SURFACE PREPARATION, PAINTING-COATING TO PREVENT CORRORSION IN OIL & GAS

informative Article

By Dr. Santosh Gupte

Overview:
In recent years the importance of surface finish-roughness, painting-coating has gained attention in Oil & Gas field significantly.

Most of the equipment manufactured for various applications during drilling oil wells or exploring it, or transporting or refining are required to follow very stringent norms of standards and specifications. These standards and specifications are becoming far more particular about surface finish, painting and coating requirements. These all stringent requirements are contributing to increase the life of equipment by protecting wear, corrosion and damages due to environment.

This article is aimed to give an overview of corrosion, it's prevention and how surface finish or surface coating helps to prevent the corrosion or detrimental effects of corrosive environment specifically in Oil & Gas Industry.

Corrosion:

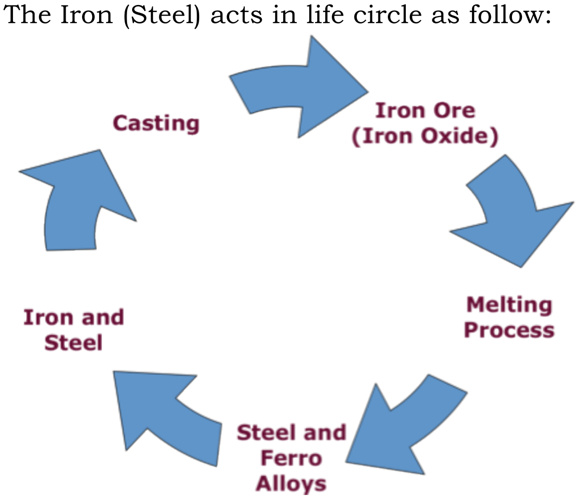
Corrosion is defined as the destruction or deterioration or oxidation or dissolution of a material because of its reaction with environment.
It can also be defined in simple terms as "getting rusted".

Iron or Steel, oxidizes into iron oxides which are weaker than steel.
Please bare in mind that the rust of metal (in case of Iron, its Iron Oxides, are the equilibrium state of the metallic reaction circle)

Both moisture and air (oxygen) are required for the corrosion of steel to take place.

The corrosion of steel is an electrochemical reaction between steel and the surrounding medium.

The Iron (Steel) acts in life circle as follow:



In Oil & Gas industry, the total loss due to Corrosion and Erosion (Wear) is calculated approx US$ 500 Billion. In India it is approx 36,000 Crores of Rs. Which is, huge and with proper care (preventive actions) it can be minimized to 50% of it was in the year 2010.

Types of Corrosion:

A. Direct Oxidation
B. Atmospheric Corrosion
C. Electro Chemical Corrosion
D. Galvanic Corrosion
E. Bacterial Corrosion
F. Stress Corrosion
G. Corrosion resulting from differential aeration. (O_2 deficiency)

