







Fitz's Atlas® of coating defects

Fitz's Atlas™ of coating defects

A comprehensive visual guide to coatings and application defects

PREFACE

The aim of this Atlas is to illustrate the range of coating and surface defects likely to be encountered, and give advice on probable causes, prevention and repair, it is not intended as a complete 'Do it yourself manual' for failure analysis. Use of this Manual will not make the user an "Instant Expert" on coating failures. Many coating failures need further evaluation and analyses to be carried out in conjunction with a qualified Chemist or Coating Specialist, often using specialised laboratory equipment.

With any coating failure, a process of elimination should be considered as the first course of action. This should take into account the type of failure; the environmental conditions; any unusual or unexpected variations from normal operating conditions; a check on application conditions to ensure these were within the accepted range for the coating system applied; was the surface preparation suitable for the type of coating system applied. The list of questions to be asked will depend on the type of failure and whether it occurred shortly after application of the coating system or much later in the life of the coating.

The first section of this Atlas includes a number of welding faults which may be encountered and which need to be addressed or corrected before application of any coating system. This is followed by a section on pre-surface conditions. Section four and five deal with surface preparation, giving guidance notes on dry abrasive blast cleaning and high pressure water jetting respectively.

Section six is the main pictorial reference of coating defects and includes a description of each defect, its probable causes, prevention and repair.

Section seven illustrates various types of marine fouling and finally, an appendix gives details of breakdown scales which will be useful to users in assessing the degree of breakdown and the potential areas in need of repair. It also includes a quick reference guide to the characteristics of certain types of paint and paint compatibility.

Each of these sections have been compiled by coating specialists who understand paint coatings and their application and as such will provide a

useful pictorial reference to all who use and encounter paint coatings, their defects and failures. We would welcome any other suggestions for future modules and any constructive criticisms of the present volume.
All photographs and information contained within this document are intended for guidance. Where standards are referred to, these should be taken as the authoritative documents on the relevant subject matter. No responsibility can be taken for any problems which may arise as a result of the use of any information contained within this document.

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WELDS

Where a protective coating system is to be applied over a weld, the application of a well brushed-in stripe coat to the prepared surface is strongly recommended to ensure adequate protection and to prevent bridging by the coating system. In addition, any welding faults of the types described below should be appropriately rectified before any coating is applied.

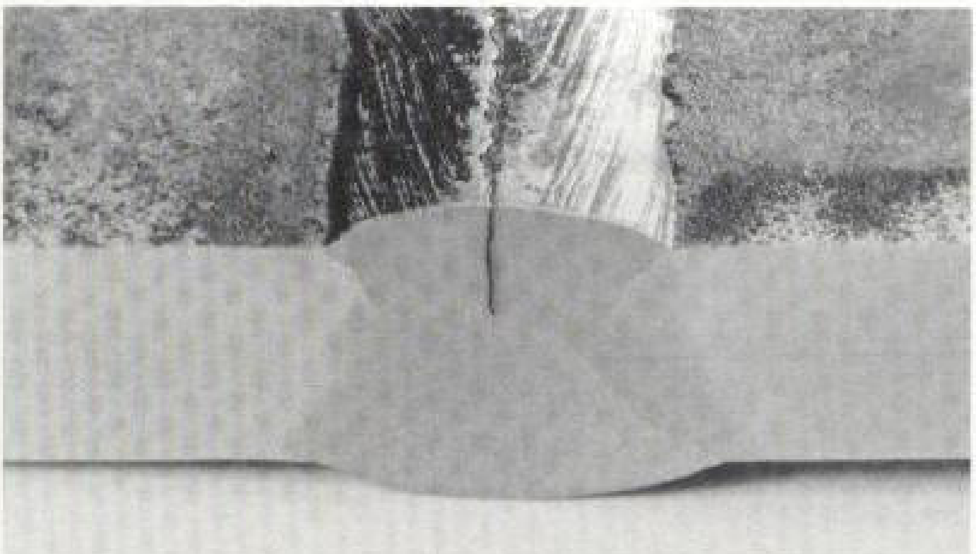
WELDING FAULTS

The following section describes various faults in fusion welds in construction steels. This is not a comprehensive compilation of all likely welding faults, only those which can present problems with the application of coatings unless the faults are rectified prior to the appropriate surface preparation and application of the protective coating system.

All comments are for guidance only.

Photographs within this section are courtesy of The Welding Institute's 'Faults in Fusion Welds' by Woodhead Publishing, Cambridge.

CRACKS



10mm

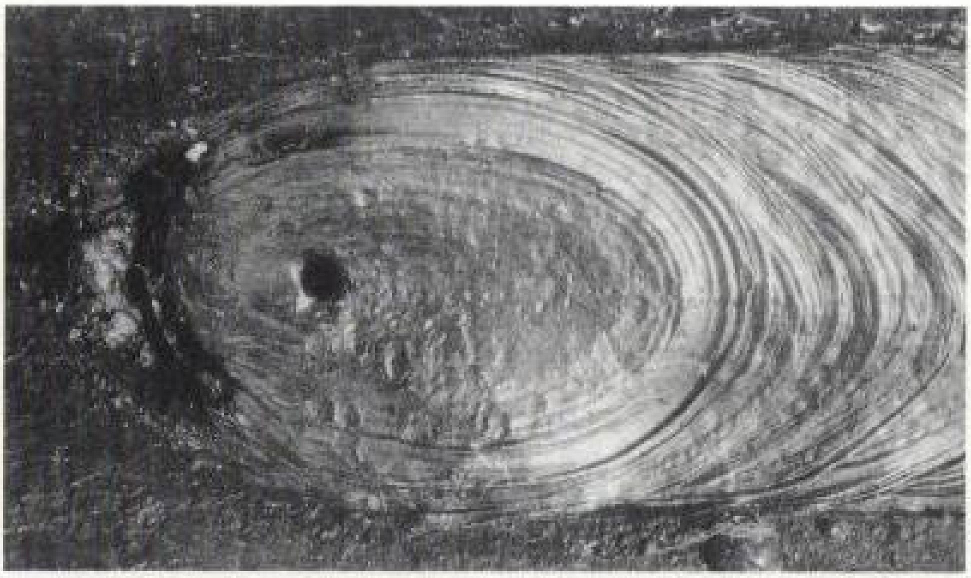
Description: Crack visible at the surface.

Probable Causes: Excessively deep or wide bead. High current and/or welding speed. Large root gap.

Repair: Cut out defective weld length plus 5 mm beyond visible end of crack and reweld.

Comment: Protective coatings can mask cracks but rarely successfully bridge cracks. Unless rectified prior to the application of the coating, such cracks can result in premature failure of the coating system, irrespective of any danger that might be caused to the structure by their presence.

CRATER PIPES



10mm

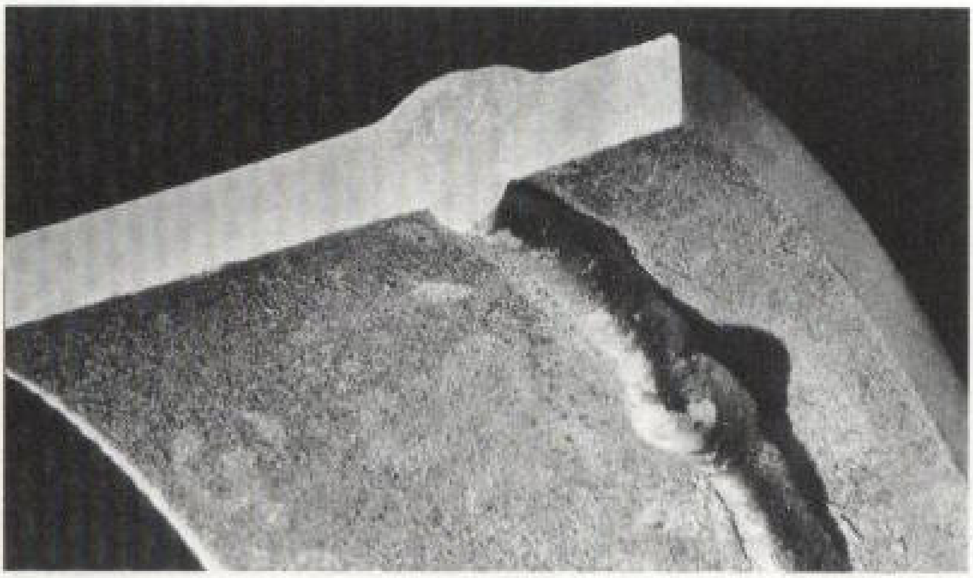
Description: Crater resulting from shrinkage at the end of a weld run.

Probable Causes: Incorrect manipulative technique or current decay to allow for crater shrinkage.

Repair: All such porosities must be appropriately filled prior to application of a protective coating system.

Comment: Coatings rarely bridge pores in a metal substrate and if they do, this can lead to premature coating failure.

EXCESS PENETRATION BEAD



20mm

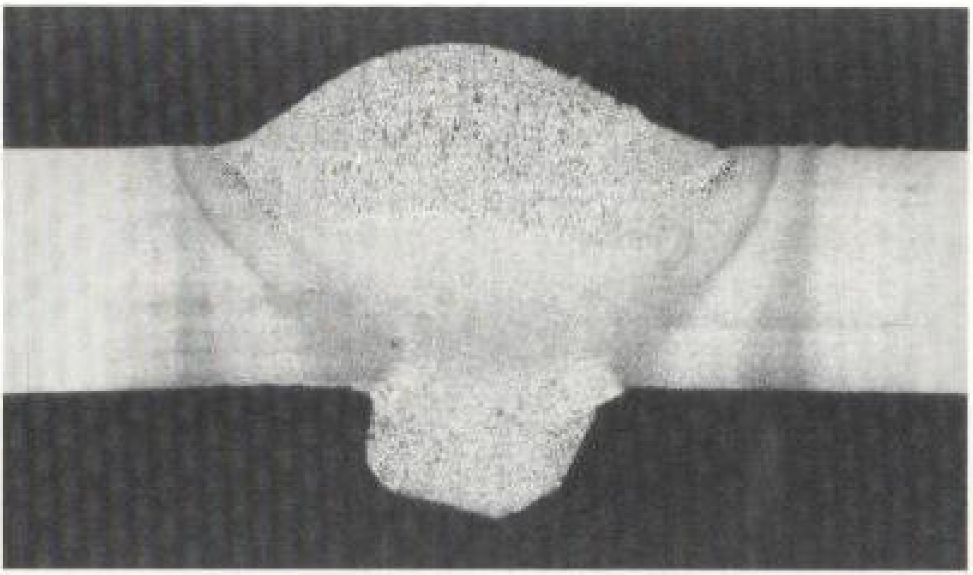
Description: Weld metal normally extends below the parent metal surface but this is only a problem when excessive and exceeds the specification.

Probable Causes: Incorrect edge preparation providing insufficient support at the root, and/or incorrect welding parameters.

Repair: Where sharp changes in contour occur these need to be smoothed to prevent bridging of the protective coating system.

Comment: Thorough brushing in of a stripe coat can be effective but some form of filling may be necessary to prevent bridging of the coating. Any undercuts must be appropriately treated to prevent bridging by the coating system.

EXCESS PENETRATION BEAD



6mm

Description: Weld metal normally extends below the parent metal surface but this is only a problem when excessive and exceeds the specification.

Probable Causes: Incorrect edge preparation providing insufficient support at the root, and/or incorrect welding parameters.

Repair: Where sharp changes in contour occur these need to be smoothed to prevent bridging of the protective coating system.

Comment: Thorough brushing in of a stripe coat can be effective but some form of filling may be necessary to prevent bridging of the coating. Any undercuts must be appropriately treated to prevent bridging by the coating system.

ROOT CONCAVITY

20mm

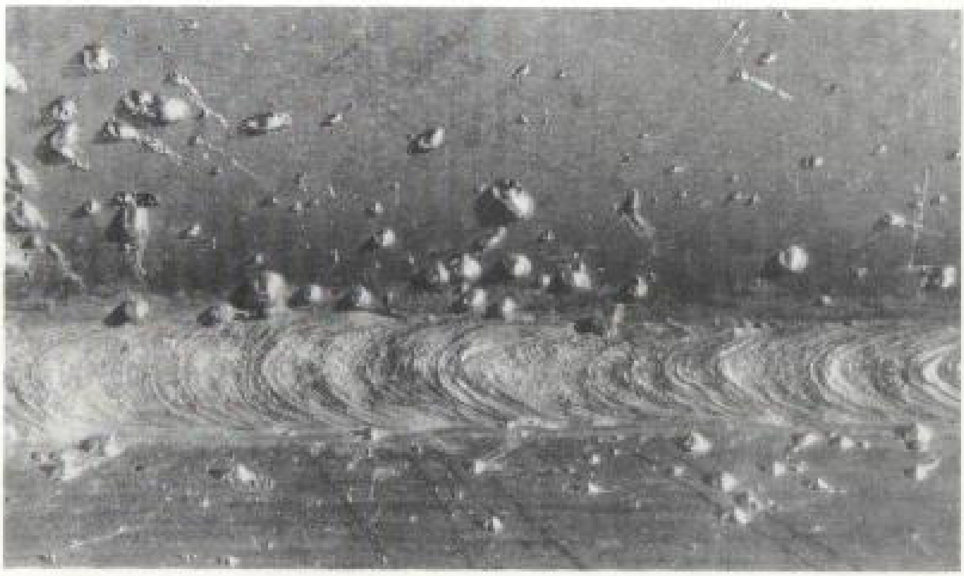
Description: Shrinkage at the weld root resulting in a deep pit along the weld.

Probable Causes: Shrinkage of molten pool at the weld root, resulting from incorrect weld preparation or insufficient heat input. Also from incorrect welding technique.

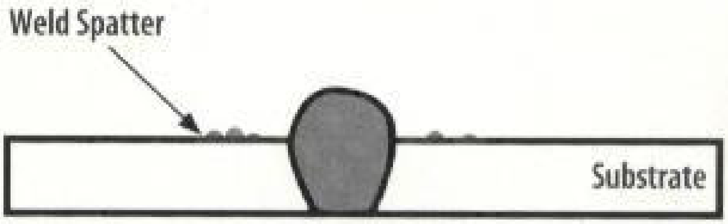
Repair: Ensure the edges are smooth with no sharp changes in contour.

Comment: All sharp edges must be ground smooth in accordance with the specification, prior to surface preparation and application of the coating system.

SPATTER



20mm



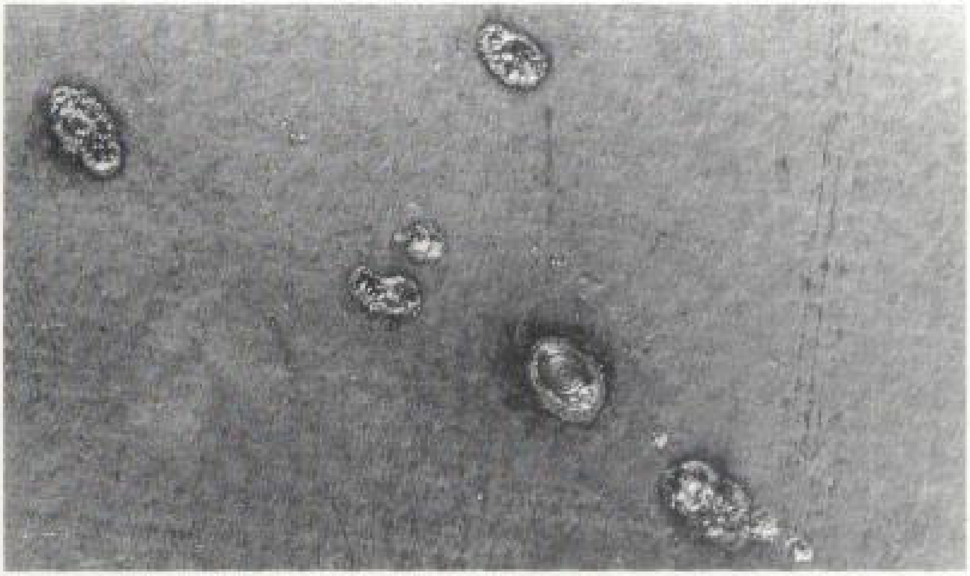
Description: Globules of metal which adhere to the metal surface, often some distance from the weld.

Probable Causes: Incorrect welding conditions, such as too high a welding current and/or contaminated consumables or preparations giving rise to explosions within the arc and weld pool.

Repair: Grind or needle gun off all globules to leave a smooth surface, prior to full surface preparation.

Comment: Weld spatter can rarely be successfully coated and can result in premature coating breakdown.

STRAY ARCING



10mm

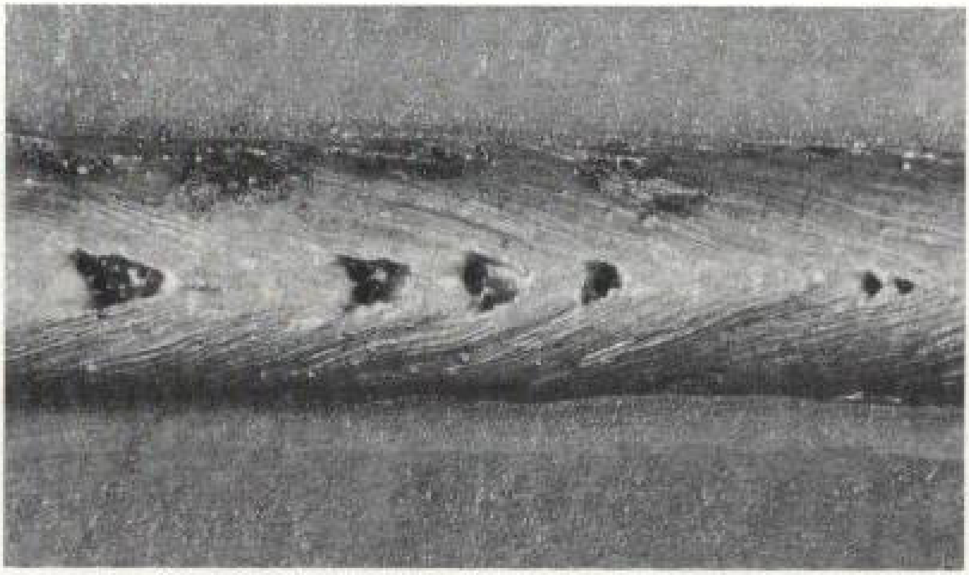
Description: Small hard spots, craters or rough surface features.

Probable Causes: Accidental contact of electrode or welding torch with plate surface remote from the weld.

Repair: Grind smooth, blast clean or use other appropriate treatment to ensure the surface is sufficiently prepared for adequate adhesion of the protective coating.

Comment: The application of a protective coating to rough insufficiently prepared areas can lead to premature coating failure.

SURFACE POROSITY



20mm

Description: Pores visible at the surface of a weld.

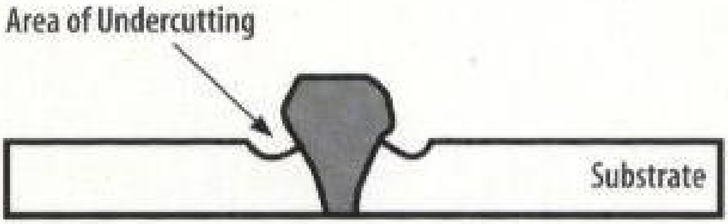
Probable Causes: Excessive contamination from grease, dampness or atmospheric entrainment. Occasionally caused by excessive sulphur in consumables or parent metal.

Repair: All such porosities must be appropriately filled prior to application of a protective coating system.

Comment: Coatings rarely bridge pores in a metal substrate and if they do, this can lead to premature coating failure.

UNDERCUT

20mm



Description: Undercut cavity which results from washing away of the edge preparation when molten.

Probable Causes: Poor welding technique and/or unbalanced welding conditions.

Repair: All such undercuts must be appropriately prepared, rewelded or filled prior to application of the coating system.

Comment: Coatings rarely bridge undercuts in a metal substrate and if they do, this can lead to premature coating failure.

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3 - SURFACE CONDITIONS

INDEX OF SURFACE CONDITIONS

SURFACE PREPARATION

This section includes pictorial examples of some typical conditions, from bare steel through to failed coating system, likely to be encountered before any surface preparation is carried out. Also illustrated are some typical problem areas which need to be appropriately treated prior to or during full surface preparation.

Various photographs are included which show mill scale on unprepared steel at various stages of degradation.

Whenever grinding is used for removal of defects, professional advice should be sought to ensure that the integrity of the structure or vessel is not compromised. Strict limits are usually applied to the thickness of metal which can be removed by grinding e.g. with high pressure pipework.

Burrs

Bolt holes and other cut areas should be thoroughly checked for burrs and rough edges, which should be removed by grinding or other suitable means.

Contamination on surface

Oil, grease and other foreign contamination must be removed by solvent cleaning or the use of an alternative suitable biodegradable cleaner prior to full surface preparation.

Edges

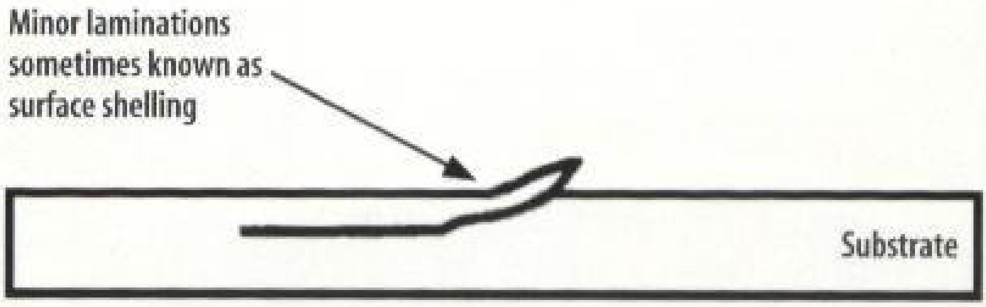
All edges should be radiused to provide a smooth round surface to which the paint can adhere to provide good protection.

Feathering

Where repairs are carried out to an already painted surface, the edge of the old paint should be feathered to a sound, well adhered thin edge using an appropriate means of abrasion, prior to overcoating.

Laminations, Surface Shelling or Hackles

The steel surface should be checked for laminations both before and after surface preparation. Any laminations found must be removed by grinding before application of any coating system. The use of an Ultrasonic thickness gauge may be necessary to determine the extent of delamination.



Mill Scale
All mill scale should be removed by appropriate cleaning techniques, usually abrasive blast cleaning, prior to application of a coating system.

Surface Porosity
All surface porosities should be filled with an appropriate filler to provide a smooth surface.

Slag
All welding slag should be removed by mechanical means so that the underlying weld may be inspected and suitably prepared. Coatings should not be applied over welding slag.

Spatter
All weld spatter should be removed by mechanical means.

Undercuts
Undercuts should not be excessive or rough.

Welds
Welds should be continuous and free from sharp projections. See also the section on Welding Defects.

CORROSION TRAP

Description: Poor design resulting in a well where water can collect.

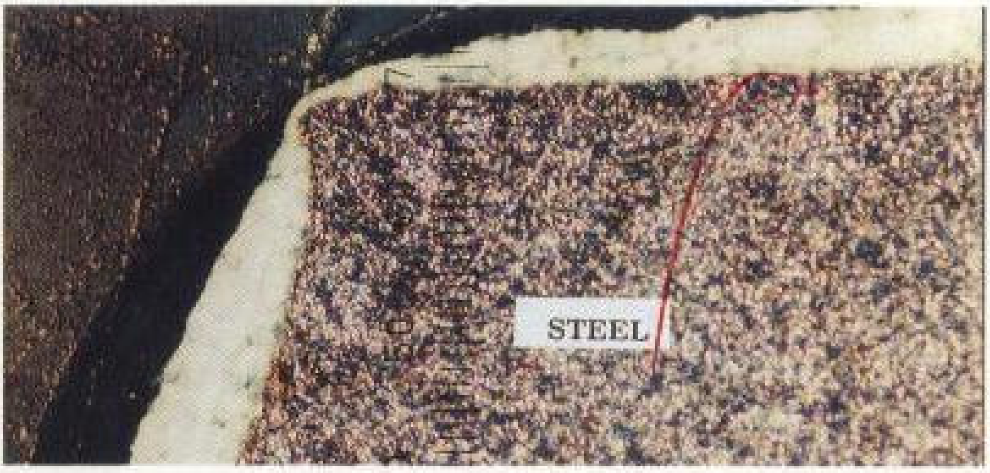
Comment: This problem should be eliminated wherever possible at the design stage, by including appropriate drainage holes or modifying the design to prevent areas where water or corrosive fluids can collect.

EDGES - FLAME CUT

Description: Sharp rough edges resulting from flame cutting.

Comment: All such rough cut edges should be ground smooth and any sharp edges radiused. A radius of 2 mm is generally recommended for good painting practice.

EDGES - SHARP



Description: Sharp edge on cut or constructional steel. Note in the second photograph how the coating becomes very thin over an untreated sharp edge.

Comment: Remove all sharp edges prior to surface preparation. A radius of 2 mm is generally recommended for good painting practice. Apply a stripe coat over all edges to ensure adequate coverage by the coating system.

