion testing 9
   3.3 Holiday detection 10

4 References and sources of information 11
   4.1 Standards 11
   4.2 Acknowledgments 12

5 Appendix: The future – emerging techniques 13
1 Introduction

Most contract work is carried out according to defined specifications that normally follow industry standards, for example, ISO standards (see table below for examples). The aim is that, with the correct governance, these standards will guarantee the quality of work and provide the end client with a protective coating system that will perform satisfactorily for the required service life for their project. The tables below show some of the standard field tests that are performed when coating steel structures, describe how they are carried out, and summarise the possible detrimental effects that could arise if they are performed incorrectly. A responsible person with a relevant inspection qualification, such as ICorr level 1, 2 or 3 (see Table 1), should perform as many of the tests indicated below as the project specific inspection and test plan deem to be necessary. The table essentially follows a standard Inspection Test Plan (ITP).

2 Pre-coating inspection

Table 1 lists the various pre-coating inspection methodologies available, citing the relevant standards and the ICorr qualification level necessary for the inspector.

<table>
<thead>
<tr>
<th>Test</th>
<th>Standards and Methodology</th>
<th>Reason</th>
<th>Qualified ICorr Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Visual inspection</td>
<td>ISO8501-1</td>
<td>Most premature coating failures can be attributed to poor surface preparation. This visual inspection makes sure that any foreign matter is detected and that the surface is properly prepared for the application of paint, to prevent premature coating failure.</td>
<td>1, 2 or 3</td>
</tr>
<tr>
<td>To verify blast or preparation standard</td>
<td></td>
<td>This is essentially just a visual inspection for comparison with a visual standard. Each visual standard is accompanied by a description to assist the qualified inspector in verifying the quality of the preparation against that standard for compliance.</td>
<td></td>
</tr>
<tr>
<td>2.2 Surface profile checks</td>
<td>ISO8503-1</td>
<td>The profile height is specified to increase the effective surface area of the substrate to enhance the adhesion of the primer coating to the surface. However, too large a peak-to-valley height will increase the volume of paint required to cover a given area and risks there being excessively high peaks which are not covered by the primer and resulting in corrosion spots, also known as rust rash.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Determination of the peak-to-valley height of a blast profile before paint is applied can be achieved using a simple visual comparator to rate the profile as fine, medium or coarse. Alternative methods, using a depth micrometer or replica tape, are applied when quantitative measurements are required, rather than just determining the rating using the comparator method.</td>
<td></td>
</tr>
</tbody>
</table>
### Test Standard and Methodology Reason Qualified ICorr Level

#### 2.3 Extraction of soluble salts

<table>
<thead>
<tr>
<th>Standard and Methodology</th>
<th>Reason</th>
<th>Qualified ICorr Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO8502-6</td>
<td>Electrolytes containing deposited salts provide the elements needed to create a corrosion cell. Some salts are also hygroscopic and they can draw moisture through a paint film. Because of the hygroscopic nature of some salts an excess quantity remaining on the paint surface can cause osmotic blistering. This effect can quickly cause premature failure of the protective coating. The failure can also spread underneath what would appear to be a sound coating.</td>
<td>1, 2 or 3</td>
</tr>
</tbody>
</table>

**Surface contamination check for soluble salt content.**

#### 2.4 Surface cleanliness checks

<table>
<thead>
<tr>
<th>Standard and Methodology</th>
<th>Reason</th>
<th>Qualified ICorr Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO8502-3</td>
<td>Dust constitutes foreign, loosely adhering matter, which can compromise the integrity of adhesion of any coating system. Some systems are more susceptible than others. The performance of all paint types is compromised by the presence of dust.</td>
<td>1, 2 or 3</td>
</tr>
</tbody>
</table>

**Verification of dust removal**

#### 2.5 Ambient monitoring

<table>
<thead>
<tr>
<th>Standard and Methodology</th>
<th>Reason</th>
<th>Qualified ICorr Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO8502-4</td>
<td>Some coatings, with the exception of moisture-tolerant coatings or those coatings that use moisture in the atmosphere to assist the cure process, are susceptible to changes caused by low temperatures, high humidity and/or rapid temperature change, and need careful monitoring. Paints applied to surfaces under ambient conditions, where condensation of moisture from the air on the uncoated</td>
<td>1, 2 or 3</td>
</tr>
</tbody>
</table>

**Climatic condition, control and measurement**

- Air temperature
- Steel temperature
- Relative humidity
- Dew point temperature

DPM devices use capacitive sensors to measure the
relative humidity (RH) and a semiconductor sensor to measure air temperature (Ta), also known as the ambient temperature. From these measurements the dew point temperature (Td) can be calculated. A separate thermocouple is used to measure the surface temperature (Ts) and the differential between the dew point temperature and the surface temperature can be determined, (\(\Delta T = T_s - T_d\)). This differential should be at least 3 °C for the surface to be painted without the risk of trapping condensation.

