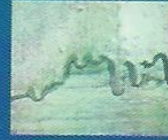
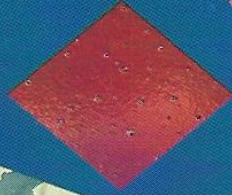


A comprehensive visual guide to  
coatings and application defects



# Fitz's Atlas 2<sup>TM</sup> of coating defects

# Fitz's Atlas 2<sup>TM</sup> of coating defects

1 - CONTENTS

### PREFACE

The fact that the first edition of Fitz's Atlas achieved such success shows that it satisfied a long standing need in the coatings industry. Since its first publication in 1996 many additional photographs of coating defects have been acquired by the author from his own work in the industry and from paint companies and individuals worldwide. Additional photographs have been added to most of the sections and some photographs have been replaced with others, which in the authors' opinion, better illustrate the coating defects or surface conditions. As microscopy is used to examine paint flakes to assist in establishing the cause and mechanism of failure, a section with photomicrographs has been added.

The aim of the second edition of the Atlas has not changed from that of the first but has been greatly enhanced to further illustrate the range of coating and surface defects likely to be encountered and to provide advice on probable causes, prevention and repair. It is however not intended to be a "do it yourself manual" for failure analysis. This Atlas will not make the user an "Instant Expert" on coating failures. Many coating failures need further evaluation and analyses to be carried out by a qualified Chemist or Coating Specialist often using specialised laboratory equipment.

With any coating failure, a process of fact finding and 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 review of the records of the surface preparation and application conditions to ensure they were within the accepted range for the coating system applied. The information to be obtained 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 is the table of contents and the second section 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 where new and additional photographs have been added.

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

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## Introduction

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consists of 93 categories (35 new) and a total of 237 photographs compared with 104 in the first edition.

Section five is new and contains 39 photomicrographs in 20 categories to demonstrate the use of microscopy in assisting the identification of coating failures.

Section six, to which new photographs have been added, illustrates various types of animal and plant marine fouling including classifications and descriptions.

An appendix provides 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 and a section on calculations and formulae.

Each of these sections have been compiled by coating specialists who understand paint coatings, their application and their modes of failure 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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**TABLE OF CONTENTS**

INTRODUCTION.....I-III

ACKNOWLEDGEMENTS..... IV

CONTENTS ..... 1-0

WELDING FAULTS .....2-0

SURFACE CONDITIONS.....3-0

COATING DEFECTS.....4-0

MICROSCOPY .....5-0

MARINE FOULING.....6-0

APPENDICES..... App-0

- Coating Breakdown Scales
- Paint Compatibility Chart
- Paint Properties Chart
- Paint Arithmetic
- Formulae for Surface Area

# Contents

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# Fitz's Atlas 2<sup>TM</sup> of coating defects

2 - WELDING FAULTS

**INDEX OF WELDING FAULTS**

WELDS ..... 2-3  
WELDING FAULTS ..... 2-3  
CRACKS ..... 2-4  
CRATER PIPES ..... 2-5  
EXCESS PENETRATION BEAD ..... 2-6  
ROOT CONCAVITY ..... 2-8  
SPATTER ..... 2-9  
STRAY ARCING ..... 2-10  
SURFACE POROSITY ..... 2-11  
UNDERCUT ..... 2-12



### 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.

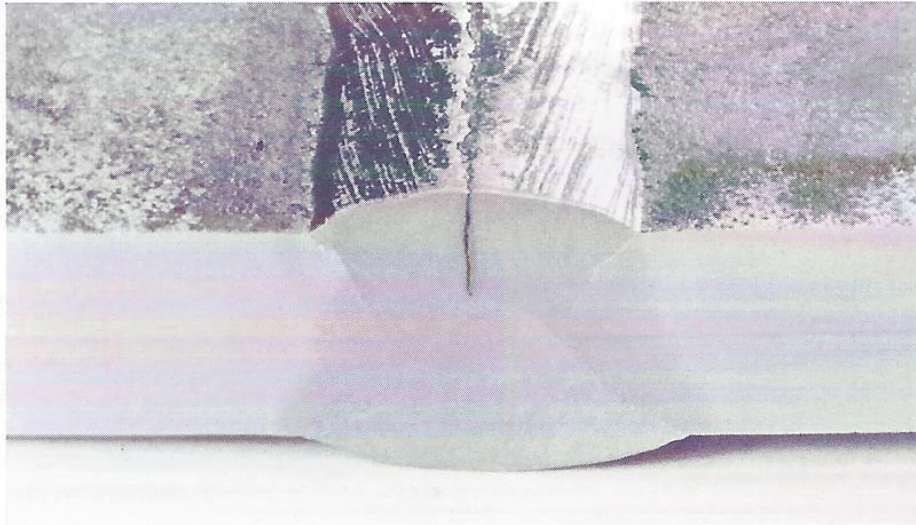
### WELDING FAULTS

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

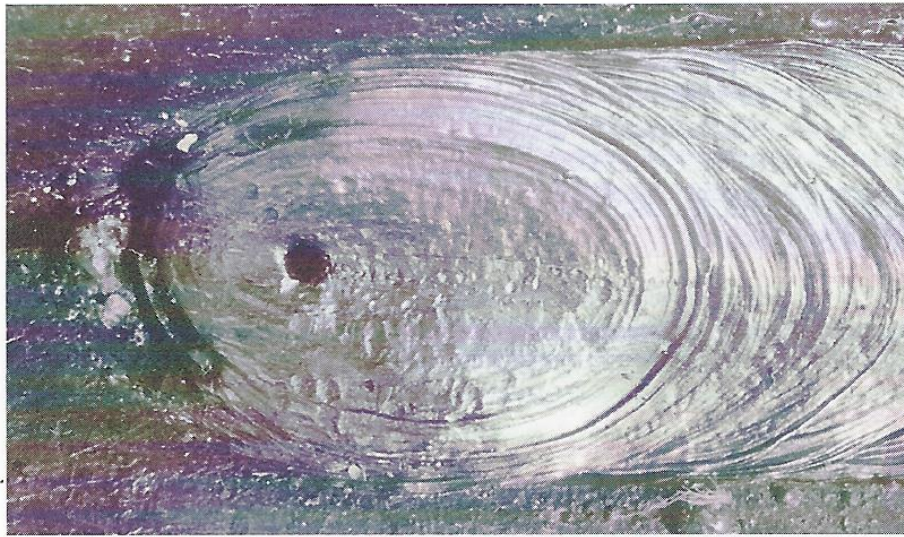
**Description:** Crack visible at the surface.

**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



10 mm

**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



---

20 mm

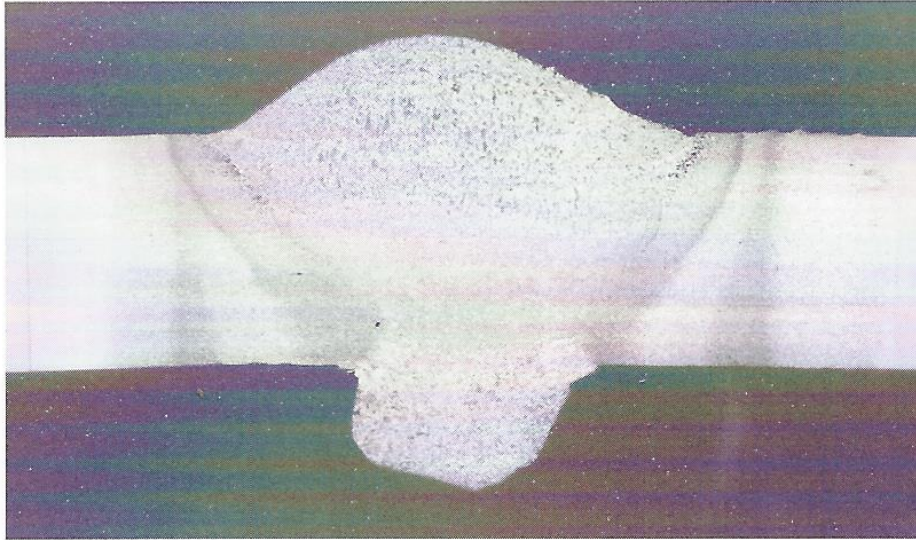
**Description:** Weld metal normally extends below the parent metal surface but this is only a problem when excessive and exceeds the specification.

**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

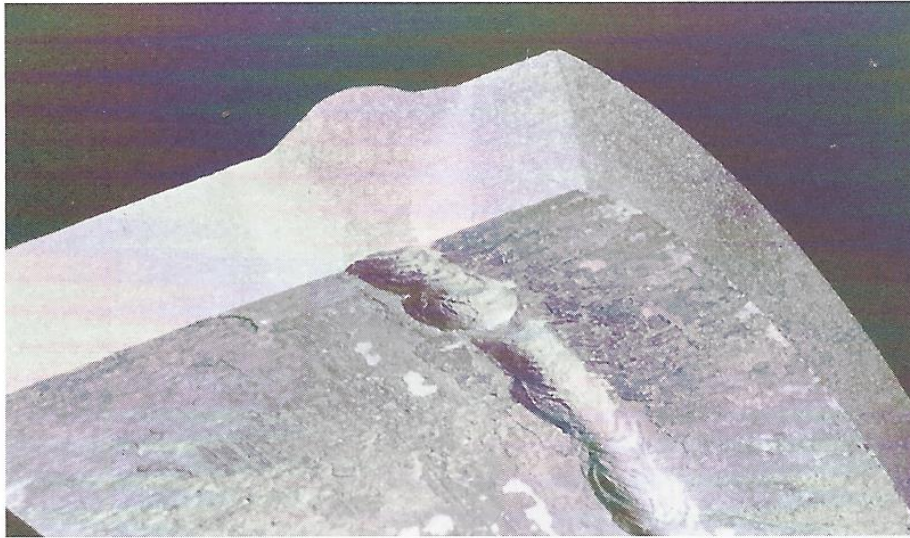
**Description:** Weld metal normally extends below the parent metal surface but this is only a problem when excessive and exceeds the specification.

**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

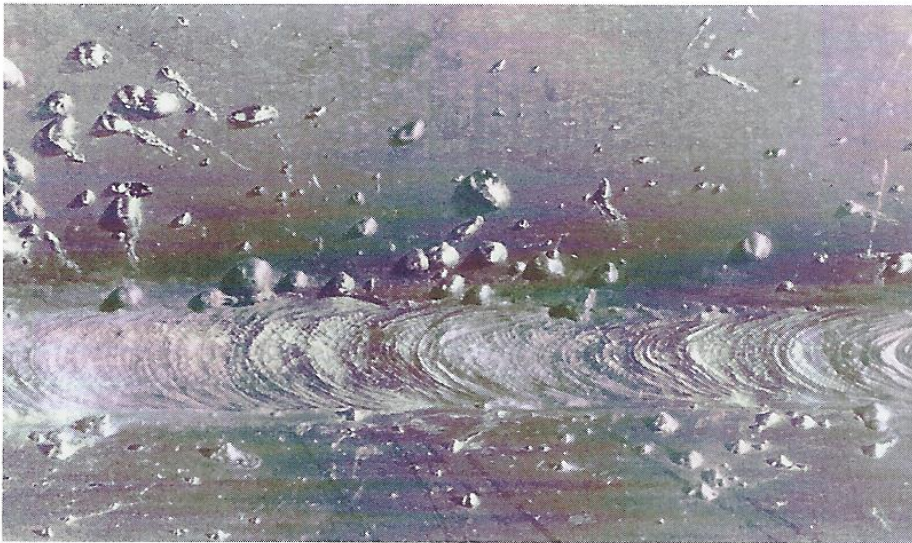
**Description:** Shrinkage at the weld root resulting in a deep pit along the weld.

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

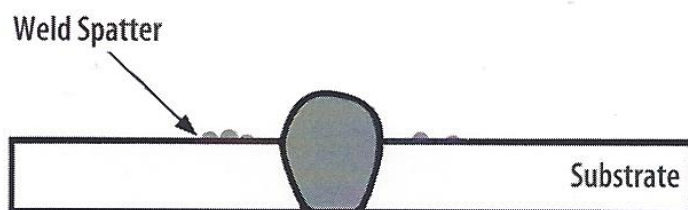
**Repair:** Ensure the edges are smooth with no sharp changes in contour.

**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



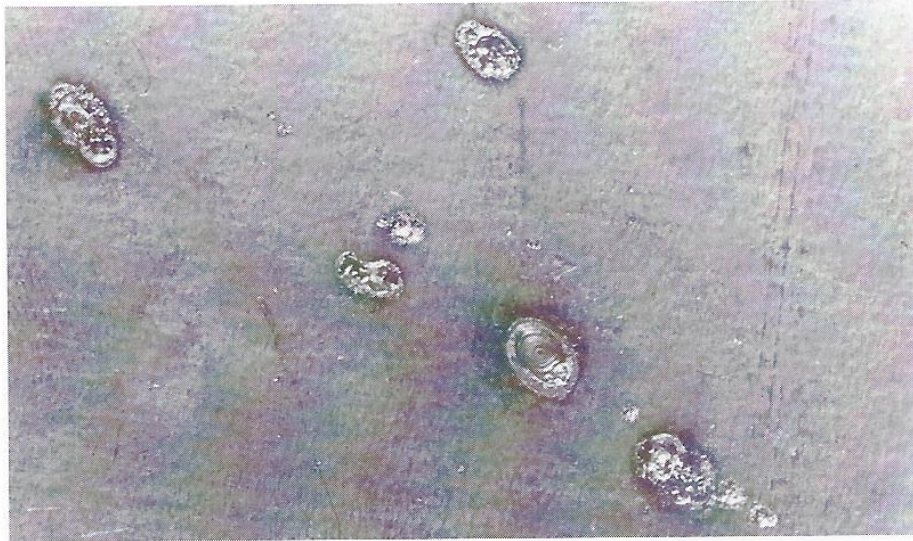
**Description:** Globules of metal which adhere to the metal surface, often some distance from the weld.

**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.

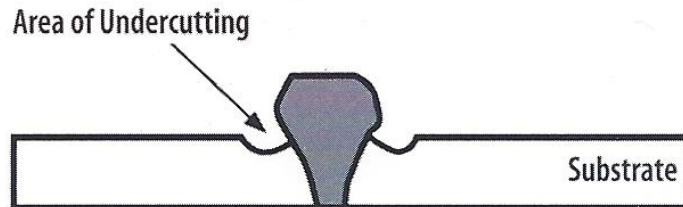
**Repair:** All such porosities must be appropriately filled prior to application of a protective coating system.

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

## **UNDERCUT**



20 mm



**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.

# Fitz's Atlas 2<sup>TM</sup> of coating defects

3 - SURFACE CONDITIONS

## INDEX OF SURFACE CONDITIONS

SURFACE PREPARATION .....	3-2
CORROSION TRAP .....	3-4
POOR DESIGN .....	3-5
EDGES - Flame cut .....	3-6
EDGES - Sharp .....	3-7
MILLSCALE .....	3-8
MILLSCALE - "A" quality steel .....	3-9
MILLSCALE - "B" quality steel .....	3-11
MILLSCALE - "C" quality steel .....	3-13
OIL CONTAMINATION .....	3-15
SKIP WELD .....	3-16
SLAG .....	3-17

### **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 millscale 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**

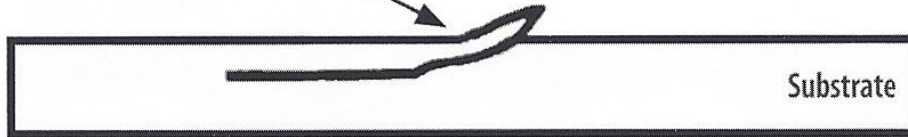
Where repairs are carried out to an already painted surface, the edge of the old paint should be feathered to a sound, well adhered thin edge using an appropriate means of abrasion, prior to overcoating.

#### **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.

Minor laminations  
sometimes known as  
surface shelling



### Millscale

All millscale 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.

## POOR DESIGN



**Description:** Poor design resulting in areas that are inaccessible for surface preparation or paint application.

**Comment:** This problem should be eliminated wherever possible at the design stage by taking into consideration protection from corrosion and accessibility for preparation and paint application.

## 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:** Untreated sharp edges on steel sections.

**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.

### MILLSCALE

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.

## MILLSCALE - "A" QUALITY STEEL



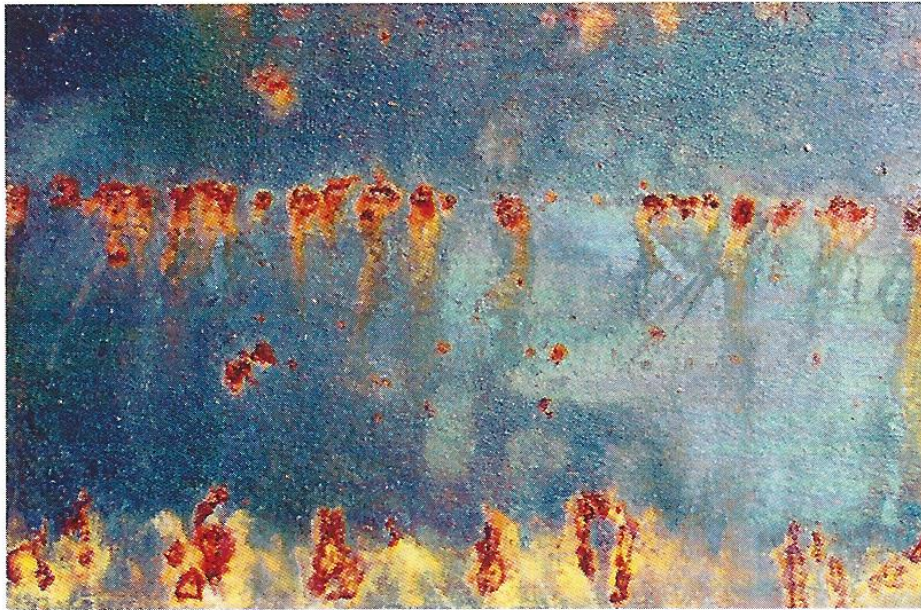
**Description:** A close view of "A" quality steel with virtually intact blue millscale.

## MILLSCALE "A" QUALITY STEEL



**Description:** Steel section where intact blue millscale is present with only light superficial rust in some places.

## MILLSCALE - "B" QUALITY STEEL



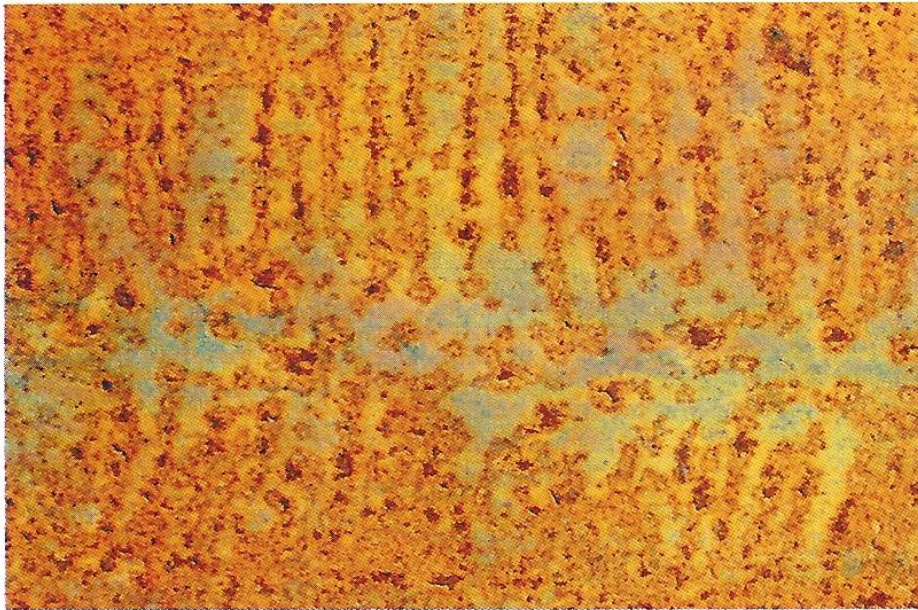
**Description:** Showing some breakdown of the millscale after weathering and formation of corrosion products.

### 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 millscale and a light film of rust has formed on the steel surfaces.

## MILLSCALE - "C" QUALITY STEEL



**Description:** The majority of the millscale has weathered away leaving corrosion products on the surface.

### 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 millscale and an overall film of rust has formed on the steel surfaces.

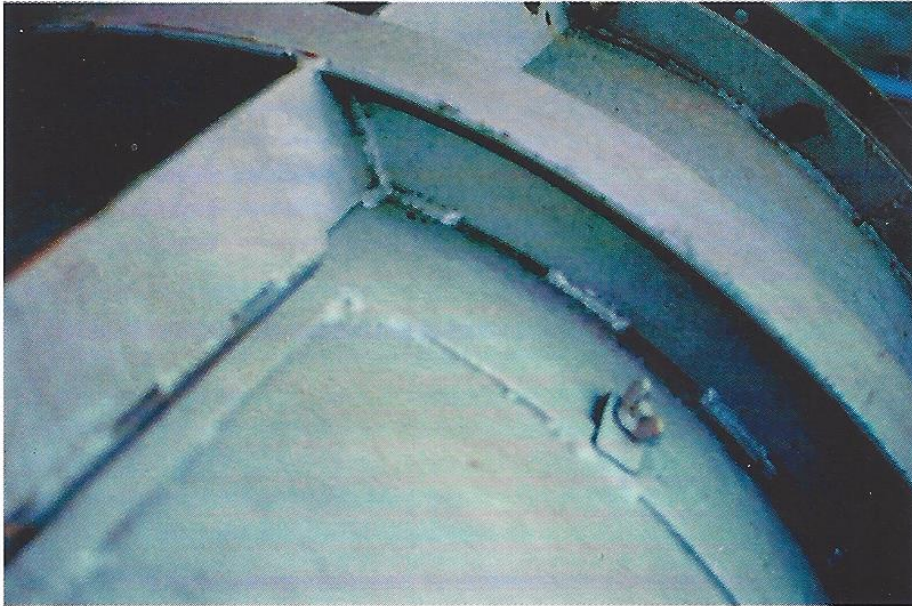
## OIL CONTAMINATION



**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



**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.



# Fitz's Atlas 2<sup>TM</sup> of coating defects

4 - COATING DEFECTS

**INDEX OF COATING DEFECTS**

CONTENTS LIST..... 4-1

ABRASION ..... 4-4

ADHESION FAILURE..... 4-6

ALLIGATORING ..... 4-10

ALUMINIUM CORROSION..... 4-12

APPLICATION DEFECTS..... 4-14

BITTINESS..... 4-18

BLEACHING..... 4-19

BLEEDING ..... 4-20

BLISTERING GENERAL ..... 4-21

BLISTERING INTERCOAT..... 4-24

BLISTERING NON-OSMOTIC..... 4-26

BLISTERING OSMOTIC ..... 4-28

BLOOM ..... 4-31

BODYING ..... 4-32

BRIDGING ..... 4-33

BRUSH MARKS ..... 4-35

BUBBLES or BUBBLING ..... 4-36

CARGO DAMAGE ..... 4-37

CATHODIC DISBONDING..... 4-40

CHALKING ..... 4-42

CHECKING..... 4-44

CHEESINESS..... 4-47

CHEMICAL EXPOSURE..... 4-49

CISSING ..... 4-51

COBWEBBING..... 4-53

CRACKING..... 4-54

CRACKING AT WELDS..... 4-58

CRATERING ..... 4-60

CRAZING..... 4-61

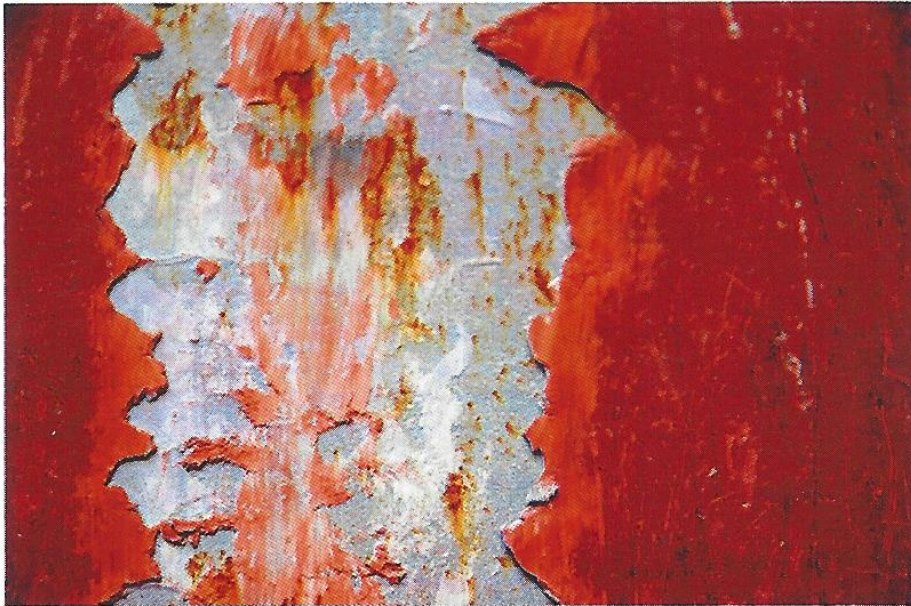
## Coating Defects

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CROWSFOOTING.....	4-63
DEGRADATION.....	4-65
DELAMINATION.....	4-66
DRYSPRAY.....	4-69
EDGE CORROSION.....	4-71
EFFLORESCENCE.....	4-73
EROSION.....	4-75
EXUDATION.....	4-77
FADING.....	4-78
FAT EDGE.....	4-79
FEATHER EDGING.....	4-80
FILIFORM (Corrosion).....	4-82
FISH EYES.....	4-83
FLAKING.....	4-84
FLOCCULATION.....	4-87
FLOODING.....	4-88
FLOTATION.....	4-89
GALVANISING (Loss of adhesion of coating).....	4-90
GRINNING.....	4-92
GRIT INCLUSIONS.....	4-93
GROWTH.....	4-95
HEAT DAMAGE.....	4-97
IMPACT DAMAGE.....	4-99
INCORRECT COATING SYSTEM.....	4-101
INCORRECT COATING THICKNESS.....	4-103
INTERCOAT CONTAMINATION.....	4-104
KNOTTING.....	4-105
LAMINATIONS or SHELLING.....	4-106
MECHANICAL DAMAGE.....	4-108
MILKINESS.....	4-110
MILLSCALE.....	4-111
MISSES/SKIPS/HOLIDAYS.....	4-113
MISSING TOPCOAT.....	4-115

MUD CRACKING .....	4-116
ORANGE PEEL.....	4-117
OVERSPRAY .....	4-119
PEELING.....	4-121
PINHOLES .....	4-123
PRIMER DEGRADATION.....	4-125
RAIN DAMAGE.....	4-127
RIPPLED COATING.....	4-129
ROT (Wood) .....	4-130
RUNS .....	4-132
RUST JACKING.....	4-133
RUST RASHING (THERMAL SPRAY).....	4-134
RUST RASHING.....	4-135
RUST SPOTTING.....	4-137
RUST STAINING .....	4-140
SAGS.....	4-142
SALTS.....	4-146
SAPONIFICATION.....	4-147
SETTLEMENT .....	4-148
SKINNING .....	4-149
SOLVENT LIFTING .....	4-150
SOLVENT POPPING.....	4-151
STAINING.....	4-152
STRESS CRACKING.....	4-154
STRIPE COATS .....	4-157
TACKINESS.....	4-159
UNDER CURED COATING.....	4-160
UNDERCUTTING .....	4-161
WATER SPOTTING.....	4-163
WRINKLING.....	4-164
ZINC SALTS .....	4-167

### ABRASION



*Other examples are shown on the following page*

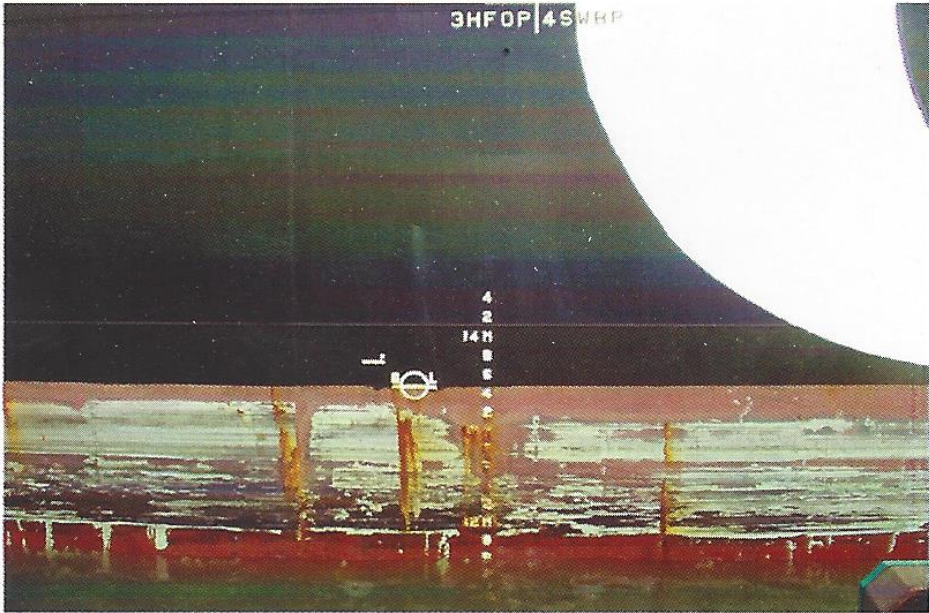
**Description:** The mechanical action of rubbing, scraping, scratching, gouging or erosion.