MILL SCALE

Several photographs are included to show the effect of outdoor exposure on untreated rolled steel stock. The extent of degradation of the surface will depend on the type of exposure conditions, whether Rural Unpolluted, Industrial Polluted, or Marine. The examples included are purely to illustrate the various types of surface conditions which might be encountered.

The photographs on the following pages are from British Steel and show "A", "B" and "C" quality steel surfaces and can be related to the appropriate quality designations included in the blast cleaning standards.

MILLSCALE - "A" QUALITY STEEL

Description: An example of steel with an "A" quality surface, showing fresh, tightly adherent mill scale. Note the overall blue oxide scale.

MILLSCALE - "A" QUALITY STEEL

Description: A closer view of "A" quality steel with virtually intact blue mill scale.

MILLSCALE - "B" QUALITY STEEL

Description: An example of steel with a "B" quality surface condition. The steel sections have been exposed to a Rural Unpolluted External atmosphere for a period of 2-3 months. The corrosion process has caused some degradation of the mill scale and a light patina of rust has formed on the steel surfaces.

MILLSCALE - "B" QUALITY STEEL

Description: A closer view of "B" quality steel indicating delamination and corrosion effects of the mill scale.

MILLSCALE - "C" QUALITY STEEL

Description: An example of a "C" quality surface condition. The steel sections have been exposed to a Rural Unpolluted External atmosphere for a period of 4 - 6 months. The corrosion process has caused total degradation of the mill scale and an overall patina of rust has formed on the steel surfaces.

MILLSCALE - "C" QUALITY STEEL

Description: A closer view of "C" quality steel where practically all residues of mill scale have disappeared. Any remaining mill scale is in a friable state.

OIL CONTAMINATION

Description: Partial oil contamination of the surface with an oil film.

Comment: All oil and grease must be removed from the surface using solvent or biodegradable detergent degreasing prior to full surface preparation. Unless this is properly carried out, a residual oil film will be transferred to the surface during dry blast cleaning, which will prevent good adhesion of the coating system.

SKIP WELD

also intermittent weld

Description: Non-continuous weld or skip weld.

Probable Causes: Used where a full weld is unnecessary for constructional purposes.

Repair: Ideally a continuous weld should be used. Where this is impractical, the gaps should be cleaned and filled with a suitable mastic to prevent bridging by the coating.

Comment: Unless the gaps are properly treated these areas will serve as initiation points for corrosion.

SLAG

Description: Weld slag which has not been removed from the surface.

Comment: All welding slag should be removed by mechanical means so that the underlying weld may be inspected and suitably prepared. Coatings should not be applied over welding slag.

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4 - DRY ABRASIVE BLASTING

INDEX OF DRY ABRASIVE BLAST CLEANING

The images within this section are courtesy of Clemco Industries Corp. The images are for illustrative purposes only and may not reflect actual surface conditions or results.

SURFACE PREPARATION

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

- **the presence of rust, millscale and previous coatings;**
- **the presence of surface contaminants, including salts, dust, oils, acid and greases;**
- **the surface profile.**

International Standards ISO 8501, ISO 8502 and ISO 8503 provide methods of assessing these factors, while ISO 4628-3 provides guidance on evaluating the degradation of paint coatings by degree of rusting and ISO 4627 covers the evaluation of the compatibility of a product with a surface to be painted. Other national standards and codes of practice contain recommendations for the various protective coating systems to be applied to the steel surface and these should be referred to for guidance on such items as:

- **suitability of the cleaning procedure and standard specified;**
- **suitability of the coating system for the environmental conditions to which the steel will be exposed;**
- **compatibility with any remaining paint coatings.**

The International Standards referred to above deal with the following aspects of preparation of steel substrates:

ISO 8501 -	*Visual assessment of surface cleanliness.*
ISO 8502 -	*Tests for the assessment of surface cleanliness.*
ISO 8503 -	*Surface roughness characteristics of blast-cleaned steel substrates.*
ISO 4627 -	*Paints and varnishes - Evaluation of the compatibility of a product with a surface to be painted - Methods of test.*
ISO 4628-3 -	*Evaluation of degradation of paint coatings.*

In the following sections include guidelines on the preparation of steel substrates before the application of paints and related products and include reproductions of visual assessment guides of surface finish and cleanliness by water jetting.

DRY ABRASIVE BLAST CLEANING

These guidance notes are intended to be a tool for the visual assessment of preparation grades by means of dry abrasive blast cleaning.

The surface finish achieved by dry abrasive blast cleaning depends on the original surface condition as well as the type of abrasive blasting equipment, size, hardness, type and abrasive shape.

The original surface conditions of steel may be one of four of the following rust grades:

A Steel surface largely covered with adhering mill scale but little, if any rust.

B Steel surface which has begun to rust and from which the mill scale has begun to flake.

C Steel surface on which the mill scale has rusted away or from which it can be scraped, but with slight pitting visible under normal vision.

D Steel surface on which the mill scale has rusted away and on which general pitting is visible under normal vision.

Preparation grades

Surface cleanliness is divided into four grades, designated by the letters 'Sa'.

Sa 1 Light blast cleaning or Brush-off.
Sa 2 Thorough blast cleaning or Commercial.
Sa 2½ Very thorough blast cleaning or Near white metal.
Sa 3 Blast cleaning to visually clean steel or White metal.

Other considerations

Apart from cleanliness of the steel, consideration needs to be given to the etch or profile roughness created by the impact of the abrasive on the steel surface. The substrate profile is regulated by:

- **Shape, type and grading of the abrasive.**
- **Blasting method and velocity of abrasive impaction.**
- **Steel condition prior to abrasive blast cleaning.**

The etched profile of the surface enables adhesion of the protective paint coatings. Of great importance is the level at which this is achieved as too severe a profile will cause a waste of paint and time in application, whilst too light a profile could result in lack of adhesion.

Profile of the surface can be measured by various items of test equipment but still the best method of obtaining a profile specification is by ensuring the correct blasting equipment/method coupled with type and size of abrasive to be used in the operation.

Once abrasive blast cleaning needs have been decided, selection of method, type of equipment and training of personnel should follow. Equipment used for surface preparation needs to be extremely reliable and simple to use. Operation and training information should be up-to-date and accurate.

The various rust grades and cleaning standards are now illustrated.

RUST GRADES
GRADE A

Steel surface largely covered with adhering mill scale but little, if any rust.

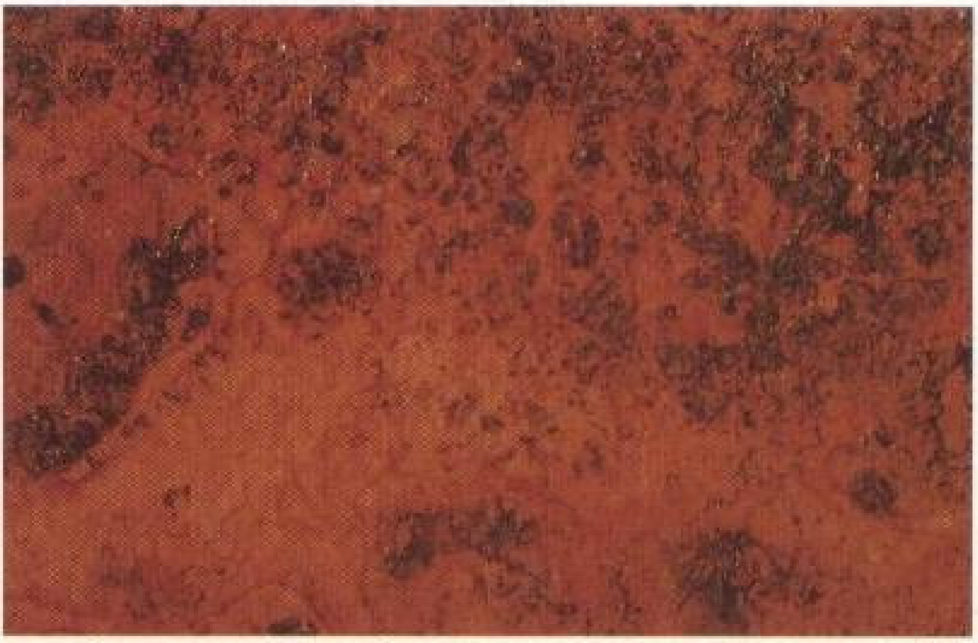
GRADE B

Steel surface which has begun to rust and from which the mill scale has begun to flake.

GRADE C

Steel surface on which the mill scale has rusted away or from which it can be scraped, but with slight pitting visible under normal vision.

GRADE D



Steel surface on which the mill scale has rusted away and on which general pitting is visible under normal vision.

LIGHT BLAST CLEANING OR BRUSH-OFF BLAST CLEANING (SA 1)

Removal of loose mill scale, loose rust, and loose paint, to the degree hereafter specified, by the impact of abrasives propelled through nozzles or by centrifugal wheels. It is not intended that the surface shall be free of all mill scale, rust, and paint. The remaining mill scale, rust, and paint should be firmly adhered and the surface should be sufficiently abraded to provide good adhesion and bonding of paint.

A brush-off blast cleaned surface finish is defined as one from which all oil, grease, dirt, rust scale, loose mill scale, loose rust and loose paint or coatings are removed completely but tight mill scale and firmly adhered rust, paint and coatings are permitted to remain provided that all mill scale and rust have been exposed to the abrasive blast pattern sufficiently to expose numerous flecks of the underlying metal fairly uniformly distributed over the entire surface.

Sa 1	SIS 05 5900 Swedish Standards Organisation
Sa 1	ISO 8501-1

RUST GRADE B (SA 1)

RUST GRADE C (SA 1)

RUST GRADE D (SA 1)

THOROUGH BLAST CLEANING OR COMMERCIAL BLAST CLEANING (SA 2)

Removal of partial mill scale, rust, rust scale, paint or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels, to the degree specified.

A commercial blast cleaned surface finish is defined as one from which all oil, grease, dirt, rust scale and foreign matter have been completely removed from the surface and all rust, mill scale and old paint have been completely removed except for slight shadows, streaks, or discoloration caused by rust stain, mill scale oxides or slight, firm residues of paint or coating that may remain if the surface is pitted, slight residues of rust or paint may by found in the bottom of pits. At least two-thirds of each square inch of surface area shall be free of all visible residues and the remainder shall be limited to the light discoloration, slight staining or firm residues mentioned above.

Sa 2	SIS 05 5900 Swedish Standards Organisation
Sa 2	ISO 8501-1

RUST GRADE B (SA 2)

RUST GRADE C (SA 2)

RUST GRADE D (SA 2)

VERY THOROUGH BLAST CLEANING OR NEAR WHITE METAL BLAST CLEANING (SA 2½)

Removal of nearly all mill scale, rust, rust scale, paint, or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels, to the degree hereafter specified.

A near-white metal blast cleaned surface finish is defined as one from which all oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint or other foreign matter have been completely removed from the surface except for very light shadows, very slight streaks or slight discolouration caused by rust stain, mill scale oxides, or light, firm residues of paint or coating that may remain. At least 95 percent of each square inch of surface area shall be free of all visible residues, and the remainder shall be limited to the light discoloration mentioned above.

Sa 2½	SIS 05 5900 Swedish Standards Organisation
Sa 2½	ISO 8501-1

RUST GRADE B (SA 2½)

RUST GRADE C (SA 2½)

RUST GRADE D (SA 2½)

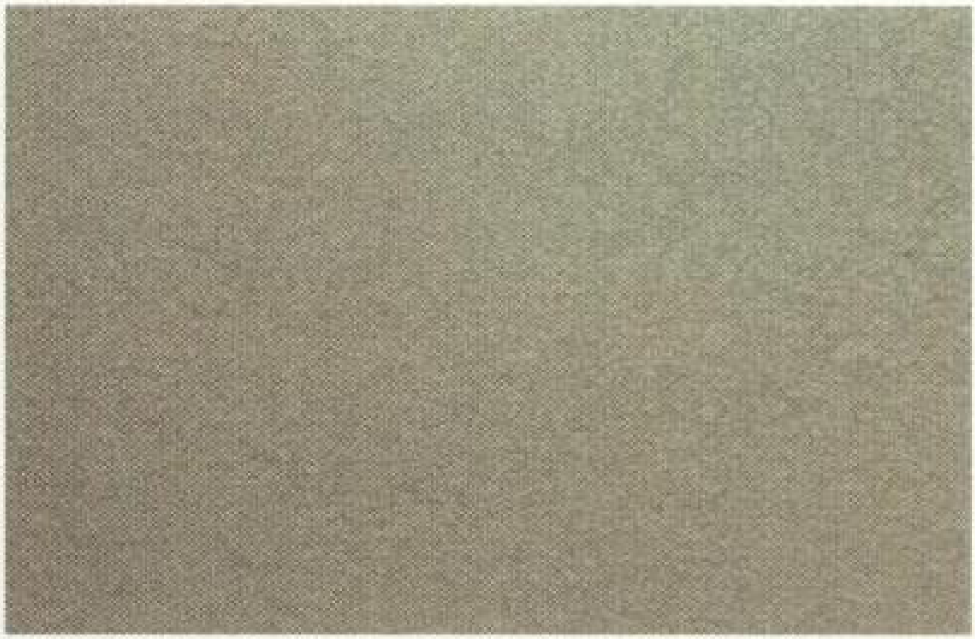
BLAST CLEANING TO VISUALLY CLEAN STEEL OR WHITE METAL BLAST CLEANING (SA 3)

Removal of all mill scale, rust, rust scale, paint or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels.

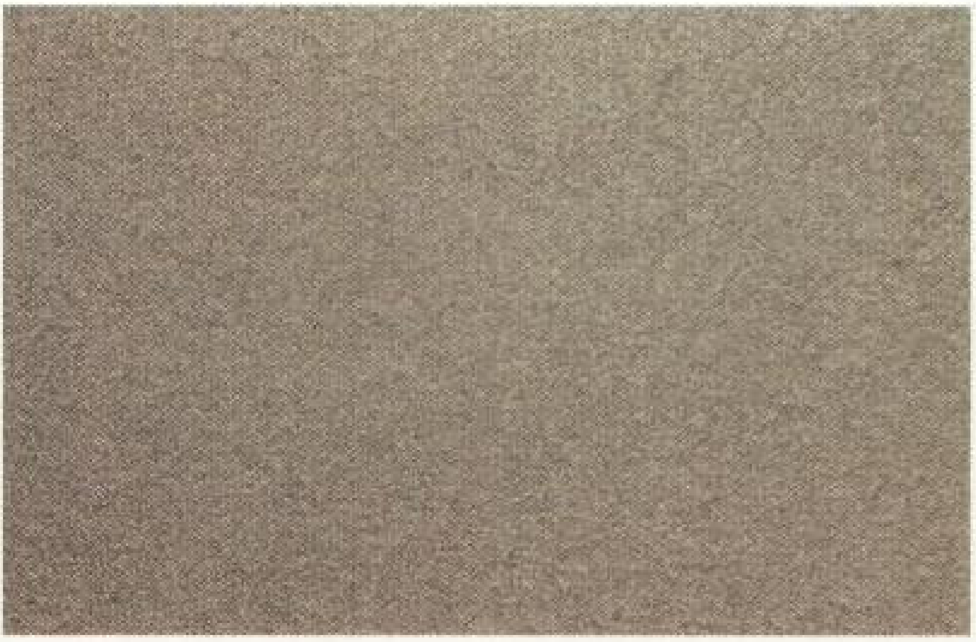
A white metal blast cleaned surface finish is defined as a surface with a grey-white, uniform metallic colour, slightly roughened to form a suitable anchor pattern for coatings. The surface, when viewed without magnification, shall be free of all oil, grease, dirt, visible mill scale, rust, corrosion products, oxides, paint, or any other foreign matter.

Sa 3	SIS 05 5900 Swedish Standards Organisation
Sa 3	ISO 8501-1

RUST GRADE B (SA 3)



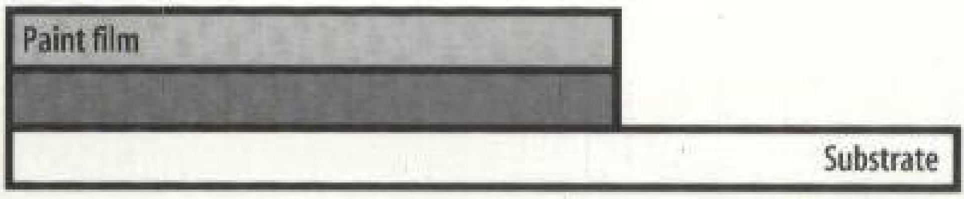
RUST GRADE C (SA 3)



RUST GRADE D (SA 3)

FEATHERING

Before Feathering



After Feathering

Description: Where repairs are carried out to an already painted surface, the edge of the old paint should be feathered to a sound, well adhered thin edge using an appropriate means of abrasion,prior to overcoating.

Caution: 1) Check compatability of new paint over old paint.
2) Ensure new paint does not soften and lift old paint, particularly at the feathered edges,

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5 - WATER JETTING

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SURFACE PREPARATION

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ISO 4628-3 -	*Evaluation of degradation of paint coatings.*

In the following sections include guidelines on the preparation of steel substrates before the application of paints and related products and include reproductions of visual assessment guides of surface finish and cleanliness by high pressure water jetting.

WATER JETTING

These guidance notes are intended to be a tool for the visual assessment of preparation grades by means of high pressure water jetting (which may also include ultra high pressure jetting). They have been produced by the use of water only, with no abrasive material included. They have been endorsed by the paint manufacturers listed below for use with their various paint products. However, specific recommendations with regard to the suitability of this technique for use with any specific paint product and under any particular environmental conditions should always be sought from the paint manufacturer concerned.

Akzo Nobel (International Coatings Ltd)
Chugoku BV
Hempel UK Ltd
Jotun-Henry Clark Ltd
Sigma Coatings
W&J Leigh & Co. Ltd

As with dry blast cleaning, the roughness characteristics of the surface should also be considered by reference to ISO 8503, although it should be noted that preparation by high pressure water jetting does not create a profile nor significantly change an existing profile.

The definitive document on high pressure water jetting, ISO standard ISO 8501 - Part 4, is in the course of preparation.

Caution

When water jetting at lower pressures is used on old coatings which have not been completely removed, it is strongly recommended that checks on adhesion and chemical compatibility between old and new coatings are carried out, particularly for solvent softening and lifting of the old coating. Frequently different generic types of coating are used when overcoating.

TERMS AND DEFINITIONS

Water jetting - this method consists of directing a jet of pressurised water onto the surface to be cleaned. The water pressure depends upon the contaminants to be removed, such as water-soluble matter, rust and paint coatings. When detergents have been used in the cleaning operation, rinsing with clean fresh water is necessary.

A number of terms are used synonymously with 'water jetting' including 'hydrojetting', 'aquajetting', 'hydroblasting' and 'aquablasting'.

Terms containing the words 'blasting' can be confusing as they may be associated with the use of abrasives and hence 'high pressure water jetting' (Wa) is the preferred description.

High pressure water jetting involves the use of water at pressures of greater than 70 MPa (700 bar).

Ultra high pressure water jetting involves the use of water at pressures greater than 140 MPa (1400 bar) and may remove millscale from partially weathered steel, but does not impart a surface profile to the steel substrate.

INITIAL SURFACE CONDITIONS

The initial surface condition applies to steelwork that has previously been blast cleaned and painted with either shop primer alone or with a full coating system.

Three degrees of damaged paint coatings by rusting, blistering, flaking are specified, and two of damaged shop primer.

DC1 A surface where the paint coating system has degraded to a major extent. This degradation being similar to that illustrated in ISO 4628-3, Ri5 or when completely degraded, as illustrated in ISO 8501-1, rust grades C and D.

DC2 A surface where the paint coating system has degraded to an extent similar to that illustrated in ISO 4628-3, Ri4.

DC3 A surface where the paint coating system has degraded to an extent similar to that illustrated in ISO 4628-3, Ri3.

DS1 An iron oxide epoxy prefabrication (shop) primer surface that has been damaged by rusting, welding, or burning.

DS2 A zinc silicate prefabrication (shop) primer surface that has been damage by rusting, welding, or burning.

PREPARATION GRADES

Three preparation grades, indicating the degree of cleaning, and three degrees of flash rusting are specified. The preparation grades are defined by written descriptions of the surface appearance after the cleaning operation with representative photographic examples.

The photographs are designated by the initial surface condition before cleaning followed by the designation of the preparation grade, e.g. DC3 Wa2.

Description of preparation grades

The letters Wa designate surface preparation by high pressure water jetting.

Wa1 Light high pressure water jetting

When viewed without magnification, the surface shall be free from oil, grease, loose rust, and foreign matter. Any residual contamination shall be randomly dispersed and firmly adherent.

Wa 2 Thorough high pressure water jetting

When viewed without magnification, the surface shall be free from visible oil, grease and dirt and most of the rust, previous paint coatings and foreign matter. Any residual contamination shall be randomly dispersed and firmly adherent.

Wa 2 1/2 Very thorough high pressure water jetting

When viewed without magnification the surface shall be free from all-visible rust, oil, grease, dirt, previous paint coatings, and foreign matter except slight traces. Some discoloration of the surface may be present adjacent to pitted areas but should show only as slight stains.

FLASH RUST GRADES

Three degrees of flash rust are specified. They are defined by written descriptions together with representative photographic examples.

FR 1 Heavy flash rust

A surface when viewed without magnification exhibits a layer of yellow / blown rust that obscures the original steel surface and is loosely adherent. The rust layer may be evenly distributed or present in patches and it will readily mark a cloth that is lightly wiped over the surface.

FR 2 Medium flash rust

A surface when viewed without magnification exhibits a layer of yellow / brown rust that obscures the original steel surface. The rust layer may be evenly distributed or in patches, but it will be reasonably well adherent and will lightly mark a cloth that is lightly wiped over the surface.

FR 3 Light flash rust

A surface when viewed without magnification exhibits small quantities of a yellow-brown rust layer through which the steel substrate can be observed. The rust/discoloration may be evenly distributed or in patches, but will be tightly adherent and not easily removed by light wiping with a cloth.

PROCEDURE FOR THE VISUAL ASSESSMENT OF STEEL SUBSTRATES

Either in good daylight or in artificial illumination (agreed between the parties) examine the steel surface and compare it with each of the photographs using normal vision. Place the appropriate photograph close to and in the plane of the steel surface to be assessed.

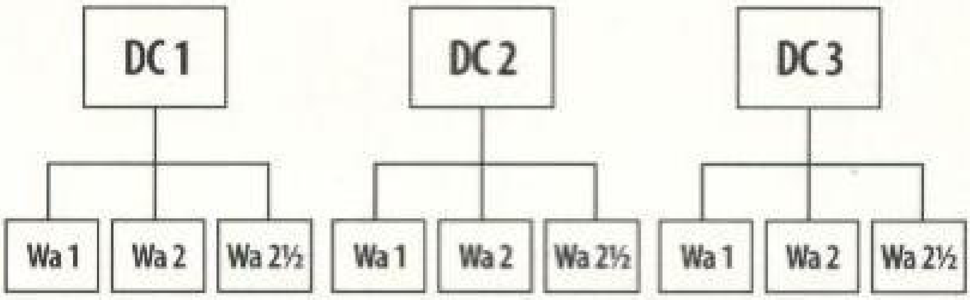
- For the initial condition record the assessment as the worst degree that is evident.
- Assessment of the cleaning degree shall be made when the surface is dry and before flash rusting occurs.
- Assessment of the flash rust degree (if any) shall be made immediately prior to paint application.

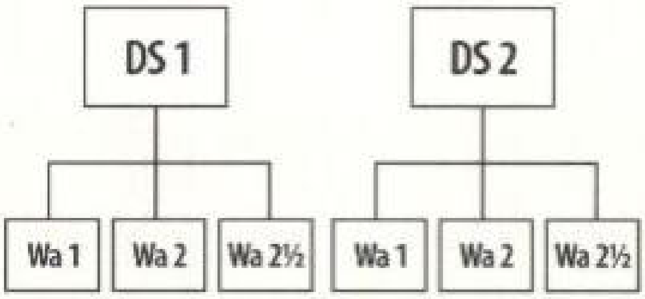
PHOTOGRAPHS

Five photographs show the condition of the damaged painted steel designated DC1, DC2, DC3, and DS1 & DS2.