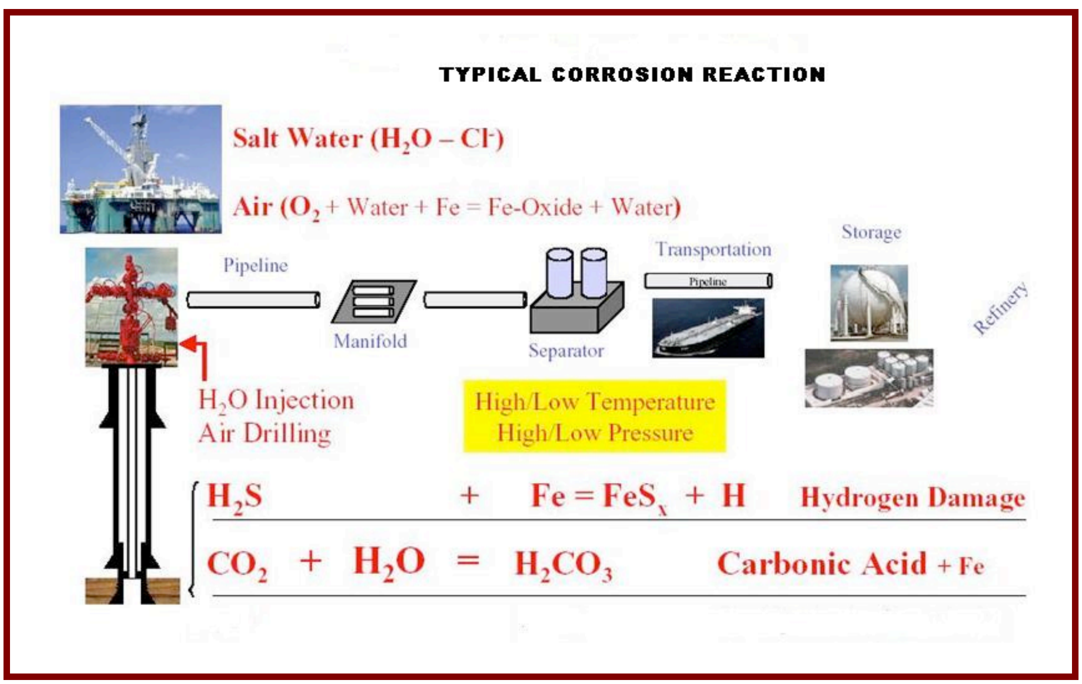
Now let us talk about Oil & Gas Industry and it's operational conditions in various phases such as Upstream, Downstream and Transportation.

Typical UPSTREAM & DOWNSTREAM Conditions:

•Temperature
–Typical E&P process temperatures range from 100ºC to >200ºC
–Corrosion rates increase with temperature

•Pressure
–Pressure: up to 10,000psi
–Increase partial pressure of dissolved gases

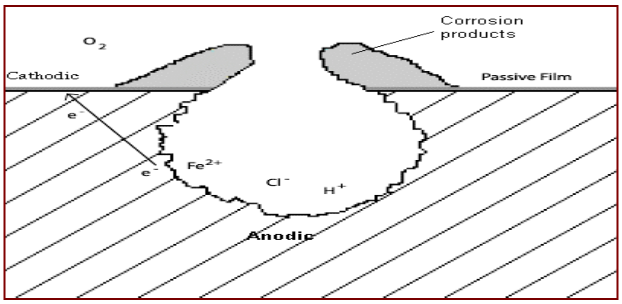
•Flowrate & flow regime
–High-flow: erosion and corrosion-erosion.
–Low-flow or stagnant conditions promote bacteria



Typical Examples of Corrosion in Oil & Gas Industry:

1. **H_2S corrosion – metal loss**

–Formation of a thin protective FeS surface film often means general corrosion rates are low on steels
–Main risk is localised pitting corrosion where film is damaged
–Pitting will be galvanically driven