**Probable Causes:** Removal of a portion of the surface of the coating or in severe cases removal to expose the substrate by contact with another object such as the use of metal chains for lifting, cargo, fenders, or the grounding of a ship.

**Prevention:** Use of abrasion resistant coatings formulated with particular regard to resins and extender pigments. With severe cases of abrasion the effects will only be reduced or limited by an abrasion resistant coating.

**Repair:** Depends on the extent of the damage and could range from individual areas prepared by mechanical cleaning to the blast cleaning of large areas. Application of an abrasion resistant coating.

ABRASION



### **ADHESION FAILURE** see also delamination and flaking



*Other examples are shown on the following pages*

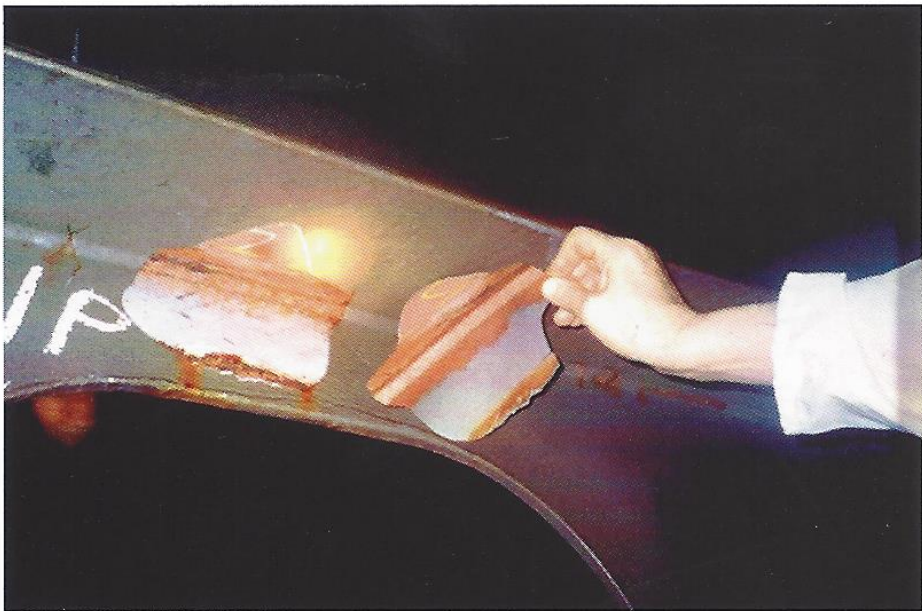
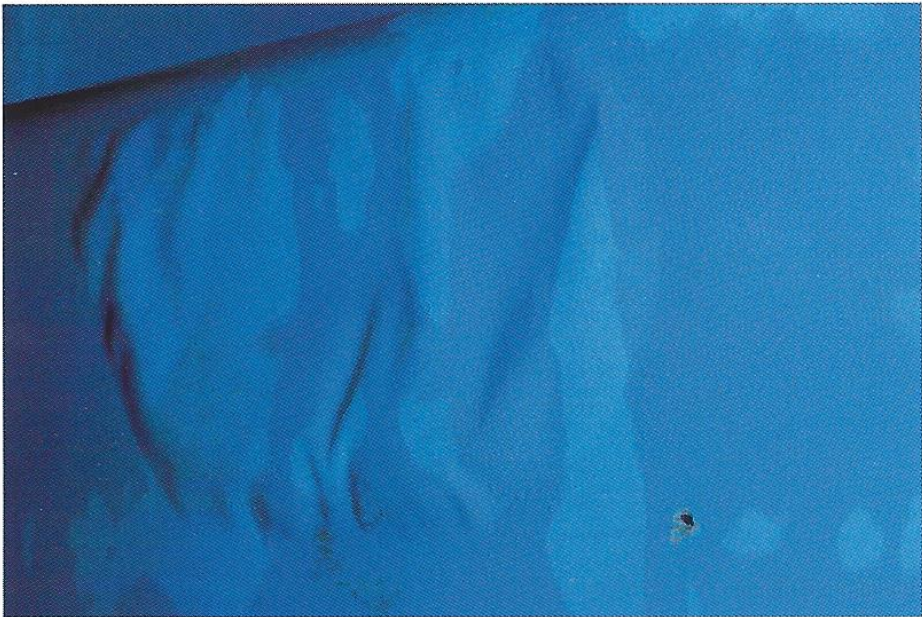
**Description:** Paint fails to adhere to substrate or underlying coats of paint..

**Probable Causes:** Surface contamination or condensation, incompatibility between coating systems and exceeding the overcoating time.

**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 and follow the advised overcoating times.

**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.

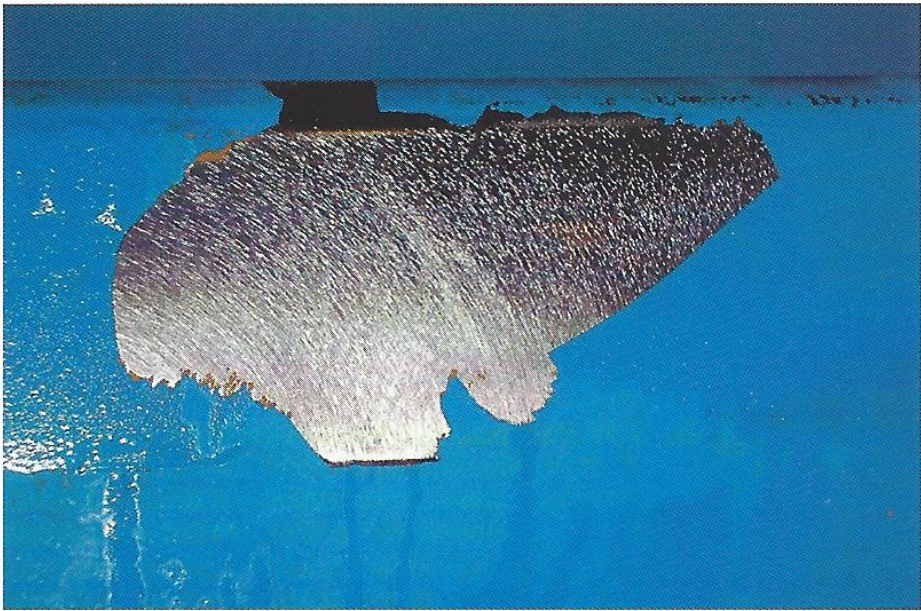
**ADHESION FAILURE**  
see also delamination and flaking



**ADHESION FAILURE**  
see also delamination and flaking



**ADHESION FAILURE**  
see also delamination and flaking



### **ALLIGATORING** (also known as Crocodiling)



*Other examples are shown on the following page*

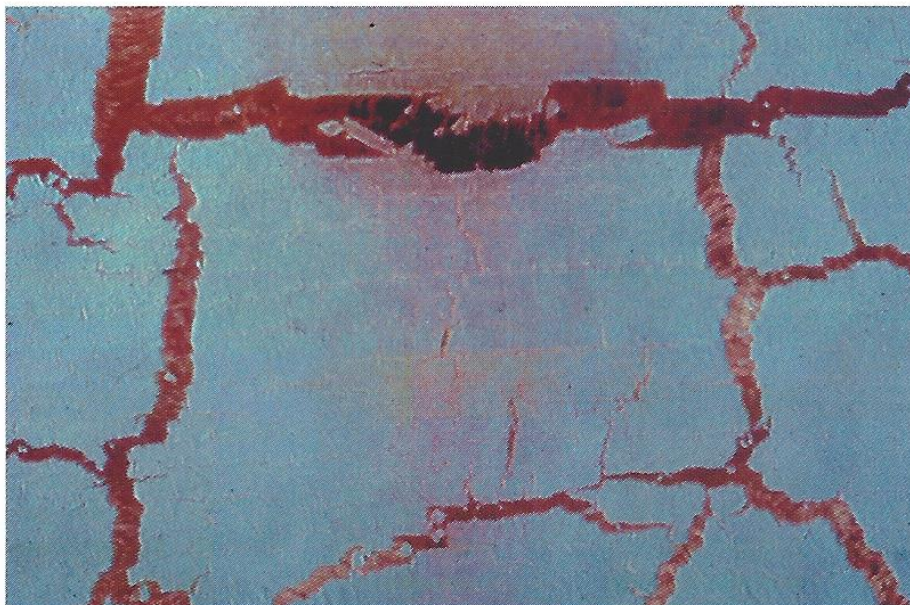
**Description:** Very large (macro) crazing/cracking which resembles the skin of an alligator or crocodile. Cracks may penetrate through to the undercoat or down to the substrate.

**Probable Causes:** Internal stresses in the coating where the surface shrinks faster than the body of the paint film. Excessive film thickness and limited paint flexibility. Application of a hard topcoat over a more flexible softer undercoat. Application of topcoat before the undercoat has dried.

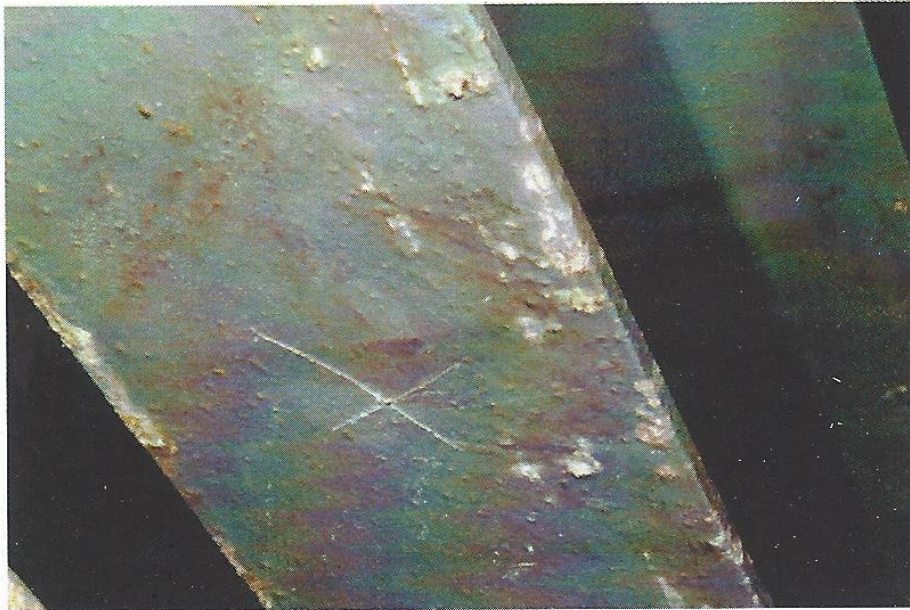
**Prevention:** Use correct coating specification and compatible materials. Avoid excessive film thickness. Avoid application at high ambient temperatures.

**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

**ALLIGATORING**  
(also known as Crocodiling)



### ALUMINIUM CORROSION



Other examples are shown on the following page

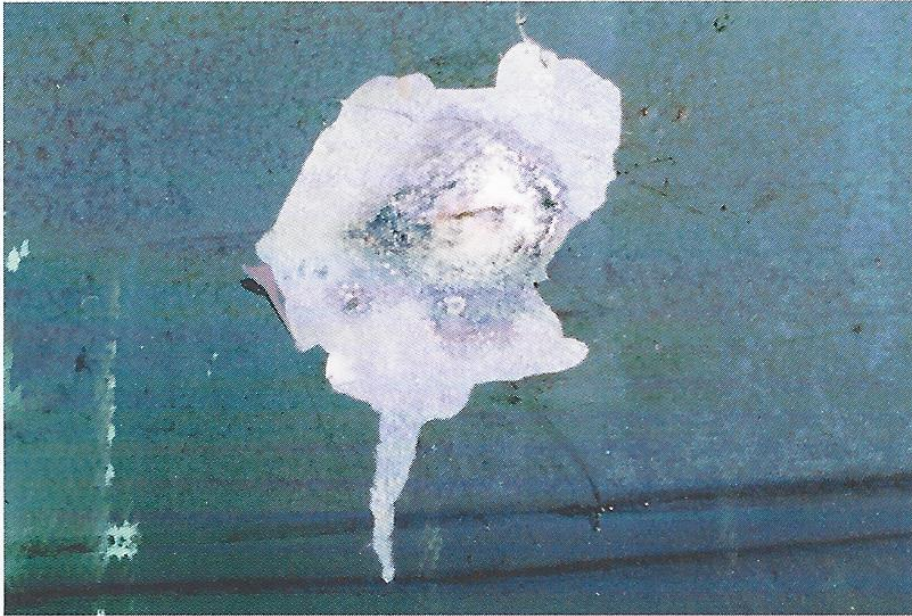
**Description:** Blistering and/or lifting/disruption of the paint coating due to the formation of aluminium corrosion products under the paint.

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

**Prevention:** Use correctly formulated coating system applied at the correct thickness as a closed film.

**Repair:** Blast clean and recoat.

## ALUMINIUM CORROSION



### APPLICATION DEFECTS



Other examples are shown on the following pages

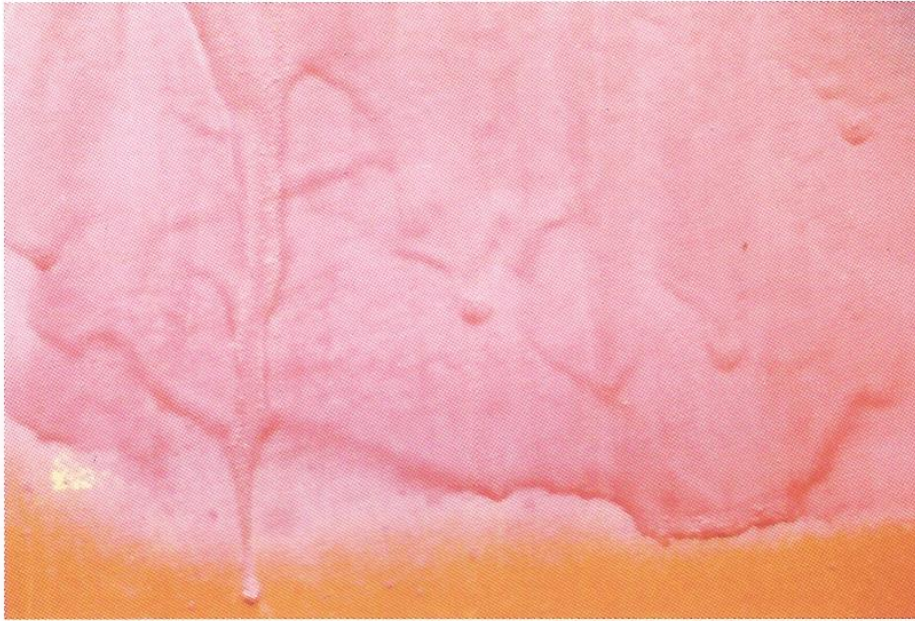
**Description:** Defects associated with application by brush e.g. brush hairs in the coating, contamination from rollers, fingering and spattering from spray application.

**Probable Causes:** Poor quality brushes and rollers, incorrect brush and roller materials, incorrect spray setup and inadequate care during application.

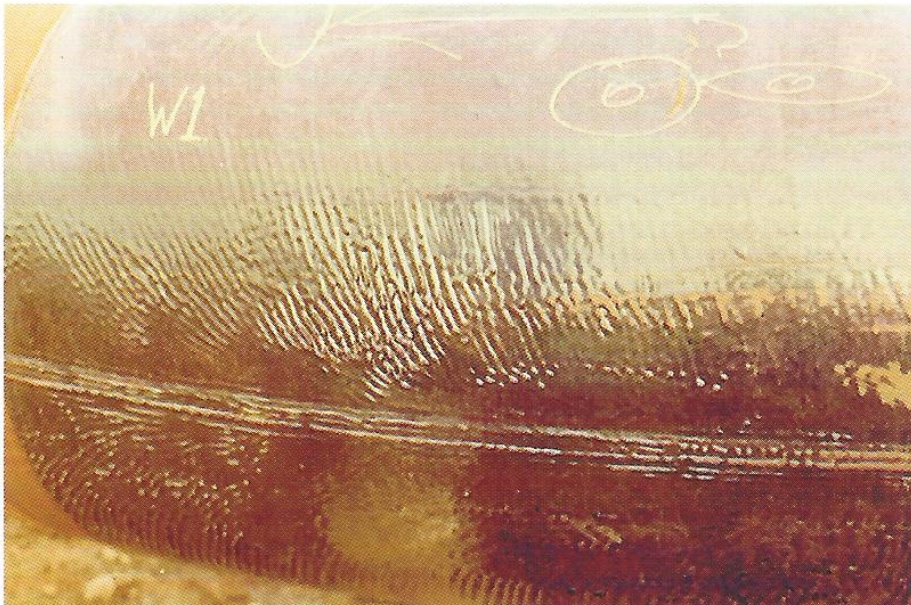
**Prevention:** Use good quality equipment of the correct type and follow the data sheet guidelines.

**Repair:** Repair is related to the type and extent of the defect but often rubbing down and recoating is adequate.

**APPLICATION DEFECTS**



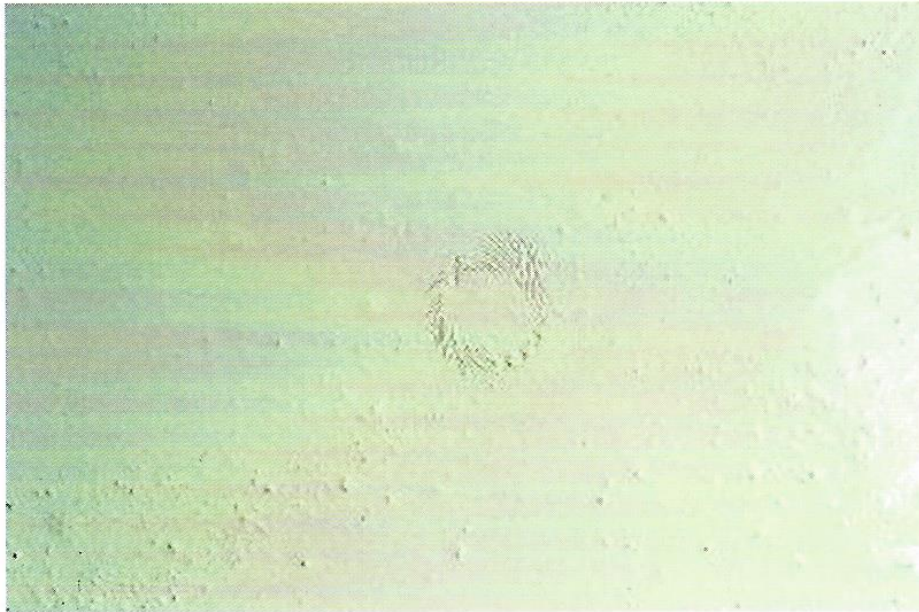
## APPLICATION DEFECTS



## APPLICATION DEFECTS



### **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 material 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



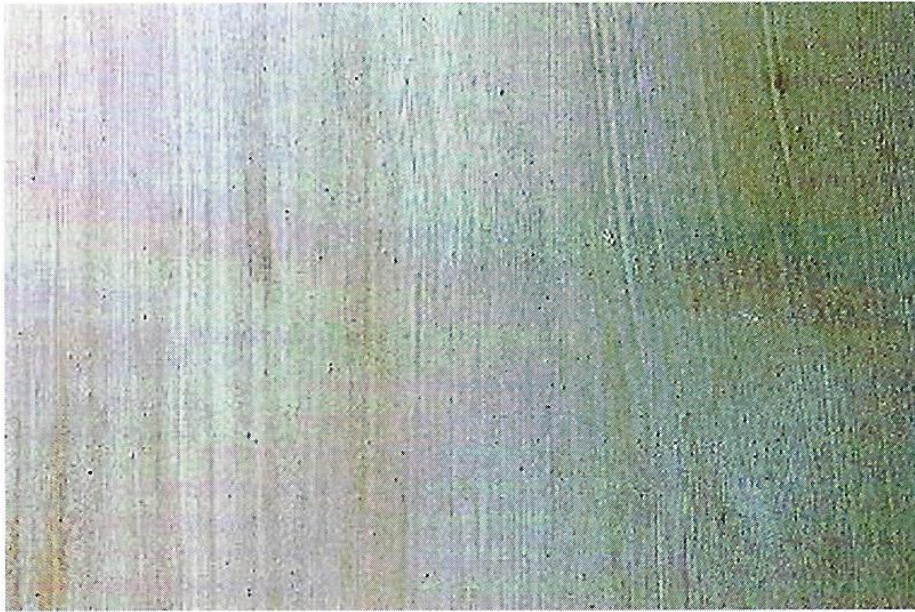
**Description:** Total loss of colour of a coating.

**Probable Causes:** Weathering or exposure to chemicals.

**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 known as 'Bleed Through')



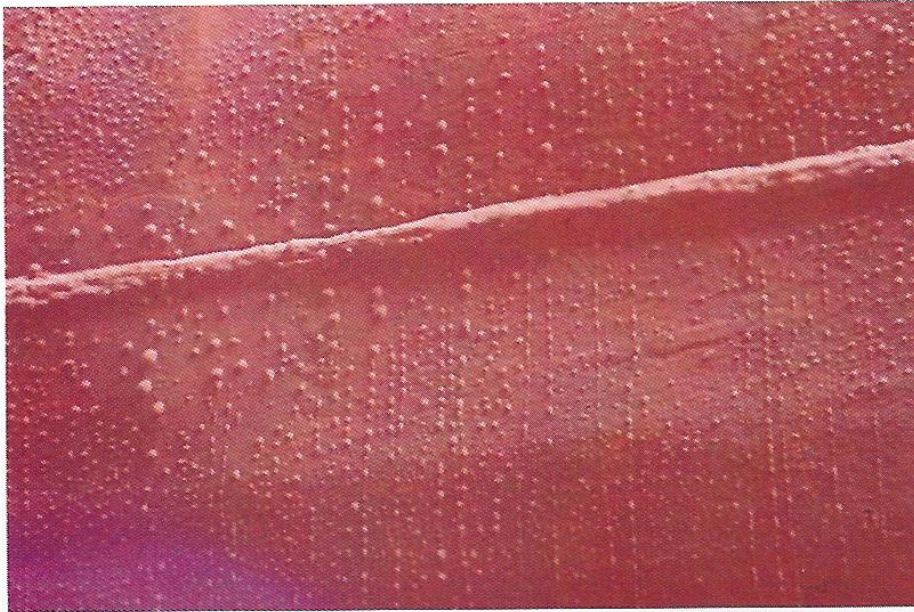
**Description:** Staining of a paint film by diffusion of a soluble coloured substance from the underlying paint to give undesirable discoloration or staining . Often seen where bituminous or tar based products are overcoated with topcoats in which the tar or bitumen is soluble. Also occurs with emulsion paints.

**Probable Causes:** 'Bleed Through' is generally a full or partial redissolving of the previous coat or an ingredient of a previous coat and can occur when strong solvents are used in the topcoats.

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

**Repair:** Remove stained or contaminated layer. Apply a suitable sealer coat which will prevent the diffusion of soluble coloured material from beneath. It may be possible to apply a sealer coat without the removal of the stained/contaminated layer.