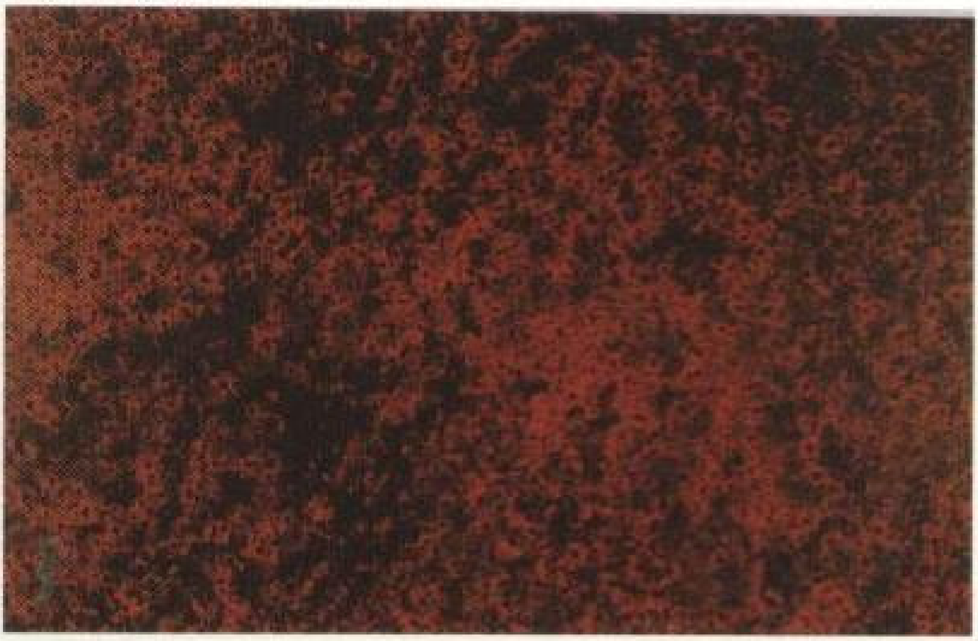
Fifteen photographs show the three degrees of preparation (Wa 1, Wa 2 and Wa 2½) for each of the original conditions.

Three photographs show the flash rusting degrees FR1, FR2 and FR3.





INITIAL SURFACE CONDITION DC1

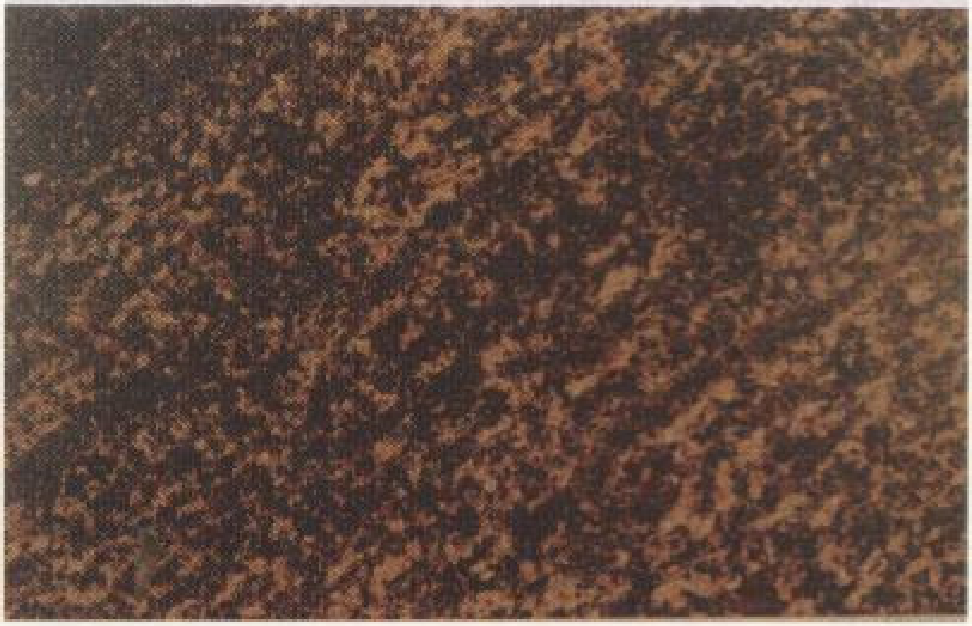


20mm

DC1 Wa 1

20mm

DC1 Wa 2



20mm

DC1 Wa $2^1/_2$

20mm

INITIAL SURFACE CONDITION DC2

20mm

DC2 Wa 1

20mm

DC2 Wa 2

20mm

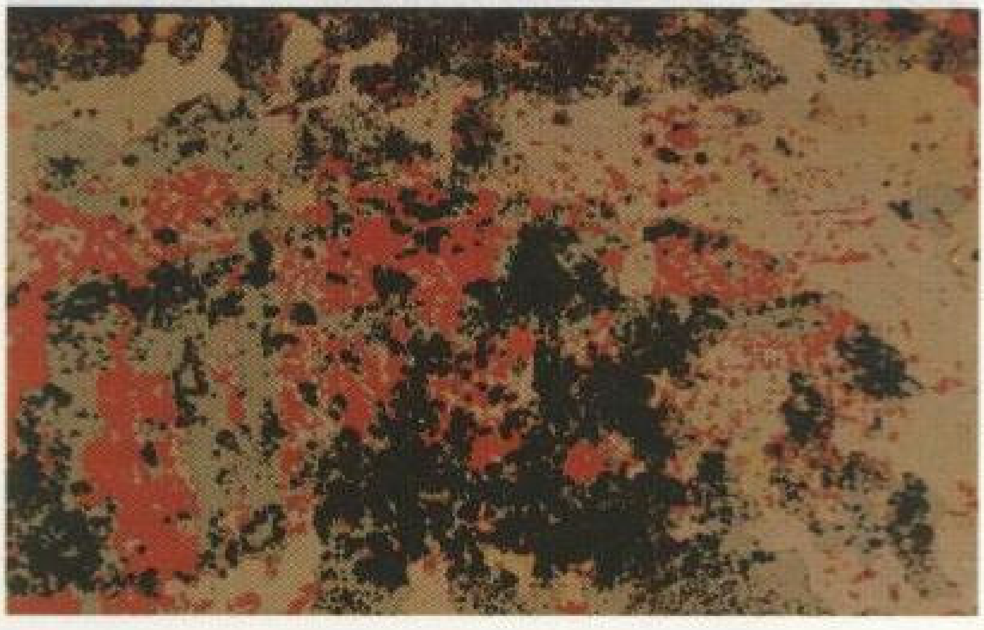
DC2 Wa 2$^1/_2$

20mm

INITIAL SURFACE CONDITION DC3

20mm

DC3 Wa 1



20mm

DC3 Wa 2

20mm

DC3 Wa 2½

20mm

INITIAL SURFACE CONDITION DS1

20mm

DS1 Wa 1

20mm

DS1 Wa 2

20mm

DS1 Wa 2½

20mm

INITIAL SURFACE CONDITION DS2

20mm

DS2 Wa 1

20mm

DS2 Wa 2

20mm

DS2 Wa 2½

20mm

DEGREES OF FLASH RUST

FR1

FR2

FR3

Fitz's Atlas™
of coating defects

6 - COATING DEFECTS

CONTENTS

ADHESION FAILURE

see also delamination and flaking

Other examples are shown on the following page

Description: Paint fails to adhere to substrate or underlying coats of paint.

Probable Causes: Surface contamination or condensation.

Prevention: Ensure that the surface is clean, dry and free from any contamination and that the surface has been suitably prepared. Use the correct coating specification.

Repair: Depends upon the extent of adhesion failure. Removal of defective areas will be necessary prior to adequate preparation and application of correct coating system to manufacturer's recommendations.

ADHESION FAILURE

see also delamination and flaking

ADHESION FAILURE

see also delamination and flaking

ALLIGATORING

(also known as Crocodiling)

Description: Very large (macro) checking or cracking which resembles the skin of an alligator or crocodile. Cracks may penetrate through to the undercoat down to the substrate.

Probable Causes: Internal stresses in the coating where the surface shrinks faster than the body of the paint film. Can be caused by excessive film thickness and limited paint flexibility. Also found on paint films having a soft undercoat with a hard topcoat.

Prevention: Use correct coating specification and materials. Avoid excessive thickness. Avoid application at high ambient temperatures.

Repair: Repair will depend upon size and extent of alligatoring. Abrade or remove all affected coats and apply suitable undercoat and topcoat. Follow recommended application procedures.

ALUMINIUM CORROSION

Description: Blistering of the paint coating due to aluminium corrosion product under the paint.

Probable Causes: Pinholes in the coating. Porosity of flame sprayed aluminium. Insufficient coating thickness.

Prevention: Use correctly formulated coating system applied in the correct thickness.

Repair: Blast clean and recoat.

BITTINESS

(also known as Peppery, Seedy or Seediness)

Description: Film contaminated by particles of paint skin, gel, flocculated material or foreign matter, which project above the surface of the paint film to give a rough appearance. The term Peppery is used when the bits are small and uniformly distributed.

Probable Causes: The main cause is contamination within or on the surface of the paint film. This can be paint skin, gelled particles, airborne sand and grit or contamination from brushes, rollers etc.

Prevention: Use clean application equipment and clean working environment. Use new, uncontaminated paint. Follow good painting practices.

Repair: Repair depends on size and extent of problem. Abrade or completely remove the contaminated layer and recoat.

BLEACHING

see also Fading

Description: Total loss of colour of a coating.

Probable Causes: Bleaching due to weathering or chemical attack.

Prevention: Use colour stable pigments or a system which will withstand the chemical environment.

Repair: Remove bleached coating or abrade and recoat using a more suitable coating system.

BLEEDING

also called 'Bleed Through'

Description: Staining of a paint film by diffusion of a soluble coloured substance from the underlying paint to give undesirable discoloration or staining . Very often, this is seen where bitumen or tar based products are over-coated with alkyd based or other conventional topcoats. Also occurs with emulsion paints.

Probable Causes: 'Bleed Through' is generally a full or partial redissolving of the previous coat. Bleeding can happen when strong solvents are used in the topcoats.

Prevention: Use correct coating specification and materials. Use compatible materials. Use appropriate sealer coat.

Repair: Remove stained or contaminated layer. Apply a suitable sealer coat which will not dissolve soluble material e.g. an aluminium pigmented coating.

BLISTERING

Other examples are shown on the following page

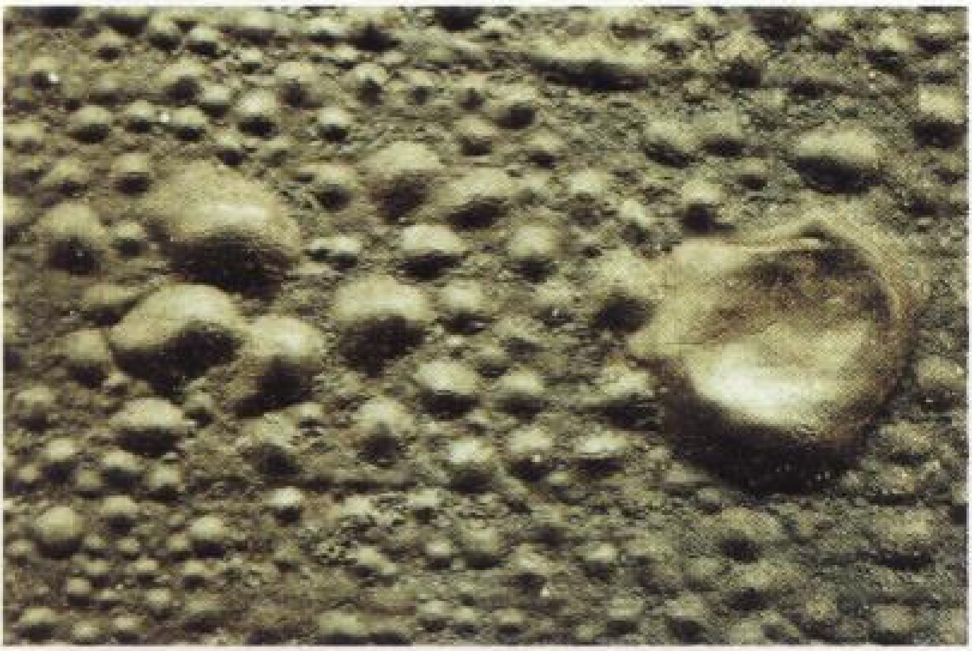
Description: Dome shaped projections or blisters in the dry paint film through local loss of adhesion from the underlying surface. Blisters may contain liquid, gas or crystals.

Probable Causes: Localised loss of adhesion caused by contamination with grease, oil, salts, rust, trapped moisture, retained solvent, hydrogen vapour pressure (on coatings used with cathodic protection), soluble pigments etc. Osmotic blistering can also occur in immersed conditions.

Prevention: Ensure correct surface preparation and application. Apply a suitable coating system.

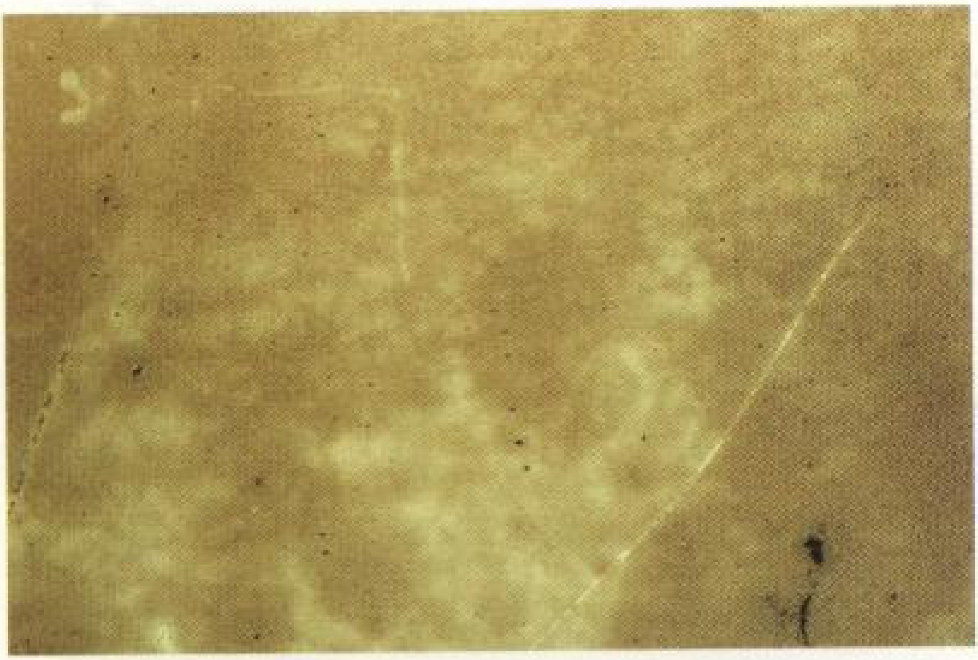
Repair: Depending upon size and type of blistering, remove blistered areas or entire coating system and repair or fully recoat.

BLISTERING



BLISTERING

BLOOM



Description: A hazy deposit on the surface of the paint film resembling the bloom on grape, resulting in a loss of gloss and a dulling of colour.

Probable Causes: Paint film exposed to condensation or moisture during curing (common phenomenon with amine cured epoxies). Incorrect solvent blend can also contribute to blooming.

Prevention: Apply and cure coating systems under correct environmental conditions and follow the manufacturer's recommendations.

Repair: Remove bloom with clean cloth or suitable solvent cleaners. If necessary, apply undercoat/topcoat following manufacturer's recommendations.

BRIDGING

Another example is shown on the following page

Description: The covering over of unfilled gaps such as cracks or corners with a film of coating material. This causes a weakness in the paint film which may crack, blister or flake off.

Probable Causes: Poor application. High viscosity paint system. Failure to brush paint into corners and over welds.

Prevention: Brush apply a stripe coat into corners and welds, and fill all cracks prior to application of the full coating system.

Repair: Remove all loose paint, abrade the surface, apply a stripe coat by brush and recoat.

BRIDGING

BRUSH MARKS

(also Laddering, Ladders or Ropiness)

Description: Undesirable ridges and furrows which remain in a dry paint film after brush application, where the paint film has not flowed out. May be found as a cross-hatch pattern (Laddering) where alternate coats have been applied in opposite directions. Pronounced brush marks are known as Ropiness.

Probable Causes: Viscosity of material may be too high for brush application; Incorrect thinners used in the paint; Inadequate mixing or poor application technique. Two-pack paints may have exceeded application pot-life.

Prevention: Use brushing grade of paint and apply adequate thickness. Thin paint to brushing viscosity. Use within pot-life

Repair: Depending on extent of brush marks, thoroughly abrade surface and recoat with a suitable viscosity paint.

BUBBLES OR BUBBLING

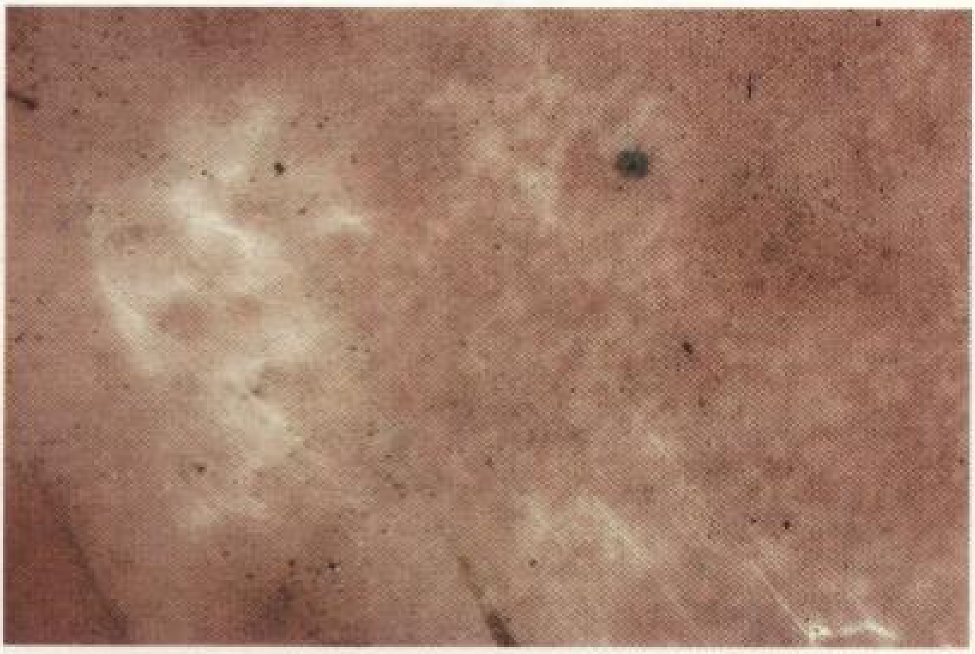
Description: Bubbles within a paint film appear as small raised blisters. These may be intact or broken (to leave a crater). Can be found in excessively thick paint films, especially if spray applied, and also with roller application. This should not be confused with blistering.

Probable Causes: Trapped air/solvent within the coating which is not released before the surface dries. Can be found with factory applied coatings where application is by dipping, electrodeposition or roller coating.

Prevention: Spray application - use airless spray equipment, adjust viscosity with thinners or modify spray temperature. Use correct mixing equipment to ensure air is not stirred in during mixing. Add defoaming agent to emulsion paints.

Repair: Depending on extent and severity of bubbling, abrade or remove the offending coat(s) and recoat.

CHALKING



Other examples are shown on the following page

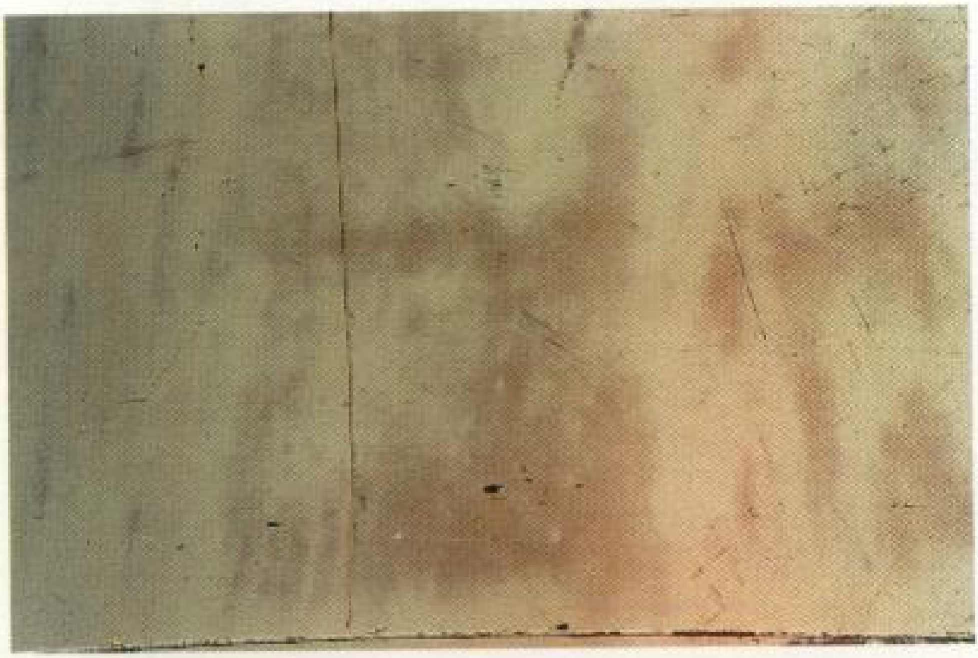
Description: A friable, powdery layer on the surface of a paint film. A change of colour or fading is also seen. Chalking rates vary with pigment concentration and choice of binder. Chalking is a known characteristic of certain paints e.g. epoxy paints.

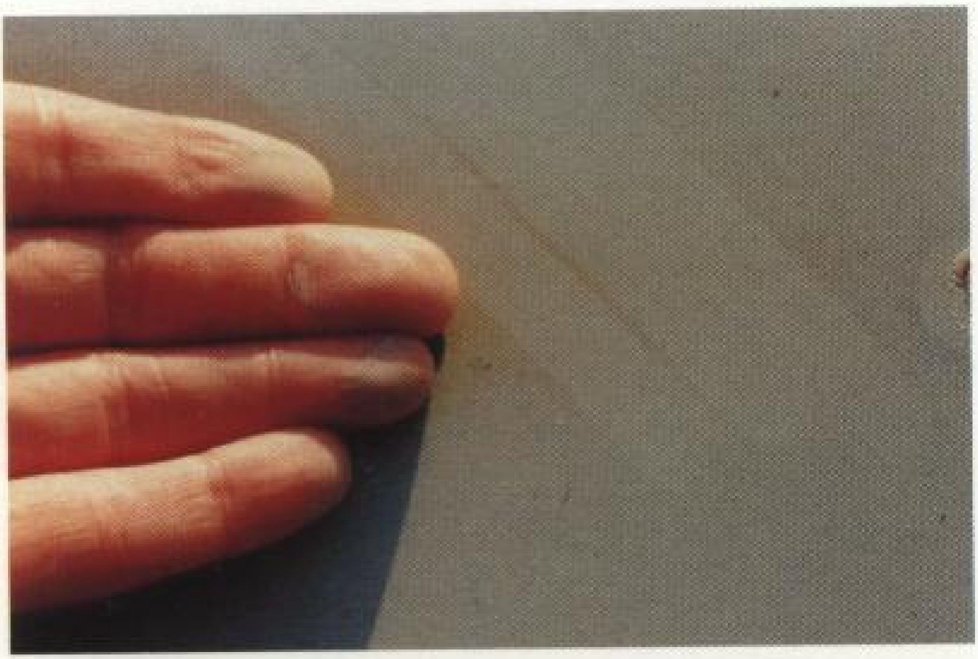
Probable Causes: Disintegration of the paint binder on exposure to weathering and/or UV light.

Prevention: Apply a suitable topcoat with high resistance to chalking, and UV resistance.

Repair: Remove all powdery deposits by abrasion or light sweep blast cleaning, wipe loose material off and apply a chalk resistant topcoat.

CHALKING





CHECKING

(see also cracking)

Other examples are shown on the following page

Description: Fine cracks which do not penetrate the topcoat of a paint system. Some checking can be so minute that it is impossible to see without magnification.

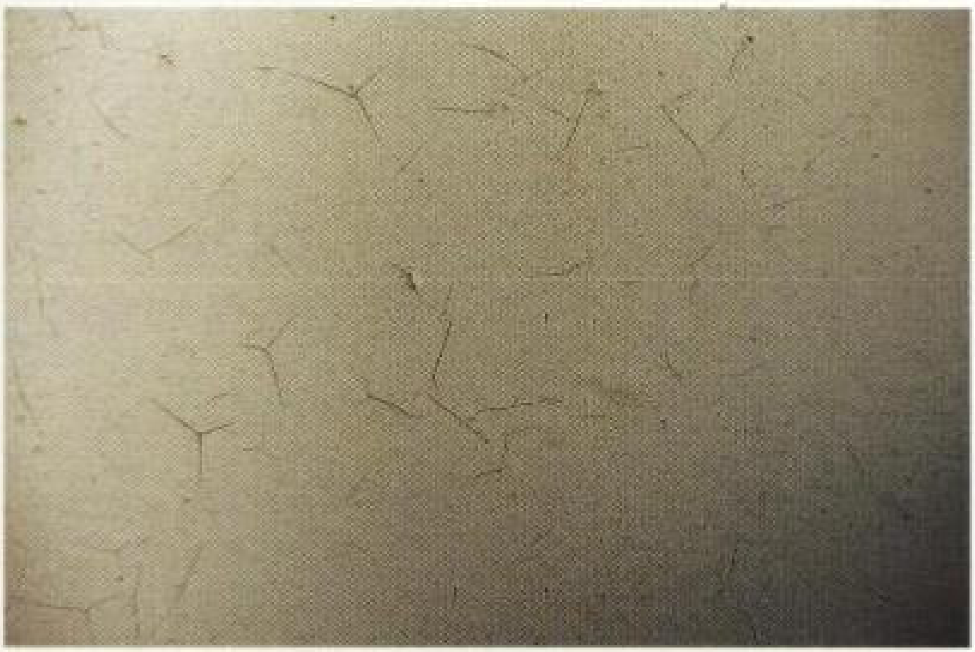
Probable Causes: Typically a formulation and/or a specification problem. As with cracking, stresses are developed which cause the surface of the paint film to become brittle and crack. Limited paint flexibility.