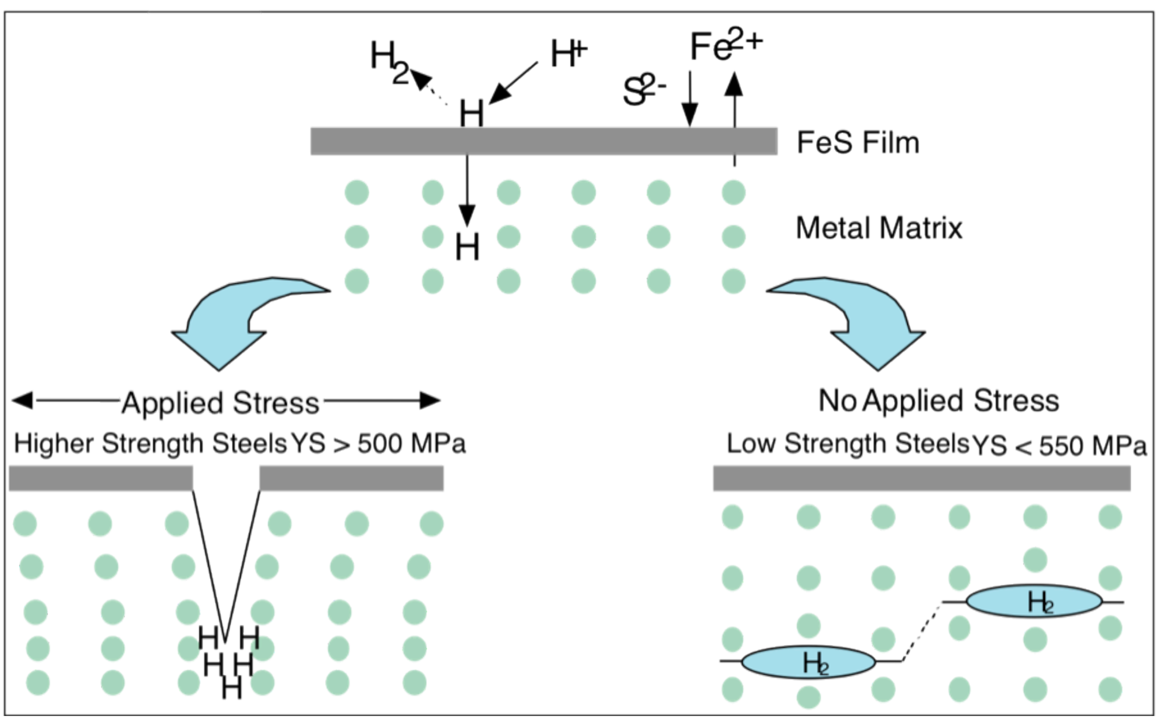


Chemical Reaction:

H_2S is soluble in water
–Produces a weak acid and lowers the pH
$H_2S \rightarrow H^+ + SH^-$

–At low concentrations, H_2S helps form protective FeS film
–Main risk is localised pitting corrosion which can be rapid

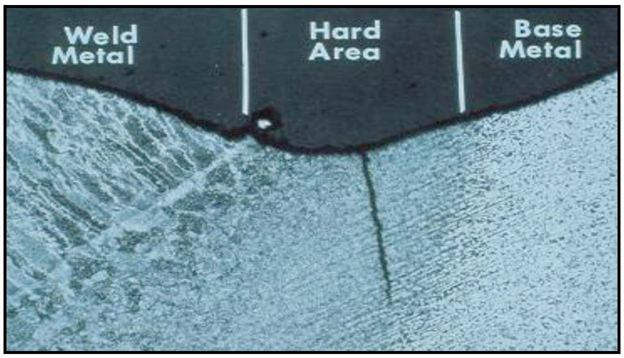
H_2S also poisons combination of atomic hydrogen into molecular hydrogen
$H^+ + e^- \rightarrow H$
$H + H \rightarrow H_2$



2. Sulphide stress cracking (SSC)

Key parameters:

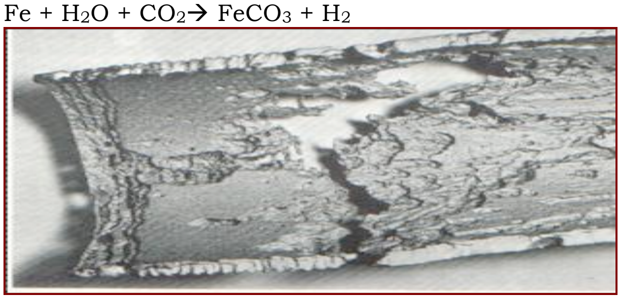
•pH and pH_2S
–Domain diagrams for carbon steel
•Material hardness
–High strength steels and areas of high hardness susceptible.
•Temperature
–Maximum susceptibility at low temperatures for carbon steels (15-25°C), higher for CRAs (5-70°C).
•Stress
–Cracking promoted by high stress levels e.g. residual welding



3. CO_2 CORROSION

•CO_2 always present in produced fluids
–Corrosive to carbon steel when water present
–Most CRAs have good resistance to CO_2 corrosion.