### BLISTERING (General)



Other examples are shown on the following pages

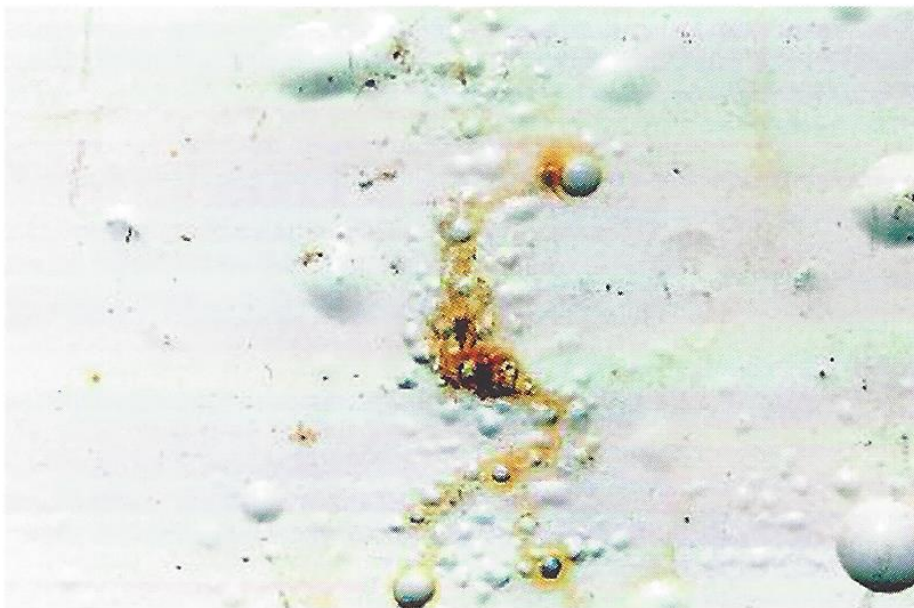
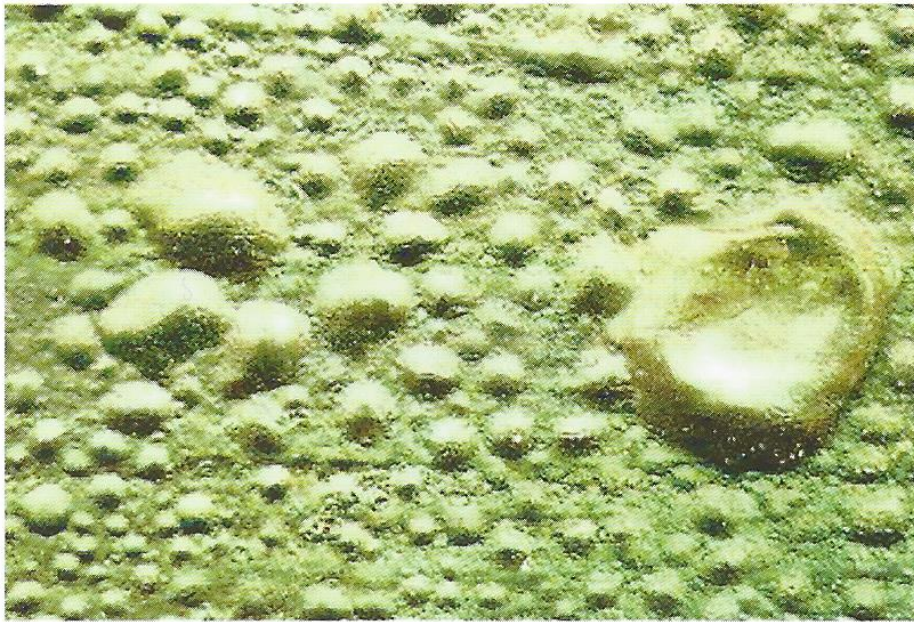
**Description:** Dome shaped projections or blisters in the dry paint film through local loss of adhesion and lifting of the film from the underlying surface. Blisters may contain liquid, vapour, gas or crystals.

**Probable Causes:** Many mechanisms can be involved including osmotic gradients associated with soluble salts, soluble pigments, corrosion products, retained solvents and solvents from cargoes. Non-osmotic blistering associated with electro endosmosis, cathodic disbonding, thermal gradients related to cold wall effects and compressive stress.

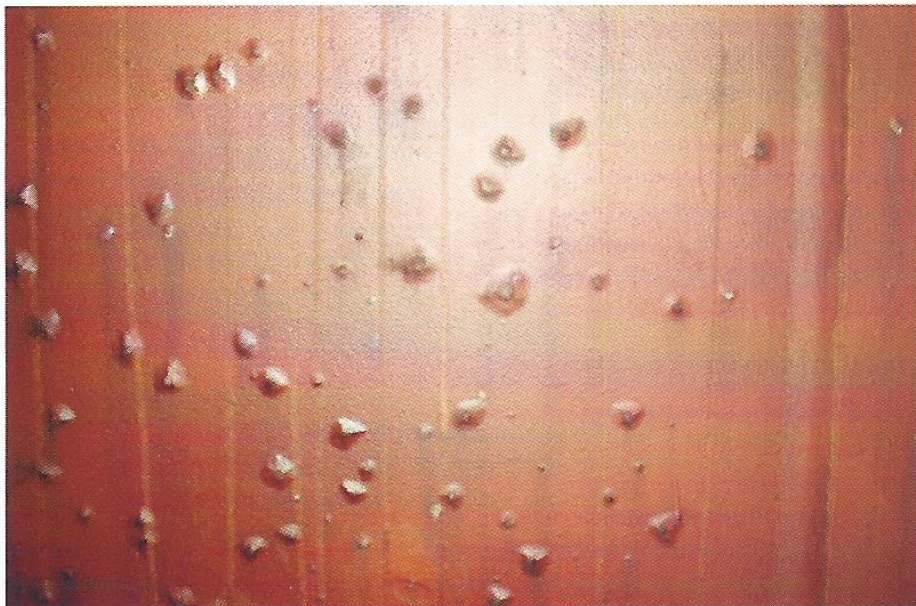
**Prevention:** Ensure correct surface preparation and application. Apply a suitable coating system after testing for soluble salts. Consider the possibility of the different blister mechanisms in the particular environment.

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

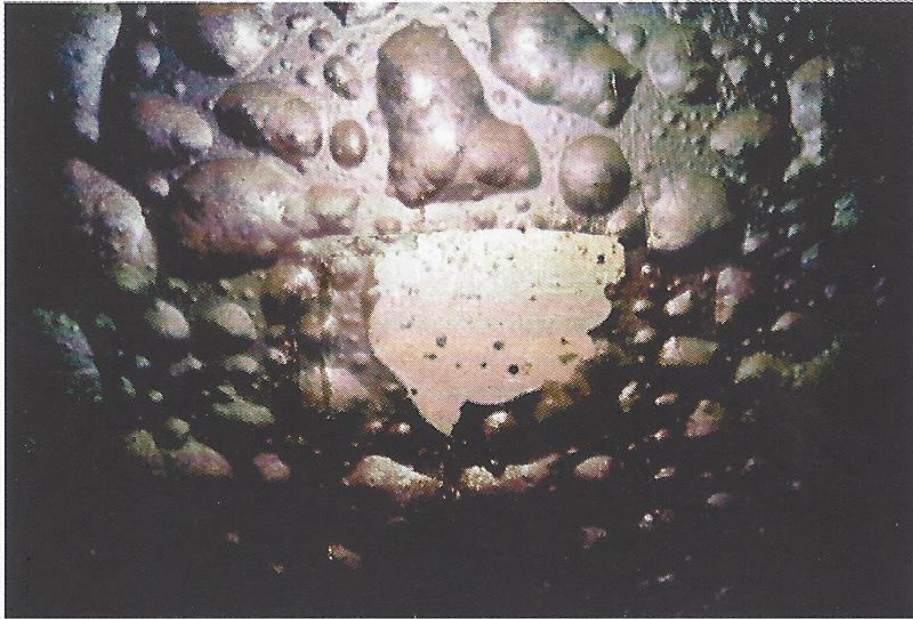
## BLISTERING (General)



## BLISTERING (General)



### BLISTERING – INTERCOAT



Other examples are shown on the following page

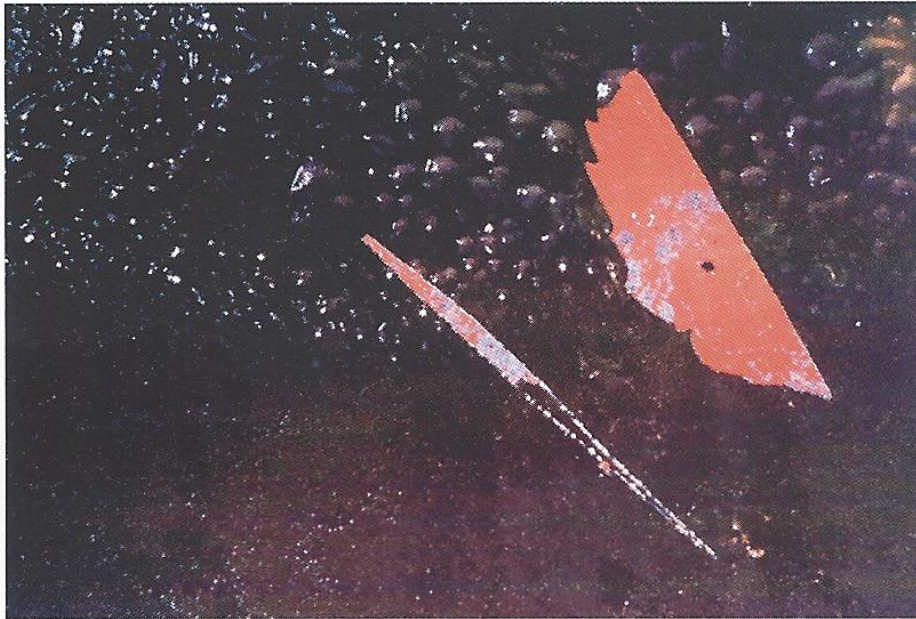
**Description:** Dome shaped projections or blisters in the dry paint film through local loss of adhesion from an underlying coating.

**Probable Causes:** Commonly the presence of soluble salt contamination between coats or soluble material in the underlying coats.

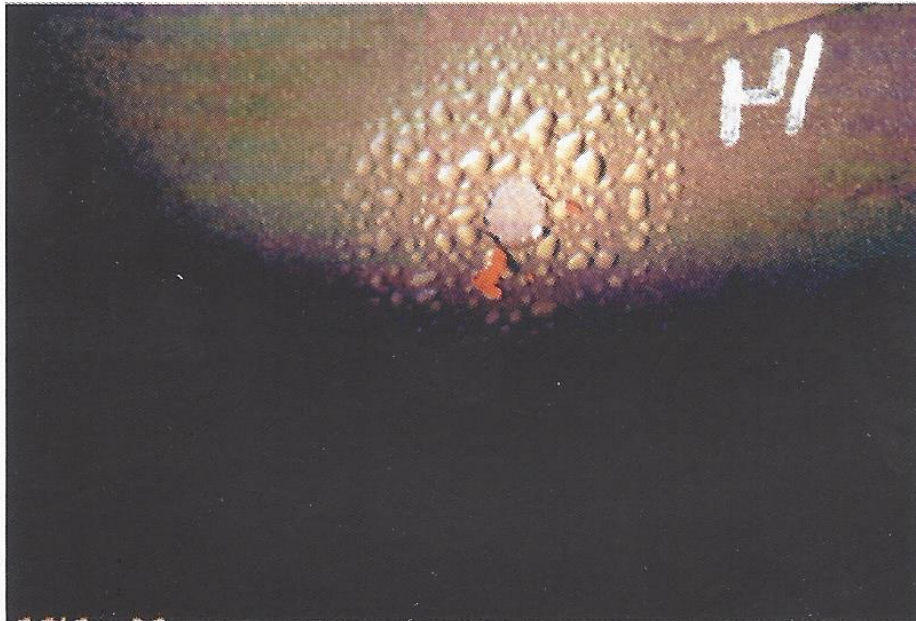
**Prevention:** Ensure that tests for soluble salts are carried out if contamination is suspected and fresh water wash if necessary

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

**BLISTERING – INTERCOAT**



### BLISTERING – NON-OSMOTIC



Other examples are shown on the following page

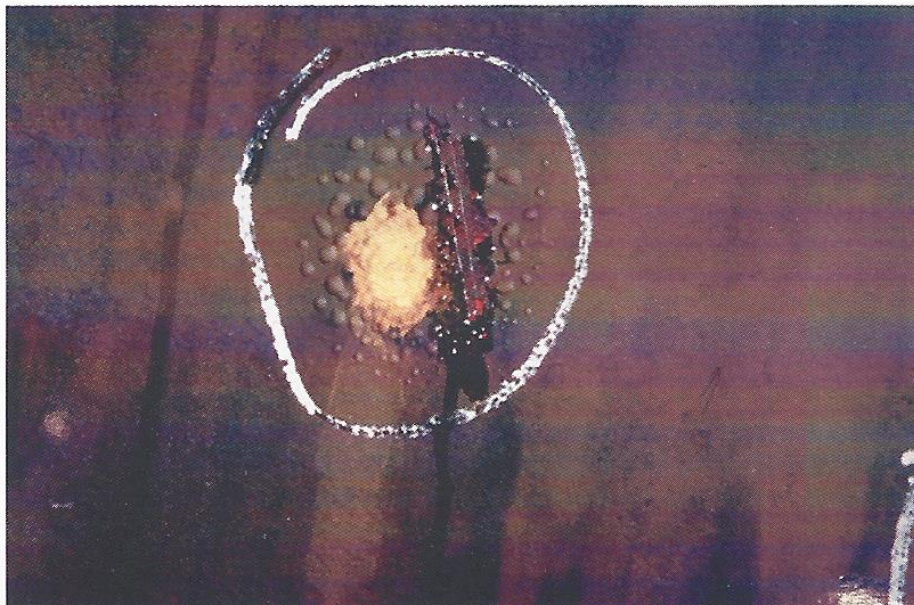
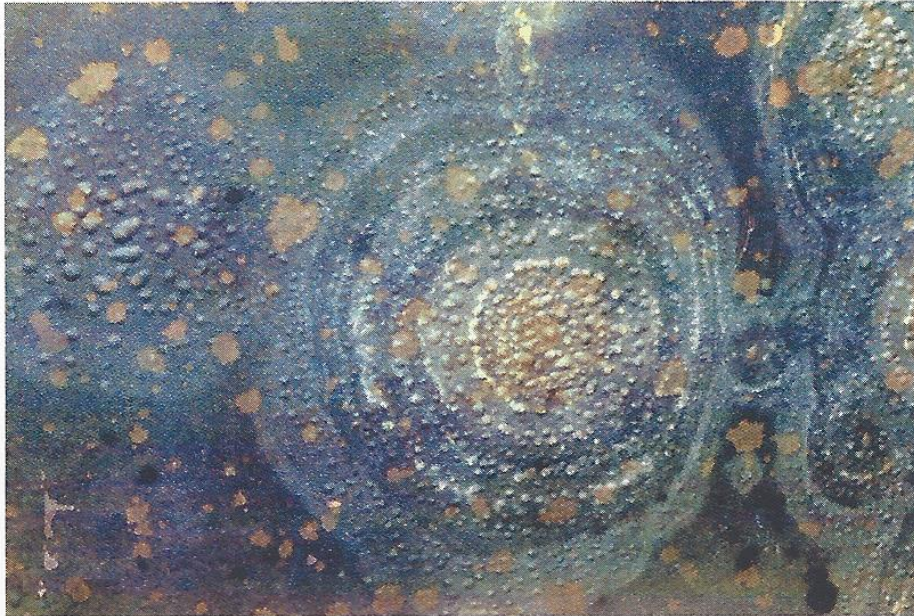
**Description:** Dome shaped projections or blisters in the dry paint film through local loss of adhesion from the steel substrate.

**Probable Causes:** Non-osmotic blistering associated with electroendosmosis, cathodic disbonding, thermal gradients related to cold wall effects and compressive stress. Where electroendosmosis is involved, the blistering is often seen as a circular pattern of blisters around a coating defect where the substrate is exposed.

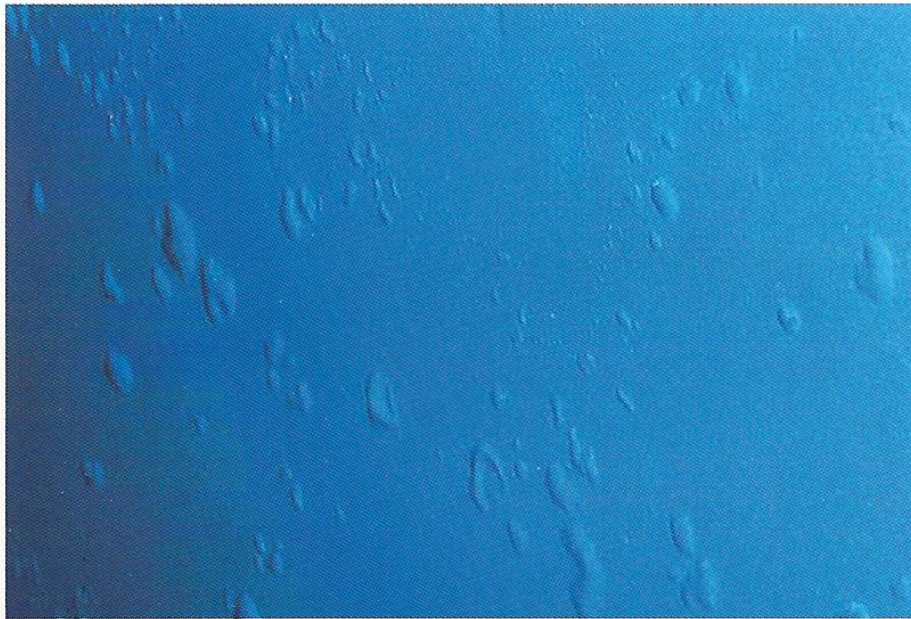
**Prevention:** Ensure correct surface preparation and application. Apply a suitable coating system after considering the possibility of the different blister mechanisms in the particular environment.

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

## BLISTERING – NON-OSMOTIC



### BLISTERING – OSMOTIC



Other examples are shown on the following pages

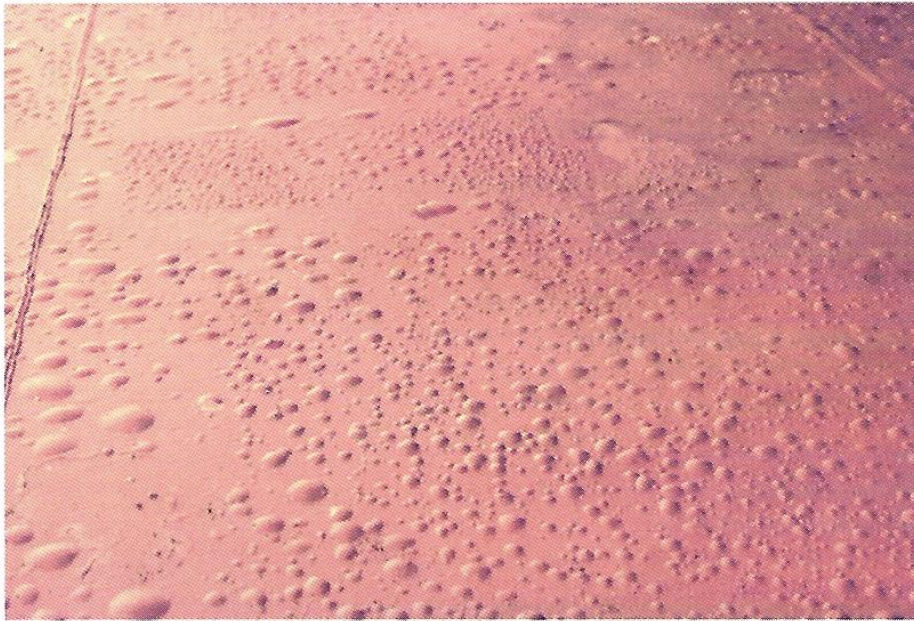
**Description:** Dome shaped projections or blisters in the dry paint film through local loss of adhesion from an underlying coating.

**Probable Causes:** Osmotic blistering is commonly associated with the presence of soluble salts, soluble pigments, soluble corrosion products, retained solvents or the absorption and retention of low molecular weight water miscible solvents, typically from the carriage of chemical cargoes.

**Prevention:** Ensure correct surface preparation and application and follow working procedures for ventilation etc. Apply a suitable coating system after testing for soluble salts. Consider the possibility of the different blister mechanisms in the particular environment.

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

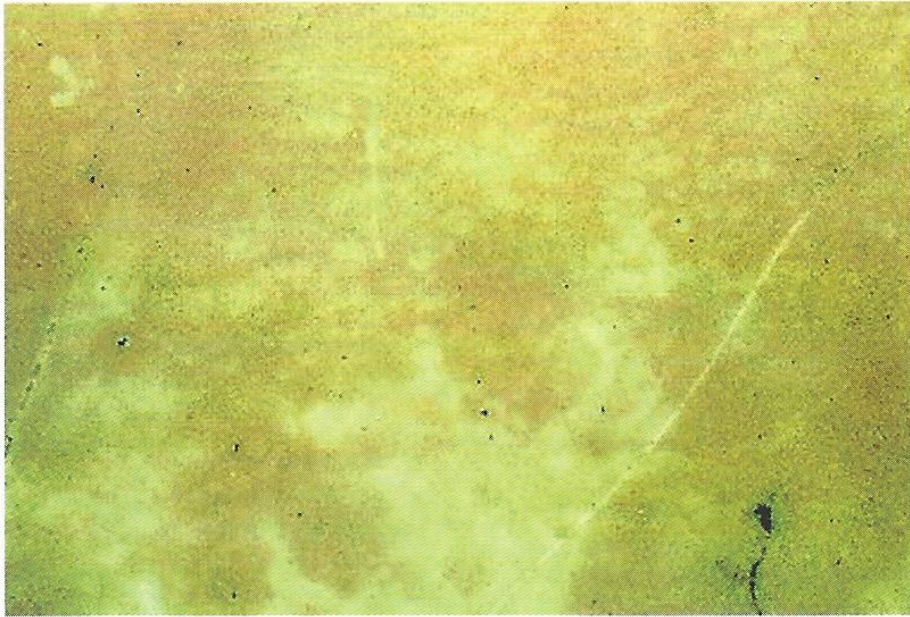
**BLISTERING – OSMOTIC**



**BLISTERING – OSMOTIC**



## BLOOM (BLUSH)



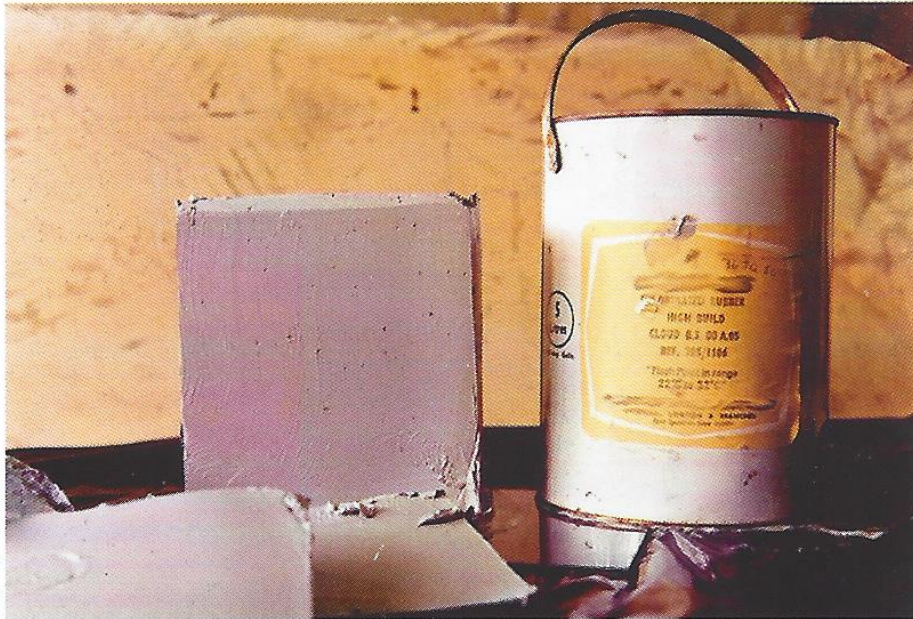
**Description:** A hazy deposit on the surface of the paint film resembling the bloom on a grape, resulting in a loss of gloss and a dulling of colour.

**Probable Causes:** Paint film exposed to condensation or moisture during curing especially at low temperature (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.

### BODYING



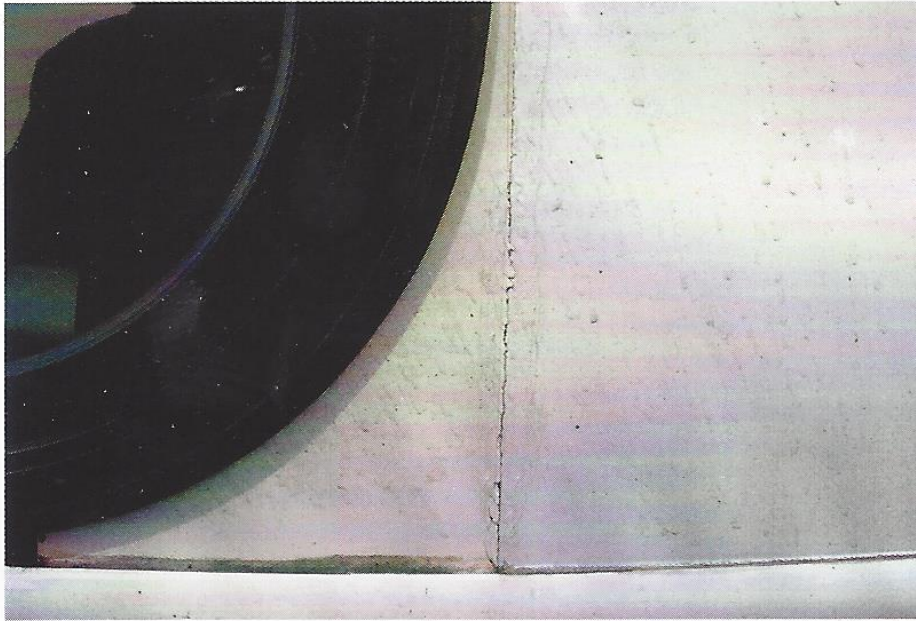
**Description:** An increase in the consistency/body of a coating that occurs during manufacture or storage often increasing the viscosity to a point that it is unusable.

**Probable Causes:** Incorporation of too much thixotrope or poor storage conditions

**Prevention:** Correct raw material control and correct storage.

**Repair:** The coating is often unusable.

### BRIDGING



Other examples are shown on the following page

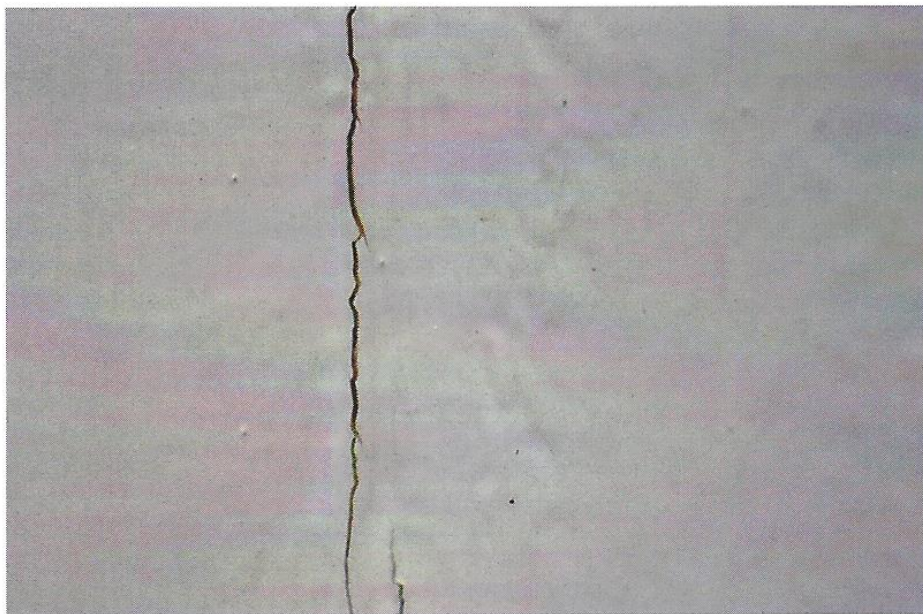
**Description:** The covering over of unfilled gaps such as cracks or corners with a film of coating material. This introduces a weakness in the paint film which may crack or flake off.