Prevention: Use a correctly formulated coating system.

Repair: Abrade and clean surface then apply an undercoat/topcoat to suit.

CHECKING

(see also cracking)



CHECKING

(see also cracking)

CHEESINESS
(Soft Coating)

Description: Coating remains soft, even after prolonged drying time.

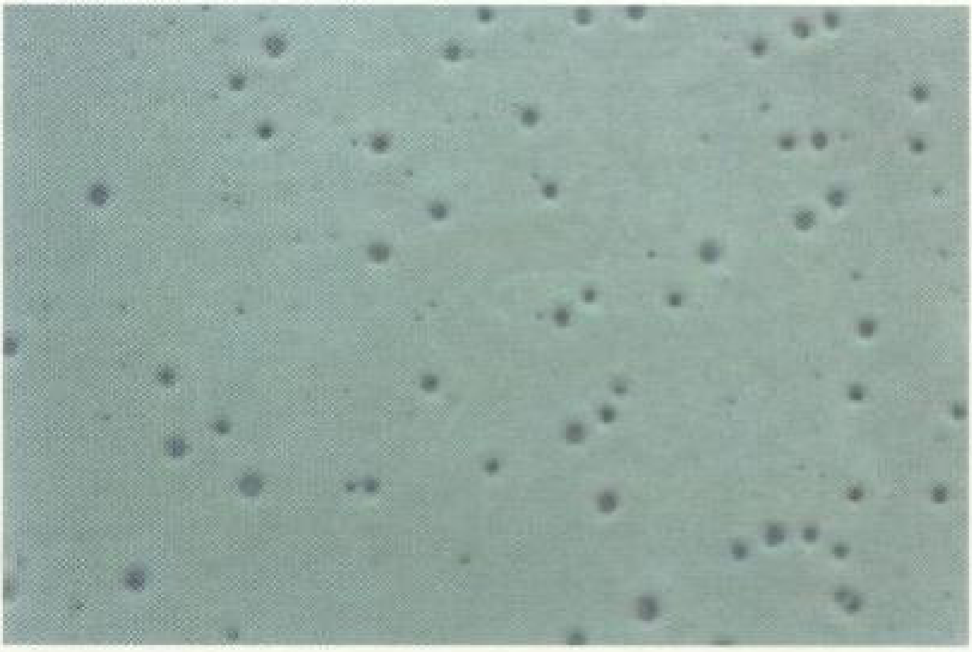
Probable Causes: Wrong mixing ratio for two-pack paints. Too low a drying/curing temperature. Excessive solvent retained within the coating.

Prevention: Ensure adequate mixing of two-pack paints. Only use the recommended amount of thinners. Apply and cure the coating under controlled environmental conditions.

Repair: Remove all soft coatings and apply suitable coating system or topcoat to coating manufacturer's recommendations.

CISSING

also referred to as Crawling and Fisheyes



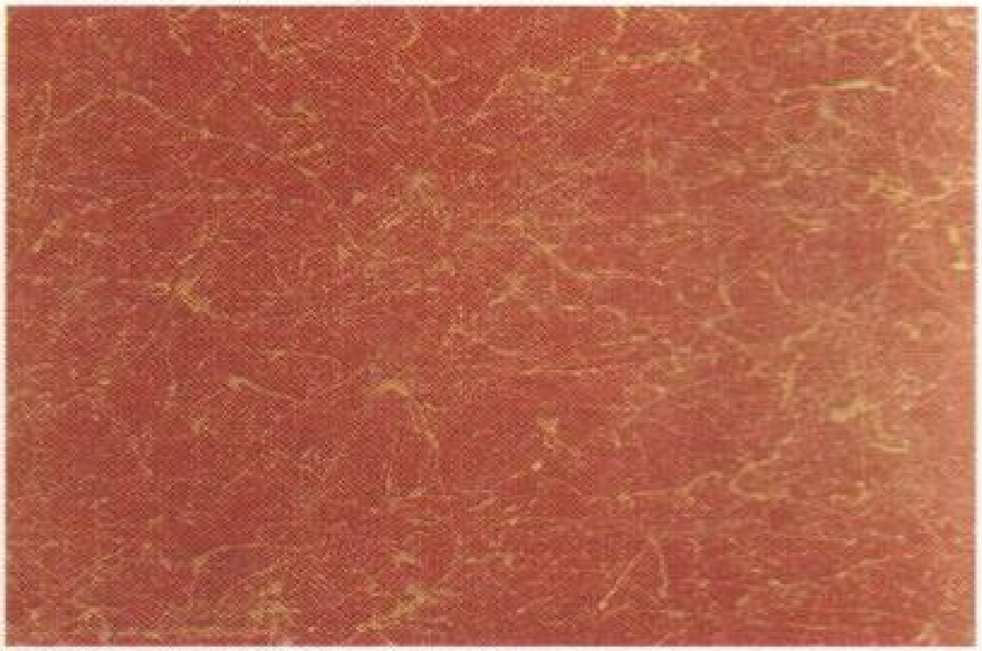
Description: Surface breaks in a wet paint film, where the paint has receded to expose the underlying substrate. Sometimes known as crawling or fisheyes. The paint is unable to wet-out the substrate. Can be very large.

Probable Causes: Surface contamination by either moisture or foreign matter such as oil, grease, silicone etc. Also known to happen when incorrect solvent blends have been used.

Prevention: Ensure surface is clean and free from grease, oil and foreign contaminates prior to application of coating.

Repair: Abrade and thoroughly clean the contaminated surface or remove the coating to achieve a clean surface. Reapply the coating system to the coating manufacturer's recommendations.

COBWEBBING



Description: The production of fine filaments instead of normal atomised particles when some solutions of high molecular weight polymers are sprayed.

Probable Causes: Too high a viscosity with some types of polymer solutions.

Prevention: Reduce the spraying viscosity. Select a more suitable solvent blend. Change the spraying conditions.

Repair: Abrade to remove all affected material and recoat.

CRACKING

(see also Alligatoring and Checking)

Other examples are shown on the following page

Description: Paint coatings with visible cracks which may penetrate down to the substrate. Cracking comes in several forms, from minute cracking to severe cracking.

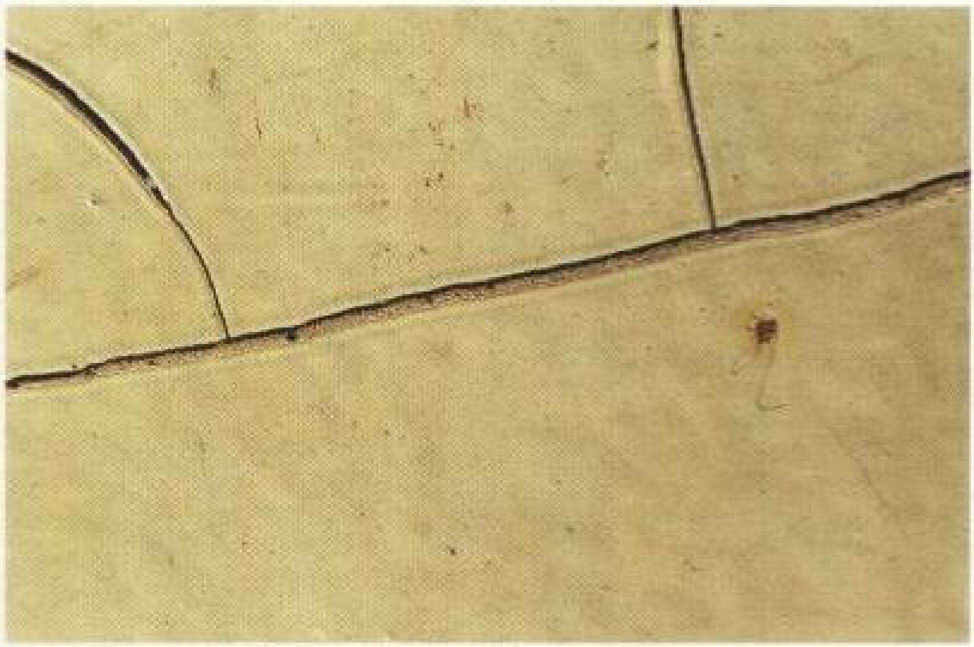
Probable Causes: Cracking is generally a stress related failure and can be attributed to surface movement, ageing, absorption and desorption of moisture and general lack of flexibility of the coating. The thicker the paint film the greater the possibility it will crack.

Prevention: Use correct coating systems, application techniques and dry film thicknesses. Alternatively, use a more flexible coating system.

Repair: Abrade to remove all cracked paint. Correctly reapply the coating system or use a more flexible system and one less prone to cracking.

CRACKING

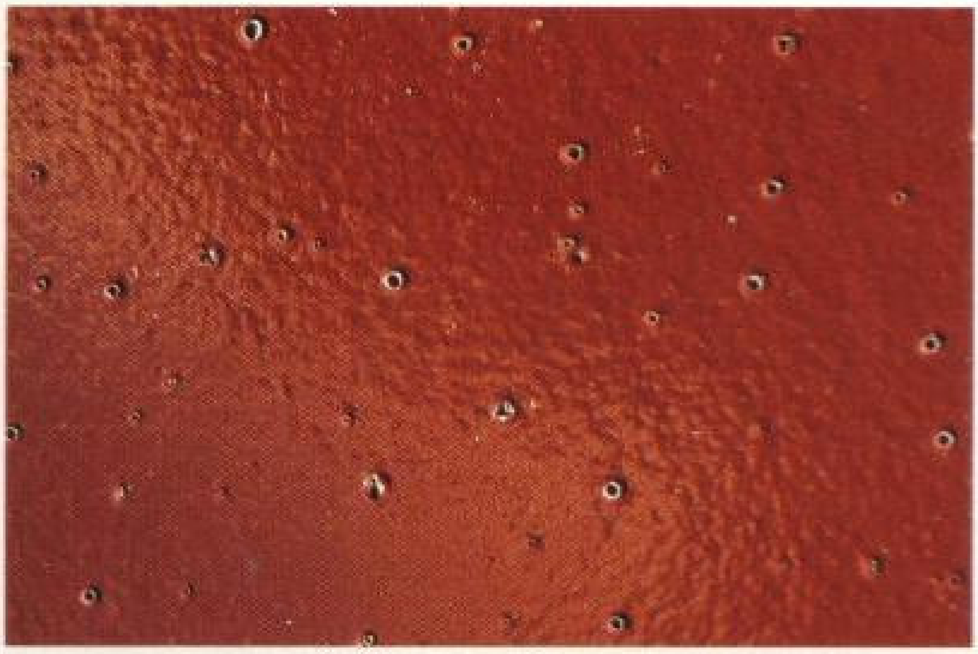
(see also Alligatoring and Checking)



CRACKING

(see also Alligatoring and Checking)

CRATERING



Description: The formation of small bowl shaped depressions in the paint film. Not to be confused with Cissing.

Probable Causes: Trapped air bubbles which have burst to leave small craters as the coating dries. The coating has insufficient time to flow into a uniform film.

Prevention: Improve spray technique to avoid air entrainment. Add thinners as recommended by the paint supplier.

Repair: Abrade and clean the surface and recoat.

CROWSFOOTING

see also Wrinkling

Description: The development of small wrinkles in the paint film which occur in a pattern resembling that of a crow's foot.

Probable Causes: Usually due to the surface drying rapidly to form a skin which then wrinkles as solvent slowly evaporates from the soft underlying paint.

Prevention: Apply a thinner coat of paint, add slower drying thinners, check application and drying conditions are correct for the paint system used.

Repair: Abrade the surface when fully dry and recoat.

DELAMINATION

see also Adhesion Failure and Flaking

Description: Loss of adhesion between coats of paint.

Probable Causes: Provided compatible paint materials have been used, delamination defects are generally related to poor surface preparation and application defects, such as contamination between coats; exceeding overcoat times; application to a glossy surface.

Prevention: Ensure no contamination between paint coats, closely follow intercoat times, lightly abrade and clean glossy surfaces between coats.

Repair: Depending on extent, abrade and recoat or completely remove the delaminated coating and reapply.

DELAMINATION

see also Adhesion Failure and Flaking

DRYSPRAY

see also Overspray

Description: Rough and uneven finish to the surface of the paint film where the particles are insufficiently fluid to flow together and are often poorly adhered.

Probable Causes: Incorrect spray application i.e. gun distance. Also associated with fast drying products and too high an application temperature.

Prevention: Use correct coating application equipment and techniques. Use a slower drying solvent or solvent blend. Follow recommended application procedures.

Repair: Abrade and remove any loose dryspray and re-apply coating or topcoat.

DRYSPRAY

see also Overspray

EFFLORESCENCE

Description: White (powdery) substance on the substrate of concrete, brick, masonry and plaster. The efflorescence, which comes from the migration of salts, lifts the paint from the substrate.

Probable Causes: Soluble salts within the substrate. Moisture brings the salts to the surface of the substrate resulting in coating adhesion failure.

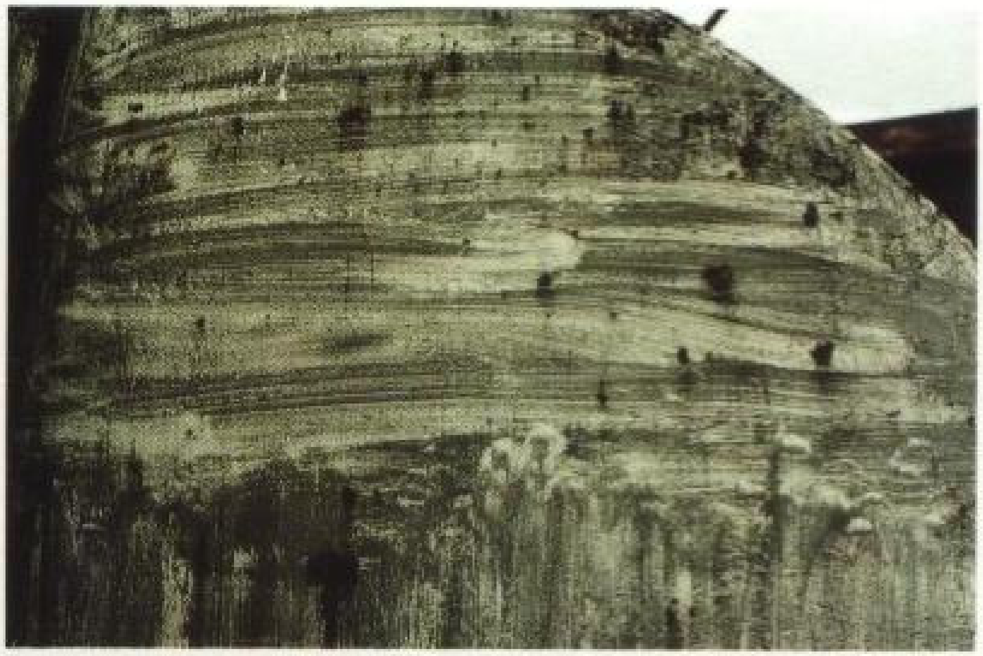
Prevention: Ensure surface is moisture free, clean and suitable for application of the coating system. Remove or eliminate the source of moisture.

Repair: Remove all powdery substances and thoroughly clean the surface. Apply a suitable sealer and coating system formulated for concrete, masonry etc.

EFFLORESCENCE

Close up example

EROSION



Description: Selective removal of paint films from areas or high spots.

Probable Causes: The wearing away of the paint film by various elements such as rain, snow, wind, sand etc. Found to be more prominent on brush applied coatings because of the uneven finish.

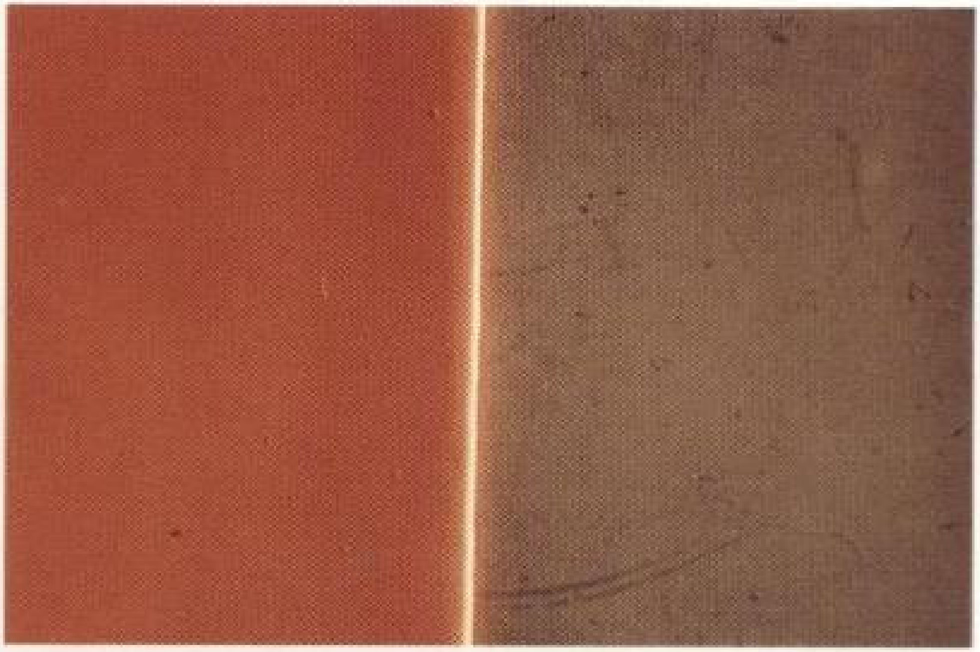
Prevention: Use a suitable coating system with resistance to surface erosion/abrasion.

Repair: Clean surface free from contamination and apply a coating system formulated and tested for the specific environment.

EROSION

FADING

see also Bleaching



Description: Discoloration or gradual decrease in colour of a paint when exposed to sunlight/weather. May be accompanied by loss of gloss. In some situations it may resemble chalking but without the powdery surface. Fading tends to accelerate in the presence moisture.

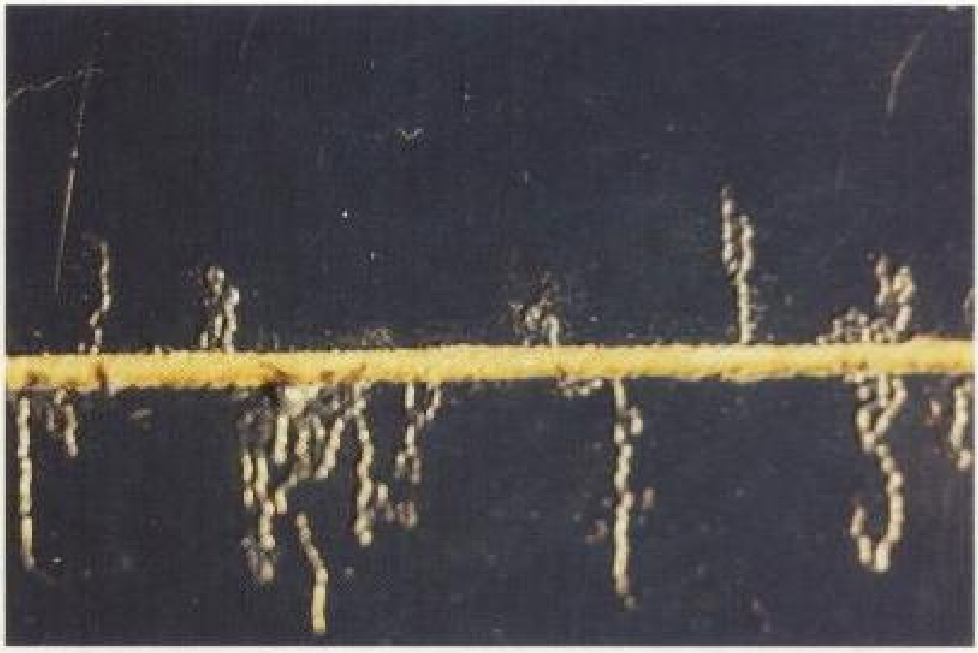
Probable Causes: Incorrect pigmentation; use of organic pigments; atmospheric contamination; porous substrate.

Prevention: Use correct coating systems which resists UV light and fading. Use a coating with light stable pigments.

Repair: Abrade and clean the surface and apply a light stable coating system.

FILIFORM

(Corrosion)



Description: Random threads of corrosion that develop beneath thin lacquers and other coating films from a growing head or point. Often seen on old 'tin' food cans, with thin electro plating but also seen on painted aluminium and other surfaces.

Probable Causes: Contamination on the metallic substrate or damage to the coating which allows a corrosion cell to develop at the tip and advance under the coating.

Prevention: Ensure no contamination exists on the substrate prior to coating application.

Repair: Remove all traces of corrosion products and non adhering coatings. Abrade, clean and coat to manufacturer's recommendations.

FLAKING

see also Delamination and Adhesion Failure

Description: A form of adhesion failure where paint literally flakes from the substrate. A familiar sight on wood substrates and on galvanising.

Probable Causes: Incorrect paint system used. Either none or incorrect pre-treatment used for certain substrate i.e. non-ferrous or galvanised. Also poor application techniques. May also be attributed to differential expansion and contraction of paint and substrate e.g. wood. Can be the result of ageing of the paint system.

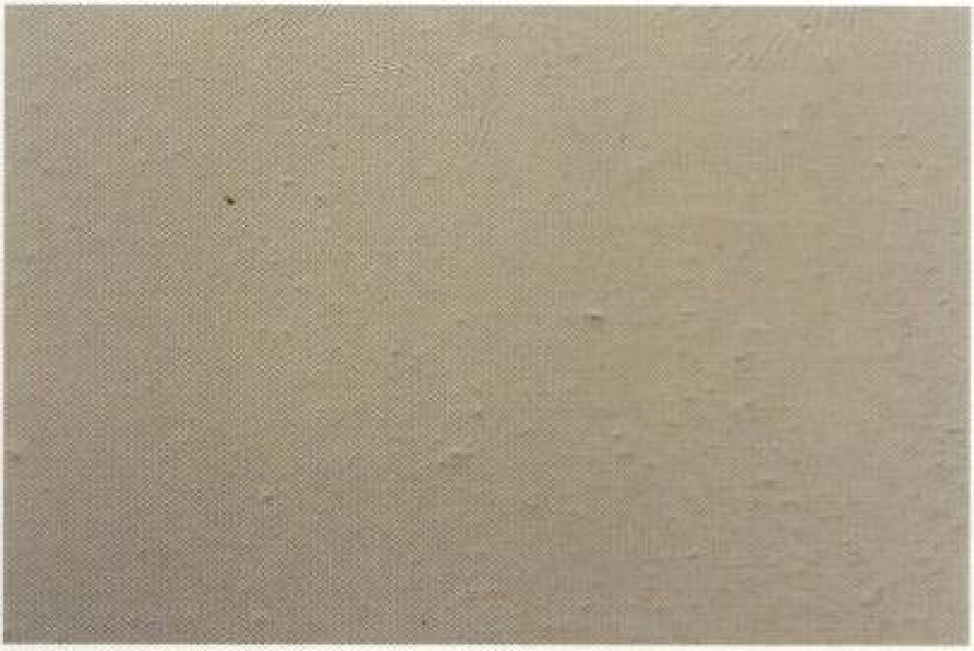
Prevention: Use correct coating system and pre-treatment.

Repair: Remove all flaking coating until a firm edge can be achieved. Abrade, sweep blast and clean overall and apply suitable coating system to coating manufacturer's recommendations.

FLAKING

see also Delamination and Adhesion Failure

FLOCCULATION



Description: The development of loosely coherent pigment agglomerates in a coating material.

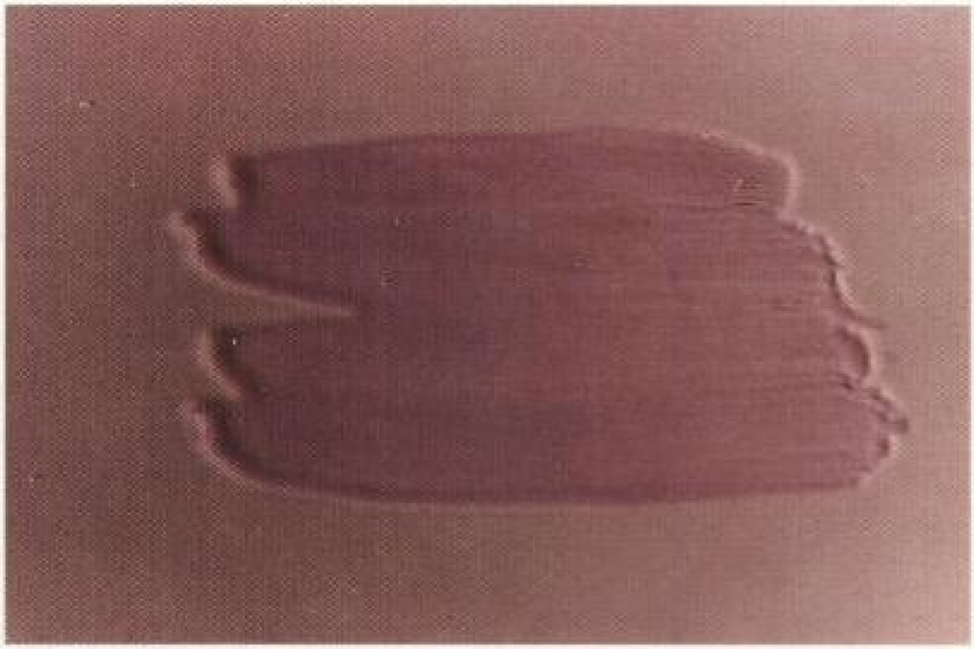
Probable Causes: Non-uniform pigment dispersion which results in the pigments forming agglomerations. Unsuitable thinners or inadequate mixing.