Some DPM devices can be used in data logging mode to monitor the ambient conditions during the paint cure process (typically 16 hours), to determine whether the ambient conditions are satisfactory for the cure.

surface is likely, will suffer premature failure due to corrosion on the surface under the coating.

Manufacturers’ technical data sheets indicate the coating tolerances. Coatings applied outside of their tolerances can be affected in a number of other ways. For example, amine-cured systems that are left to cure at temperatures below that recommended by the manufacture, can suffer from a defect called ‘bloom’ or ‘amine bloom’. This results in loss of gloss for finishing coats and poor inter-coat adhesion properties if over-coated with additional layers.
### 3 Post-coating inspection

Table 2 lists the various post-coating inspection methodologies available and cites the relevant standards and the ICorr qualification level necessary for the inspector.

**Table 2: Post-coating inspection methodologies and standards**

<table>
<thead>
<tr>
<th>Test</th>
<th>Methodology &amp; Standard</th>
<th>Reason</th>
<th>Qualified ICorr Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Coating thickness checks</td>
<td>ISO2808 / ISO19840</td>
<td>Verifying the thickness of the coating can be carried out at two stages: (i) during application (wet film) and (ii) after curing (dry film). Most products have the %volume solids content quoted in the technical data sheet and from this you can estimate what loss of thickness will be experienced during the curing. Wet film combs or wet film wheels can be used to determine the wet film thickness immediately after application. A simple calculation is used to determine the final thickness (dry film) after cure.</td>
<td>1, 2 or 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>There are several different methods available for determining the dry film thickness, ranging from a Paint Inspection Gauge (PIG) to magnetic gauges.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The PIG has a range of angled cutters which are used to make a cut through the paint film to the surface of the substrate. The film thickness is calculated from the width and angle of the cut. Although the cut must be repaired before the coating goes into service, this is a useful method if the coating has magnetic properties which would interfere with the workings of a magnetic thickness gauge.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The coating thickness is vital in ensuring the service life of an asset. Checking the wet film thickness ensures that the right thickness is achieved first time, thereby eliminating the need for multiple applications. ISO12944 categorises environments, thereby enabling manufacturers to specify systems with minimum thickness. Failure to achieve these thicknesses can result in a reduced service life and premature failure is a distinct possibility.</td>
<td></td>
</tr>
</tbody>
</table>
If the coating is non-magnetic and the substrate is magnetic, non-destructive dry film thickness measurements can be made based on magnetic principles (e.g. using a magnetic pull-off gauge, ISO 2808-6A).

Electronic dry film thickness gauges use either the electromagnetic induction principle or the Hall Effect principle (ISO 19840).

<table>
<thead>
<tr>
<th>3.2 Adhesion testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pull-off testing</td>
</tr>
</tbody>
</table>

ISO 4624 Adhesion test methods, ISO 2409 / ISO 16276-2 and ISO 4624 / ISO 16276-1

There are a number of test methods to evaluate the quality of adhesion of a coating system to its underlying steel substrate. For example the cross-hatch test (ISO2409/ISO16276-2) and the pull-off test (ISO4624/ISO16276-1). The favoured quantitative method is the pull-off adhesion test. This determines the value in psi/MPa and the result is then cross-referenced to the specification for acceptance criteria.

The test method involves tensile measurement using ‘dollies’ which are glued onto the coating at given sites.

ISO16276-1 defines the use of inspection areas, with areas <1,000 m² requiring three valid measurements per 250 m² area or part thereof, and inspection areas >1,000 m² requiring 12 valid measurements plus one for each additional 1,000 m² or part thereof.

Adequate adhesion when dry, and particularly when wet, is essential for an anti-corrosive organic coating if it is to fulfil its purpose. Without this test, the coating-substrate adhesion values cannot be assessed or quantified. Note that not all specifications call for this test.

2 supervised by 3, or 3 alone.
It should be noted that a failure of the glue is considered to be an invalid measurement.

The adhesive is allowed to cure and the dollies are then either forcefully pulled from the surface to the point of total detachment from the coating layer, or placed under a pressure equal to the specific adhesion requirements. The adhesion value can then be read.