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

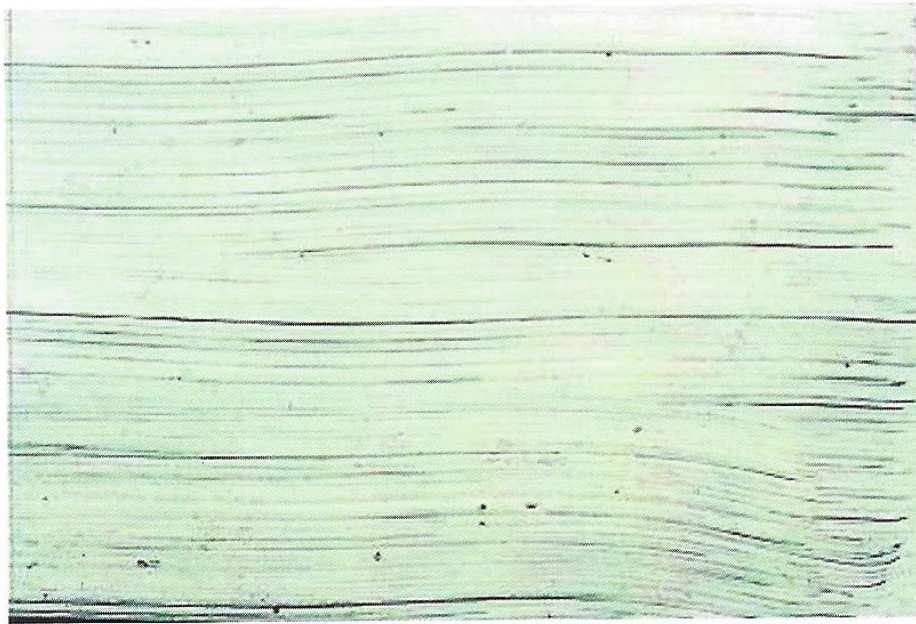
**Prevention:** Brush apply a stripe coat into corners and welds and fill all cracks or weld them prior to application of the full coating system.

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

## BRIDGING



### **BRUSH MARKS (also Laddering, Ladders or Ropiness)**



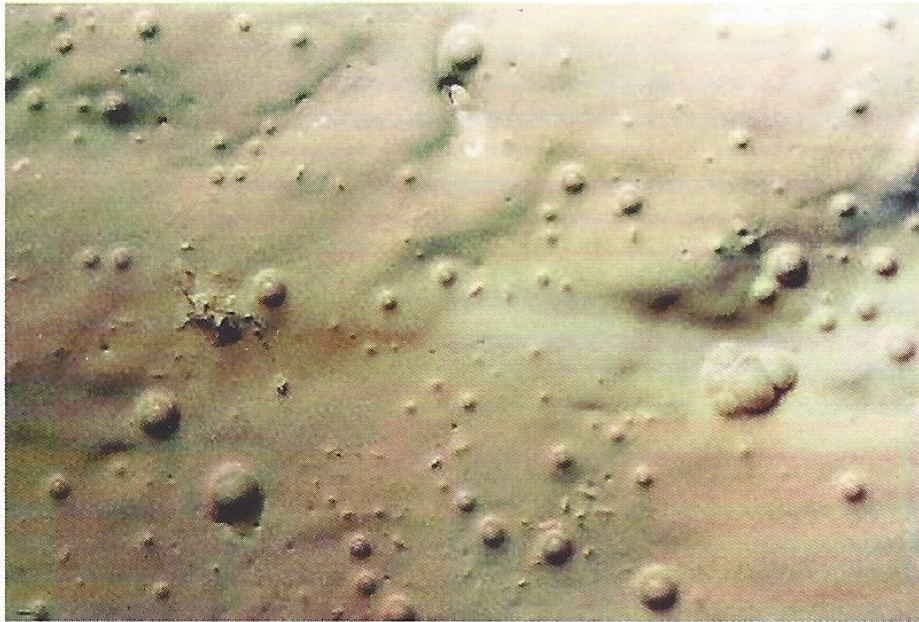
**Description:** Undesirable ridges and furrows which remain in a dry paint film after brush application, where the paint film has not flowed out. May be found as a cross-hatch pattern (Laddering) where alternate coats have been applied in opposite directions. Pronounced brush marks are known as Ropiness.

**Probable Causes:** Viscosity of material may be too high for brush application; Incorrect thinners used; Inadequate mixing or poor application technique; paint has poor leveling properties; 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 suitable viscosity paint.

### BUBBLES OR BUBBLING



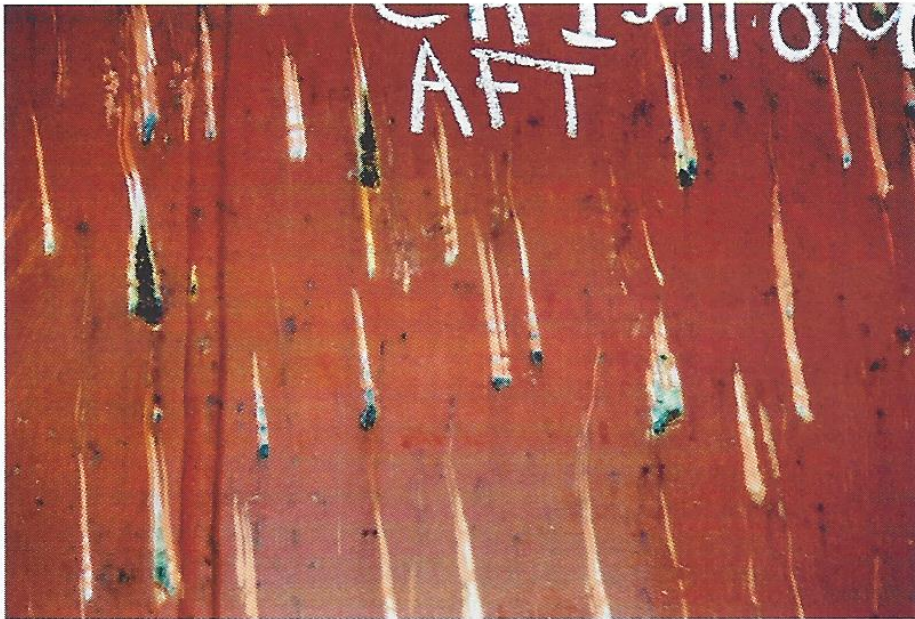
**Description:** Bubbles within a paint film appear as small blisters. These may be intact or broken (to leave a crater). Can be found in excessively thick paint films, especially if spray applied, and also with roller application. This should not be confused with blistering.

**Probable Causes:** Trapped air/solvent within the coating which is not released before the surface dries. Air entrainment during mixing. High ambient temperature during application. Also seen when overcoating antifouling without removal of the leached layer and zinc silicates. Can be found with factory applied coatings where application is by dipping, electrodeposition or roller coating.

**Prevention:** Spray application - adjust viscosity with thinners and follow data sheet requirements for maximum application temperature. Use correct mixing equipment to ensure air is not stirred in during mixing. Apply a mist coat. Add defoaming agent to emulsion paints.

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

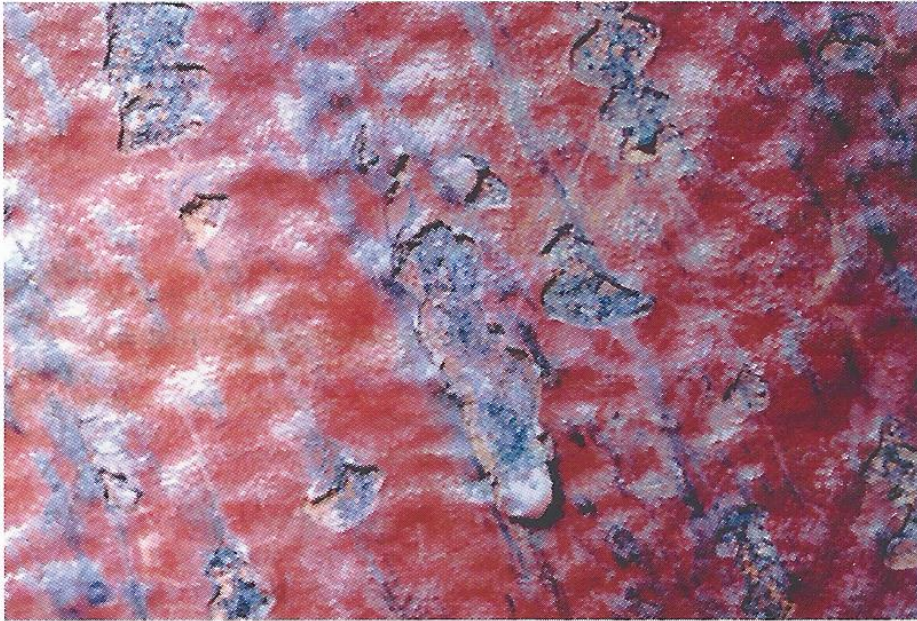
## CARGO DAMAGE



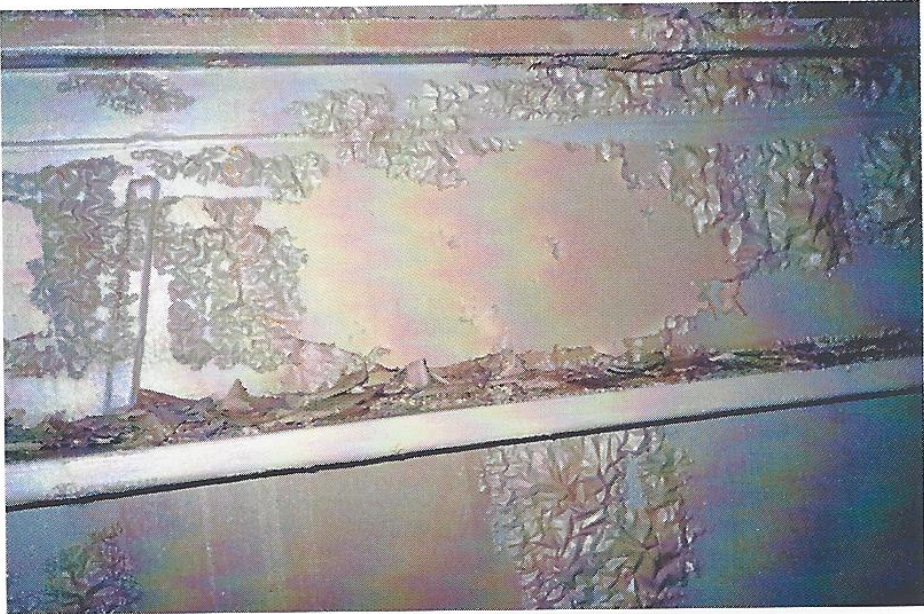
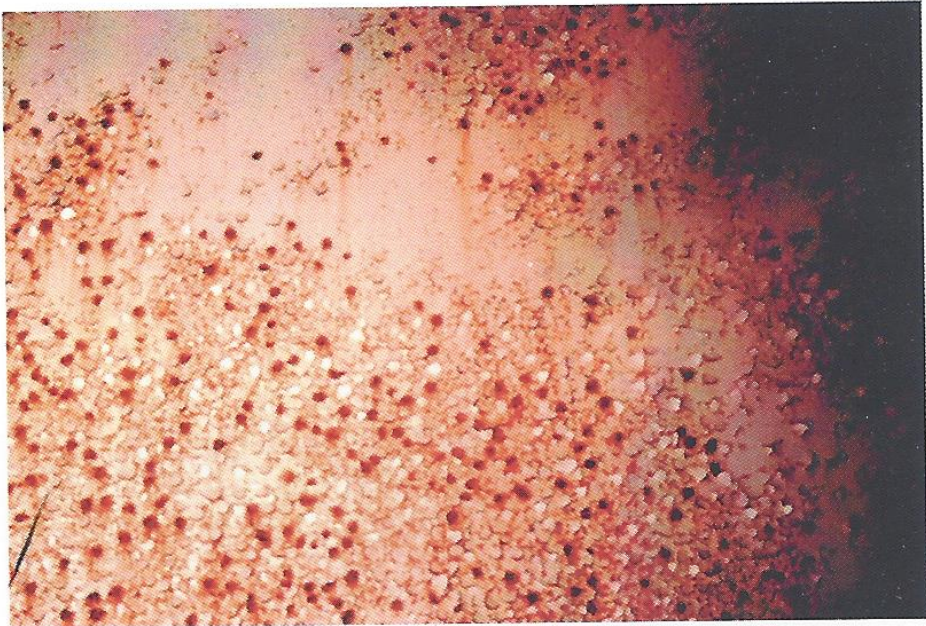
Other examples are shown on the following pages

- Description:** Deformation or removal of a coating by physical action or chemical action
- Probable Causes:** An example of physical action is the abrasive contact of a hard angular cargo on the holds of a bulk carrier and an example of chemical action is that of an aggressive chemical cargo on a tank lining.
- Prevention:** Use an abrasive resistant coating (in most cases this will reduce/limit but not prevent the abrasion) or a coating compatible with the cargo to be carried.
- Repair:** In the case of isolated mechanical damage, spot repair and touch up. In the case of extensive damage blast clean and recoat may be required.

## CARGO DAMAGE



CARGO DAMAGE



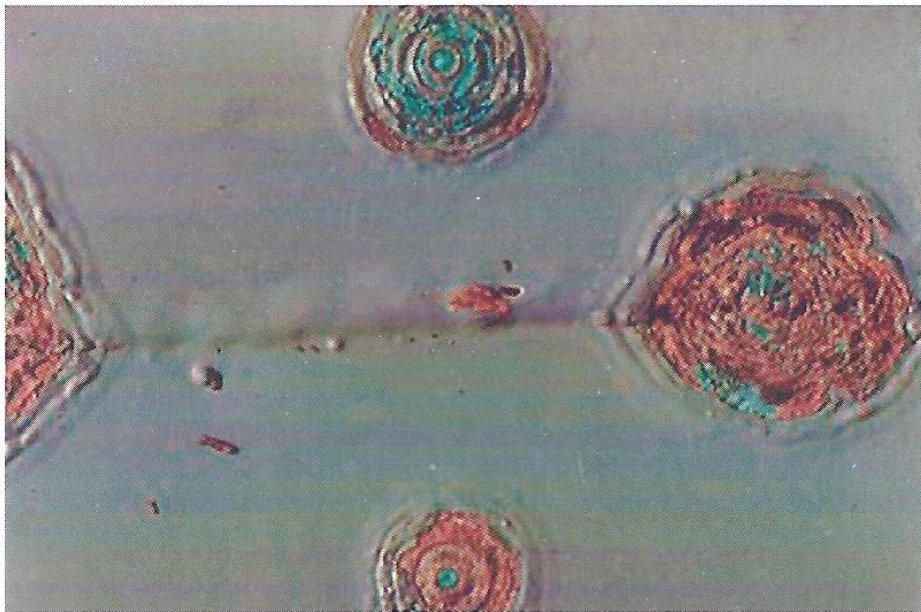
### CATHODIC DISBONDING



Other examples are shown on the following page

- Description:** Blistering and delamination of a coating system around bare steel areas and coating defects associated with cathodic protection on buried pipelines, immersed structures and the hulls of ships.
- Probable Causes:** High overvoltage principally from impressed current systems but also to a lesser extent with sacrificial anodes when the number of anodes is excessive. Factors are incorrect installation, poor monitoring, and incompatible coating systems.
- Prevention:** Use a well designed cathodic protection system, regularly monitored with well placed reference electrodes and application of an alkali resistant coating system.
- Repair:** Eliminate the source of the overprotection. Blast clean the affected areas and apply a suitable coating system.

## CATHODIC DISBONDING



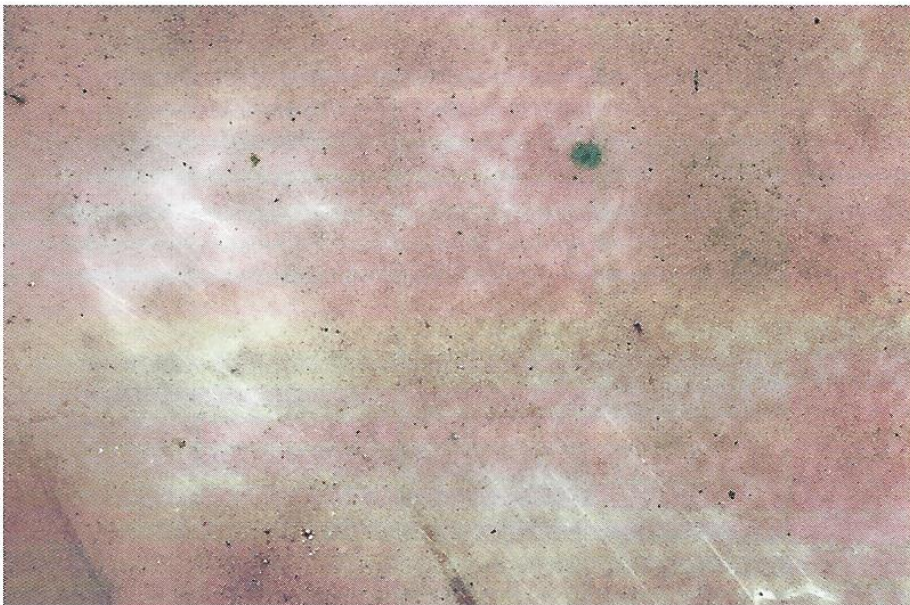
### CHALKING



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 with UV resistance.
- Repair:** Remove all powdery deposits by wiping, scrubbing, high pressure washing or abrasion. Wipe loose material off and apply a chalk resistant topcoat.

## CHALKING



### CHECKING



Other examples are shown on the following page

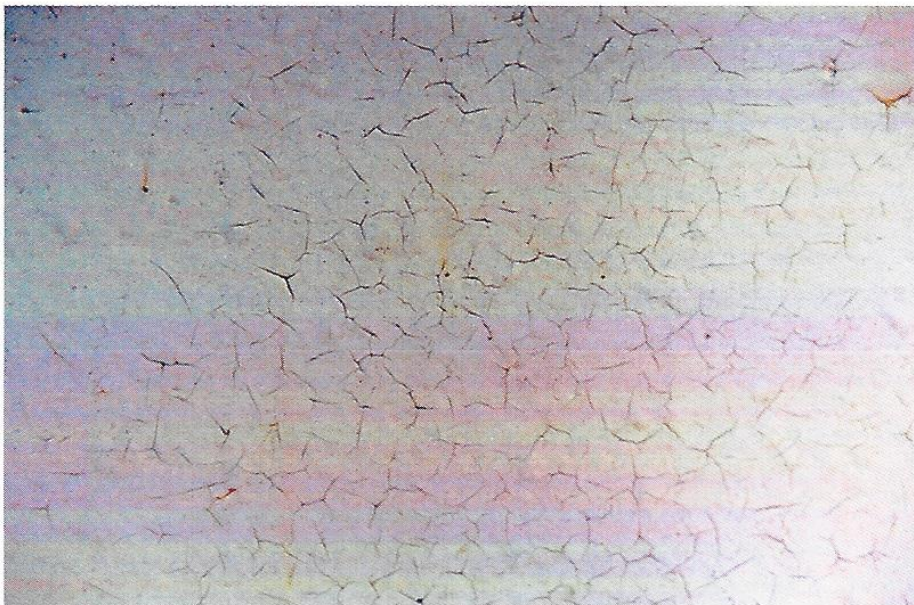
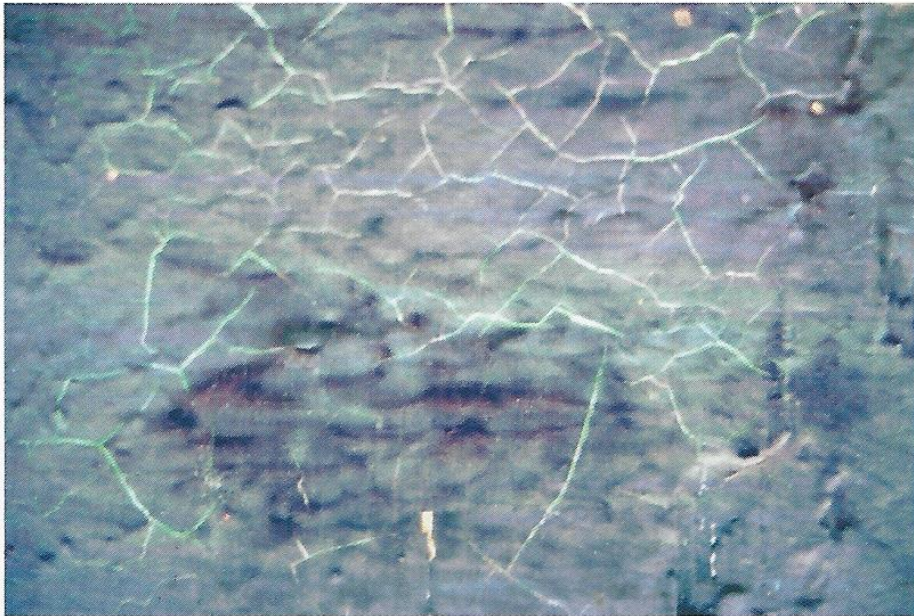
**Description:** Fine cracks which do not penetrate the topcoat of a paint system. Some checking can be so minute that it is impossible to see without magnification.

**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.

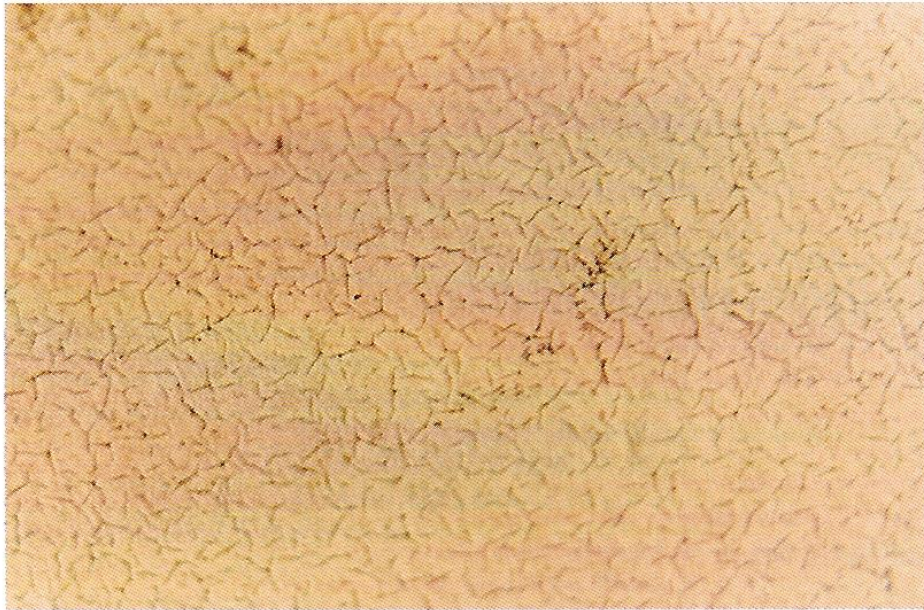
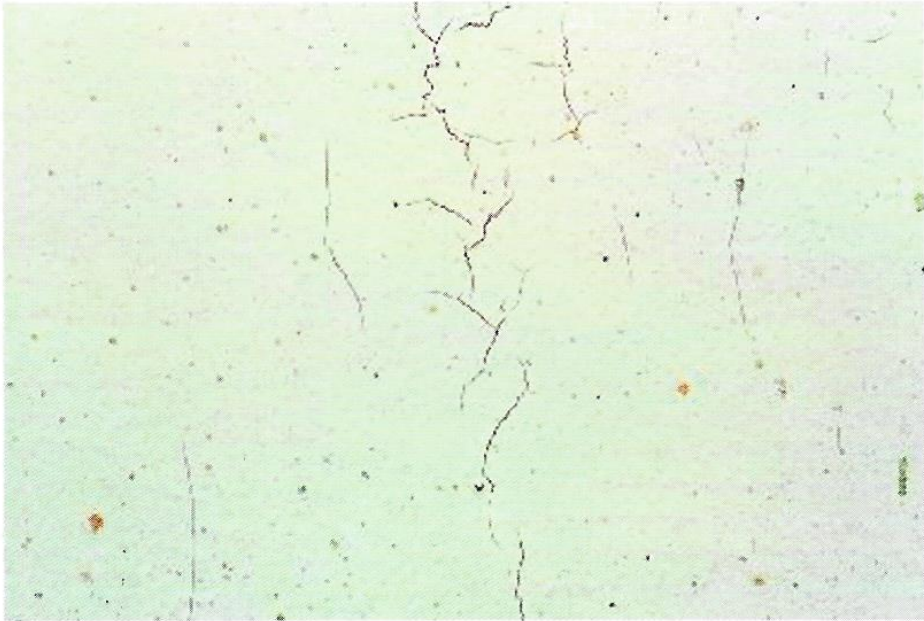
**Prevention:** Use a correctly formulated coating system.