Prevention: Ensure only properly formulated and mixed products are used. Use recommended thinners.

Repair: Remove coating where flocculation is visible. Abrade and clean the surface and apply a properly formulated and mixed coating system.

FLOODING

see also Flotation



Description: A defect which appears soon after application due to pigment separation. The visual appearance is a deepening of the colour. The affected area dries to a deeper shade than the remainder of the surface.

Probable Causes: Pigment separation and settlement.

Prevention: Use correctly formulated products.

Repair: Lightly abrade and clean and then recoat with a suitably formulated material.

FLOTATION

see also Flooding

Description: Occurs in coloured materials containing mixtures of different pigments. It closely resembles flooding, although a mottled or streaky effect is produced when the different pigments separate.

Probable Causes: The mottled effect, which is visible to the eye, is caused by separation of the different coloured pigments. It may also result from the addition of excessive thinners.

Prevention: Use correctly formulated products. Do not over thin with solvent.

Repair: Abrade and clean overall and apply a suitable sealer or topcoat.

GRINNING

or 'Grinning Through'

Description: The underlying surface is visible through the paint film due to inadequate hiding power of the coating material. This is sometimes called 'Grinning-Through'. Often seen where dark colours are overcoated with lighter colours.

Probable Causes: Low film thickness of penultimate coat. Poor opacity and covering power of topcoat coat. Strong colour of primer/ undercoats.

Prevention: Apply adequate dry film thickness between individual coats. Use opaque coatings with good covering properties.

Repair: Apply additional compatible coats to clean surface.

GRIT INCLUSIONS

Description: Particles of grit and dust embedded within the coating system.

Probable Causes: Failure to remove used grit from the surface prior to application of the paint. Contamination of the wet primer or undercoat with grit from other blast cleaning operations. Wind blown grit particles adhering to the topcoat.

Prevention: Ensure all used grit is removed before application of fresh paint. Do not carry our blast cleaning whilst there is wet paint on nearby surfaces. Ensure than all cans of paint and brushes etc. are protected during blast cleaning operations.

Repair: Abrade or blast clean the surface to remove all grit contamination, thoroughly clean the surface and recoat.

GROWTH

(on the surface of paint film)

Description: Growth and attachments of natural and organisms to surface of finished products. These vary in form, size and lifespan, e.g. algae, mosses etc.

Probable Causes: Generally, natural organisms within moist, wet or immersed conditions. Growth may continue after attachment.

Prevention: Use correct coating specification and products suitable for the environment. Where practical, clean regularly to prevent build-up of moss and algae.

Repair: Clean and remove all growth, abrade the surface and apply a suitable coating system.

INCORRECT COATING SYSTEM

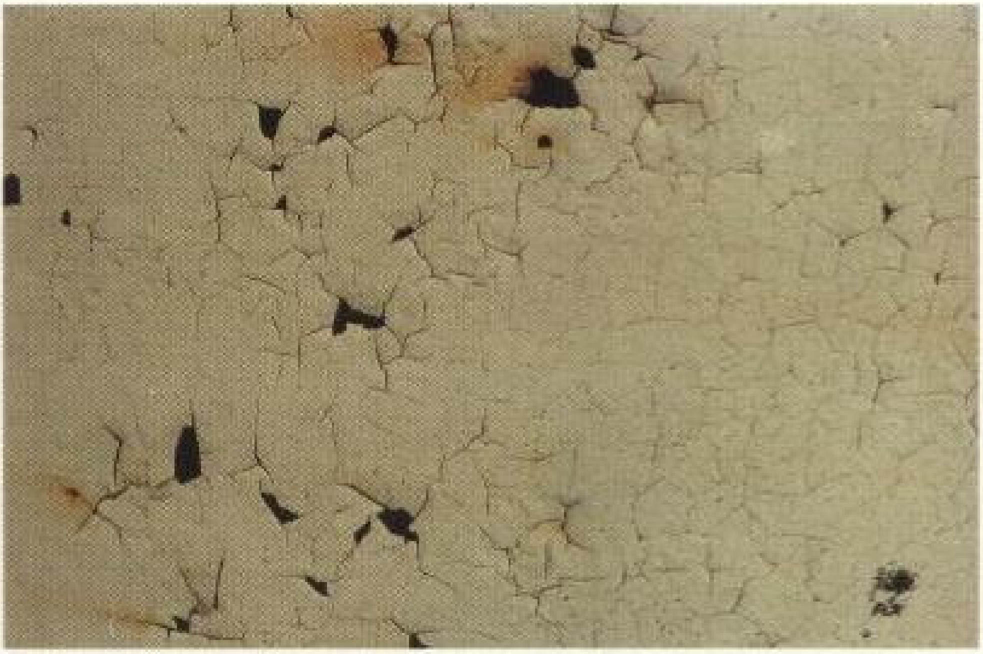
Description: An unsuitable or incompatible coating system has been used which results in rapid failure.

Probable Causes: Use of incompatible or unsuitable coating materials.

Prevention: Use correct coating specification and materials. Ensure that different coats are compatible with each other.

Repair: Remove all defective coating and apply correct coating system to manufacturer's recommendations.

INCORRECT COATING SYSTEM



IMPACT DAMAGE

(Star cracking)

Description: Cracks which radiate from a point of impact.

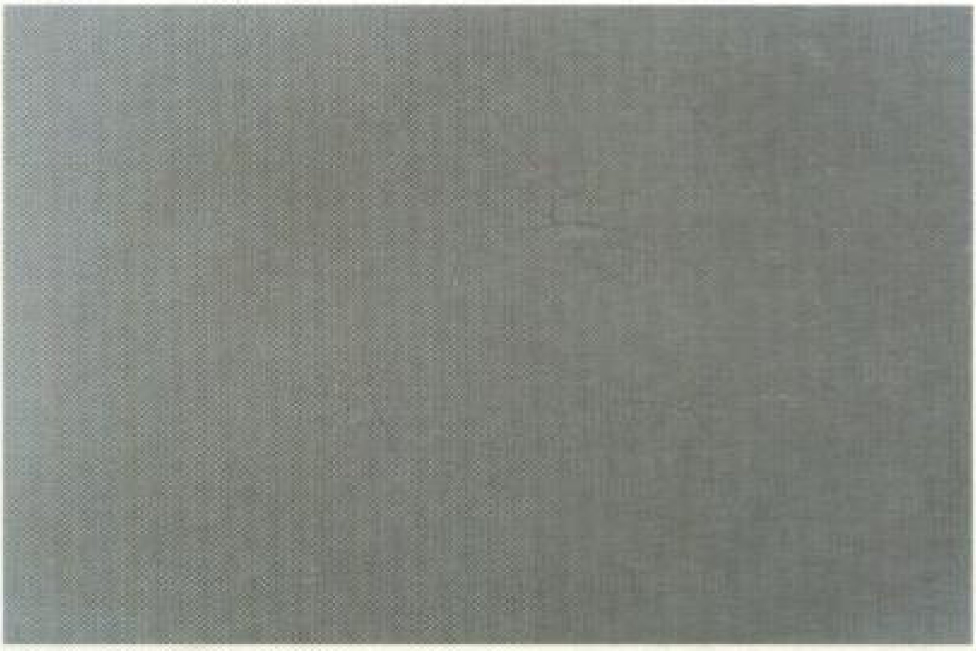
Probable Causes: Impact damage to a relatively brittle coating. Often see on glass fibre reinforced plastics.

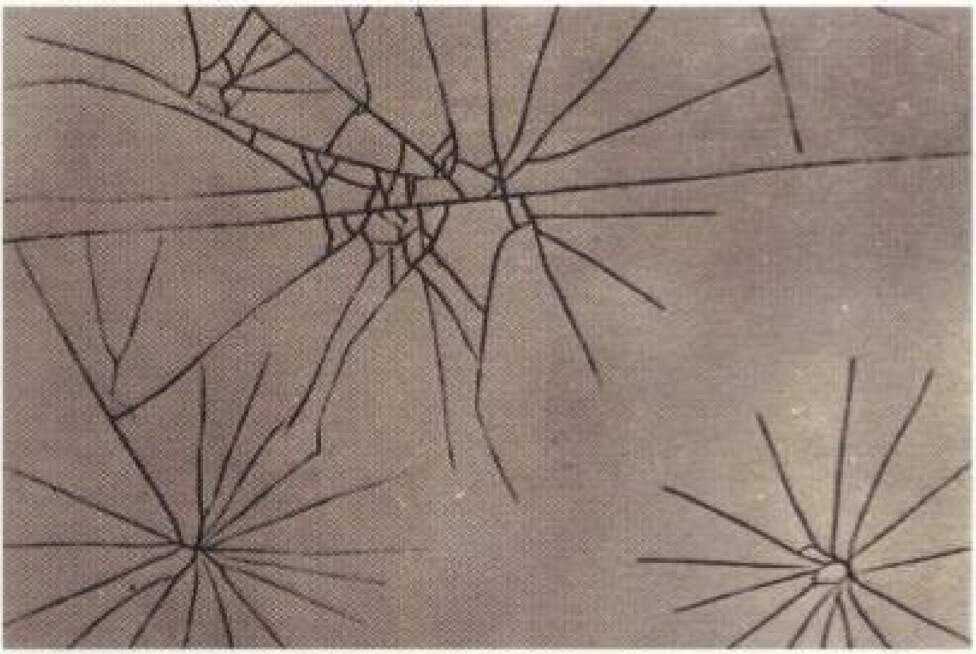
Prevention: Prevent impact damage.

Repair: Abrade all damaged areas and recoat.

IMPACT DAMAGE

(Star cracking)





LAMINATIONS OR SHELLING

(of cast iron)

Description: The photograph shows flaking or shelling of sections of cast iron from the surface which have been overpainted and which have led to subsequent rust staining.

Probable Causes: Failure to remove or treat delaminated sections prior to application of the coating system.

Prevention: Ensure proper surface preparation is carried out.

Repair: Grind all laminations to remove them, blast clean the surface and recoat.

MISSES/SKIPS/HOLIDAYS

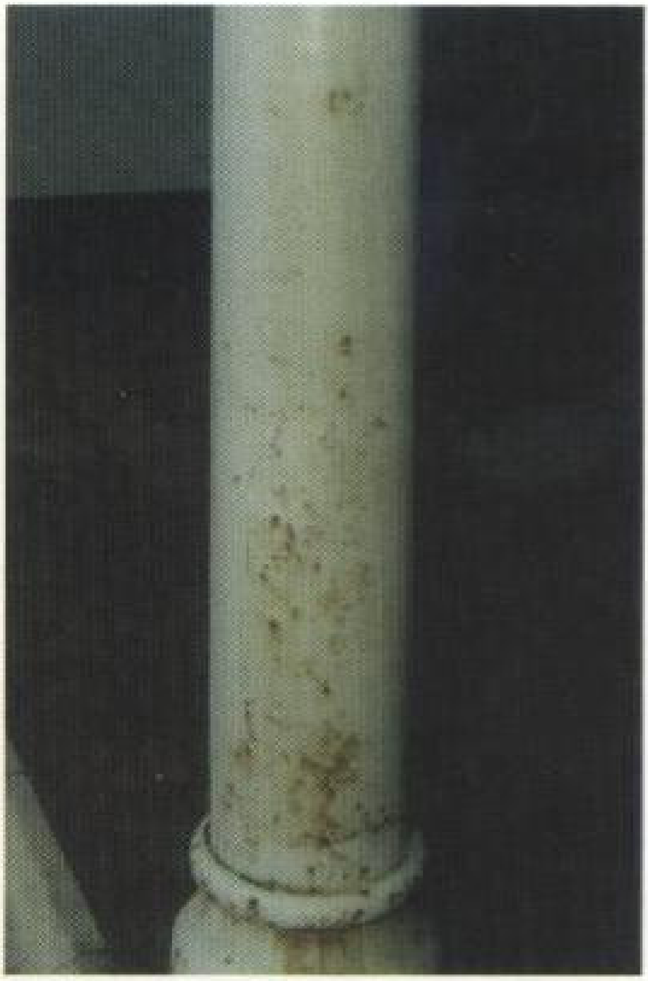
Description: Exposed areas of substrate when the intention was to coat the entire area. Could be confined to a single coat in a multi-coat paint system.

Probable Causes: Poor application techniques. Lack of quality control.

Prevention: Use correct application techniques. Apply good painting practices. Use qualified inspectors.

Repair: Apply coatings to suitable prepared and cleaned substrates to original specification and manufacturer's repair procedures.

MISSING TOPCOAT



Description: Failure to apply the topcoat leaving the undercoat exposed.

Probable Causes: Poor coating application and quality control. Inadequate dry film thickness.

Prevention: Thoroughly inspect all surfaces to ensure each coat has been correctly applied.

Repair: Abrade the surface and either apply the topcoat, or an additional undercoat and topcoat, in accordance with the paint suppliers recommendations.

MUD CRACKING

Description: The dried paint film has the appearance of a dried-out mud bath. Cracks vary in size and amount but form a network of cracks.

Probable Causes: Generally over application of heavily pigmented primers such as inorganic zinc silicates or water based coatings, although can occur with other over thick systems.

Prevention: Only apply the recommended coating thickness. Use recommended application techniques with suitably formulated products.

Repair: Remove all cracked and flaking paint back to a sound base. Abrade and clean surface. Re-apply coating to manufacturer's recommendations.

ORANGE PEEL

also known as Pock-marking

Description: The uniform pock-marked appearance, in particular of a sprayed paint film in which the surface of the paint film resembles the skin of an orange.

Probable Causes: Failure of the paint film to flow out. Usually caused by poor application techniques or by incorrect solvent blend.

Prevention: Use correct application techniques with suitably formulated products.

Repair: Where aesthetics are of concern, abrade overall, clean and recoat.

ORANGE PEEL

also known as Pock-marking

OVERSPRAY

see also Dryspray

Description: Small particles of paint adhering to the surface of the previous dry coat, generally adjacent to the area being sprayed. Often appears as a pebbly surface. Similar to dry spray.

Probable Causes: Particles of wet paint falling outside the spray pattern. Solvent evaporates too rapidly. Spray application under windy conditions.

Prevention: Spray paint under suitable environmental conditions. Adjust spray pattern to minimise overspray onto dry paint.

Repair: Before cure or drying: remove by dry brushing followed by solvent wipe. After cure: abrade and apply another coat.

PEELING

see also Flaking

Another example is shown on the following page

Description: Similar to flaking, although peeling tends to produce soft and pliable coatings which can be pulled away from or spontaneously flake away from the substrate or from between coats, due to loss of adhesion.

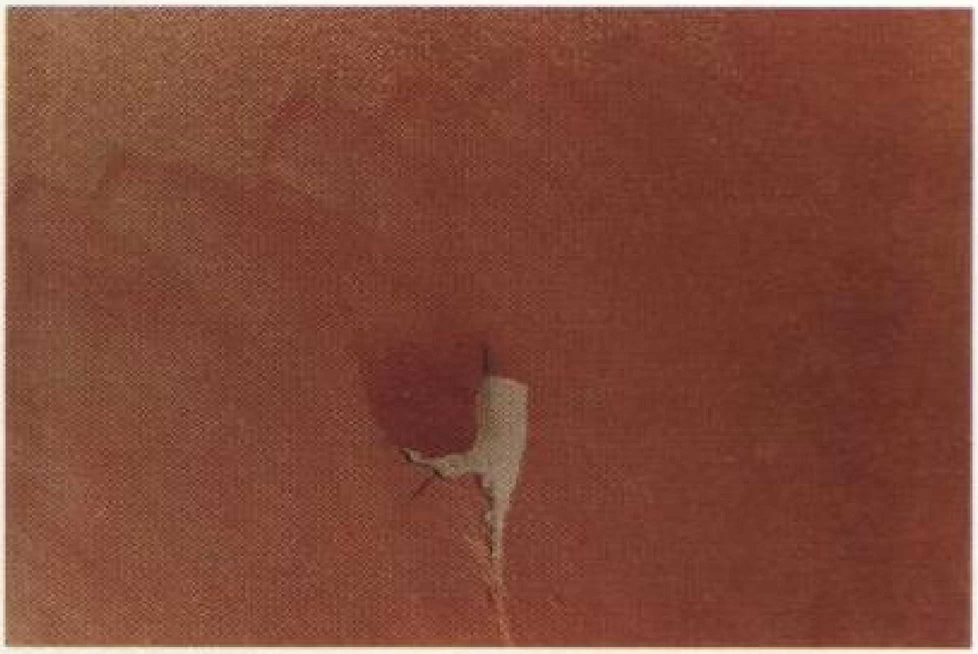
Probable Causes: Peeling is the reduction in bond strength of the paint film due to contamination or incompatibility of coats.

Prevention: Use correct coating system and specification applied to clean and uncontaminated surfaces.

Repair: Remove all soft and pliable coating back to a firm edge or total removal. Abrade, clean and apply suitable coating system to coating manufacturer's recommendations.

PEELING

see also Flaking



PINHOLES

Another example is shown on the following page

Description: The formation of minute holes in the wet paint film during application and drying, due to air or gas bubbles which burst, giving rise to small craters or holes which fail to coalesce before the film dries.

Probable Causes: Solvent or air entrapment within a paint film. A common problem when coating porous substrate such as zinc filled primers, zinc silicates and metal sprayed coatings etc. Pinholes can also be caused by incorrect spray application or incorrect solvent blend.

Prevention: Use correct application techniques with suitably formulated products. Correct solvent blends and environmental conditions. Check spray equipment and distance of spray gun from the surface.

Repair: Abrade, clean overall and apply suitable tiecoat/undercoat and topcoat as necessary.

PINHOLES

RAIN DAMAGE - WATER SPOTTING

Description: Craters and water marks on the surface of the paint film caused by rain or heavy condensation.

Probable Causes: Rain falling on a freshly painted surface causes craters to form on the surface before it has hardened sufficiently.

Prevention: Allow coating (where practicable) to surface harden prior to exposure to rain or heavy condensation.

Repair: Abrade, clean all surface damage areas and apply overall undercoat/topcoat.

RIPPLED COATING

Description: A rippled effect on the surface of the paint.

Probable Causes: Strong wind blowing across the surface of wet paint causes it to ripple. Where this is on the underside, the ripples can hang down in the form of small stalactites. Can also be caused by poor application techniques.

Prevention: Do not apply paint under unfavourable conditions. Use correct application equipment and workmanship.

Repair: When mild ripples are seen, abrade the surface and recoat. Where this is a major effect, remove the coatings and recoat.

ROT
(wood)

Description: Damp and rotten wood exposing friable substance, splitting, flaking and cracking of paint.

Probable Causes: Generally poor maintenance or application over soft and rotten wood. Occasionally, use of incorrect paint system.

Prevention: Correct and ongoing maintenance to the wood and coating. Ensure all wooden surfaces are sound and free from rot before application of paint.

Repair: Replace rotten wood, preferably with treated wood. Apply a suitable coating system formulated for wood surfaces.

RUNS OR SAGS

also described as curtains or wrinkles

Description: Downward movement and tears of paint which appear soon after application to vertical surfaces due to excessive paint application. In severe situations it may be described as curtains.

Probable Causes: Over application of paint, excessive thinners, wrong (lack) of curing agent or just poor workmanship. Could, in extreme circumstances, be a formulation problem.

Prevention: Use correct application techniques with suitably formulated products.

Repair: While the paint is still wet, brush out runs and sags. When the paint has dried, abrade and clean defective areas and apply overall coat or spot repair, as necessary.

RUNS OR SAGS

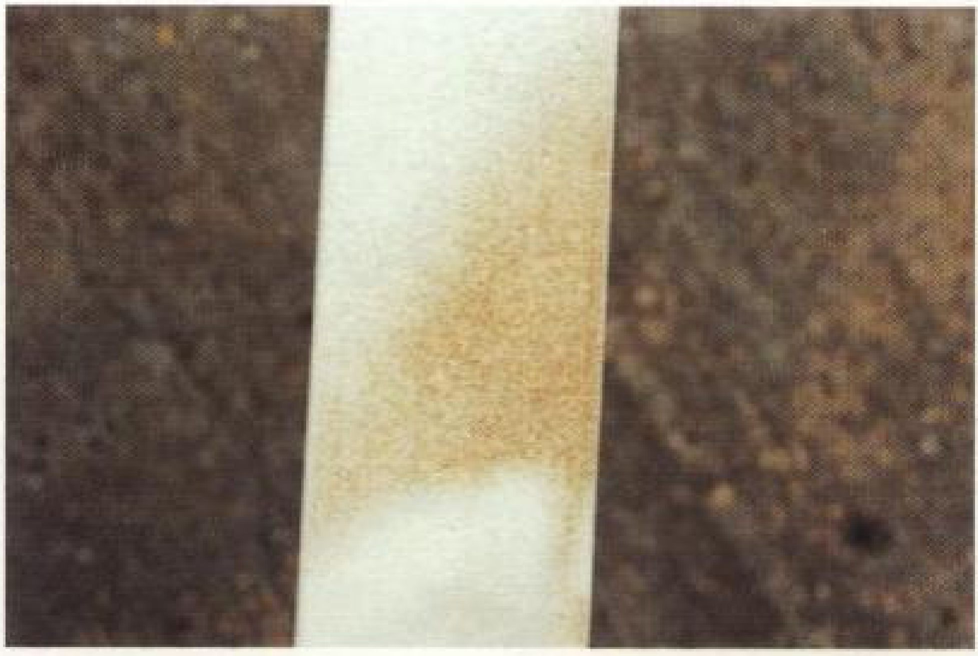
also described as curtains or wrinkles

Other examples are shown on the following page

RUNS OR SAGS

also described as curtains or wrinkles

RUST RASHING
to Thermal Spray Coating



Description: Spots of ferrous oxide develop within the pores of a sprayed metal coating. Similar to rust spotting of a paint film.

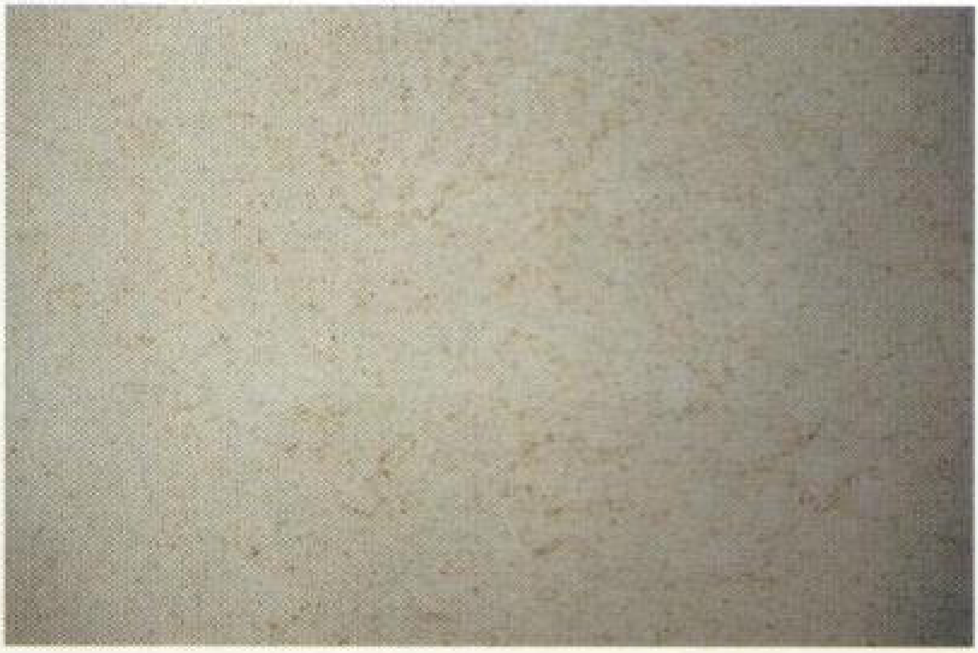
Probable Causes: A phenomenon which can develop on aluminium thermal sprayed coatings soon after application. Moisture is absorbed into the metal coating and reacts with the ferrous substrate. Early sealing with an appropriate coating prevents such events.

Prevention: Apply thermal spray coating in a controlled environment. Seal metal sprayed surface immediately after application.

Repair: Clean rust rashing locations, wire brush, fresh water clean. Providing dry film thickness of the thermal spray is adequate, apply sealer coat to coating manufacturer's recommendations.