### 3.3 Holiday detection

#### Pinhole detection

ISO 2746 >500µm ‘High Voltage’

ISO 8289 <500µm ‘Low Voltage’

ISO 29601

To ensure that the coatings are free from ‘pinholes’, also known as ‘holidays’, it is vital to choose the correct voltage in relation to the thickness of the coating being tested. Holiday detection testing uses a probe that is moved backwards and forwards across the coated surface. It applies a high electrical voltage across the dry coating and where there is lack of coating this effectively creates a short circuit which is detected.

For coatings with thicknesses <500 µm, the low voltage “wet sponge” method is described in ISO 29601. The detection of current flow through a film of tap water signals a defect that penetrates the non-conductive film through to the conductive substrate.

For coatings with thickness >500 µm a high voltage DC or Pulsed DC Holiday Detector is recommended. Typically these detectors

Premature coating failures can occur if small weaknesses within the coating caused, for example, by air bubbles or dust particles, or regions where there is no significant amount of coating present, allow easy pathways for oxygen, water and ions to travel through the coating and reach the interface. Such defects need to be detected and any found must be repaired.

2 supervised by 3, or 3 alone.
can be adjusted to deliver a test voltage between 0.5 kV and 30 kV, depending on the thickness of the coating and the dielectric strength of the cured coating.

When using a high voltage holiday detector, the test voltage must be set to allow the column of air in a defect to break down without being so high as to damage the coating.

### 4 References and sources of information

In this report the sources of information are all standards which are included within the tables. These standards are listed in numerical order in this section.

#### 4.1 Standards

ISO 2409/16276-2: Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating — Part 2: Cross-cut testing and X-cut testing

ISO 2746: Vitreous and porcelain enamels - High voltage test

ISO 2808-6A: Paints and varnishes - Determination of film thickness

ISO 2808/19840: Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces

ISO 4624/16276-1: Corrosion protection of steel structures by protective paint systems - Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating - Part 1: Pull-off testing

ISO 8289: Vitreous and porcelain enamels - Low voltage test for detecting and locating defects


ISO 8502-3: Preparation of steel substrates before application of paints and related products - Tests for the assessment of surface cleanliness - Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)

ISO 8502-4: Preparation of steel substrates before application of paints and related products - Tests for the assessment of surface cleanliness - Part 4: Guidance on the estimation of the probability of condensation prior to paint application

4.2 Acknowledgments

The original version of this document was authored by Andrew Patterson. The present version includes the original material with additional material by John Fletcher. The Appendix was produced by Douglas Mills.
5 Appendix: The future – emerging techniques

Table 3 describes novel and emerging post-coating inspection and monitoring techniques, citing the relevant standards and the ICorr qualification level necessary for the inspector.

Table 3: Emerging post-coating inspection and monitoring techniques and relevant standards

<table>
<thead>
<tr>
<th>Test</th>
<th>Methodology &amp; Standard</th>
<th>Reason</th>
<th>Qualified ICorr Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion protection monitoring</td>
<td>ISO 17093 Appendix 3 (Full standard in development)</td>
<td>The ability of a coating system to protect against corrosion depends on its electrochemical integrity, particularly the degree to which it can provide a high electrolytic resistance under the low (0.5-1V) driving voltage that arises during the corrosion process. This process creates a circuit with electrochemical reactions taking place and an Electrochemical Noise Measurement enables the speed at which these reactions are occurring, and hence the degree to which iron is being consumed by corrosion, to be estimated. It has been shown that the value of one particular parameter (Rₙ) is a very good indication of the level of protection against corrosion being provided by the coating at that point in time. If this value is monitored, for example annually, the time for a recoat can be identified. For more information on the use of electrochemical techniques - see Progress in Organic Coatings (POC) Vol 102 part A Jan 2017 pp 8-17.</td>
<td>Level 3 (training required)</td>
</tr>
<tr>
<td>Electrochemical noise measurement</td>
<td>Electrochemical Noise Measurement (ENM) is performed by securing (temporarily) two probes on the wetted, coated surface of the structure. These are connected to a data gathering device (e.g. a ProCoMeter). The small, spontaneous electrochemical signals produced by the metal/coating system are collected over a period of typically ten minutes, then analysed and the value of resistance noise (Rₙ) extracted. From this value the degree of anticorrosive protection is assessed: Rₙ values of &lt; 10⁵ ohms-cm² indicate poor protection, 10⁶-10⁸ ohms-cm² indicate intermediate protection and &gt;10⁸ ohms-cm² indicates good protection.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>