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

**CHECKING**



**CHECKING**



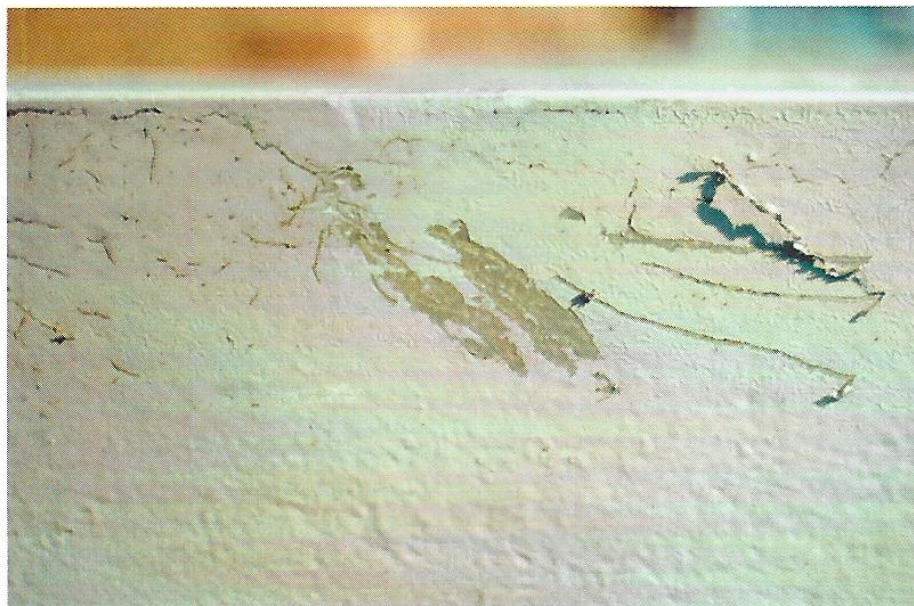
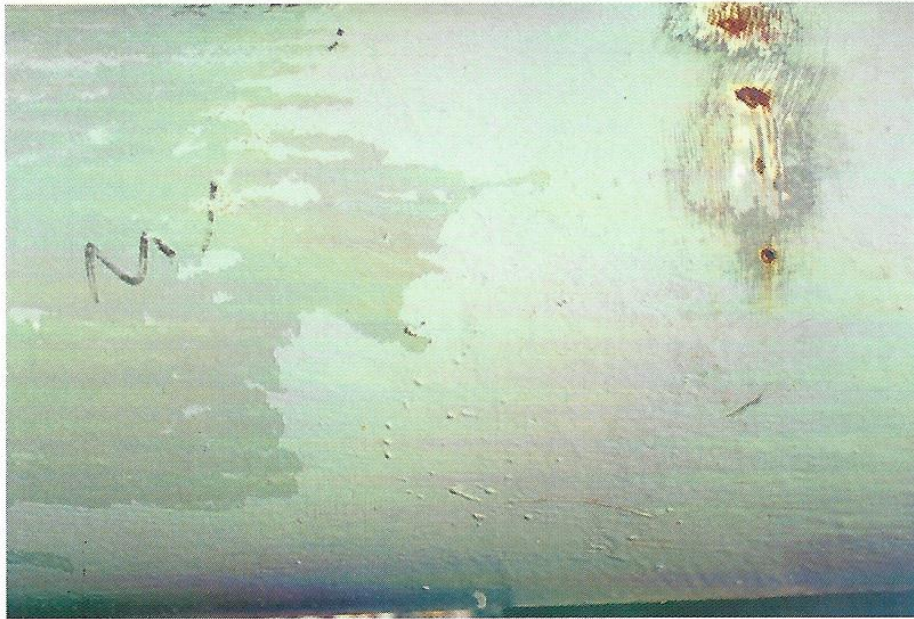
### **CHEESINESS (Soft Coating)**



Other examples are shown on the following page

- 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.

**CHEESINESS  
(Soft Coating)**



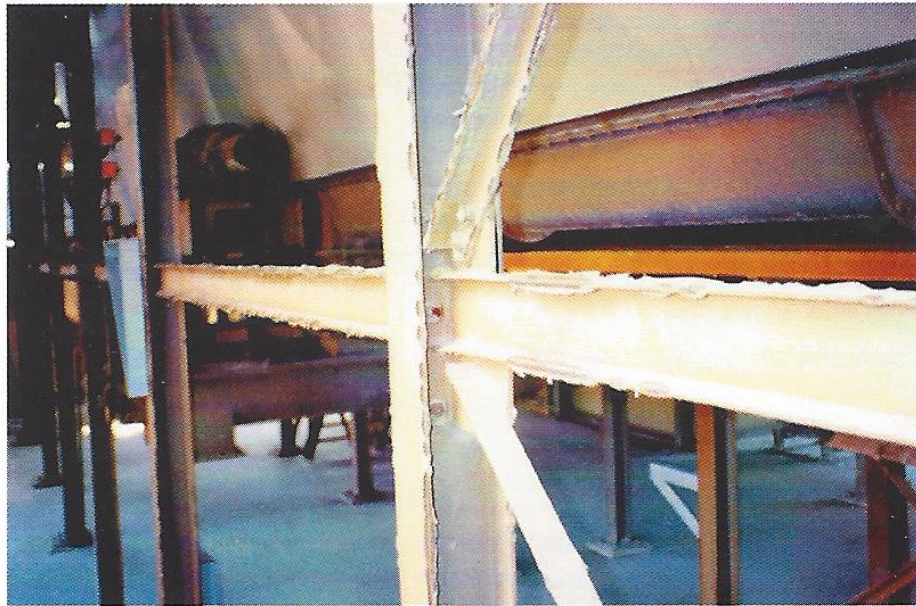
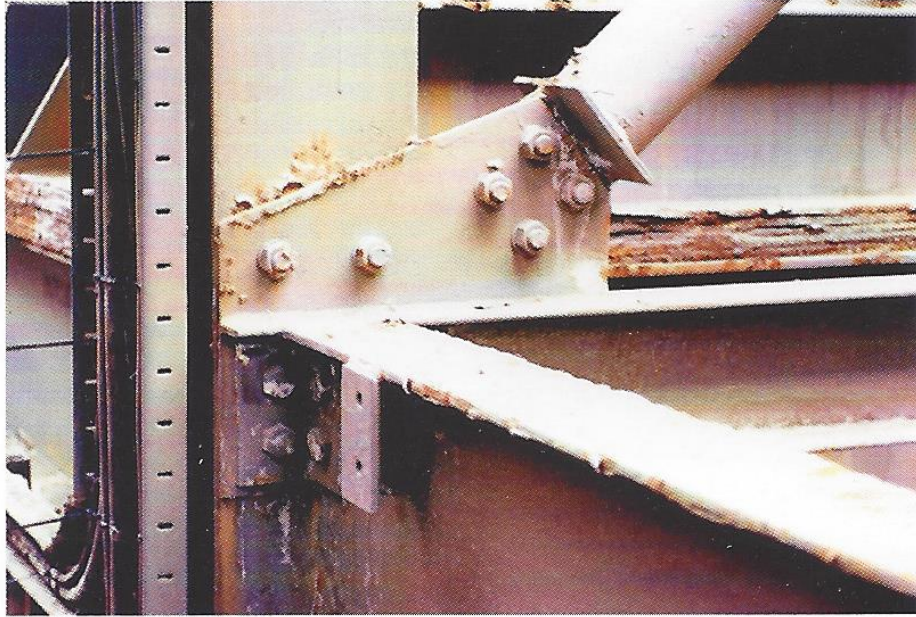
## CHEMICAL EXPOSURE



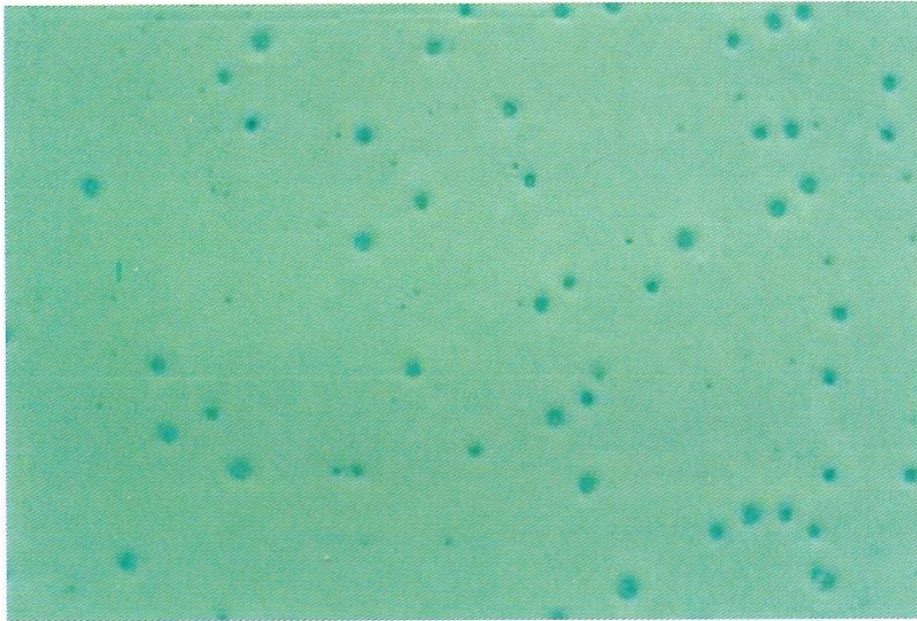
Other examples are shown on the following page

- Description:** Chemical breakdown of a coating after exposure to aggressive chemicals.
- Probable Causes:** The reaction of a coating with a chemical or atmosphere (either organic or inorganic) that it is not resistant to.
- Prevention:** Use coating systems suitable for the environment or prevent the chemical from reaching the coated surface.
- Repair:** Will depend on the extent of failure but removal or neutralization of the chemical and fresh water washing essential. Use a chemically resistant coating and consider isolation from the source of the chemical.

## CHEMICAL EXPOSURE



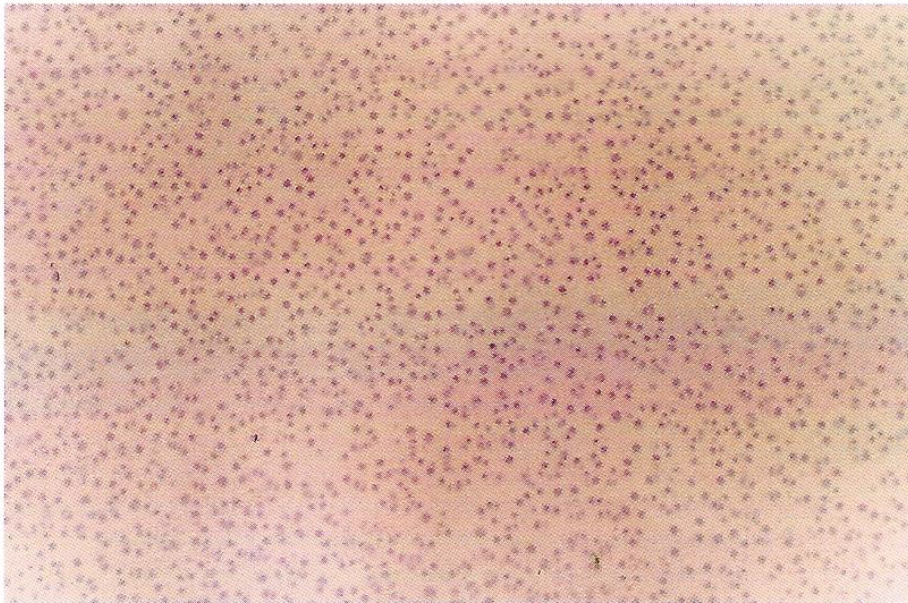
### CISSING



Other examples are shown on the following page

- Description:** Surface breaks in a wet paint film, where the paint has receded to expose the underlying substrate. 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 contaminants 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.

## CISSING



## COBWEBBING



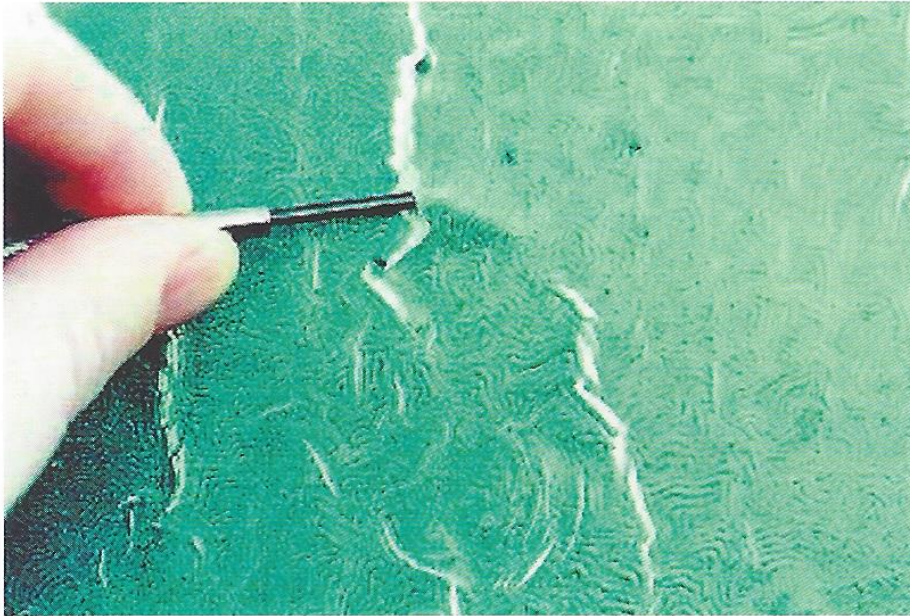
**Description:** The production of fine filaments instead of normal atomised particles when some solutions of high molecular weight polymers are sprayed. Traditionally when applying chlorinated rubber coatings by conventional spray.

**Probable Causes:** Too high a viscosity with some types of polymer solutions. Will occur with chlorinated rubber at almost any viscosity.

**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



Other examples are shown on the following pages

**Description:** The splitting of a dry paint film through at least one coat to form 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.

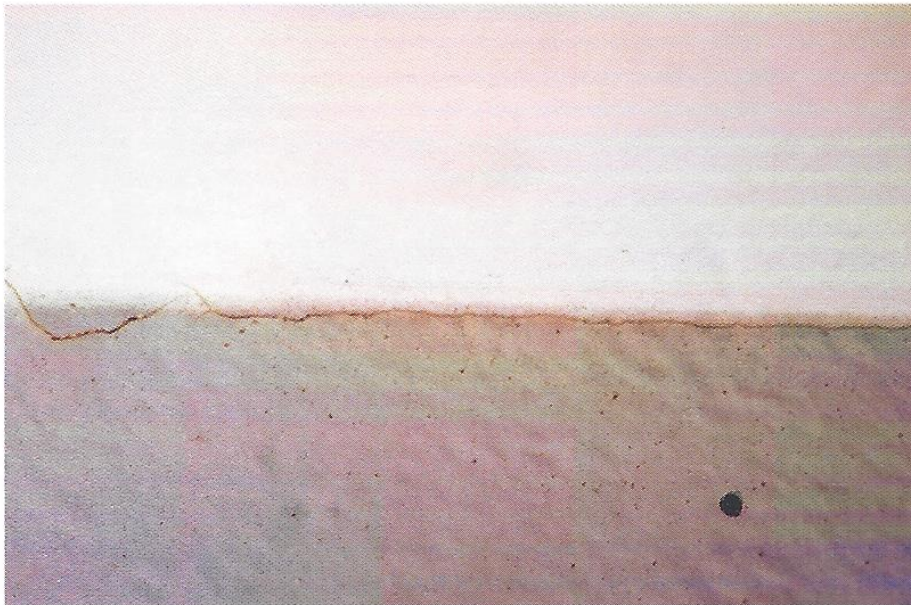
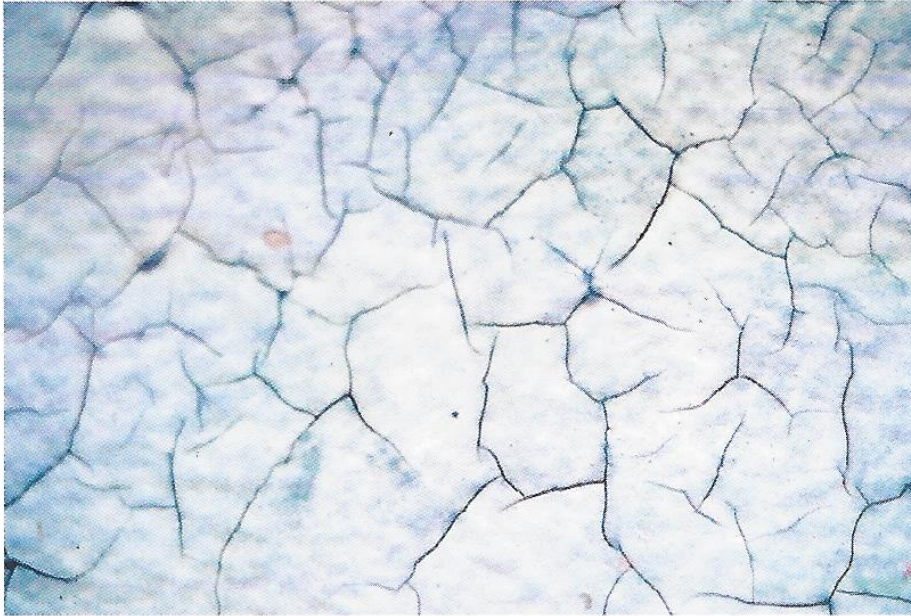
**Prevention:** Use correct coating systems, application techniques and dry film thicknesses. Alternatively, use a more flexible coating system.

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

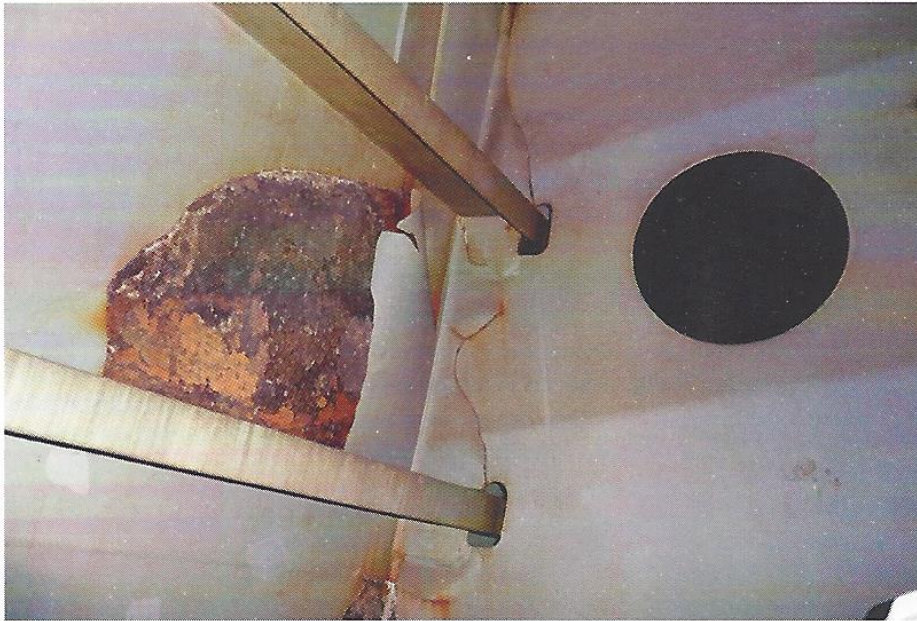
**CRACKING**



## CRACKING



**CRACKING**



### CRACKING AT WELDS



Other examples are shown on the following page

**Description:** Paint coatings with visible cracks at weld seams which may penetrate down to the substrate.

**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. Also occurs when the adhesion of the coating is insufficient to bear the stress.

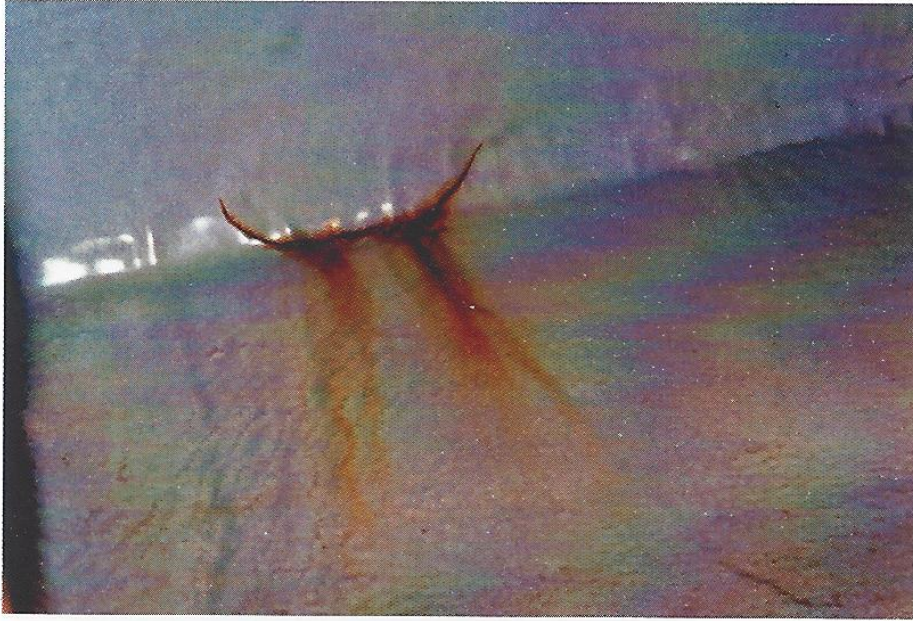
**Prevention:** Use correct coating systems, application techniques and dry film thicknesses or use a more flexible coating system.

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

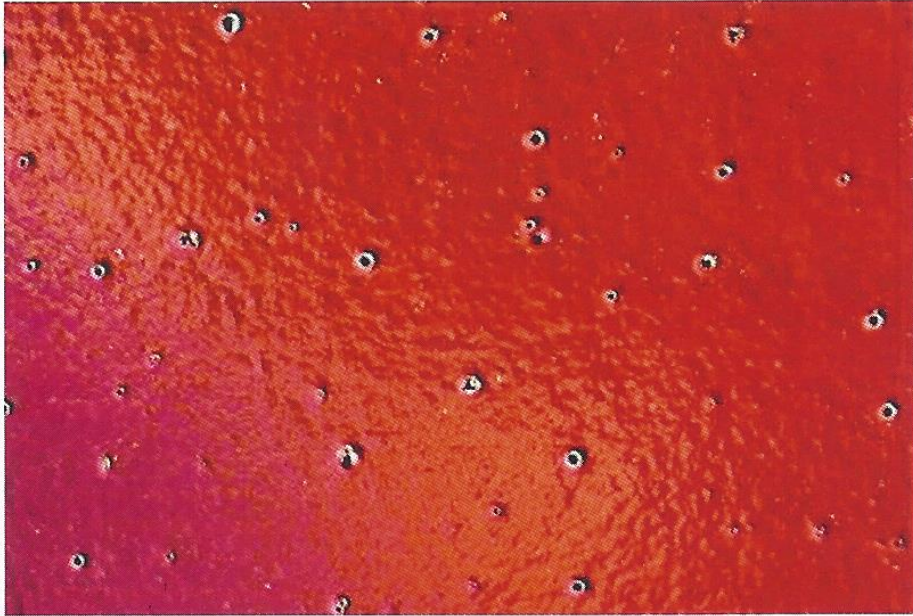
## CRACKING AT WELDS



## CRACKING AT WELDS



### CRATERING



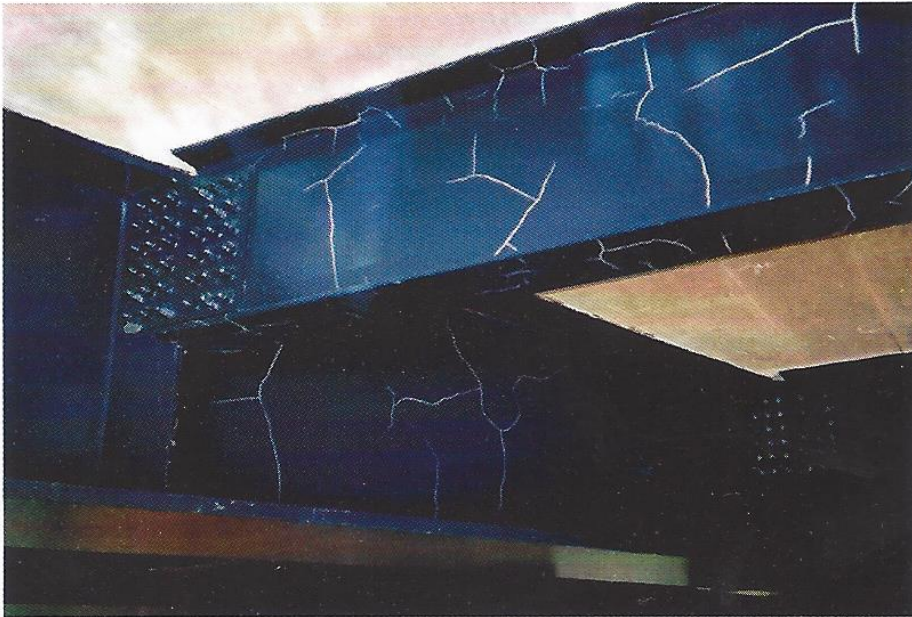
**Description:** The formation of small bowl shaped depressions in the paint film. Not to be confused with Cissing.

**Probable Causes:** Trapped air or solvent 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, apply a mist coat and avoid air entrainment during mixing. Add thinners as recommended by the paint supplier.

**Repair:** Abrade and clean the surface and recoat.

## CRAZING



Other examples are shown on the following page

**Description:** Similar to checking but the cracks are generally wider and penetrate deeper into the film.

**Probable Causes:** Application temperature too low, incompatibility with previous coating, ageing and high film thickness.

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

**Repair:** Abrade and clean the surface and recoat.

## CRAZING



## CROWSFOOTING



Other examples are shown on the following page

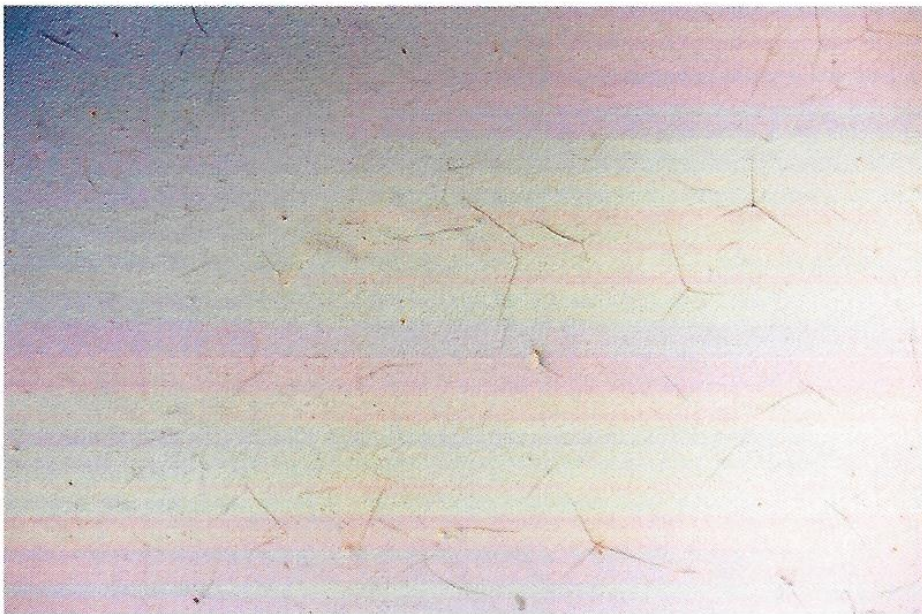
**Description:** The development of small wrinkles in the paint film which occur in a pattern resembling that of a crow's foot.