RUST SPOTTING

also referred to as rash rusting



Description: Fine spots of rust which appear on a paint film, usually a thin primer coat. This frequently starts as localised spotting but rapidly spreads over the surface.

Probable Causes: Low film thickness, voids and holidays, also defects in the steel i.e. laminations. Too high a surface profile may cause penetration of peaks through a paint film and cause rust spotting. May also occur from metallic contamination of a coated surface by grinding dust etc.

Prevention: Apply an adequate primer coat. Ensure coating system adequately covers the surface profile. Use a thicker coating system or a lower blast profile. Protect coating from contamination with grinding dust etc.

Repair: Depending on type and extent, abrade or blast clean surface and recoat. Remove all foreign debris and abrade, clean damaged areas. Apply spot repair or recoat overall.

RUST SPOTTING
also referred to as rash rusting

Another example is shown on the following page

RUST SPOTTING

also referred to as rash rusting

RUST STAINING

Description: A light staining on the surface of the paint caused by the precipitation of ferrous oxide.

Probable Causes: Water run-off from a rusty surface above a soundly coated surface. Rust staining occurs when the rust is wetted-out and contaminated water runs over and discolours other items or locations. Usually more of an eye-sore than a defect. The coating itself may not be defective, only stained.

Prevention: Adequate design and suitable maintenance.

Repair: Remove staining and apply a cosmetic coating, as necessary.

SAPONIFICATION

Description: The coating appears to be soft and sticky. Can be sporadic isolated spots or an overall effect.

Probable Causes: A soap formation reaction between esters, alkali and water. Often found in alkyd and oil coatings. Notably found on concrete coated structures and coating used in conjunction with cathodic protection.

Prevention: Use correct coating specifications and materials.

Repair: Remove all soft coatings where saponification has occurred, abrade, clean and re-apply undercoat/topcoat (non-saponifiable).

SETTLEMENT

Description: A term used to describe the settled pigment/solids in a liquid prior to application. Found during paint storage. Settlement which occurs after mixing and during application can result in different colours in different areas.

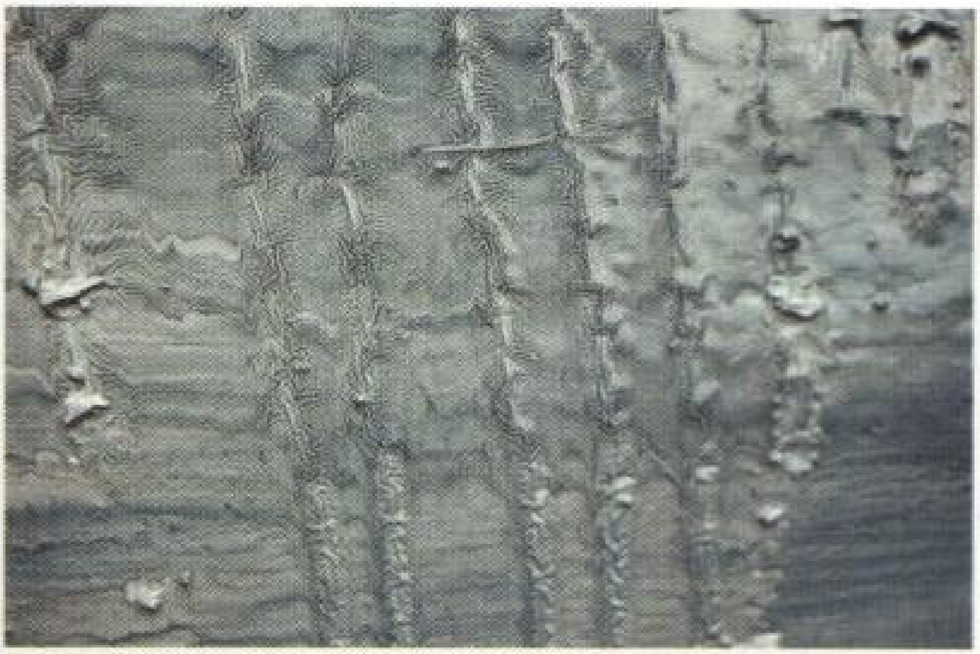
Probable Causes: Old stock, heavily pigmented paint, wrong formulation or contamination of product. Can be a problem with zinc rich primers.

Prevention: Use products within shelf life. Use adequate mixing procedures. Keep paint mixed or recirculated during spray application.

Repair: As Prevention: Where the results is a patchy finish, remove the affected coating and recoat taking precautions against settlement.

SOLVENT LIFTING

see also Wrinkling



Description: Eruption of the surface of the paint film. Wrinkling and blistering which leads to a weak surface and ultimate coating breakdown.

Probable Causes: Incompatible paint systems used. Topcoats with a strong solvent blend can attack previous and weaker solvent blended coatings. Overcoating before the previous coat has adequately hardened.

Prevention: Use correct coating specification, overcoating times and materials. Conduct compatibility trials with undercoat/ topcoats.

Repair: Remove all defective coatings. Abrade, clean and recoat with correct coating system, following the recommended overcoating times.

SOLVENT LIFTING

see also Wrinkling

SOLVENT POPPING

Description: Solvent (clear) bubbles on the surface of the paint film soon after application.

Probable Causes: Incorrect solvent blends, porous surfaces and wrong environmental conditions.

Prevention: Use correct coating specifications and materials. Correct application techniques and environmental conditions.

Repair: Lightly abrade and clean the surface and apply undercoat/topcoat.

TACKINESS

No photograph available

Description: Soft film of applied coatings. Although beyond the wet and liquid stage, the paint film remains as a tacky and soft surface. Sometimes only apparent on touching the substrate.

Probable Causes: There are various reasons why a paint will remain tacky:
- Over thickness;
- Excessive thinners;
- Wrong (lack of) curing agent;
- Low drying/curing temperature;
- Use of coating beyond pot life or shelf life.

Prevention: Use correct coating specifications and materials. Ensure two-pack materials are correctly mixed. Follow paint suppliers recommendations.

Repair: Remove defective coating. Abrade, clean and recoat.

UNDERCUTTING

Description: Visual corrosion beneath a paint film. Corrosion travels beneath the paint film and lifts the paint from the substrate. Severe cases can show as blistering, flaking, cracks and exposed rust.

Probable Causes: Application of paint to corroded substrate. Rust creep from areas of mechanical damage and missing primer coat. Can be found in areas of poor design or access where inadequate preparation and coating thickness was applied. Could also be due to lack of maintenance.

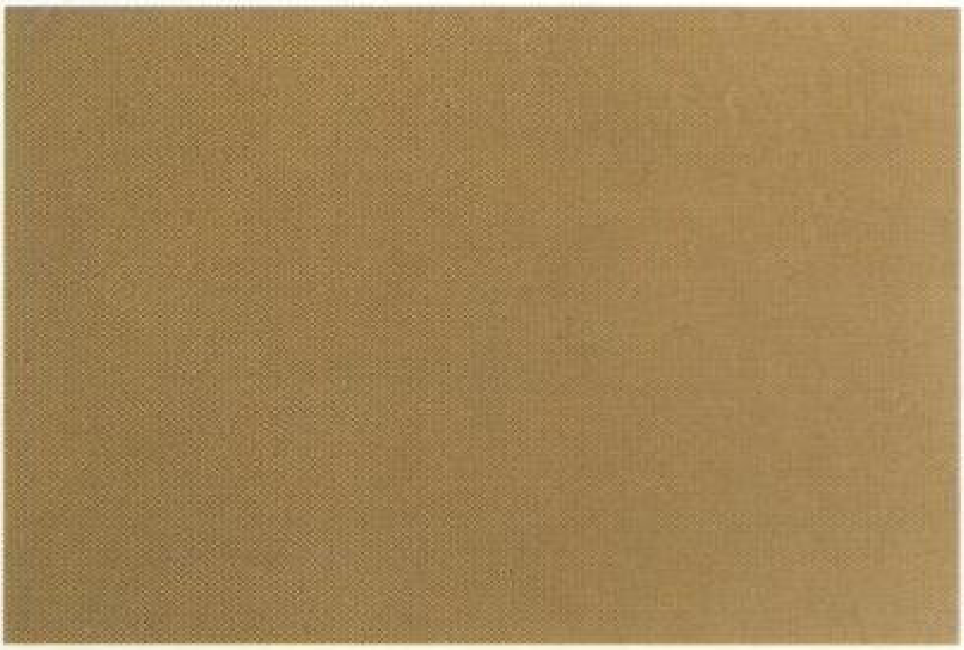
Prevention: Use adequate coating specifications and maintenance procedures. Apply a suitably formulated primer.

Repair: Spot repair localised areas. Clean areas back to sound base, apply suitable repair coating to manufacturer's recommendations.

UNDERCUTTING

WATER SPOTTING

see also Rain spotting



Description: The spotty appearance of the paint film caused by drops of water on the surface and which remains after the water has evaporated. The effect may or may not be permanent.

Probable Causes: Rain drops falling on the wet paint film. These leave permanent marks. Rain drops falling on a freshly dried but hard surface. When the water evaporated, marks may be seen which can be rubbed off.

Prevention: Do not apply paint when rain is threatened.

Repair: Where the marks are just on the surface these may be washed off but where there is cratering or permanent damage to the paint film, abrade the surface and recoat.

WRINKLING

also Rivelling (see also Crow's footing)

Other examples are shown on the following page

Description: The development of wrinkles in the paint film during drying, wrinkling, swelling and blistering of the coating.

Probable Causes: Usually due to the initial formation of a surface skin with solvent based paints. Also swelling of the coating from solvent attack. Can arise from overcoating before the previous coat has adequately hardened.

Prevention: Use correct coating specification and materials. Adequate mixing, application and curing of materials. Follow the paint suppliers recommended overcoating times.

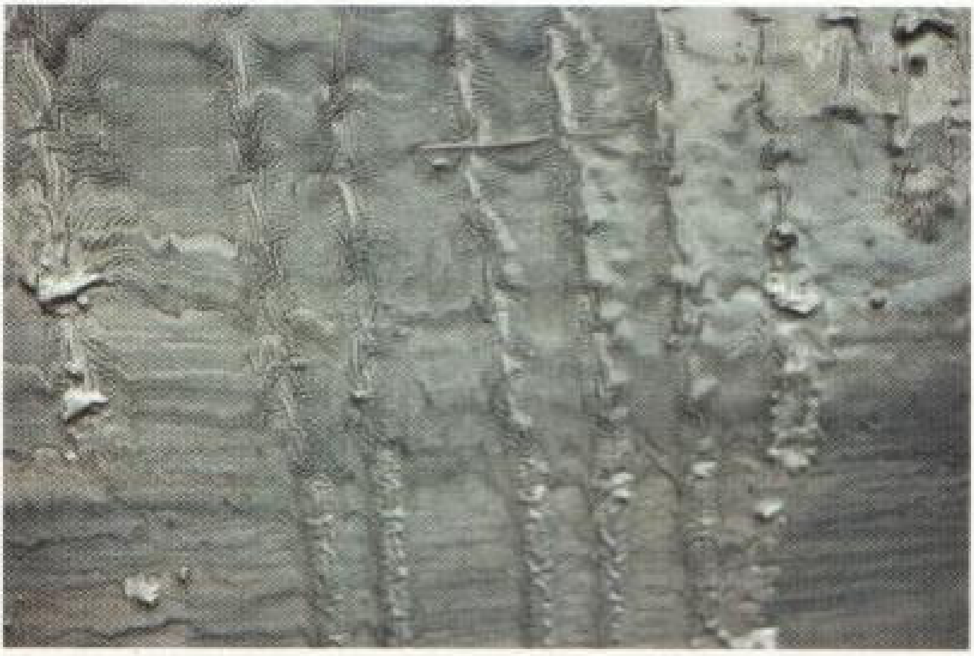
Repair: Remove defective coatings. Abrade, clean and recoat.

WRINKLING

also Rivelling (see also Crow's footing)

WRINKLING

also Rivelling (see also Crow's footing)



ZINC CARBONATES

Description: Loss of adhesion to galvanised surfaces. Blistering of paint on a galvanised surface.

Probable Causes: White rust or carbonates on the surface of galvanising prior to application of the paint coating. Corrosion of zinc under the paint surface. Can be similar to rash rusting but white in colour.

Prevention: Seal zinc coating from the environment and application of an appropriate protective coating system.

Repair: Water wash the surface to remove all traces of zinc corrosion products. Sweep blast or abrade, clean and apply a suitable coating system.

Fitz's Atlas™ of coating defects

7 - MARINE FOULING

INDEX OF MARINE FOULING

MARINE FOULING

Fouling is a natural phenomenon which occurs continuously in the marine environment. On sea-going vessels this leads to a significant increase in fuel consumption. The term 'fouling' describes the growth of marine plants and animals on structures in the sea. The fouling organisms of concern are those we encounter on ship's hulls. It is estimated that the number of fouling species involved in fouling is in the region of 4500-5500 although only a small number of these species are of great concern to ship Owners and Operators. Classification of fouling can be demonstrated by the two main groups; Macrofouling and Microfouling with further sub classification between animals, plants and slimes.

MACROFOULING		MICROFOULING
Animal	**Plant**	**Slimes**
Barnacles	Brown Algae	Marine Bacteria
Hydroids	(Ectocarpus)	Diatoms (Plants)
Molluscs	Green Algae	
Polyzoa	(Enteromorpha)	
Tube Worms	Red Algae	
Tunicates	(Rhodophycea)	

CLASSIFICATION OF FOULING

As can be seen above, plant fouling is an assemblage of different types of seaweed, mainly green and brown varieties, while animal fouling comprises principally barnacles (acorn and gooseneck), tube worms, polyzoa (hydroids and bryozoa), and mussels. The slime consists of microscopic forms of both plants and (diatoms) and bacteria.

Contrary to some belief, the adult forms of fouling such as mussels and barnacles are not floating around in the water ready to be attached to structures, it is the larvae or sea spores which float around in the top 100 feet or so of the waters. The moment a larvae settles on a structure the metamorphosis begins. The length of time a larvae remains freely swimming is variable and may range from about six weeks, in the case of barnacle larvae, to a matter of hours in the case of larvae of some tube worms and hydroids. Such an existence is hazardous and to ensure survival the animals produce large numbers of larvae. A native barnacle, for example, will produce 10,000 in a season. Reproductive potential is only one of several attributes that characterise the marine fouling forms found on ships. As a consequence of the intertidal character of their natural environment they have the ability to withstand extremes of temperature and salinity, also the ability to attach quickly and firmly to surfaces; the capacity for rapid growth highlights the severe problem of marine fouling to ships. Although it has been shown that seaweed spores and certain gooseneck barnacles are capable of attaching in water flows up to 10 knots and other barnacle larvae at water flow of up to 5 knots, it is still assumed that the bulk of settlement to ship's hulls occur while the vessel is stationary. Algae spores attach themselves within minutes of contact with a surface, whereas animal larvae require considerably longer periods for firm attachment. On ship's hulls the settlement of plant fouling occurs where there is available sunlight, i.e. around the waterline and a few meters below. Light is necessary for them to survive, light energy being converted to chemical energy (food) by photosynthesis. Animal organisms, however, do not require light and can therefore be found on any underwater area.

ANIMAL FOULING

Prior to the mid sixties, commercial vessels tended to be comparatively small and lack of port facilities determined that lengthy stationary periods were encountered in most types of vessel operation. This predisposed shipping to fouling by marine animals, especially barnacle fouling, and up to the mid-sixties biologists working on fouling problems worked on barnacle fouling. The introduction of large ships and improved port facilities resulted in considerably decreased stationary time during vessel operation and the fouling emphasis in shipping changed from an animal dominated problem to an algae dominated problem. However, if a ship does encounter a lengthy stationary period it becomes vulnerable to animal fouling. Animal fouling problems are caused by the larvae stages, the larvae being comparatively large (1mm), and as with all animal fouling problems a period of time of around 2 - 3 days is required for the establishment of the problem to allow the larval stage of metamorphosis to become the miniature adult. Where light is the food for plants the microscopic 'drifting life', consisting of micro organisms (planktonic), is the food for many types of animal fouling.

Barnacles - Acorn The most commonly encountered fouling animals and in consequence much is known about their biology. These animals live within hard calcareous shells and again have a net of tentacles to trap planktonic food. Barnacle larvae are selective in choosing their settlement sites and can actually recognise the presence of other barnacles. This results in barnacles attaching close to other members of their own species which ensures close enough proximity to allow cross fertilisation. Removal of accumulations of barnacle fouling by underwater scrubbing results in a roughening of the surface and also in a spreading around of a biologically attractive 'flavour'. Rapid recolonisation by yet more barnacles is the inevitable result! When the animals die, the shell remains on the ship's hull.

Barnacles - Gooseneck Specifically adapted for planktonic life attached to floating objects, gooseneck barnacles are the exception to the rule that the shoreline plant and animal communities are the source of all macroscopic fouling problems. They differ from acorn barnacles in having long feathery stalks. When adult they are around 10cm in length. The 'lepas' barnacle is commonly found attached to floating objects, but a more severe problem is caused by 'conchoderma' a gooseneck typically found attached to whales.

Hydroids (typically tubularia) Although plant-like in appearance, hydroid are typical animal fouling forms. The so called 'flower heads' are actually batteries of stinging cells which are used to paralyse and capture planktonic food. Hydroids are colonial forms. Each animal is placed in a little cup, the body has a single opening which serves both as mouth and anus. They are often found on the flats of vessels and are often misrepresented as algae forms. In general there is insufficient light to allow algae fouling to grow on the flats of large vessels; filamentitious growths found on these areas are generally types of hydroid.

Molluscs Molluscs are paired shells and are similar to mussels and oysters. Although molluscs have a hard shell the attachment threads are relatively weak which limits its ability to attach to moving structures; growth is normally found on stationary objects.

Polyzoa As the name suggests, these animals are composed of many cells. They have a hard calcareous skeleton. Some forms are flat and encrusting while others have an erect growth habit. In each case close observation reveals their lace-like appearance. They use a net of tentacles with which to catch their planktonic food.

Tube Worms Easily recognised by their hard white calcareous tubes, these tube-dwelling animals are again plankton feeders and entrap their food using a net of adapted tentacles. Again, the larvae can exercise a degree of selection over their attachment site and are capable of recognising the presence of their own species often resulting in the build up of large complex colonies.

Tunicates Tunicates are sessile marine animals, some of which are important fouling organisms. Tunicates live in a wide range of habitats, from the lower part of the seas down to waters of great depth. Some species are attached to solid surfaces, such as ships, while others are attached to loose substrata of sand and mud. Most species feed mainly on minute plant cells of the plankton, which they filter from a stream of water down through the oral opening into the perforated pharynx and expel through the atrial opening. This current brings required oxygen and carries away waste products.

ANIMAL FOULING

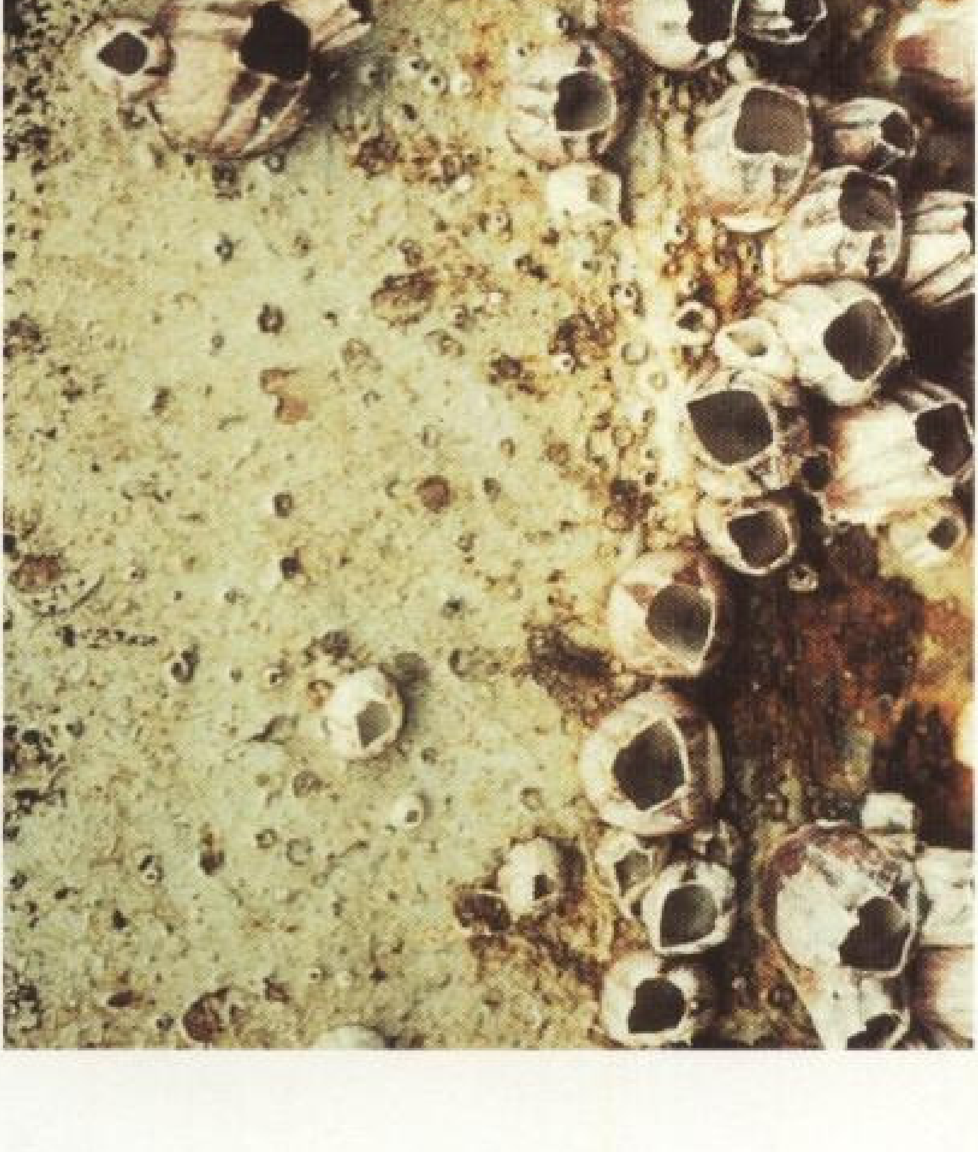
Severe animal fouling to the underwater location of a ship. Fouling can add considerable weight to a ship and increase fuel consumption dramatically.

Removal of the fouling by high pressure water washing. Note damage to existing paintwork.

BARNACLES

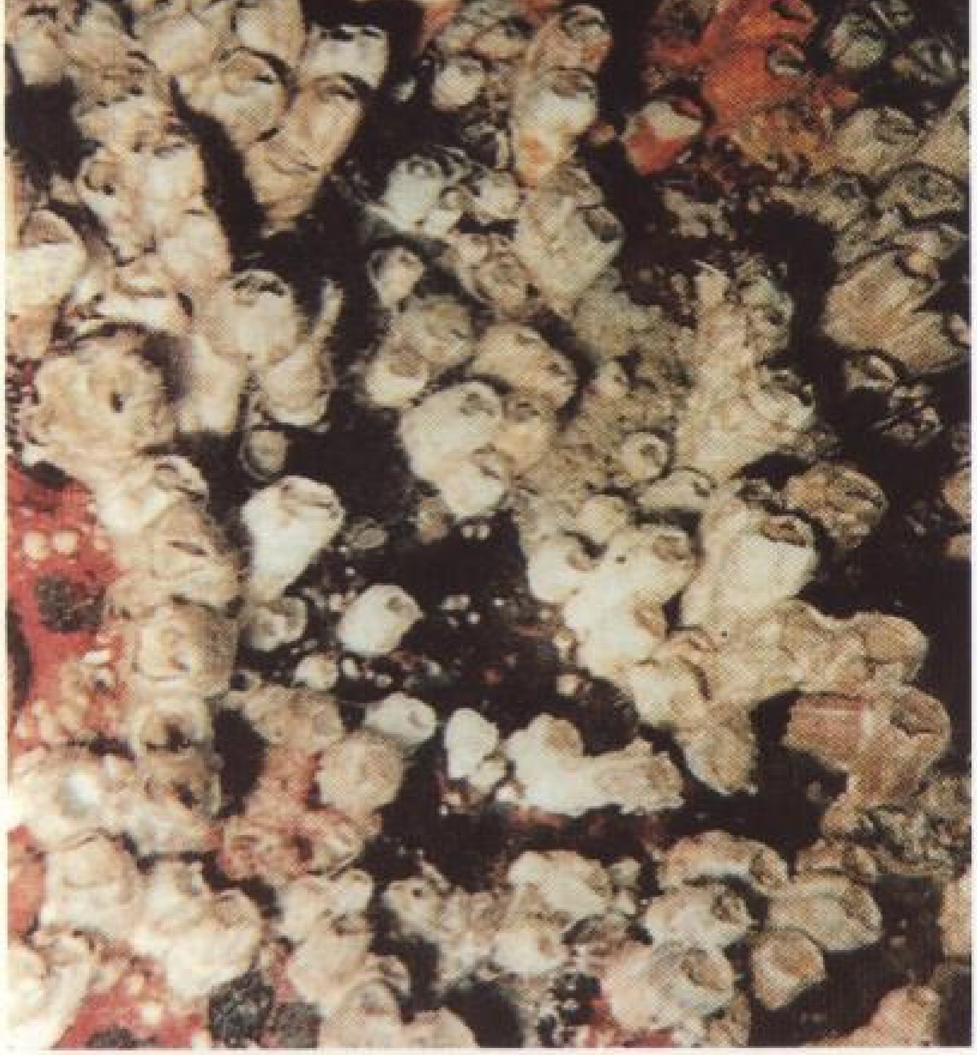
A scattering of tiny barnacles with sporadic mussels attached to the side of a ship.