<u>Mechanism</u>
$CO_2 + H_2O \rightarrow H_2CO_3$
$H_2CO_3 + e^- \rightarrow HCO_3^- + H$
$2H \rightarrow H_2$
$Fe \rightarrow Fe^{2+} + 2e^-$
$Fe + H_2O + CO_2 \rightarrow FeCO_3 + H_2$



4. EROSION & EROSION-CORROSION

Various multi-phase flow regimes possible;
−erosion characteristics
−distribution of phases
−carrier phase for solids

Flow regimes with particles in the gas show higher erosion rates than those with particles in the liquid phase.

Apart from above 4 types of corrosion, there are many other corrosion mechanisms such as Galvanic Corrosion, Pitting, High Temperature Corrosion, CUI, Crevice Corrosion, Biological Growth Corrosion, Chemical Corrosion, etc.
It will not be possible to discuss all of the types of corrosions, in this article.

CORROSION PREVENTION & CONTROL

Generally, the metal selected or protective system applied to the metal should be such that no corrosion occurs at all, but this is seldom technologically or economically feasible.
It is necessary, therefore, to tolerate a rate and a form of corrosion that will not be significantly detrimental to the properties of the metal during the anticipated life of the structure.

Generally corrosion rate up to 225 μm/year in case of bare plain carbon structural steel and up to 100 μm/year in case of stainless steel are tolerated. However, suitable protection must be employed, if corrosion penetration in bare condition exceeds 1,500 μm/year for mild steel and 500 μm/year in case of stainless steel.

STEEL STRUCTURES

Corrosion in structural elements is important depending upon environment. The rate of corrosion of depends upon how long the steel remains wet. The protection problem arises from rain rapidly saturating the outer skin, particularly through mortar joints, and wetting the exposed steelwork. The design should ensure adequate drainage the steelwork. Various parts of connections need to be protected by a coating system including high performance paint systems. Based on need stainless steel, weathering steel or hot dip galvanized connections/fasteners are to be considered.

Nowadays hollow sections are used very efficiently for steel structures and Inner surface of these sections need protection if the section is sealed. Completely open sections, e.g. box girders, may require internal protection. Galvanizing, fusion bonded epoxy coatings or chemical resistant paints are all possible solutions. Sheet profiles used, as cladding is available with hot dip zinc or zinc/aluminium coated for protection

Usability	Expensive Material (Ag, Ti, Zr)	Moderately Expensive Material (Al., Cu., SS)	Cheap Material (MS,CI)
Satisfactory	<75	<100	<225
Acceptable	75 - 250	100 - 500	225 - 1500
Not acceptable	> 250	> 500	> 1500

PROTECTION OPTIONS

Design Stage: Designs can never be absolute and often there is a tendency for compromise based on cost and availability of materials and resources. The prevention of corrosion should be taken into account during the design and detailing stage of a project itself. The following points are to be taken into consideration. Figure 3 provides typical design tips.

- Entrapment of Moisture and Dirt/ Radius edges and corners
- Provide vent-holes and drain-holes for items to be hot-dip galvanized
- Provide adequate access for metal spraying, paint spraying, etc.
- Flat surface, Ease of maintenance
- Contact with other Materials &Coating Application

Material selection - At ordinary atmospheric temperatures oxidation of steel takes place in the presence of moisture. Therefore the only way to prevent the atmospheric oxidation is to create a barrier between the steel surface and the atmosphere. Weather resistant steel rusts at a much lower rate than plain carbon steels and under a favourable climatic condition develops an impervious adherent rust layer of hydrated iron oxide over the surface of steel. This acts as a protective film, which with time causes the corrosion rate to reduce reaching a terminal level usually between 2-3 years. Paint systems suitable for conventional structural steel are equally applicable for weather resistant steel, whenever painting is required to further enhance corrosion resistance.

MAJOR PROTECTION METHODS

Quite apart from the simple fact that the methods of protection are by no means universally applicable, choice is partly governed by the actual environmental condition, air movement, etc.