**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.

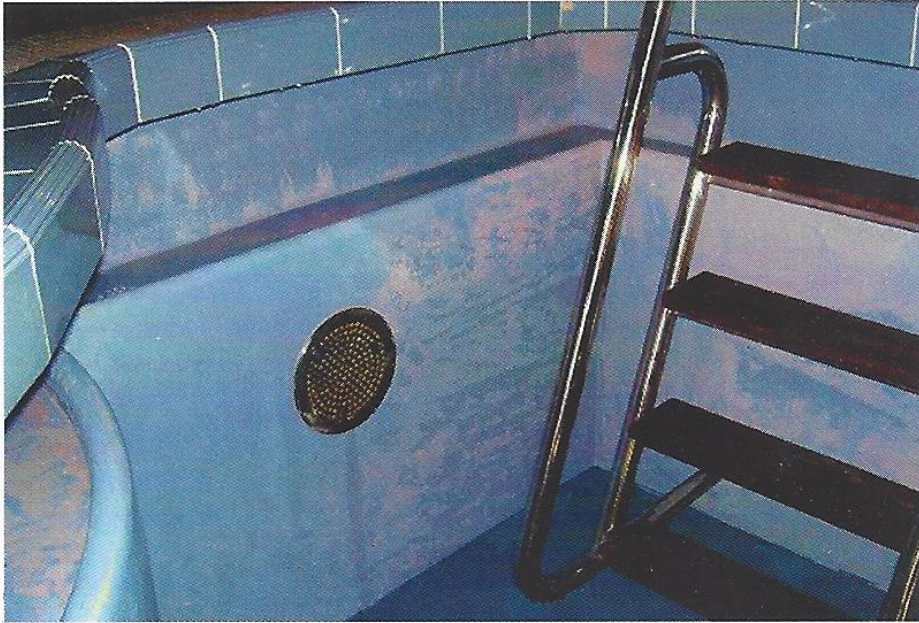
**Prevention:** Apply a thinner coat of paint; add slower drying thinners, check application and drying conditions are correct for the paint system used.

**Repair:** Abrade the surface when fully dry and recoat.

## CROWSFOOTING



## DEGRADATION



**Description:** Deterioration in the form of surface discolouration and/or a friable powdery surface e.g. exposure to chlorinated water and ultraviolet light.

**Probable Causes:** Use of a coating with an unsuitable binder and/or pigment for the exposure conditions.

**Prevention:** Apply a suitable topcoat with high resistance to the exposure conditions.

**Repair:** Remove all powdery deposits by abrasion or high pressure washing and apply a resistant topcoat.

### DELAMINATION



Other examples are shown on the following pages

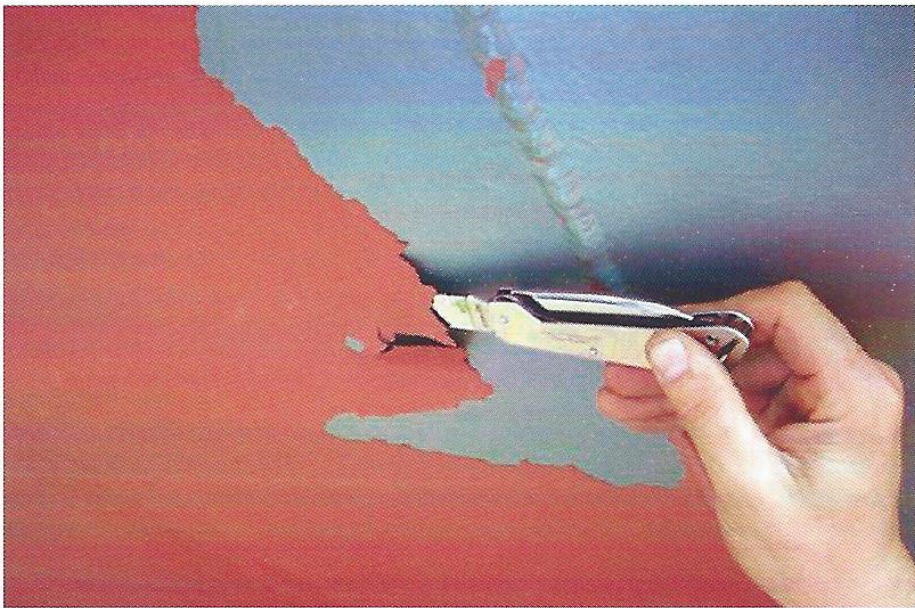
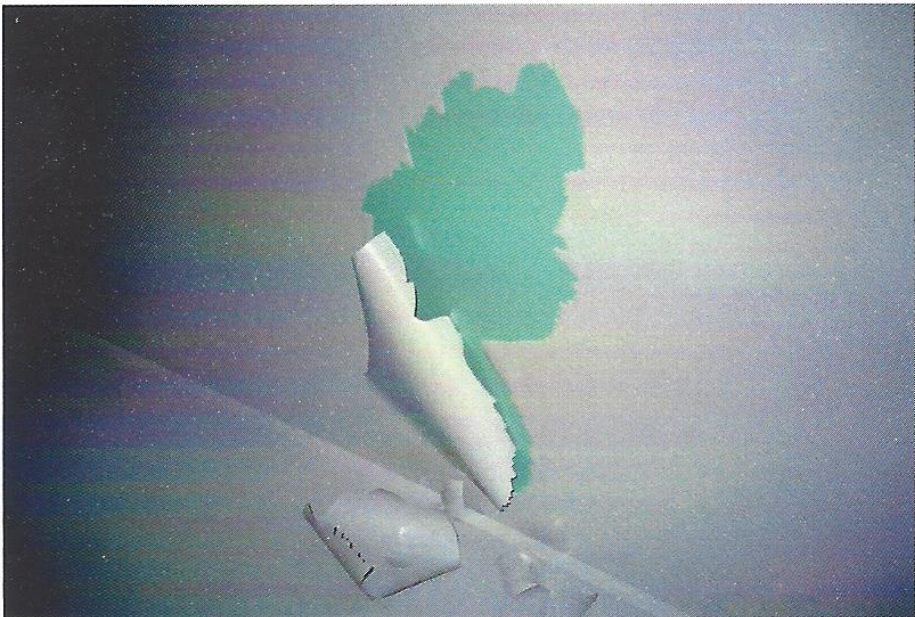
**Description:** Loss of adhesion between coats of paint.

**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. Follow the recommended overcoating intervals. Lightly abrade and clean glossy surfaces between coats.

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

**DELAMINATION**



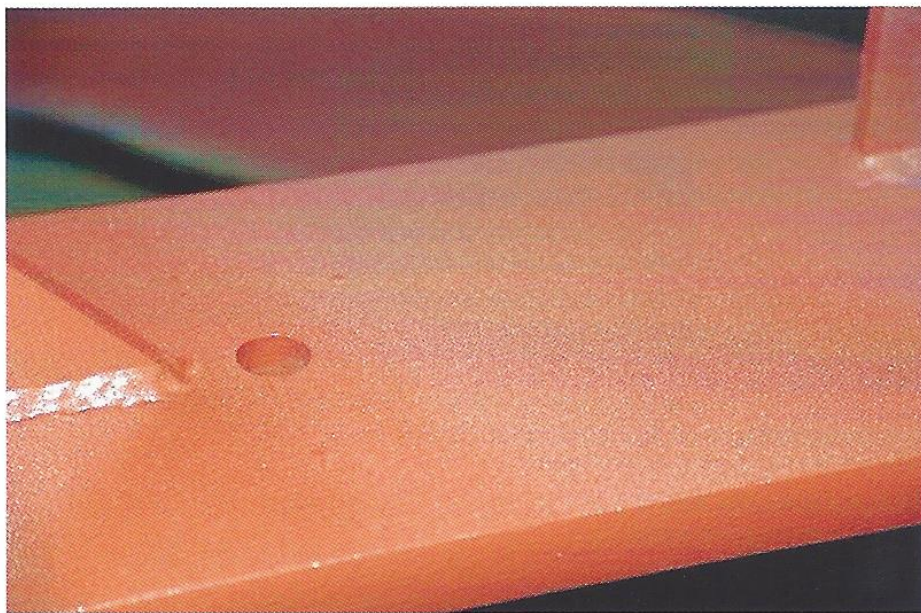
### DRYSPRAY



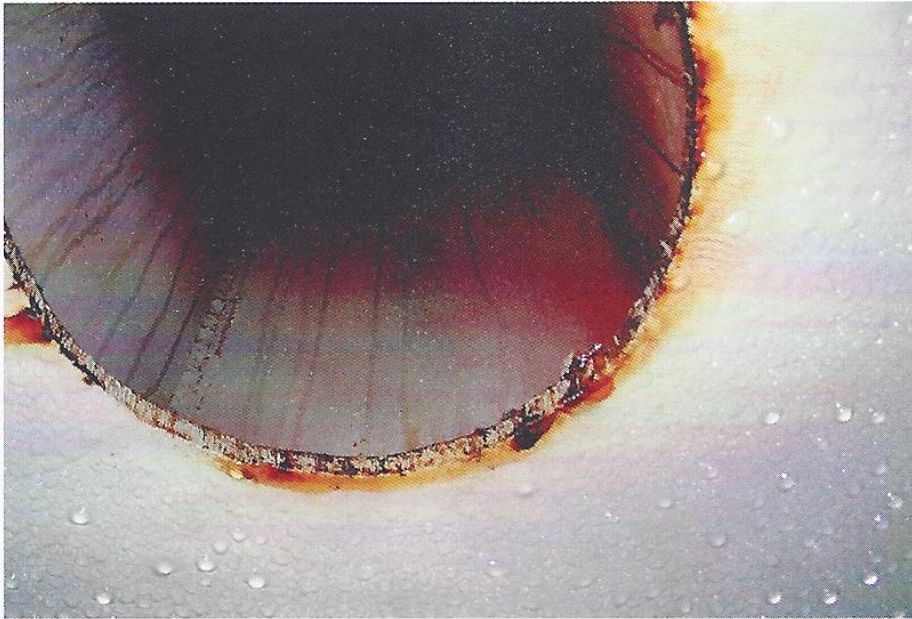
Other examples are shown on the following page

- 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 reapply coating or topcoat.

## DRYSPRAY



## EDGE CORROSION



Other examples are shown on the following page

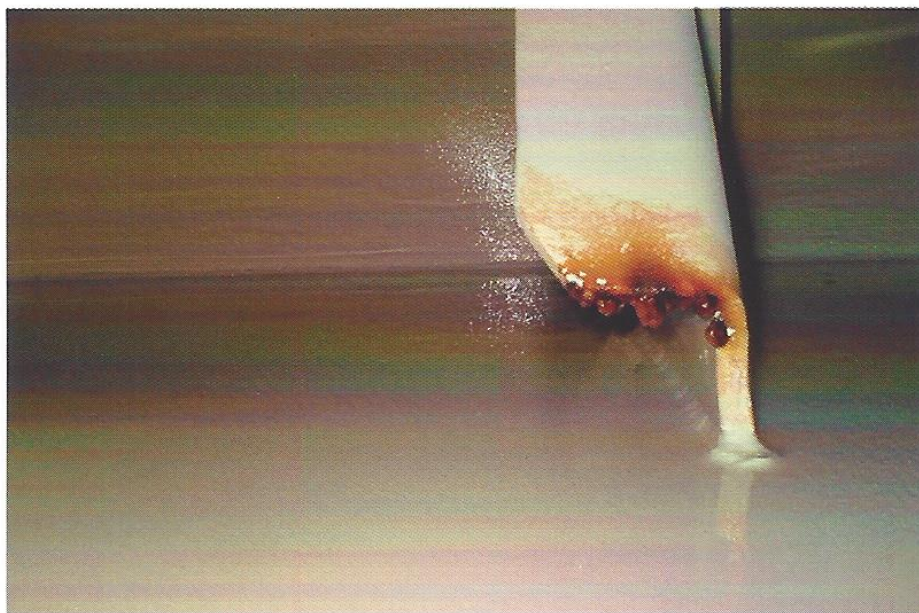
**Description:** Breakdown at edges resulting in corrosion.

**Probable Causes:** Low film thickness, sharp edges, lack of stripe coats and flow away from the edges.

**Prevention:** Ensure that all edges are radiused, stripe coats are applied and the coating has good edge retention.

**Repair:** Remove coating by abrading, radius the edges and reapply the coating system with adequate stripe coats.

## EDGE CORROSION



## EFFLORESCENCE



Other examples are shown on the following page

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



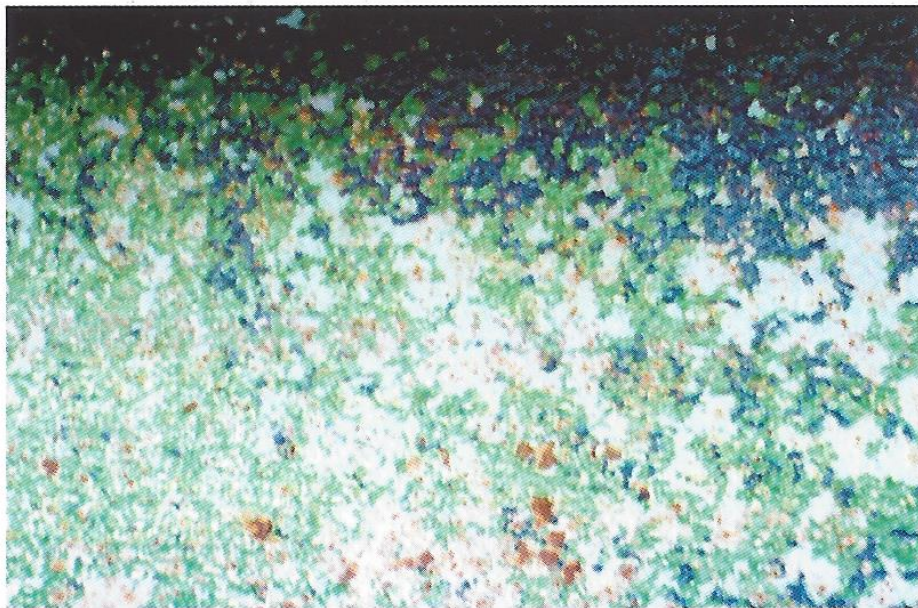
### EROSION



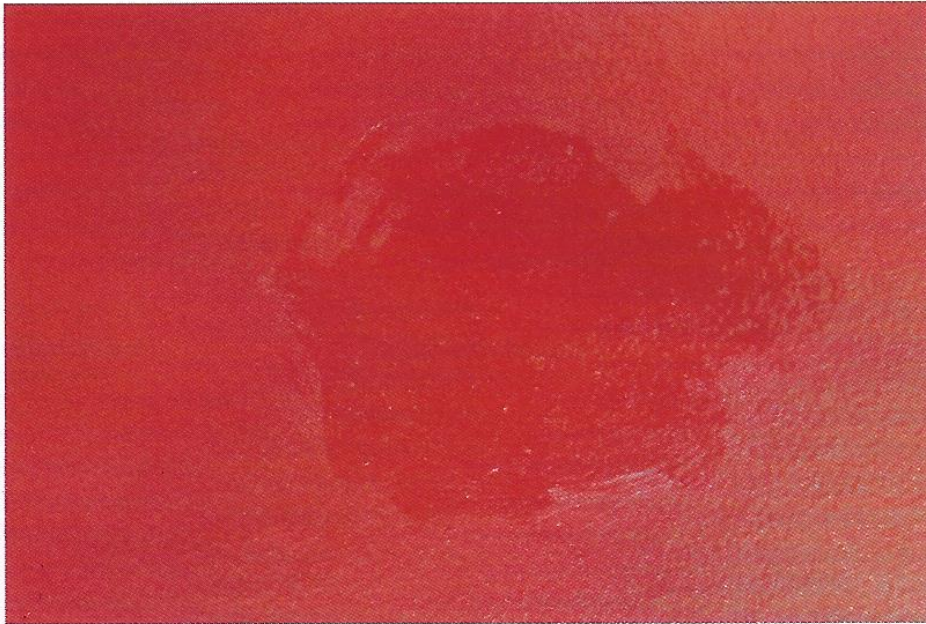
Other examples are shown on the following page

- 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



### EXUDATION



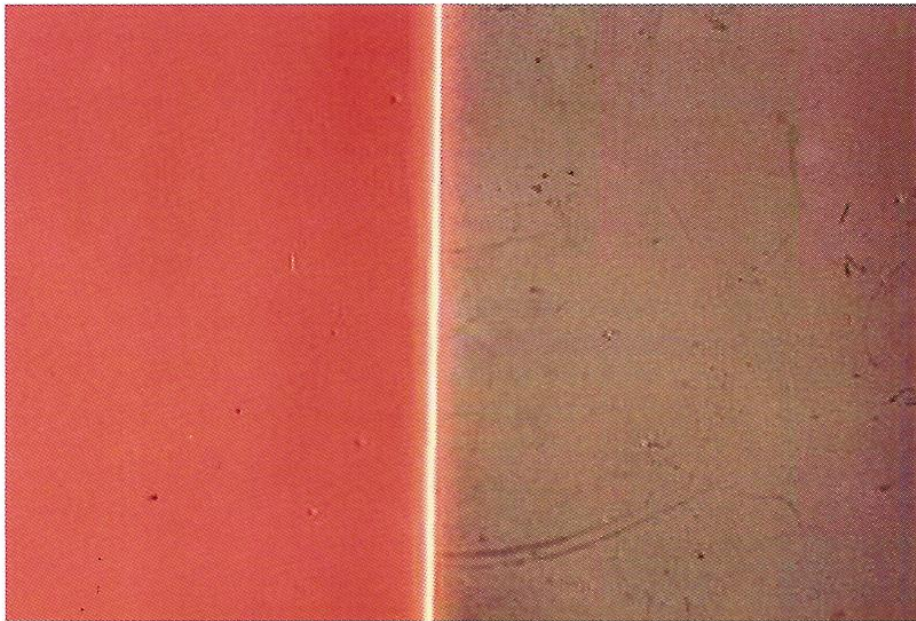
**Description:** The appearance of an oil-like film on the surface of the coating after drying. Also described as sweating but not to be confused when the term is used to explain condensation on a surface.

**Probable Causes:** Migration of a component of the coating e.g. plasticizer, additive, or curing agent that remained unreacted. Often associated with poor environmental conditions during or after application.

**Prevention:** Apply under good environmental conditions and use a more suitable coating.

**Repair:** Depends on the extent of the defect but may be resolved by solvent washing and re-application of a suitable topcoat under controlled environmental conditions.

### FADING



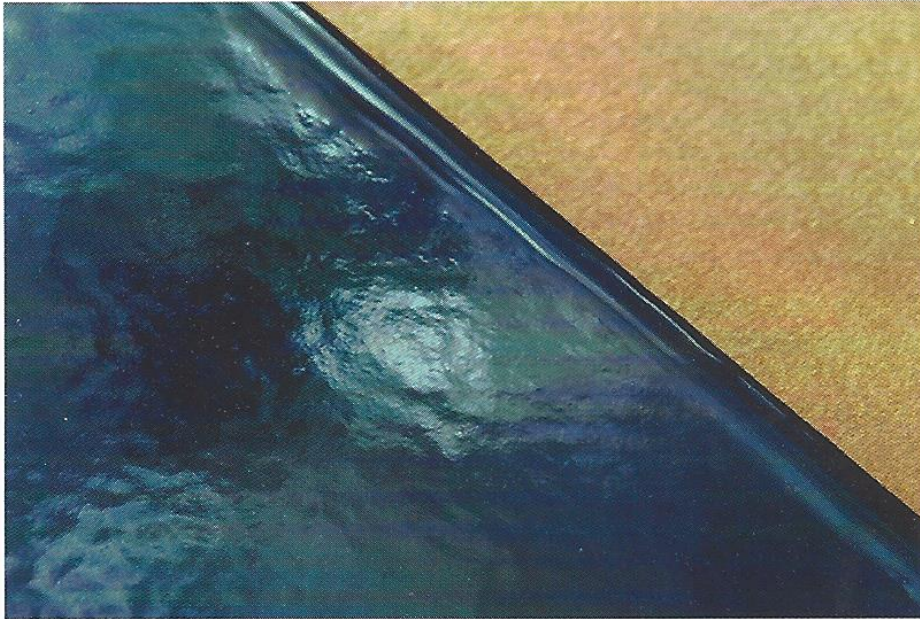
**Description:** Discolouration or gradual decrease in colour of paint when exposed to sunlight/weather. May be accompanied by loss of gloss. In some situations it may resemble chalking but without the powdery surface. Fading tends to accelerate in the presence of moisture.

**Probable Causes:** Incorrect pigmentation; use of non light stable organic pigments; atmospheric contamination; porous substrate.

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

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

## FAT EDGE



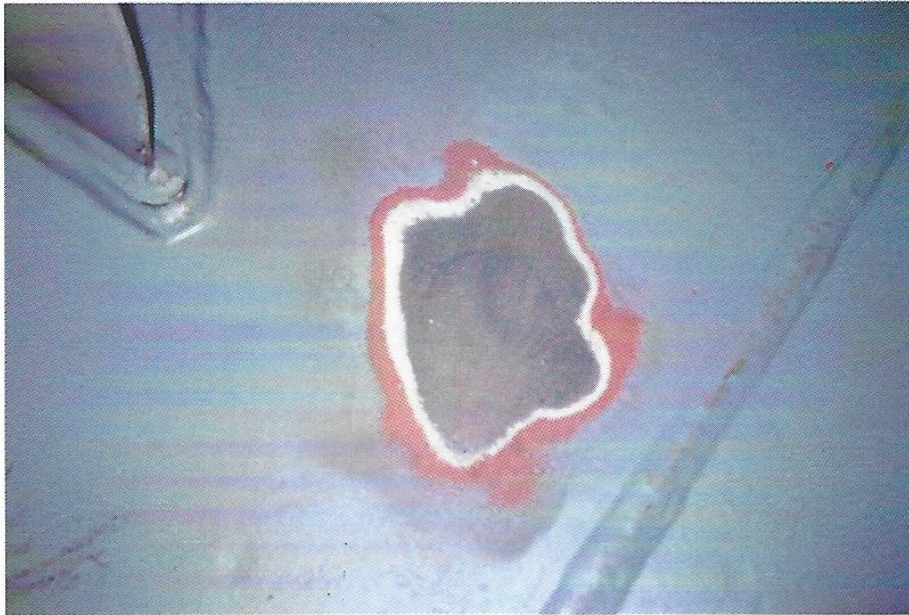
**Description:** An accumulation of a ridge of coating at an edge of the article being coated often occurring during drainage after dip application.

**Probable Causes:** Rheology of the coating not suitable for dip application.

**Prevention:** Re-formulate or use a more suitable coating.

**Repair:** Abrade the area and recoat.

### FEATHER EDGING



An example of poor feather edging is shown on the following page

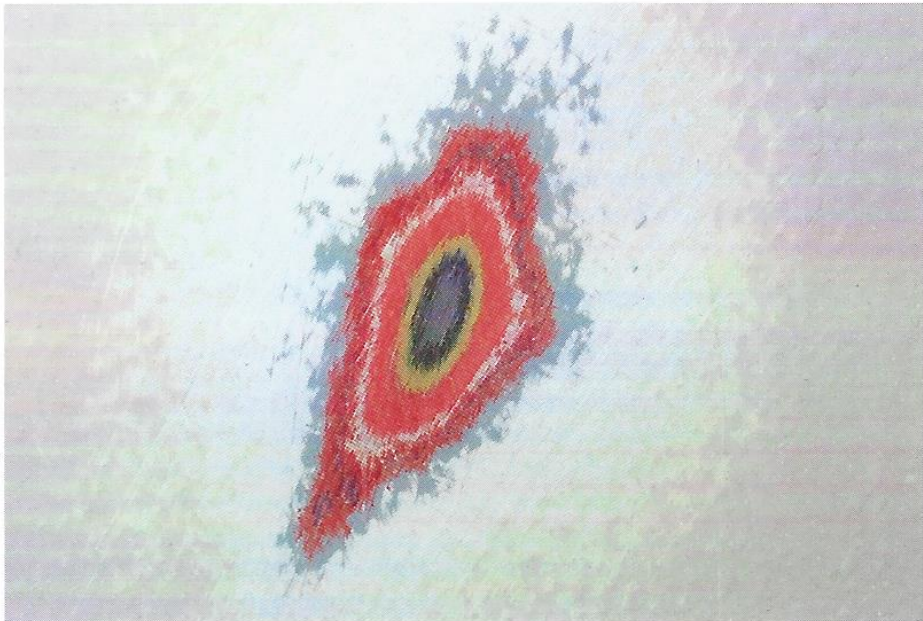
**Description:** Bevelling/tapering the edges of a repair area of a coating by abrading to gradually reduce the thickness and expose the different underlying layers.

**Probable Causes:** Untreated edges of spot blast cleaned repair areas.

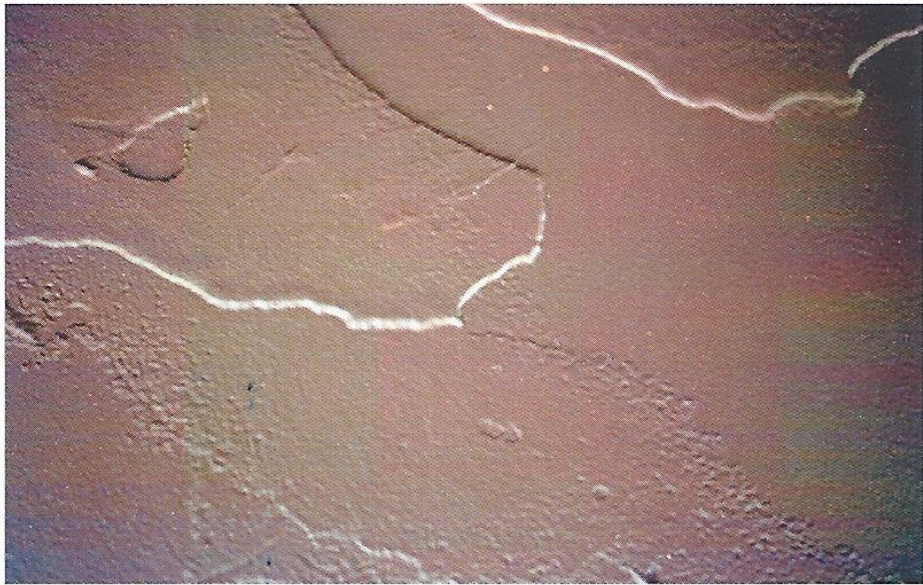
**Prevention:** Abrade all edges of spot blast cleaned repairs. This is only practical on small areas. On extensive spot blasting it is impractical

**Repair:** Bevel/taper the edges to gradually expose previous coats and recoat.

**FEATHER EDGING**

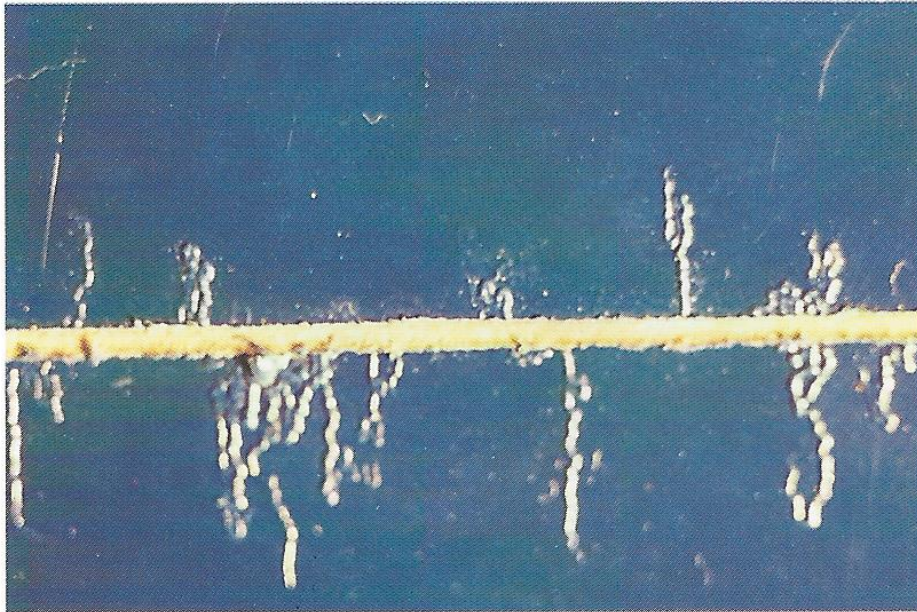


Good Feather Edging



Poor Feather Edging

### **FILIFORM (Corrosion)**



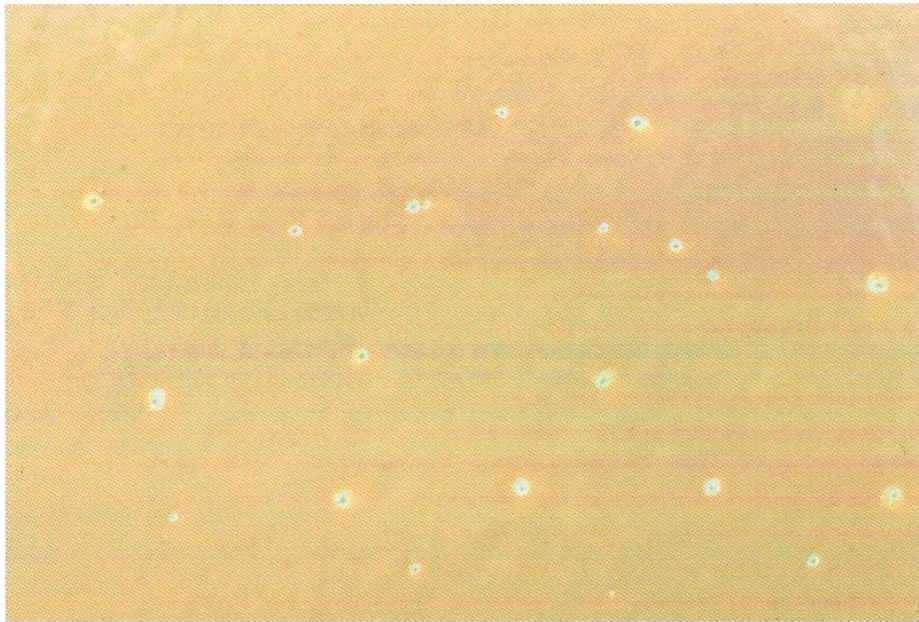
**Description:** Random threads of corrosion that develop beneath thin lacquers and other coating films from a growing head or point. Often seen on old 'tin' food cans, with thin electro plating but also on painted aluminium and other surfaces.