BARNACLES



A close-up shot of barnacles. Note the various sizes along with paint damage to the surrounding areas.

BARNACLES - ACORN



A colony of acorn barnacles. The barnacle larvae can recognise the presence of other barnacles which result in close contact and cross fertilisation.

BARNACLES - ACORN

Small acorn barnacles and mussel fouling on the underside of the bilge keel turn of bilge. The shell of the barnacles remains attached to the substrate even when the life of the animal has ended.

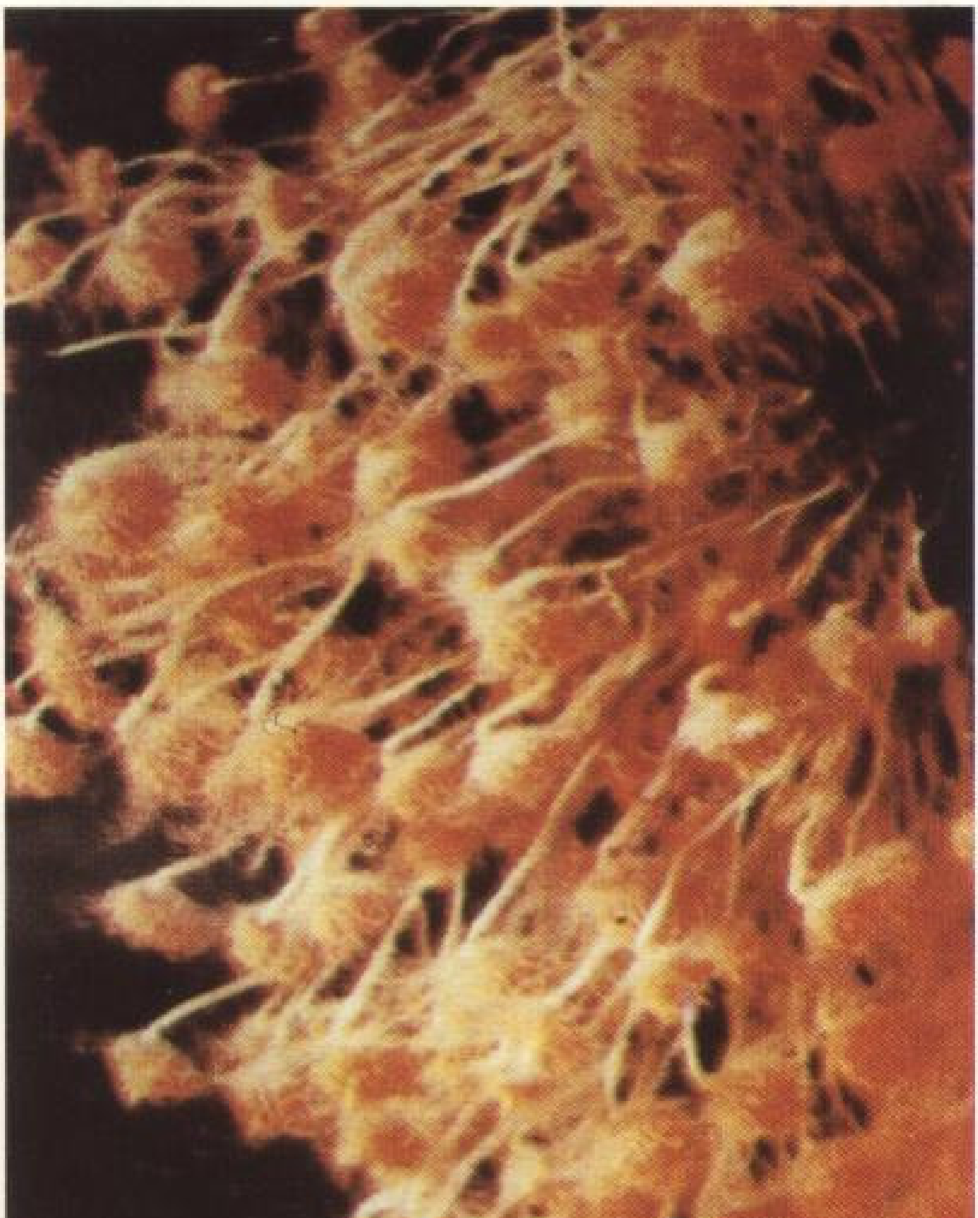
BARNACLES - GOOSENECK

Gooseneck Barnacles – specially adapted for planktonic life. The fouling goosenecks are all oceanic and prefer to settle on a substrate which is in motion i.e. ship's hulls. Some gooseneck barnacles even settle when the ship runs at a speed of 10 knots.

BARNACLES - GOOSENECK

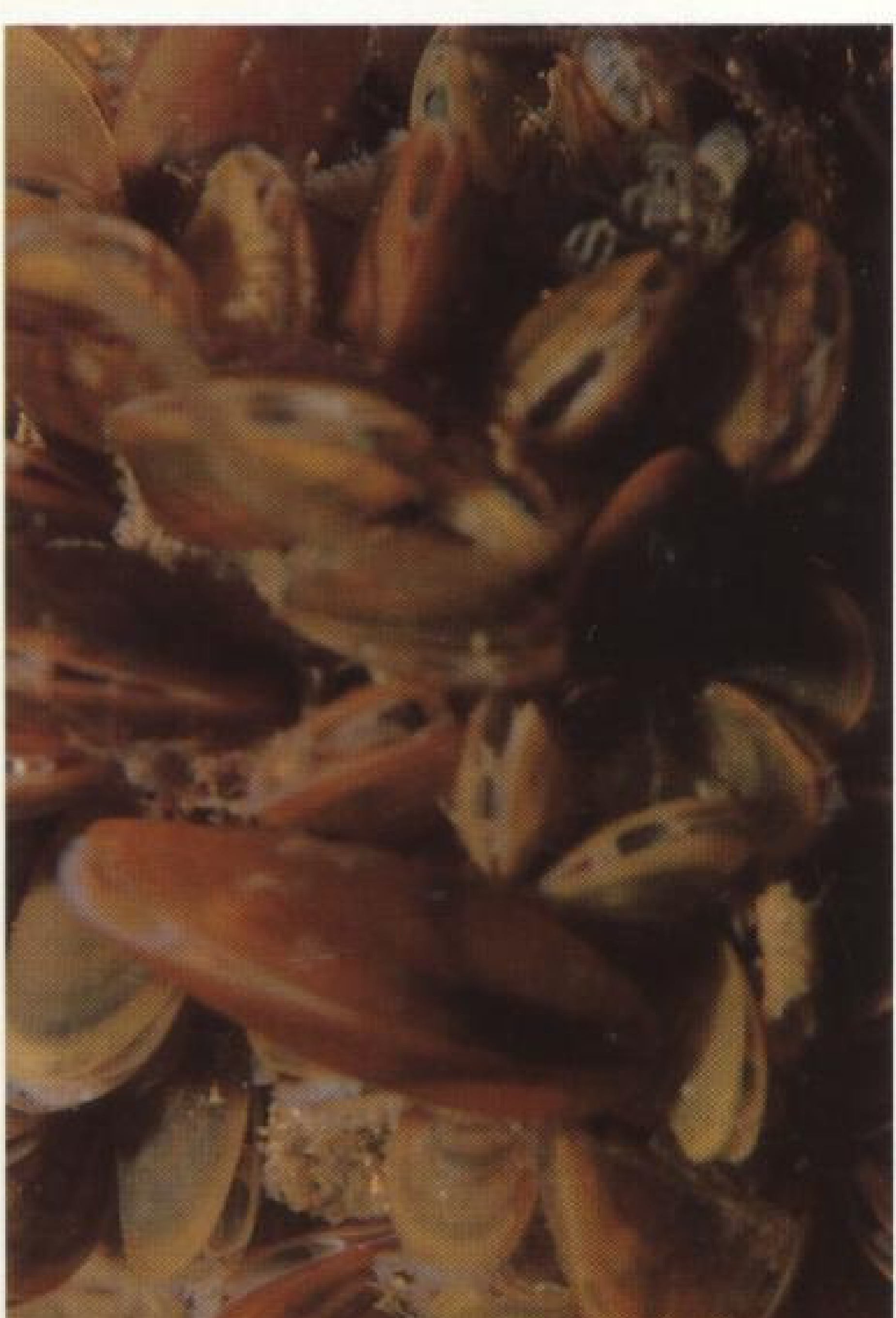
Gooseneck Barnacles – Underwater exposure.

HYDROID - TUBULARIA



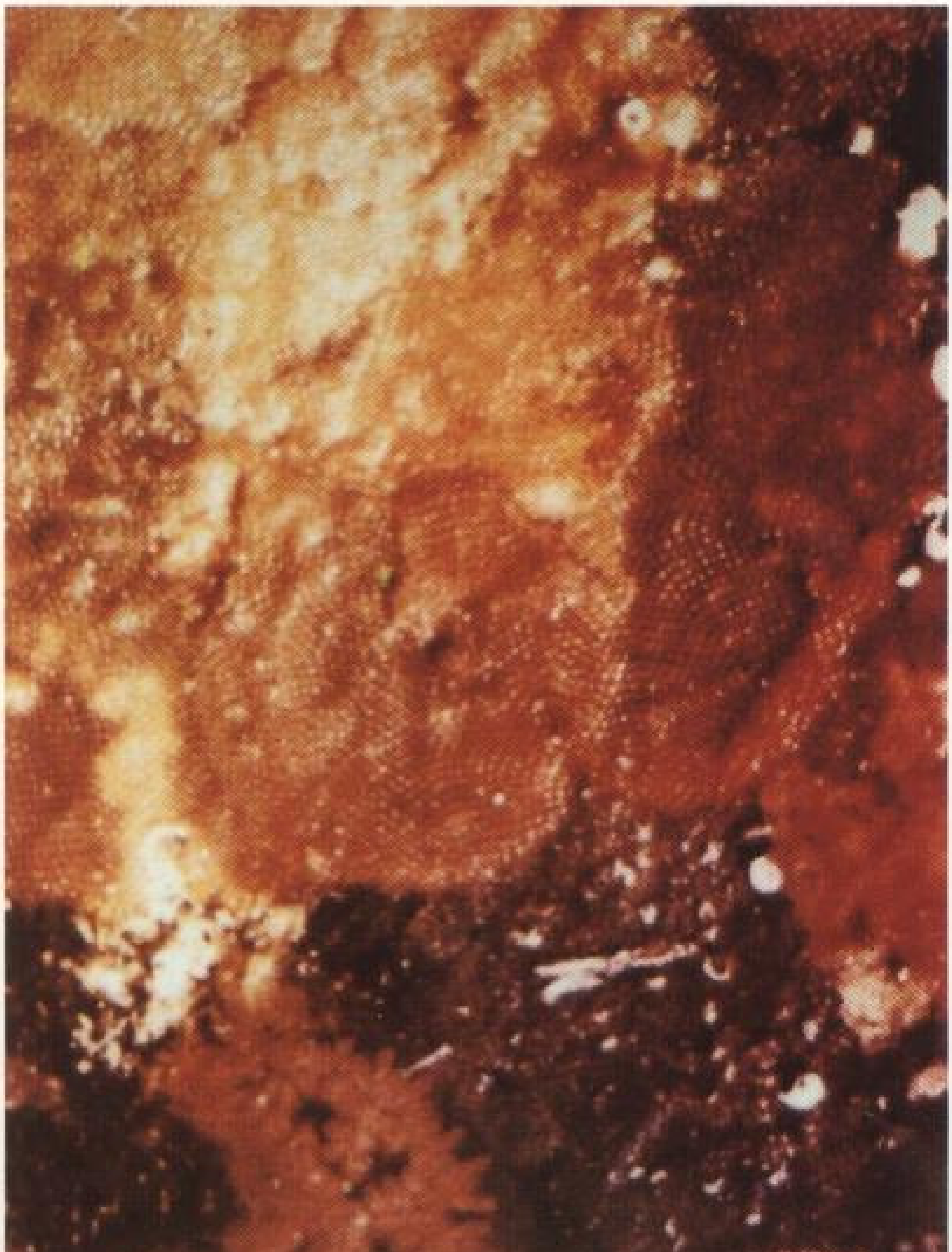
Tubularia - a typical Hydroid. Although plant-like in appearance, hydroids are typical animal fouling. Hydroids are, in fact, one of the most important animal fouling. They can be distinguished from algae and some bryozoa, which they superficially resemble, by the polyp which appears as enlargements to the ends of the branches.

MOLLUSCS



Molluscs - A close-up view of a colony of molluscs

POLYZOA



Polyzoa - colonial animals with a great variety of forms, which may at first result in confusion with organisms such as hydroids, compound tunicates and even tufted seaweed. Divided into 2 groups; encrusting and erect.

TUBEWORMS

Tubeworms - Also called Serpulids. Settlement is heavier in warmer waters. Feeding is conducted on the planktonic microscopic organisms carried past them in the water currents.

TUNICATE (SEA SQUIRT)

Sea squirt fouling on the bottom of the ship.

PLANT - WEED OR ALGAE FOULING

Regularly encountered are the finely branched brown algae 'Ectocarpus' and the green algae ' Enteromorpha', commonly known as 'grass' fouling because of the similarity in appearance. There the resemblance ends. Algae are very simple plants, deriving their nutrient requirements by uptakes directly into their body cells from the surrounding seawater, the root structures being non absorptive with use for anchorage only. When divers have to remove algae growth by scrubbing, they leave the root structures embedded on the surface. Because of the simplicity of the plant, rapid growth occurs and further cleaning becomes necessary. Indeed the more a surface is scrubbed the rougher and more attractive it becomes to further algae colonisation. Algae fouling is caused by spores which are too small to be seen by the unaided eye and on a roughened surface those spores are capable of attaching within seconds and becoming established in a few hours.

Fouling by the brown algae 'Ectocarpus' is similar to that already described for 'Enteromorpha'. The green algae tend to dominate in positions of higher light intensity while 'Ectocarpus' dominate in conditions of lower light intensity. Since all algae require light for growth they are not generally found on the flat bottoms of commercial ships. With few exceptions all green algae are green grass colour owing to the predominance of chlorophyll. Red algae is basically filamentitious, but compaction of cells may conceal this feature. The life cycle is peculiar and complicated, and the reproductive products are dispersed passively by the water currents.

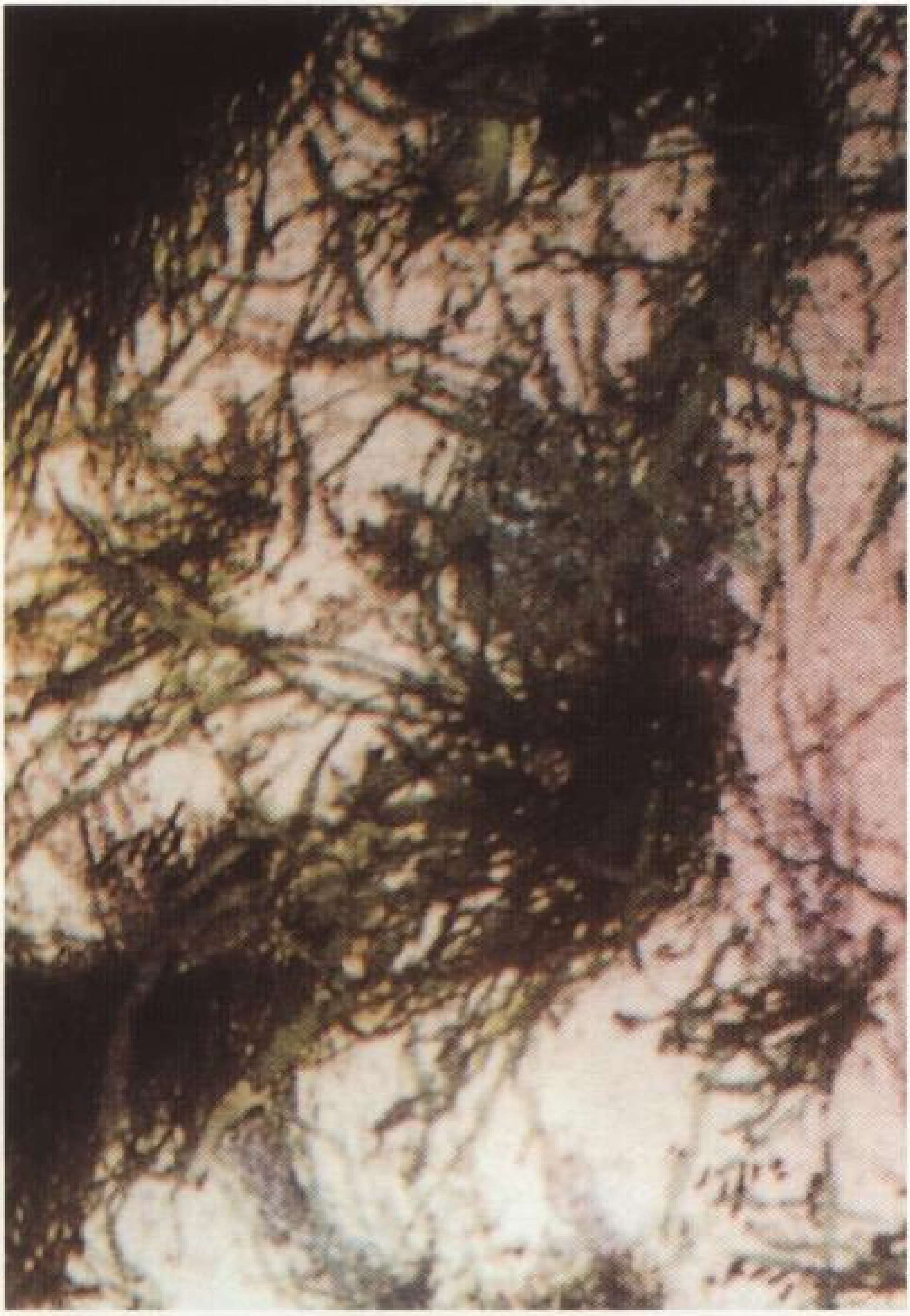
ECTOCARPUS (BROWN ALGAE - GRASS)

Ectocarpus (brown algae – grass) - underwater exposure. The colour is attributed to the pigment fucoxanthin. The spores of the Ectocarpus are very small and can be planktonic for one day before they settle. Ectocarpus dominates in conditions of lower light intensity.

ECTOCARPUS (BROWN ALGAE - GRASS)

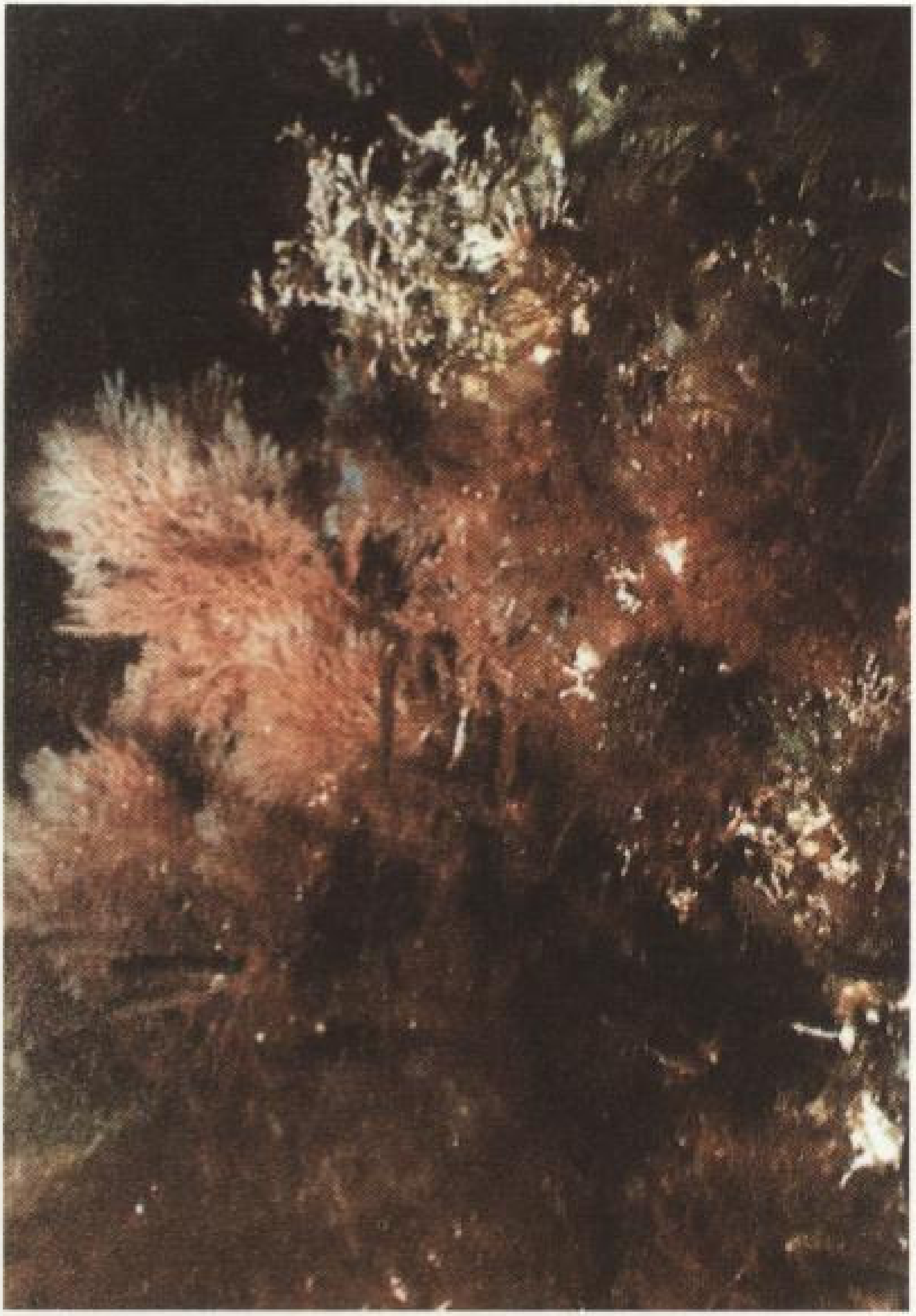
Ectocarpus (brown algae – grass) - underwater exposure. The colour is attributed to the pigment fucoxanthin. The spores of the Ectocarpus are very small and can be planktonic for one day before they settle. Ectocarpus dominates in conditions of lower light intensity.

ECTOCARPUS AND ENTEROMORPHA



Ectocarpus and Enteromorpha. Most common forms of green and brown grass.

ECTOCARPUS AND ENTEROMORPHA



Ectocarpus and Enteromorpha. Most common forms of green and brown grass.

ENTEROMORPHA (GREEN GRASS)

Enteromorpha (green grass). Thicker and more continuous around the waterline where the algae can obtain more sunlight and energy through photosynthesis.

Removal of green algae, exposing sound anti-fouling paint.

ENTEROMORPHA (GREEN GRASS)

Severe forms of green grass. All green algae are of green grass colour, owing to the predominance of chlorophyll.

Severe forms of green grass. All green algae are of green grass colour, owing to the predominance of chlorophyll.

RHODOPHYCEA (RED ALGAE)

Rhodophycea - severe forms of red algae.

Fitz's Atlas™ of coating defects

APPENDIX

CONTENTS OF APPENDIX

COATING BREAKDOWN SCALES

The Extent of Coating Breakdown Scales on the following pages should be used in conjunction with the following Standards;

European Scale of Corrosion
ISO 4628
ASTM 610

The above Standards illustrate the type of coating failure observed on a small area of a given substrate.

The scales are used to represent the failure mode expanded over a much larger surface area such as tank surfaces or a large pipe surface.

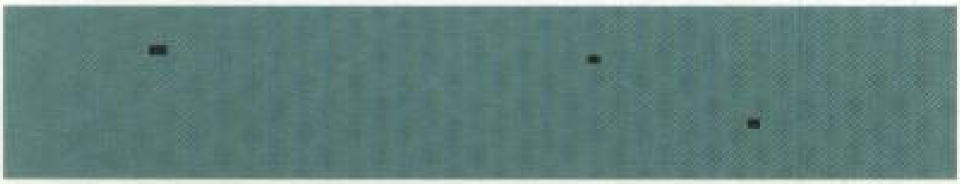
It can be seen that in most cases where 'scattered' failure has taken place it would be uneconomical to attempt a patch repair. Total removal and replacement of the coating system is warranted. However, where the coating has failed in a 'localised' mode, a patch repair can often be economically justified.

Wherever possible the assessor or surveyor should view and categorise coating failure modes on a global scale rather than isolated or localised area.