The protection methods can be divided into the following categories.

1. Controlling electrode potential by applying cathodic/anodic protection.
2. Addition of corrosion inhibitors to the environment
3. Applying organic or inorganic protection coatings.
4. Inorganic/Metal Coatings or Organic/Paint Systems

Sacrificial metal coating/cathodic protection is used extensively and coating material is zinc, Al, Mg and their alloys whose electrode potentials are more negative than Fe or steel. Al/Zn/Mg provides cathodic protection to iron and steel. For many applications metal-spray coatings are further protected by the subsequent application of paint coatings. A sealer is first applied which fills the pores in the metal spray coatings and provides a smooth surface for application of the paint coating.

SURFACE PREPARATION

Metal surface is covered with a paint system, which is able to prevent or delay the corrosion of the metal surface. Durability of each paint system is a function of surface preparation and this may be done by various methods depending upon the situation/locations.
There are several standards like SSPC, Sa, NACE etc corresponding to Hand and power tools, Blast cleaning, Flame cleaning, Wet (Abrasive) blast cleaning, Commercial metal cleaners and Acid Pickling

Surface preparation also gives a proper surface for bonding in case the next process is surface facing or lining for making the surface harder. To protect from wear or erosion.

Surface finish also plays an important part in surface wear and fatigue cracking.
Grades of surface finish
The following four preparation grades (in accordance with ISO 8501-1) are recognized:

- Sa 1 - Light blast-cleaning
- Sa 2 - Thorough blast-cleaning
- Sa 2½ - Very thorough blast-cleaning
- Sa 3 - Blast cleaning to visually clean steel

Following are the typical standards and their requirements for surface preparation.

S.No.	QUALITY	NACE	SSPC	SIS (ISO 8501-1)	REMARKS
1	White Metal Blast Cleaning	No. 1	SP-5	Sa 3	When viewed without magnification, the surface shall be free from millscale, rust, paint coatings and foreign matter.
2	**Near White Blast Cleaning**	No.2	**SP-10**	**Sa2 1/2**	**When viewed without magnification, the surface shall be free from millscale, rust, paint coatings and foreign matter, except for staining as noted below. Random stainging sall be limited to no more than 5% of each unit area of surface as defined in section 2.6 and may consist of light shadows, slight streaks, or rust stains of mill scale, or stains of previously applied coating**
3	Commercial Blast Cleaning	No.3	SP-6	Sa 2	When viewed without magnification, the surface shall be free from visible oil, grease and dirt, and from most of the millscale, rust, paint coatings and foreign matter. Any residual contamination shall be firmly adhering.
4	Brush-off Blast Cleaning	No. 4	SP-7	Sa 1	Light Blast cleaning
5	Solvent Cleaning		SP-1		Cleaning the substrate by solvent
6	Hand Tool Cleaning		SP-2	St2	Through hand and power tool cleaning
7	Power Tool Cleaning		SP-3	St3	Very through hand and power tool cleaning
8	Mineral and Slag Abrasives		AB-1		