**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.

### FISH EYES



**Description:** Small quasi-circular areas of substrate that are exposed through the applied coating immediately after application and which have at their centre a source of contamination.

**Probable Causes:** Surface contamination in the form of small spots of wax, silicone, grease or particles from contaminated airlines.

**Prevention:** Thoroughly degrease the surface and maintain equipment.

**Repair:** Abrade the affected area, degrease and reapply the coating system. In automotive applications fish eye eliminators can be used.

### FLAKING



Other examples are shown on the following pages

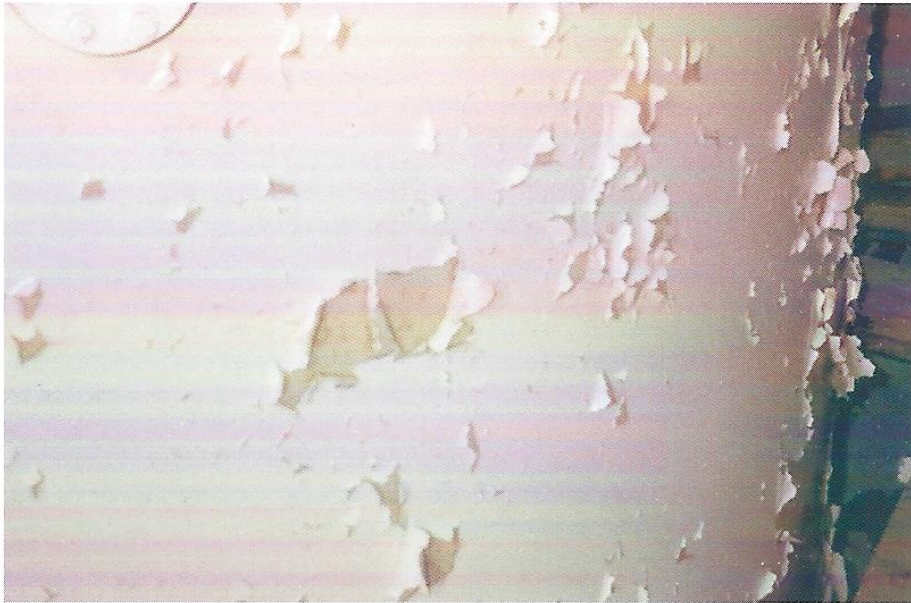
**Description:** A form of adhesion failure where paint flakes from the substrate. A familiar sight on wood substrates and on galvanising.

**Probable Causes:** Incorrect paint system used. Either none or incorrect pre-treatment used for certain substrates 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**



## FLAKING



## FLOCCULATION



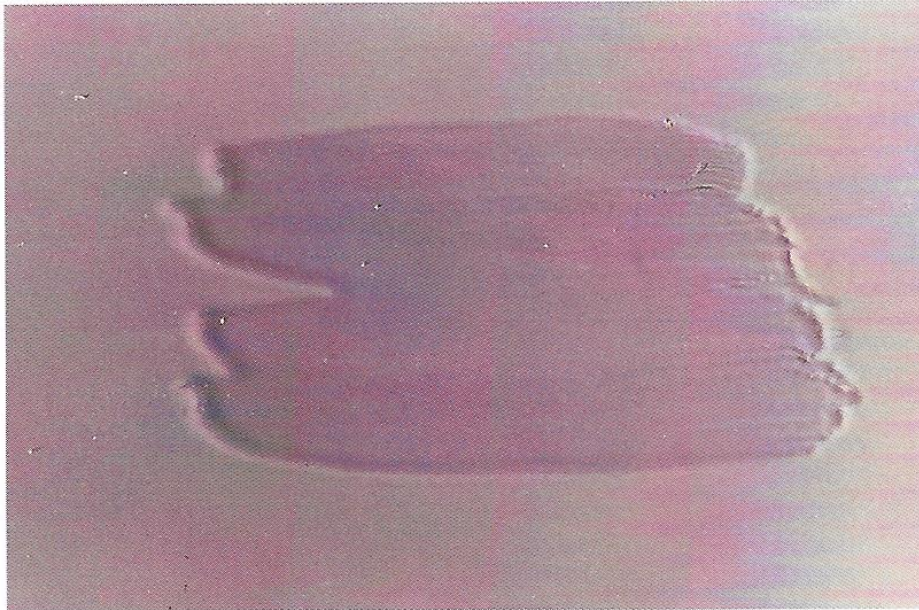
**Description:** The development of loosely coherent pigment agglomerates in a coating material.

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

**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



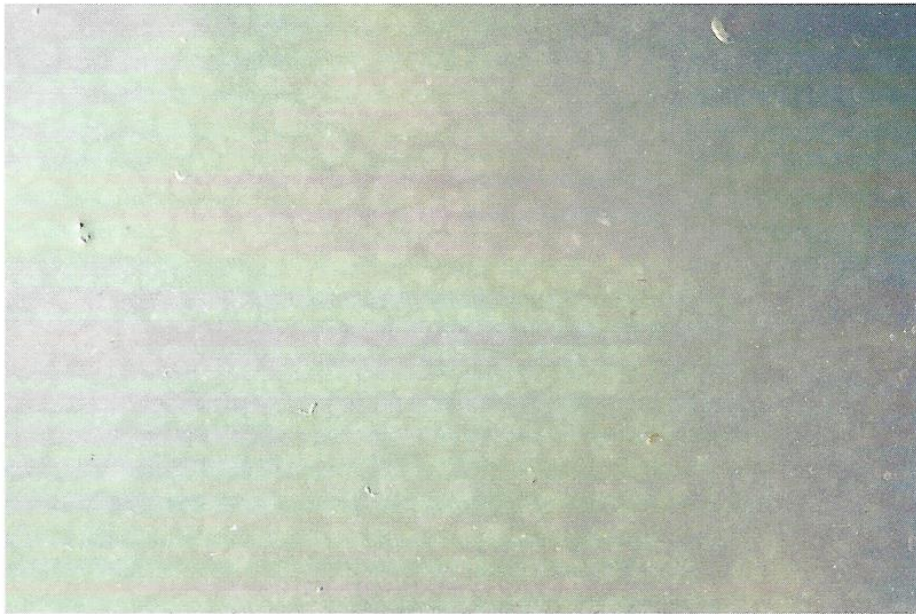
**Description:** A defect which appears soon after application due to pigment separation. The visual appearance is a deepening of the colour. The affected area dries to a deeper shade than the remainder of the surface.

**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



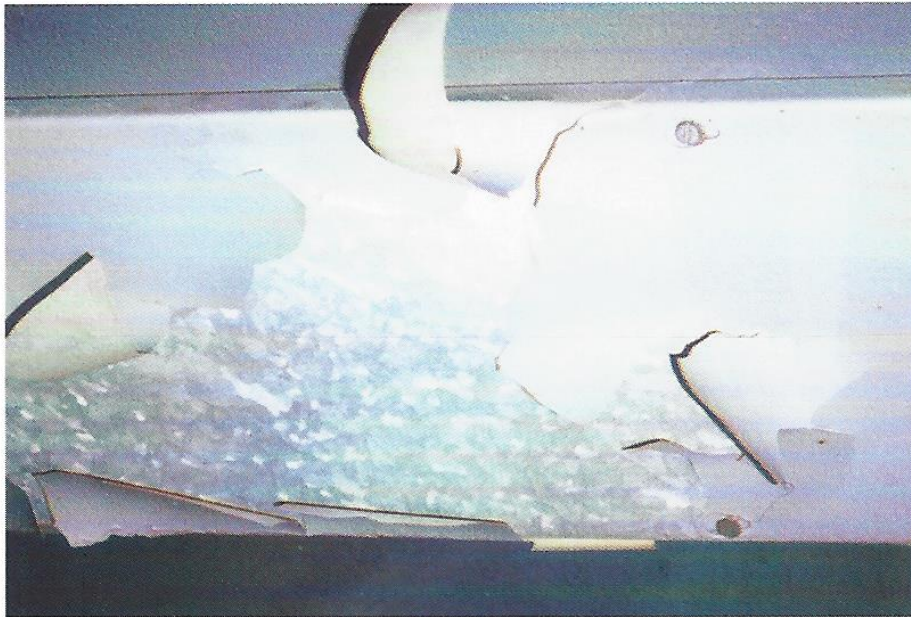
**Description:** Occurs in coloured materials containing mixtures of different pigments. It closely resembles flooding, although a mottled or streaky effect is produced when the different pigments separate.

**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.

### **GALVANISING (Loss of adhesion of coating)**



Other examples are shown on the following page

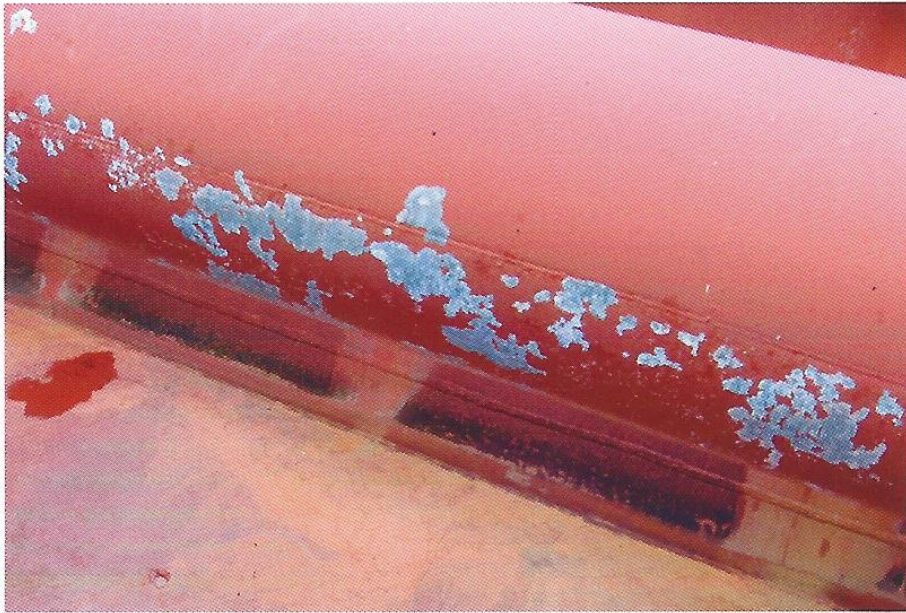
**Description:** Loss of adhesion to a galvanized substrate.

**Probable Causes:** Incorrect surface preparation or absence of an etch primer/"T-Wash".

**Prevention:** Abrade weathered galvanizing or apply etch primer/"T-Wash" to fresh galvanizing after degreasing.

**Repair:** Remove detached paint, degrease, fresh water wash and abrade weathered galvanizing or apply etch primer/"T-Wash" to fresh galvanizing.

**GALVANISING**  
**(Loss of adhesion of coating)**



### GRINNING or 'Grinning Through'



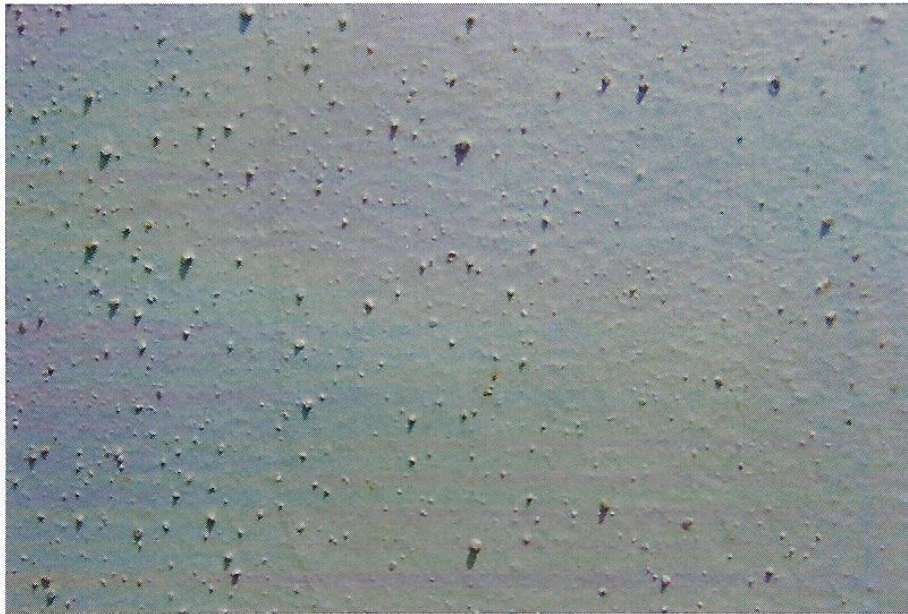
**Description:** The underlying surface is visible through the paint film due to inadequate hiding power of the coating material. This is sometimes called 'Grinning-Through'. Often seen where dark colours are overcoated with lighter colours.

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

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

**Repair:** Apply additional compatible coats to clean surface.

## GRIT INCLUSIONS



Other examples are shown on the following page

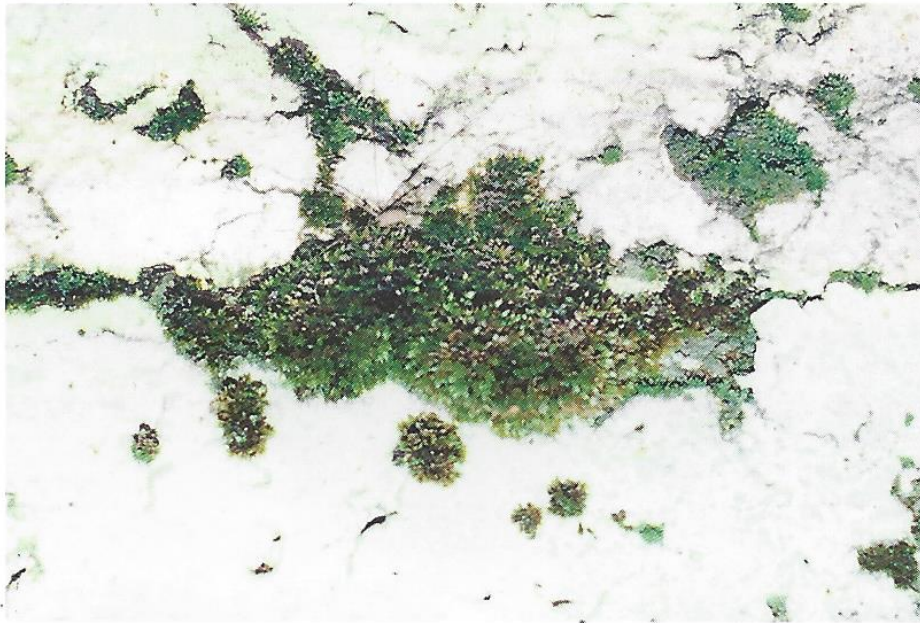
**Description:** Particles of grit and dust embedded within the coating system. The particles will rust if ferrous.

**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. Windblown grit particles adhering to the topcoat.

**Prevention:** Ensure all used grit is removed before application of fresh paint. Do not carry out blast cleaning whilst there is wet paint on nearby surfaces. Ensure that 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 a paint film)**



Other examples are shown on the following page

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

**Probable Causes:** Natural organisms associated with moist, wet or immersed conditions. Growth may continue after attachment.

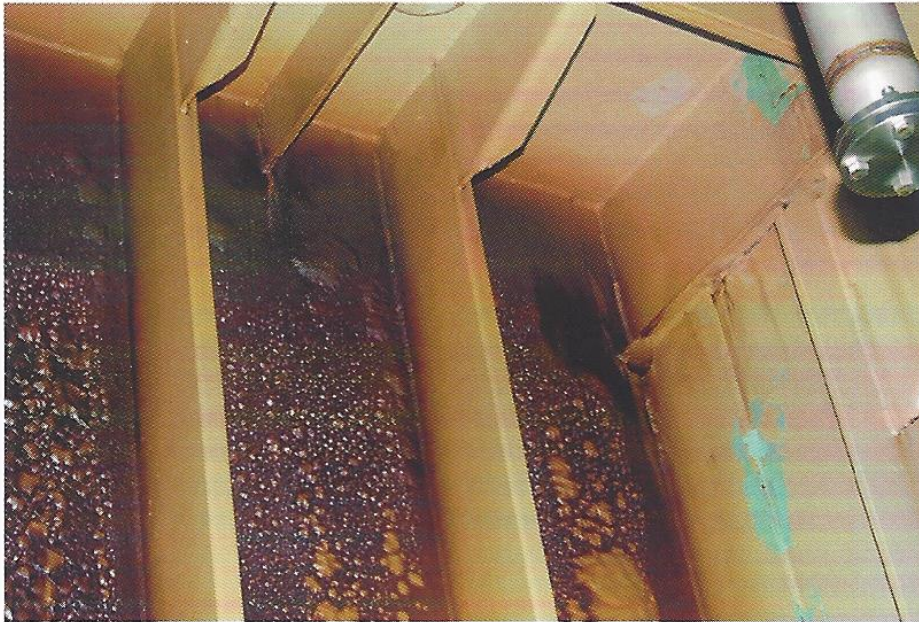
**Prevention:** Use correct coating specification and products suitable for the environment. Where practical, clean regularly to prevent build-up of moss and algae.

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

**GROWTH**  
**(on the surface of paint film)**



### HEAT DAMAGE



Other examples are shown on the following page

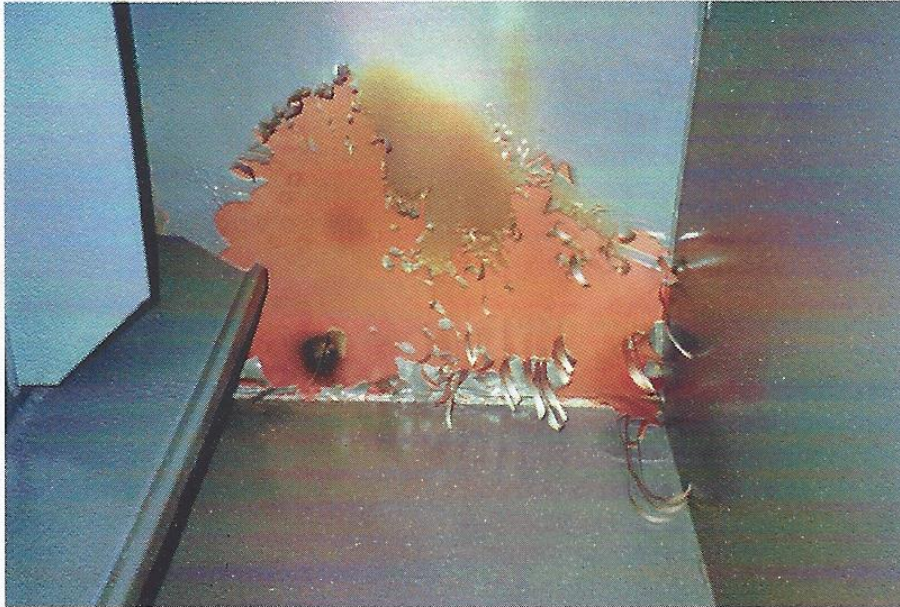
**Description:** Discolouration, detachment and/or blistering and general degradation of a paint film.

**Probable Causes:** Effect of high temperature often applied to the reverse side of a steel plate from burning, welding or fire.

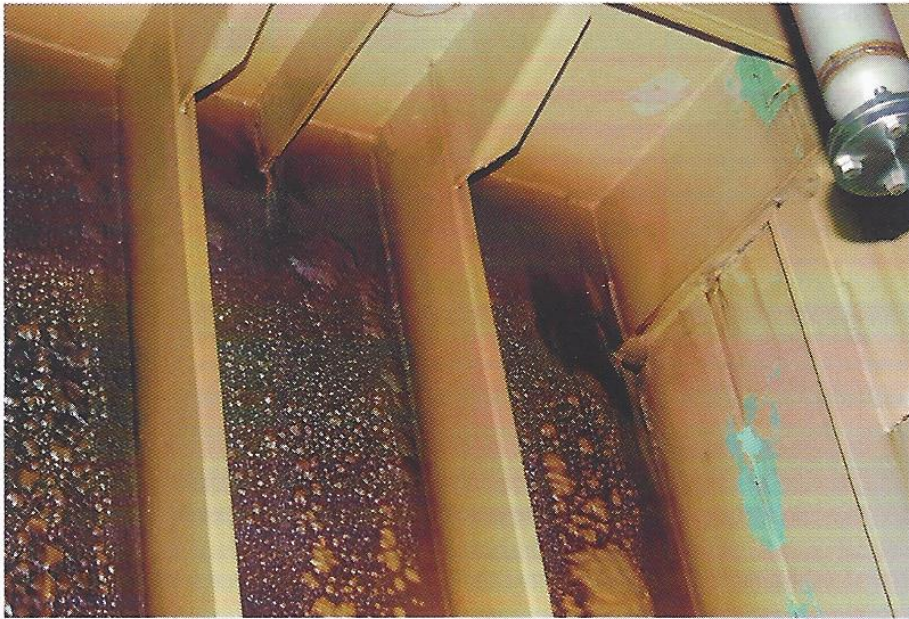
**Prevention:** Ensure that all welding/burning is completed prior to painting.

**Repair:** Abrade small areas or blast clean large areas prior to reinstating the coating system.

## HEAT DAMAGE



## HEAT DAMAGE



Other examples are shown on the following page

**Description:** Discolouration, detachment and/or blistering and general degradation of a paint film.

**Probable Causes:** Effect of high temperature often applied to the reverse side of a steel plate from burning, welding or fire.

**Prevention:** Ensure that all welding/burning is completed prior to painting.

**Repair:** Abrade small areas or blast clean large areas prior to reinstating the coating system.

## IMPACT DAMAGE (Star cracking)



Other examples are shown on the following page

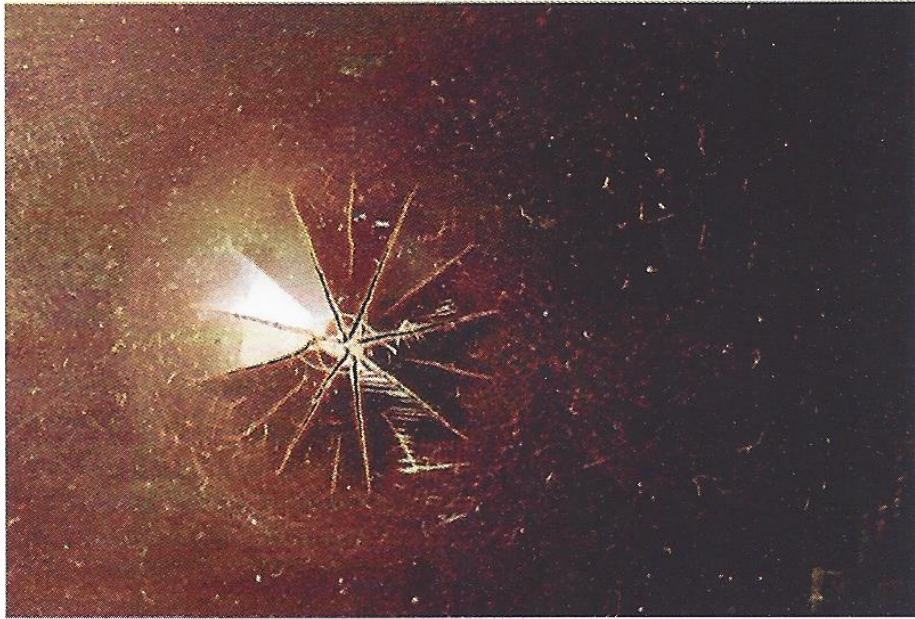
**Description:** Cracks which radiate from a point of impact.

**Probable Causes:** Impact damage to a relatively brittle coating. Often seen on glass fibre reinforced plastics. Also occurs when steel is deformed by impact.