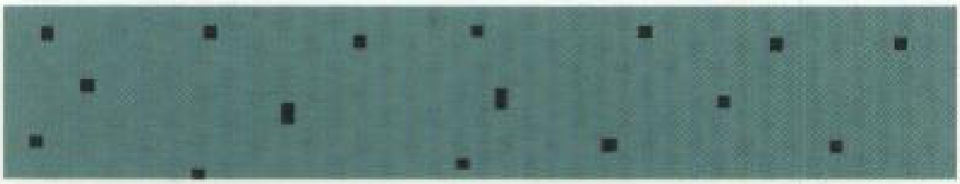
Coating Breakdown Scales courtesy of TCI

COATING BREAKDOWN (SCATTERED)

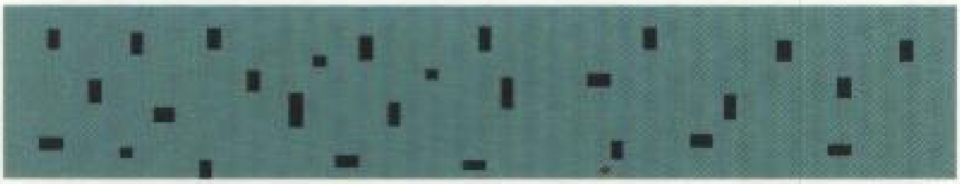
0.1% Coating Breakdown



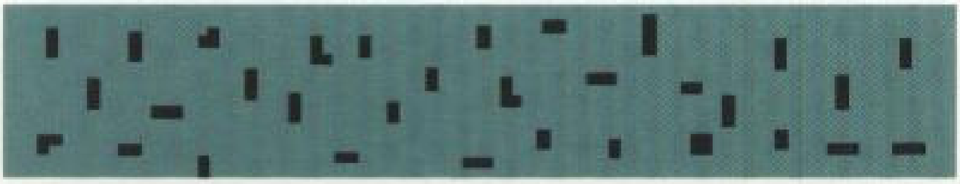
1% Scattered



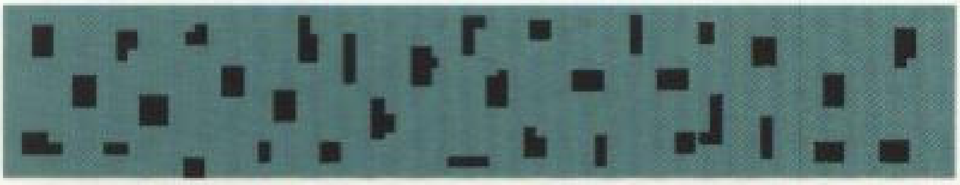
3% Scattered



5% Scattered

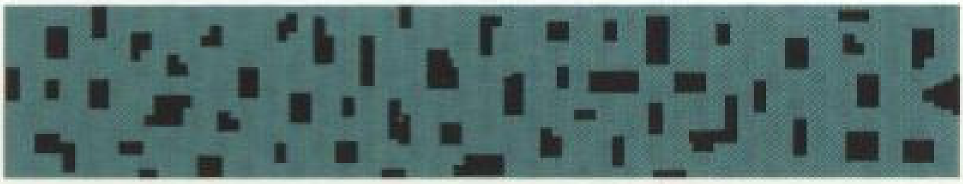


10% Scattered

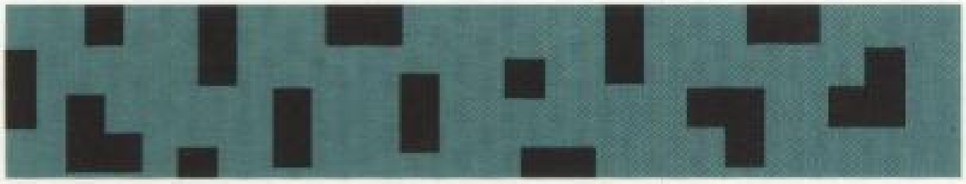


COATING BREAKDOWN (SCATTERED)

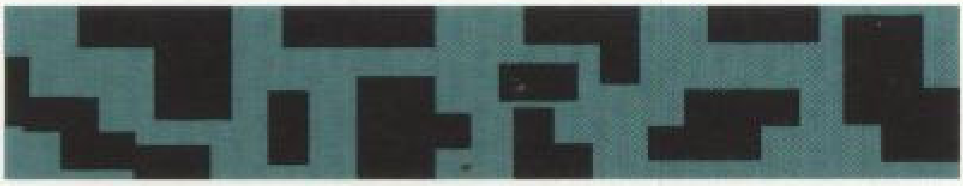
15% Scattered



25% Coating Breakdown



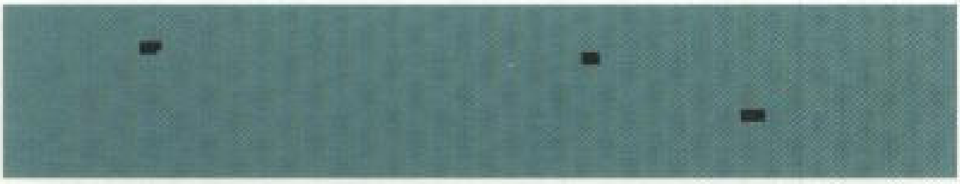
50% Coating Breakdown



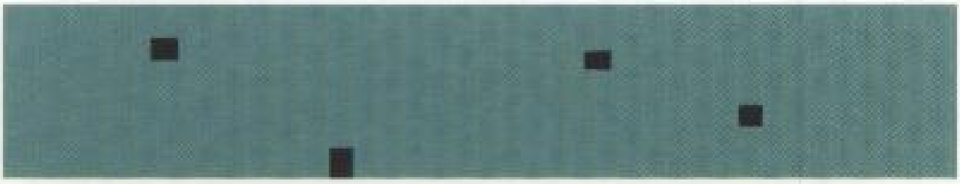
90% Coating Breakdown

COATING BREAKDOWN (LOCALISED)

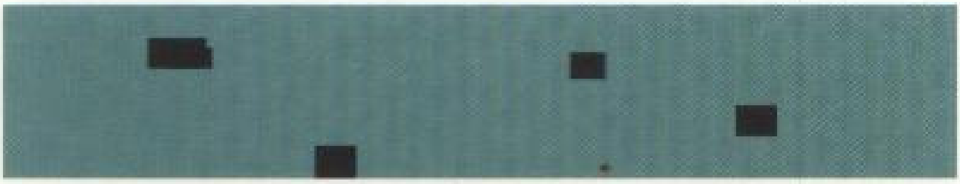
0.3% Coating Breakdown



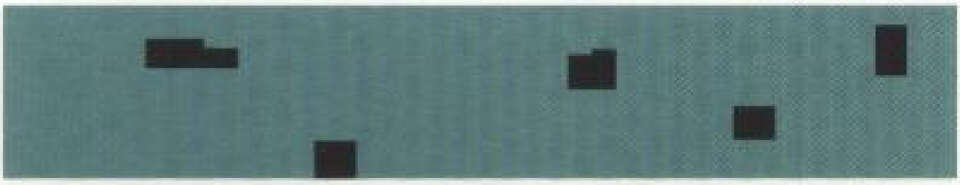
1% Localised



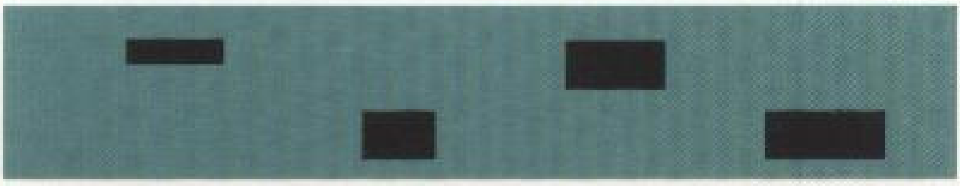
3% Localised



5% Localised

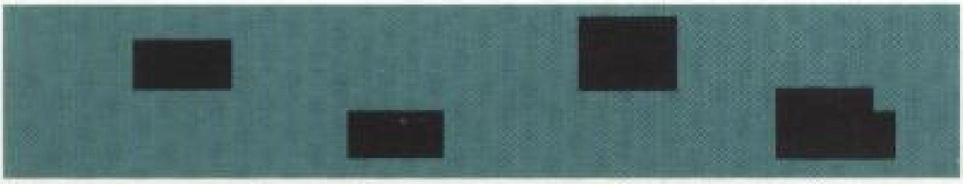


10% Localised

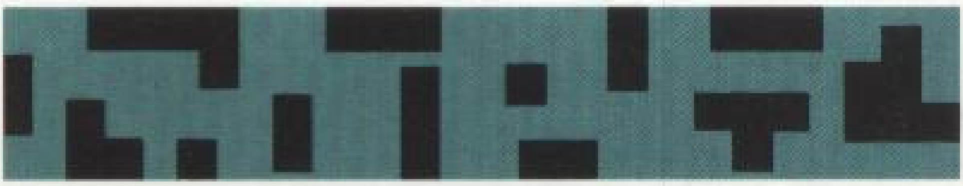


COATING BREAKDOWN (LOCALISED)

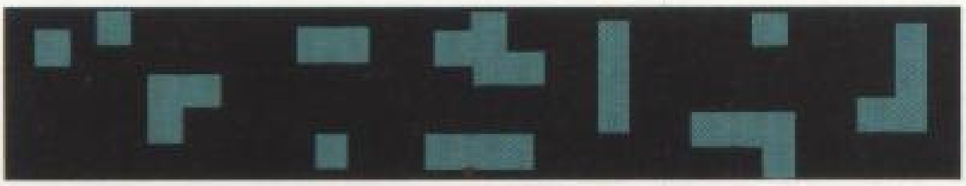
15% Localised



33% Coating Breakdown



75% Coating Breakdown



100% Coating Breakdown

PAINT COMPATIBILITY CHART

EXISTING TOPCOAT	TOPCOAT: Acrylated Rubber	Alkyd	Amine Epoxy	Bitumen	Chlor. Rubber	Coal Tar Epoxy	Epoxy Ester
Acrylated Rubber	E	X	X	X	X	X	X
Alkyd	F [1,4]	E [2]	X	F [4]	P	X	G [2]
Amine Epoxy	F [1,4]	X	E [2,3]	F [1]	F [3]	G [3]	X
Bitumen	X	X	X	E	X	X	X
Chlor. Rubber	X	X	X	F [1,4]	E	X	X
Coal Tar Epoxy	F [3,4]	X	G [3,4]	F [3,4]	F [3,4]	E [3]	X
Epoxy Ester	F [1,4]	E [2]	X	F [4]	P	X	E [2]
Ethyl Zinc Silicate	F [1,4]	X	G [4]	F [1,4]	G [4]	F [1,4]	X
M.C. Urethane	F [1,4]	F [1,4]	F [2,3]	F [1,4]	F [4]	F [3,4]	F [1,4]
Polyamide Epoxy	F [1,4]	P	F [2,3]	F [1,4]	F [4]	G [3]	P
Silicone Alkyd	F [1,4]	E [2]	X	F [4]	P	X	G [2]
Urethane (2 pack)	F [1,4]	F [1,4]	F [2,3]	F [3,4]	F [1,4]	F [3,4]	F [1,4]
Urethane Acrylic	F [1,4]	F [1,4]	F	F [1,4]	F [1]	F [4]	F [1,4]
Vinyl	X	X	F [4]	F [1,4]	F [1]	X	X

E = Excellent
G = Good
F = Fair
P = Poor
X = Not recommended

[1] = Guide only - conduct test patch
[2] = Apply primer or undercoat first - same generic type as new topcoat
[3] = Flash blast - abrade overall
[4] = Apply tie/sealer coat

PAINT COMPATIBILITY CHART

EXISTING TOPCOAT	TOPCOAT: Ethyl Silicate	M.C. Urethane	Polyamide Epoxy	Silicone Alkyd	Urethane (2 pack)	Urethane Acrylic	Vinyl
Acrylated Rubber	X	X	X	X	X	X	X
Alkyd	X	P [1]	P [1]	G [2]	X	F [1,4]	P [1]
Amine Epoxy	X	F [3]	G [2,3]	X	F [3]	F [3]	F [3]
Bitumen	X	X	X	X	X	X	X
Chlor. Rubber	X	F [1,4]	P [1]	X	F [1,4]	F [1,4]	F [1,4]
Coal Tar Epoxy	X	F [3,4]	G [3,4]	X	F [3,4]	F [3,4]	F [3,4]
Epoxy Esler	X	P [1]	P [1]	G [2]	X	F [1,4]	P
Ethyl Zinc Silicate	P [1]	G [4]	E	X	G [4]	G [4]	G [4]
M.C. Urethane	X	E [2]	F [1,2]	F [1,4]	G [4]	G [2]	F [1,4]
Polyamide Epoxy	X	G [4]	G [2]	P	F [4]	G [4]	F [4]
Silicone Alkyd	X	P [1]	P [1]	E [2]	X	F [1,4]	P [1]
Urethane (2 pack)	X	G [2]	F [2,3]	F [1,4]	E [2]	G [2]	F [3,4]
Urethane Acrylic	X	G [1]	F	F [1,4]	G	E	F [1]
Vinyl	X	F [1,4]	X	X	F [1,4]	F [1,4]	G [1]

Note: The above chart is a generalisation and provides a rough indication of paint compatibility. Paint formulations vary widely between different manufacturers. It is strongly recommended that you check with the manufacturer regarding the compatibility of the products in question.

PAINT PROPERTIES CHART

Product	Alkyd	Bitumen	Chlor. Rubber	Coal Tar Epoxy (2 pack)	Epoxy Ester
Resistance to UV light	Good	Chalks	Chalks	Chalks	Chalks badly
Resistance to Water Immersion	Poor	Fair in fresh water	Excellent	Excellent	Fair
Resistance to Mechanical damage	Fairly good	Fair	Fair	Good	Good
Resistance to oils and Cutting oils (2)	Fair	Not resistant	Not resistant permanently softened	Good	Excellent
Curing Agent	Oxygen	N/A	N/A	Usually polyamide isocyanate or amine adduct	Oxygen
Drying Mechanism	SE & OX	SE	SE	SE & CC	SE & OX
Intercoat Adhesion (coat on coat) - aged	Good with right tie coat	Excellent (solvent weld)	Excellent (solvent weld)	Poor	Good with right tie coat
Temperature Resistance Dry Continuous (cured film) (2)	90°C	70°C	70°C	90°C	100°C
Chemical Resistance (2)	Poor	Poor	Excellent	Good	Good
Solvent Resistance (aged)	Fair	Poor	Poor	Good Pitch bleed through can occur	Good
Resistance to Vapour Permeation	Fairly high	High	Very high	Very high	High
Minimun Application Temperature	4°C	0°C	0°C	10°C (3)	4°C
Colour Availability	Full range	Usually Black & dark brown	Full range	Usually Blk, dark brown, dark grey	Full range

Drying Mechanism:

SE = Solvent Evaporation
CC = Chemical Cure
OX = Oxidation

Notes:

[1] = Reaction with moisture necessary
[2] = Check with specific manufacturers
[3] = Isocyanate cure types down to 0°C

PAINT PROPERTIES CHART

Ethyl Silicate	Grease Coatings	Pure Epoxy (2 pack)	Pure Urethane (1 pack)	Silicone Alkyd	Solution Vinyl	Urethane (2 pack)	Urethane Acrylic
N/A	Good but very high dirt pickup	Chalks	Very high low chalking - aliphatic grade	Exceptional very low chalking	Chalks	Very high low chalking	Good
Excellent when sealed	Very good	Very good	Very good	Fair	Very good	Very good	Very good
Very good	Very poor	Excellent	Very good	Fairly good	Very good	Out standing	Very good
Excellent but may be absorbed	Non resistant	Excellent	Excellent	Excellent	Good	Excellent	Excellent
Zinc dust and moisture	N/A	Usually isocyanate polymide or amine adduct	Moisture from atmo-sphere or substrate (min 35%)	Oxygen	N/A	Aliphatic or aromatic isocyanate	Topcoats= aliphatic isocyanate Primer= aromatic isocyanate
SE & CC (1)	SE	SE & CC	SE (1)	SE & OX	SE	SE & CC	SE & CC
Poor	Excellent	Good with right tie coat	Good with right tie coat	Good	Excellent	Good (not gloss on gloss)	Good (incl. gloss on gloss)
450°C	50°C	110°C	120°C (non-thermo plastic)	120°C	80°C	120°C (non-thermo plastic)	120°C
Poor	Good	Excellent	Very good	Good	Very good	Very good	Good
Excellent	Good	Excellent	Very good	Good	Fair	Very good	Good
Low	Very high	Very high	Fair	High	High	Low	Low
5°C	4°C	Min 5°C (3)	<0°C	4°C	0°C	<0°C	<0°C
Grey only primer	Full range	Full range	Full range	Full range	Full range	Full range	Full range

Note: The above chart provides a rough indication of paint properties. Paint formulations vary widely between different manufacturers. It is recommended that you check these properties with the manufacturer concerned.

PAINT ARITHMETIC

When assessing the cost of painting an estimator needs to take into account various factors before arriving at the true cost.

To calculate the total cost or cost per square meter of different paints with differing volume solids for achieving a D.F.T. of 375 microns over an area of 15,000 sq.m.

Paint A Epoxy, volume solids 62% - cost per litre £1.35

Paint B Epoxy, volume solids 55% - cost per litre £1.22

Paint C Epoxy, volume solids 50% - cost per litre £1.19

Calculations for Total Costs

Paint A

$$\text{Volume} = \frac{15000 \times 375}{10 \times 62} = 9073 \text{ litres} \times \text{Cost @ £1.35} = \text{£12248.55}$$

Paint B

$$\text{Volume} = \frac{15000 \times 375}{10 \times 55} = 10227 \text{ litres} \times \text{Cost @ £1.22} = \text{£12476.94}$$

Paint C

$$\text{Volume} = \frac{15000 \times 375}{10 \times 50} = 11250 \text{ litres} \times \text{Cost @ £1.19} = \text{£13387.50}$$

It can be clearly seen that the volume solids affect the material calculation and the costs. Although initially Paint C appears cost effective only after calculation does it becomes clear that Paint A is the more economic paint because of its higher V.S.%.

Peripheral factors such as poor quality control, delayed deliveries, poor technical support and service are subjective, however, they affect choice of supplier and materials to be used.

Once the estimator has calculated his initial total cost the "Loss Factors" need to be considered.

Depth of Profile

As a general rule optimum surface amplitude is specified at 50 - 75 microns. However, higher build materials, i.e. glassflake materials, require amplitude of 75 to 100 microns. Therefore, more material will be required to fill the troughs and cover the peaks, since dry film thickness measurements are usually taken over the peaks.

Irregularity of Shape

It is difficult to achieve uniform paint application on complex shapes and fabricated structures and, therefore, losses due to over-spray or excess paint build up in corners will inevitably need to be taken into consideration. This can usually increase the paint consumption rate to plus 30% or more, depending on substrate configuration.

Overspray

Even on relatively uncomplicated substrates, this can amount to 5%, even with efficient airless spraying.

Wind Loss

When applying paint in the open in high wind conditions, losses of 20 - 50% can be experienced.

General Losses

Exceeding potlife, pilferage, spillage etc, need to be considered in any paint consumption calculation.

Absorbent Surfaces

Wood surfaces, if not properly sealed, would tend to absorb paint into the substrate and a factor of 2%-5% should be considered for such surfaces.

General

Even with well trained operatives, "on the job" inspection, good QA/QC procedures, the paint estimator should add a baseline factor of 25% to his original paint consumption calculation. All other factors listed above will then need to be taken into consideration.

When comparing solventless/solvent free, coatings, with normal solvent bound types, one will invariably find that the former is much more expensive than the latter. However, one must consider that for a given dry film thickness, the coverage rate will be much higher with the solventless/solvent free type. The following example illustrates this point.

Paint 1: Solventless materials V.S. = 97.5% @ £4.80 per litre
Paint 2: Solvent free materials V.S. = 100% @ £4.90 per litre
Paint 3: Solvent bound types V.S. = 50% @ £2.70 per litre

To obtain the coverage for 250 µm D.F.T. use $\frac{\text{D.F.T.}}{\text{W.F.T.}} = \text{V.S.\%}$

The W.F.T. required for **Paint 1** = $\frac{250 \times 100}{97.5} = 256.41\ \mu m$

The W.F.T. required for **Paint 2** = $\frac{250 \times 100}{100} = 250\ \mu m$

The W.F.T. required for **Paint 3** = $\frac{250 \times 100}{50} = 500\ \mu m$

Therefore the volume required to cover $1m^2$

with **Paint 1** = $\frac{256.41 \times 100 \times 100}{10{,}000}$ ccs/mls = 256.41mls

with **Paint 2** = $\frac{250 \times 100 \times 100}{10{,}000}$ ccs/mls = 250 mls

with **Paint 3** = $\frac{500 \times 100 \times 100}{10{,}000}$ ccs/mls = 500 mls

Therefore the cost per m^2 using; **Paint 1** = £4.80 x .25641 = £1.23
Paint 2 = £4.90 x .250 = £1.22
Paint 3 = £2.70 x .500 = £1.35

In this hypothetical case, the use of solvent free materials (Paint 2), although more expensive in cost per litre, actually works out cheaper.

FORMULAE FOR SURFACE AREAS

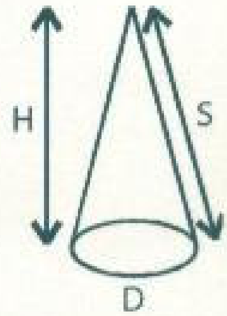
Abbreviations

Length = L Width = W Height = H Radius = R
Diameter = D Area = A $\pi = 3.142$ approx.

Cone

(Slant side = S, Base diameter = D)
Area of the curved surface of a cone is:

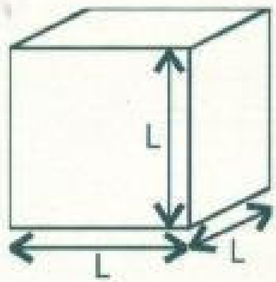
$$A = \frac{\pi \times D \times S}{2}$$



Cube (Side = L)

A cube has six identical square faces. Total surface area is six multiplied by the square of the length of one side.

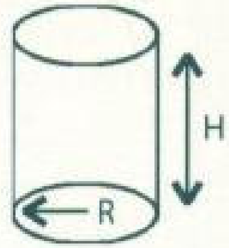
$$A = 6 \times L^2$$



Cylindrical Tank

The surface area consists of the cylindrical shell ($2 \times \pi \times R \times H$) plus the two flat ends $2 \times (\pi R^2)$.

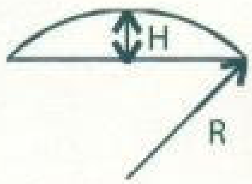
$$A = (2 \times \pi \times R \times H) + 2(\pi \times R^2)$$



Domed end of Tank

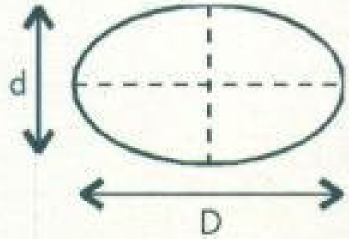
(Height of dome = H)

$$A = 2 \times \pi \times R \times H$$



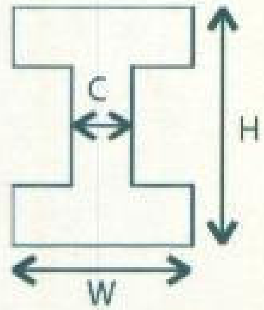
Ellipse (Major axis=D, Minor axis=d)

$$A = \frac{\pi \times D \times d}{4}$$

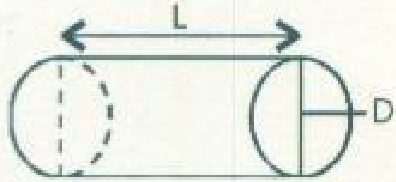


I Beam
(Plate thickness = C)

$$A = 2 \times (2W + H - C) \times L$$



Pipe
The surface area of a pipe is calculated by multiplying the diameter by π and then multiplying by the pipe length.

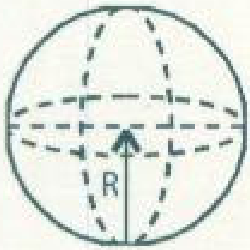


$$A = \pi \times D \times L$$

Ring
(Outer radius = R, Inner radius = r)

$$A = \pi \times R^2 - \pi \times r^2$$

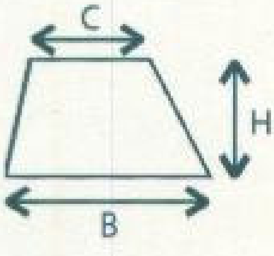
Sphere
The surface area of a sphere is calculated by multiplying the square of radius (R) by π by 4.



$$A = 4 \times \pi \times R^2$$

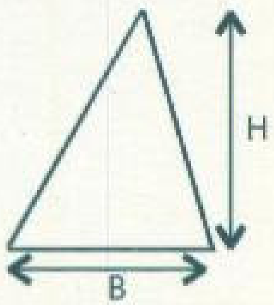
Trapezium
(Parallel sides length=B&C)

$$A = \frac{(B + C)}{2} \times H$$



Triangle
(Base length=B)

$$A = \frac{B \times H}{2}$$



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