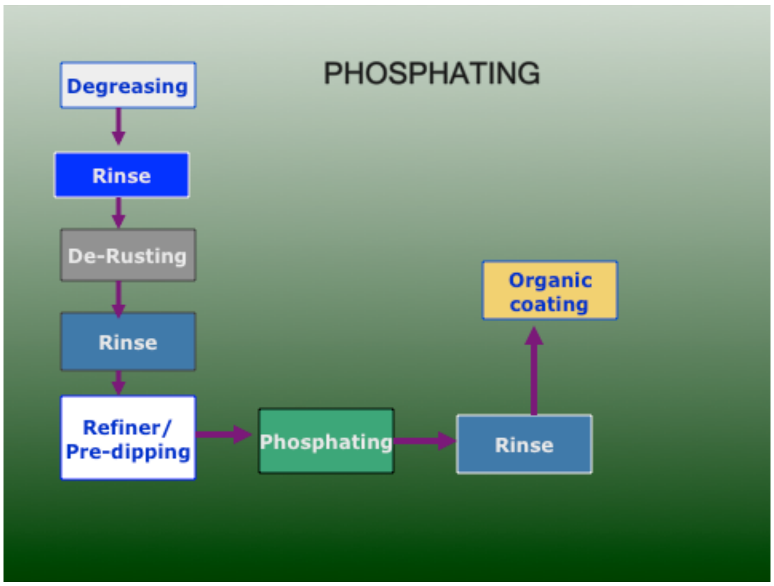
SURFACE PROTECTION METHODS

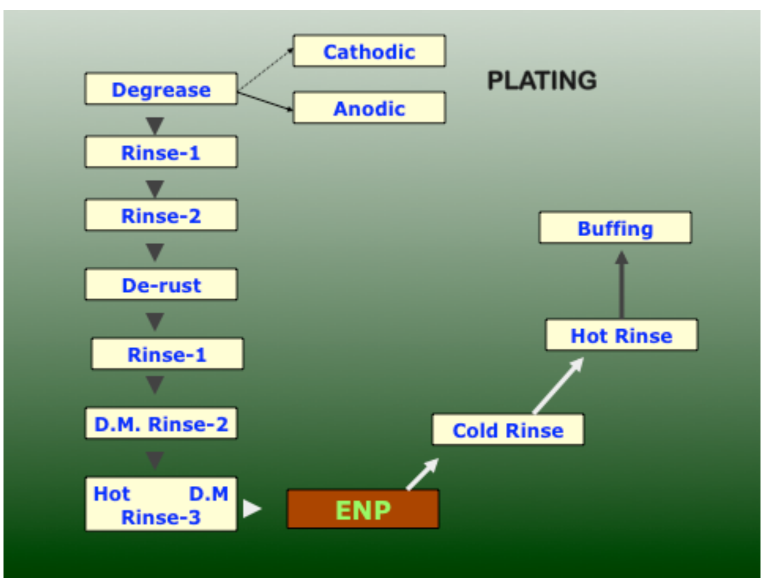
1. PHOSPHATING

2. ACID PICKLING

3. PLATING

4. PAINTING





PAINTING

Paint normally contains

1. Binder
2. Pigment
3. Solvent
4. Additives

1. Binder

–Binder or resin forms the bulk of the dried paint film. It gives of its mechanical and weathering properties.

2. Pigment

–Pigment is the colored part of the coating. It is dispersed into fine particles with the binder.

3. Solvent

–Solvents are used to dilute the Binder. There are normally several solvents in one coatings, each performing a different task.

4. Additive

–Additives are chemicals which when used in small quantities can improve certain properties of a wet paint or a cured film.

TYPES OF PAINT

<u>Organic</u>

a. Epoxy
b. Phenolic Epoxy
c. Poly Urethane
d. Acrylic

<u>Inorganic</u>

1. Silicone
2. Ethyl Zinc Silicate

GENERIC PAINT CHARACTERISTICS

For ease of reference a generic description of the paints with a specific characterization of some of their properties, is given below.

High solids, amine-cured epoxies : Polyamine-cured epoxies generally have a good resistance to chemicals and solvents.

High build, polyamide-cured epoxies: Polyamide-cured epoxies exhibit a longer potlife, superior flexibility and durability compared with amine-cured epoxies. They possess adequate chemical resistance.

High build, aliphatic polyurethanes: Two component isocyanate-free urethanes produce extremely hard, resistant and durable coatings. Aliphatic urethanes are preferred over aromatic urethanes because of their excellent durability and gloss retention.

Phenolic epoxies: Two component, high build, amine-cured phenolic epoxy coatings have excellent resistance to a wide range of solvents and (organic) acids.

(Alkyl) zinc silicates: Two component, moisture curing, zinc (alkyl) silicate coating, containing a minimum of 87% metallic zinc, is a hard, abrasion resistant coating that can withstand temperatures up to 600 °C.

Aluminium pigmented silicates: One component, (alkyl) silicate, zinc-free coating is suitable for temperatures up to 600 °C.

Aluminium silicones: Aluminium pigmented, silicone resin-based paint. Heat resistant up to 450 °C. A minimum temperature of 200 °C is required for 2 hours to obtain a sufficient cure.

Silicone acrylics: One component, aluminium (or colour) pigmented acrylic-modified silicone resin. Heat resistant up to 350 °C. Full cure can be achieved at ambient temperature.

Zinc-rich epoxy primer: Solvent free epoxies: Two component, epoxy-based primer. Developed to provide sacrificial protection to steel surfaces.

Solvent free epoxies: Two component, amine-cured, modified epoxies without solvent. They can be applied as a heavy duty coating up to 700 μm thick.

Polysiloxane: Two component, inorganic polysiloxane. Used for heat resistance (continuous and cyclic) up to 1110 °C. Current experience with this coating is good but still very limited.

Thermally sprayed metal coatings: Thermally sprayed metallic coatings may be used in applications where organic coatings are ineffective or cause product contamination.

INSPECTION AND TESTING

The following coating inspections and tests is carried out in Oil & Gas Industry:

1. SURFACE CONTAMINATION
   Tests indicating the extent of substrate contamination as a result of iron, chlorides and dust are specified in ISO 8502-1, ISO 8502-2 and ISO 8502-3, respectively.

2. WET FILM THICKNESS, WFT
   Spot checks shall be carried out during the course of the painting operation to ensure that film thickness is being maintained. These shall be performed according to the procedure described in ISO 2808, Method No. 7B.

3. DRY FILM THICKNESS, DFT
   ISO 2808, Method No.6, describes the test techniques suitable for measurement of the dry film coating thickness.

4. HOLIDAY TESTING
   Holiday testing shall be conducted in accordance with ASTM D 5162 on equipment where the continuity of the coating is important, for example internal tank linings which are subjected to corrosive conditions. The Principal shall specify the maximum number of holidays permissible.

5. ADHESION
   The adhesion of the primer to the steel substrate and the intercoat adhesion of the subsequent coat(s) after curing shall be determined by the application of either a cross-cut test in accordance with ISO 2409 or a pull-off test described in ISO 4624.

6. INSPECTION RECORDS AND REPORTS
   Generally following reports are included for reporting and review:
   General
   - - Names of personnel and their certifications.
   - - Dates when work was carried out.

     Materials preparation
     - Equipment and techniques used.
     - Materials receipt condition.
     - Type and calibration of instruments used.

Environmental conditions

- Weather and ambient conditions.
- Painting periods

Surface preparation

- Condition of surface before preparation.
- Tools and methods used to prepare surface.
- Condition after preparation.

Paints and painting

- Information on systems being applied.
- Mixing and testing prior to application.
- Paint application techniques.

Testing

- Type of quality control checks carried out, and results.
- Compliance or otherwise with specification.

Some of the International Standards used in Oil & Gas Industry.

AMERICAN STANDARDS ASTM D 5162

Standard practice for discontinuity (holiday) testing of non- conductive protective coating on metallic substrates

Issued by:
American Society for Testing and Materials 1916 Race Street
Philadelphia, Pa 19103
USA.

BRITISH STANDARDS BS 4800

Paint colours for building purposes

Issued by:
British Standards Institution 389 Chiswick High Road London W4 4AL
England, United Kingdom.

GERMAN STANDARDS

RAL - colour cards

Issued by:
RAL Bornheimerstraße 180 D-5300 Bonn 1 Germany.

ISO

Paints and Varnishes - Cross-cut test for adhesion	ISO 2409
Paints and varnishes - Determination of film thickness	ISO 2808
Paints and Varnishes - Pull-off test for adhesion	ISO 4624

Issued by:
International Organisation for Standardisation
1 Rue de Varembe
CH-1211 Geneva 20
Switzerland.
Copies can also be obtained from national standards organisations.