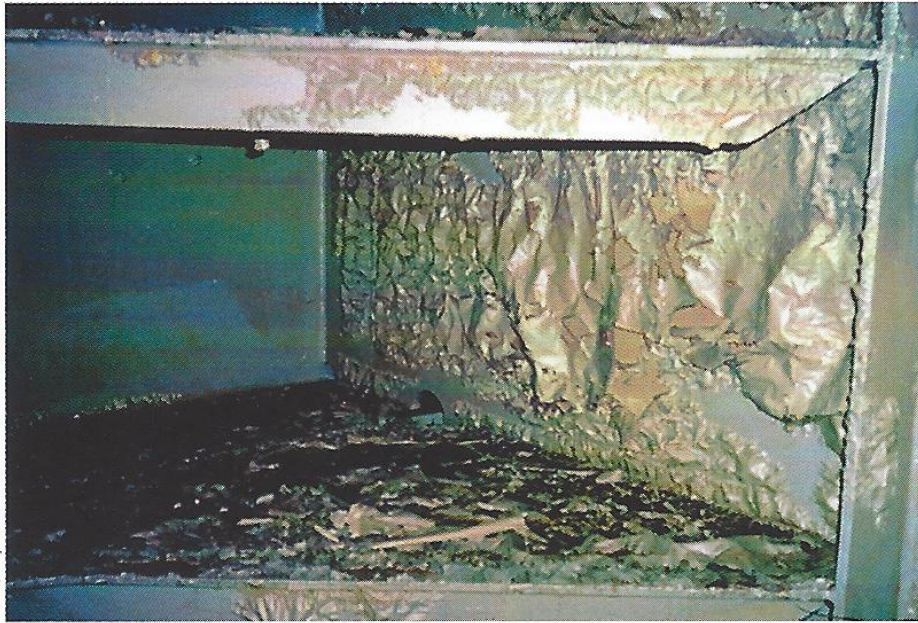
**Prevention:** Prevent impact damage.

**Repair:** Abrade all damaged areas and recoat.

**IMPACT DAMAGE  
(Star cracking)**



### INCORRECT COATING SYSTEM



Other examples are shown on the following page

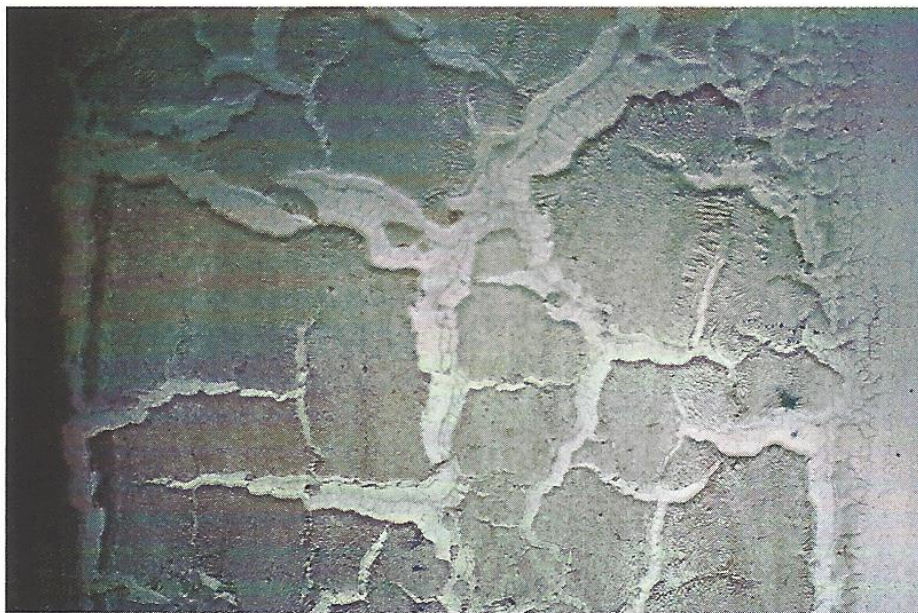
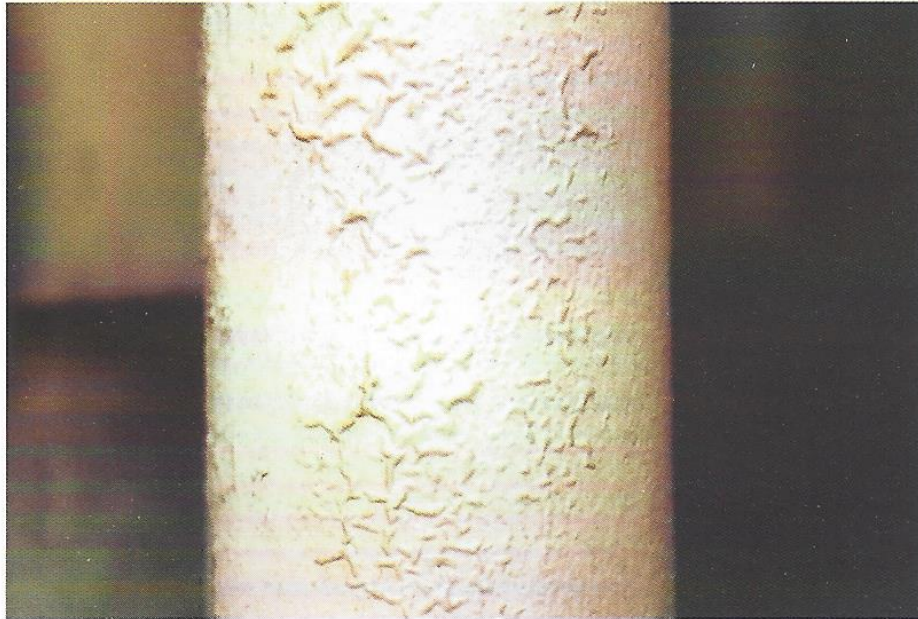
**Description:** An unsuitable or incompatible coating system has been used which results in rapid failure.

**Probable Causes:** Use of incompatible or unsuitable coating materials for the service required.

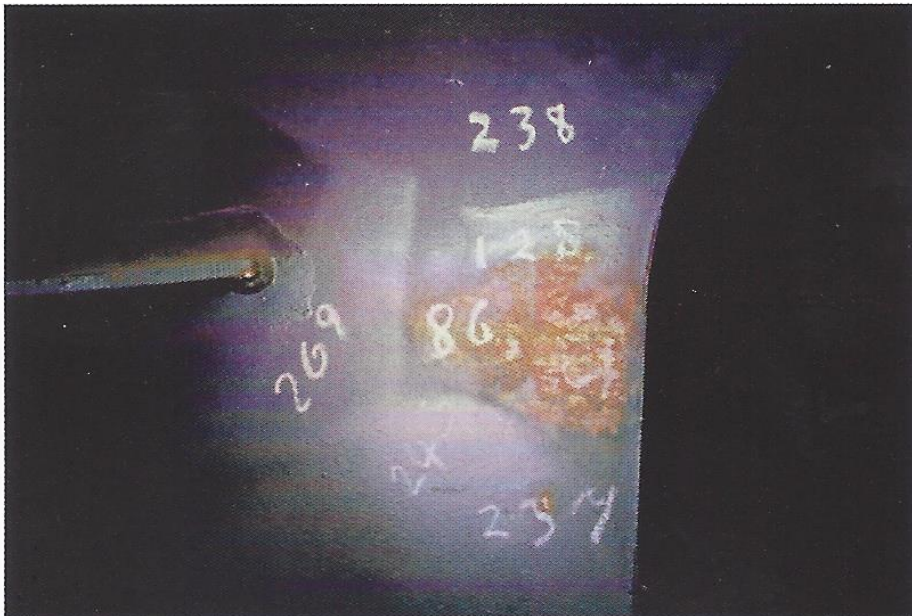
**Prevention:** Use correct coating specification and materials. Ensure that different coats are compatible with each other.

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

**INCORRECT COATING SYSTEM**



## INCORRECT COATING THICKNESS



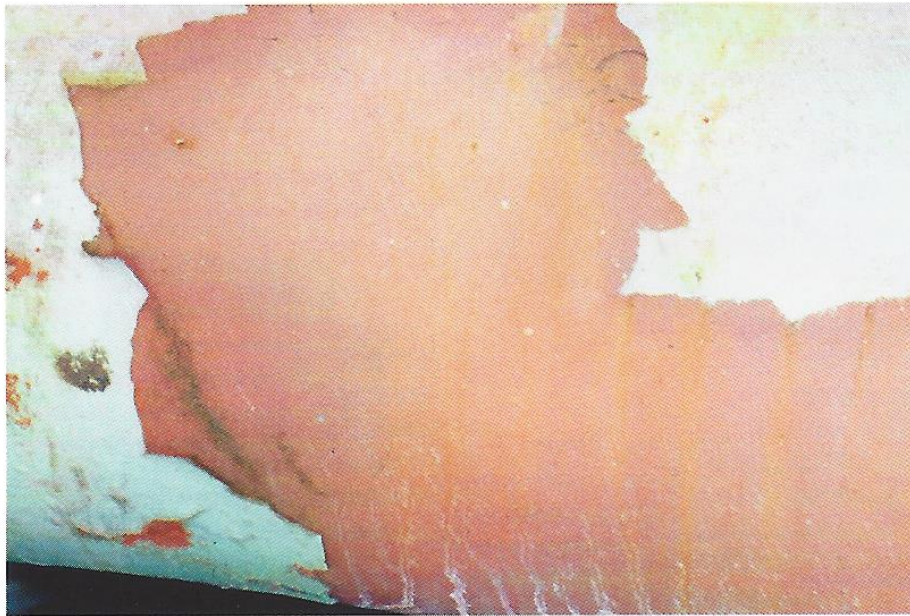
**Description:** A coating system that has been applied at inadequate thickness often leading to premature breakdown.

**Probable Causes:** Poor spray application, poor quality control and difficult access.

**Prevention:** Improve spray application and quality control.

**Repair:** Abrade area and overlaps and reapply to the correct thickness.

### INTERCOAT CONTAMINATION



**Description:** The presence of contamination between coats in a multi-coat system.

**Probable Causes:** The contamination could be present due to inadequate washing down, salts from weathering of shopprimer or deposits from nearby operations.

**Prevention:** Carefully inspect and test the surface before paint application and wash down with fresh water if required.

**Repair:** Abrade to remove poorly adherent paint, fresh water wash and recoat.

### KNOTTING



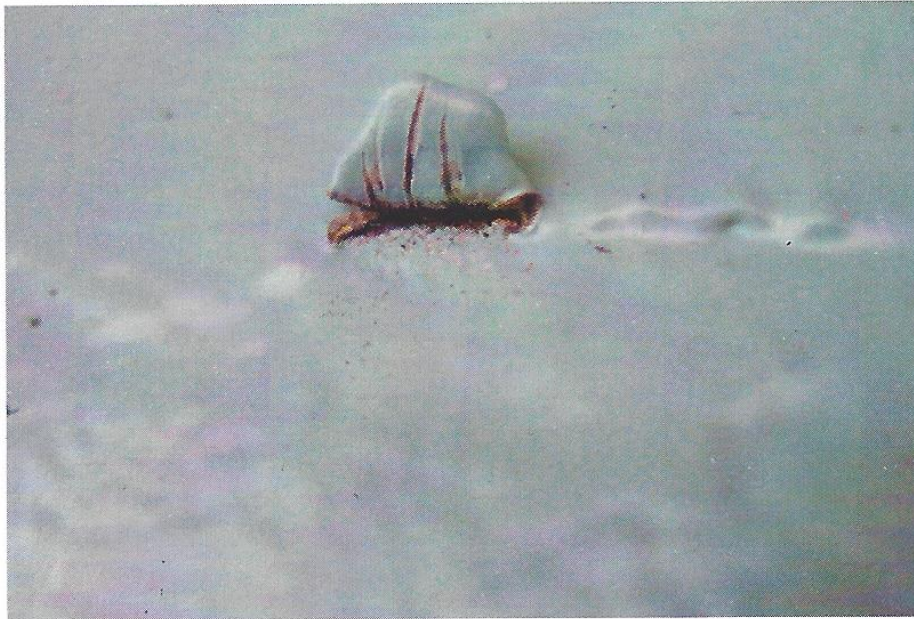
**Description:** Bleed through of resin/sap from knots in timber and staining of the surface with brownish marks.

**Probable Causes:** Knots not treated with knotting agent before painting.

**Prevention:** Treat knots with shellac based solution.

**Repair:** Clean area with methylated spirit, abrade and recoat.

### LAMINATIONS OR SHELLING



Other examples are shown on the following page

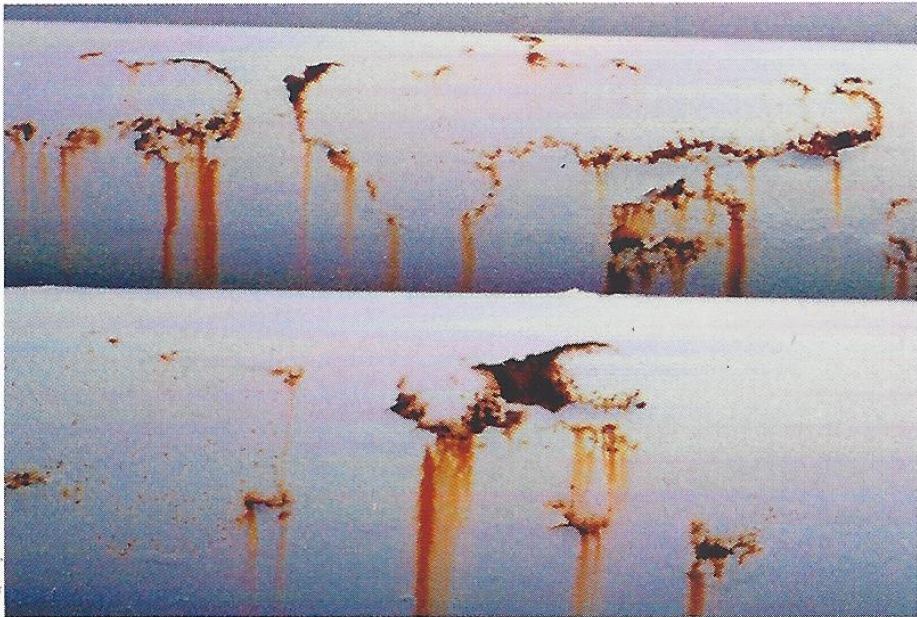
**Description:** Sub-surface planar metallic defects appearing as isolated thin strips or layers with poor adhesion to the parent metal. Overpainting without treatment results in paint breakdown, rusting and rust staining.

**Probable Causes:** Laminations are associated with non-metallic inclusions which have been deformed during the rolling process and run in the direction of rolling. They are often only visible after blast cleaning.

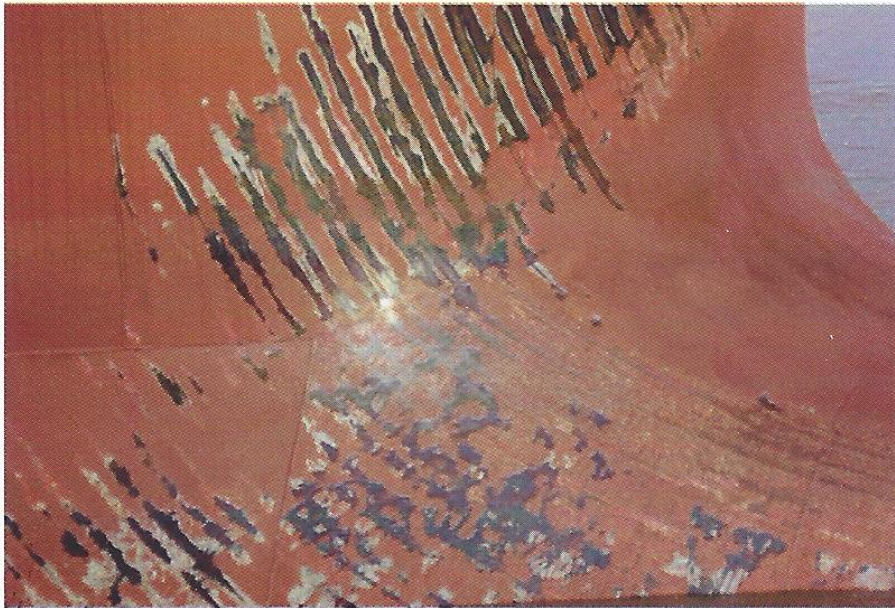
**Prevention:** Use good quality steel plate and ensure proper surface preparation is carried out.

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

LAMINATIONS OR SHELLING



### MECHANICAL DAMAGE



Other examples are shown on the following page

**Description:** Paint removal by scraping and scratching from contact with external objects.

**Probable Causes:** Contact with anchor chains, fenders, grounding and use of chains rather than slings for lifting.

**Prevention:** Use abrasion resistant coatings to minimize damage and use appropriate lifting equipment.

**Repair:** Mechanically clean small areas and blast clean larger areas prior to recoating.

## MECHANICAL DAMAGE



### MILKINESS



**Description:** A milky white surface appearance that is apparent shortly after application and often seen on transparent varnish films.

**Probable Causes:** Moisture condensing on the film in humid conditions when the steel temperature is below the dew point. Can be aggravated by incorrect solvent balance.

**Prevention:** Ensure environmental conditions are as recommended in the data sheet.

**Repair:** Apply heat to the affected area or recoat after the environmental conditions have been corrected.

## MILLSCALE



Other examples are shown on the following page

**Description:** The blue/black thin layer of iron oxides formed on the steel surface during the hot rolling process.

**Probable Causes:** Millscale is not uniform and not well adherent to the steel, hence if painted over will detach from the steel substrate together with the paint as moisture laden air penetrates beneath and/or differential expansion/contraction occurs.

**Prevention:** Abrasive blast clean to remove the millscale and impart a surface profile.

**Repair:** Abrasive blast clean and apply a suitable coating system.

**MILLSCALE**



## MISSES/SKIPS/HOLIDAYS



Other examples are shown on the following page

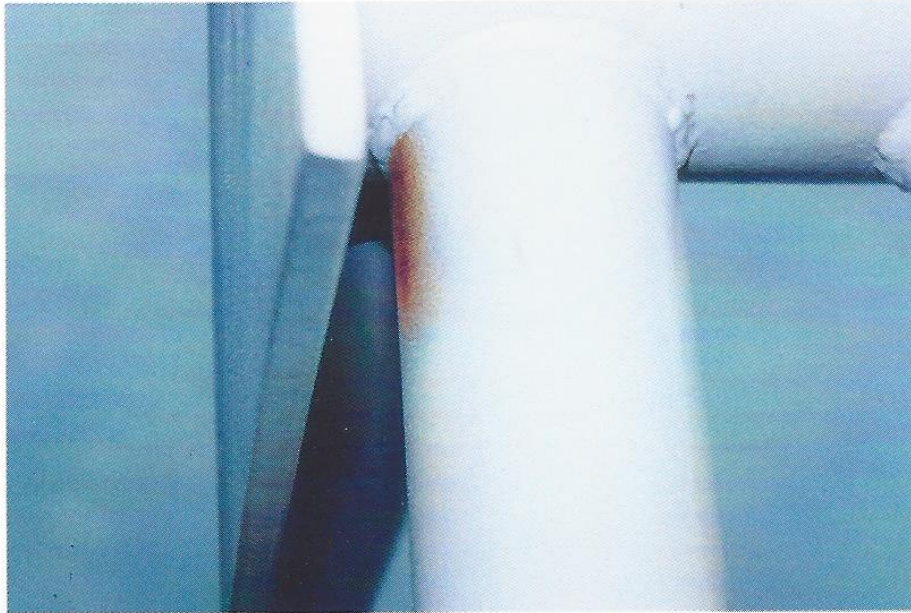
**Description:** Exposed areas of substrate when the intention was to coat the entire area. Could be confined to a single coat in a multi-coat paint system.

**Probable Causes:** Poor application techniques. Lack of quality control. Poor access and design.

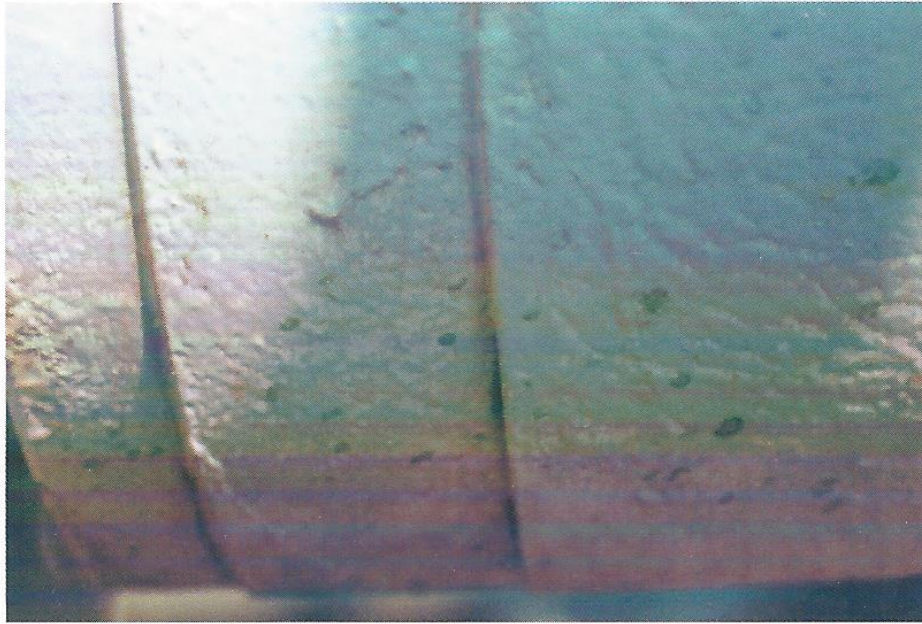
**Prevention:** Use correct application techniques. Apply good painting practices. Use qualified inspectors.

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

**MISSES/SKIPS/HOLIDAYS**



## 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 flat. The cracks appear as a network that can vary in size and amount.

**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 or blast clean the surface. Reapply coating to manufacturer's recommendations.

**ORANGE PEEL**  
also known as Pock-marking



Other examples are shown on the following page

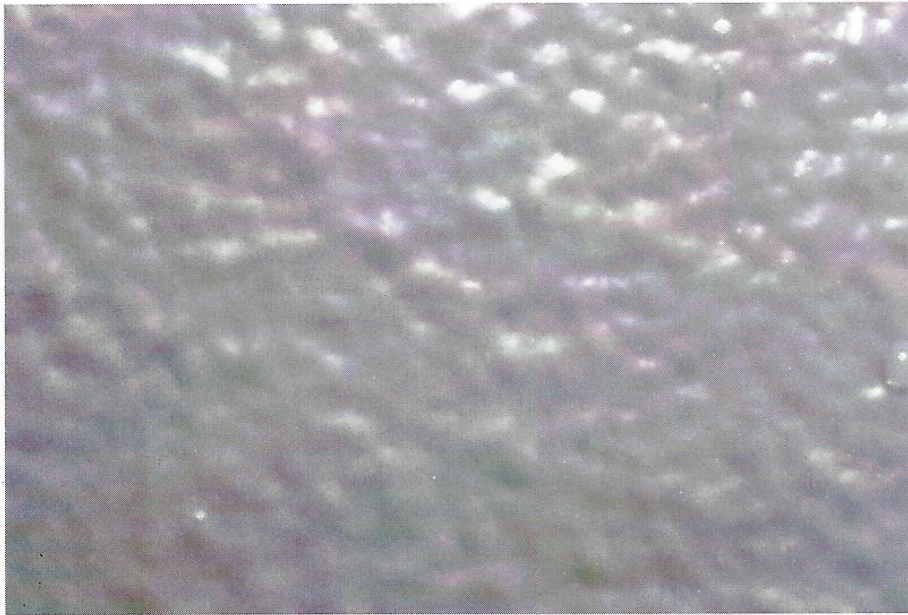
**Description:** A uniform pock-marked appearance, in particular of a spray applied coating in which the surface of the paint film resembles the skin of an orange.

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

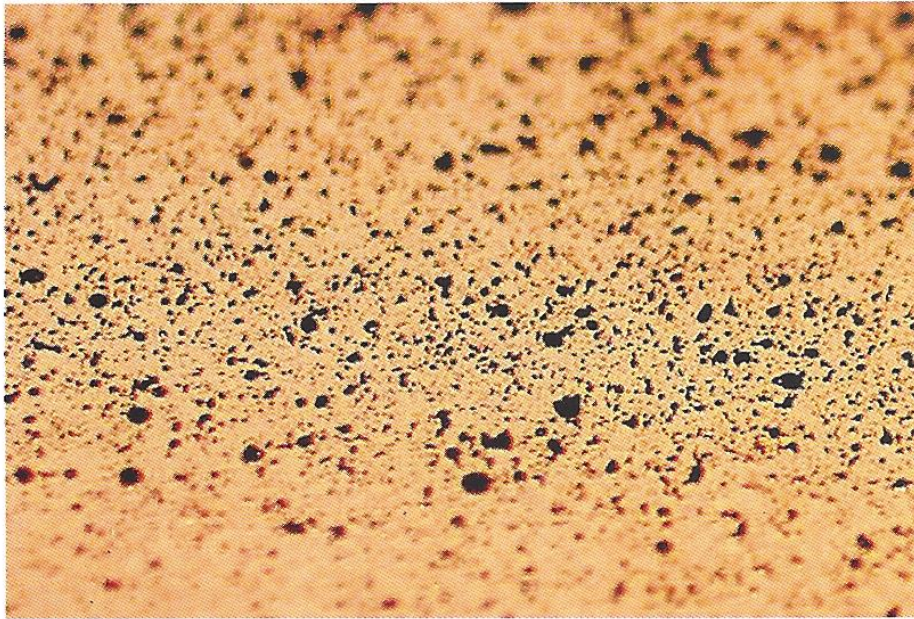
**Prevention:** Use correct application techniques with suitably formulated products.

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

**ORANGE PEEL**  
also known as Pock-marking



## OVERSPRAY



Other examples are shown on the following page

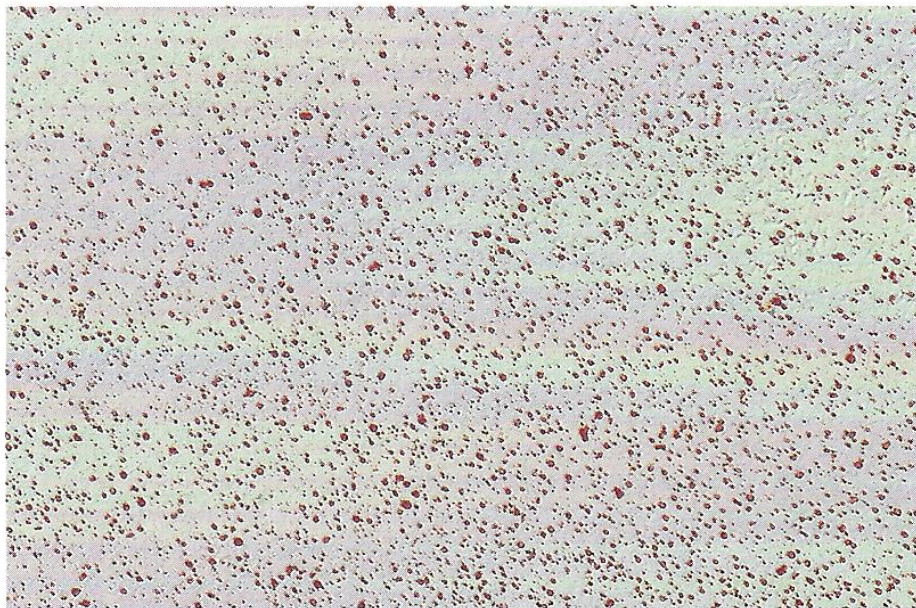
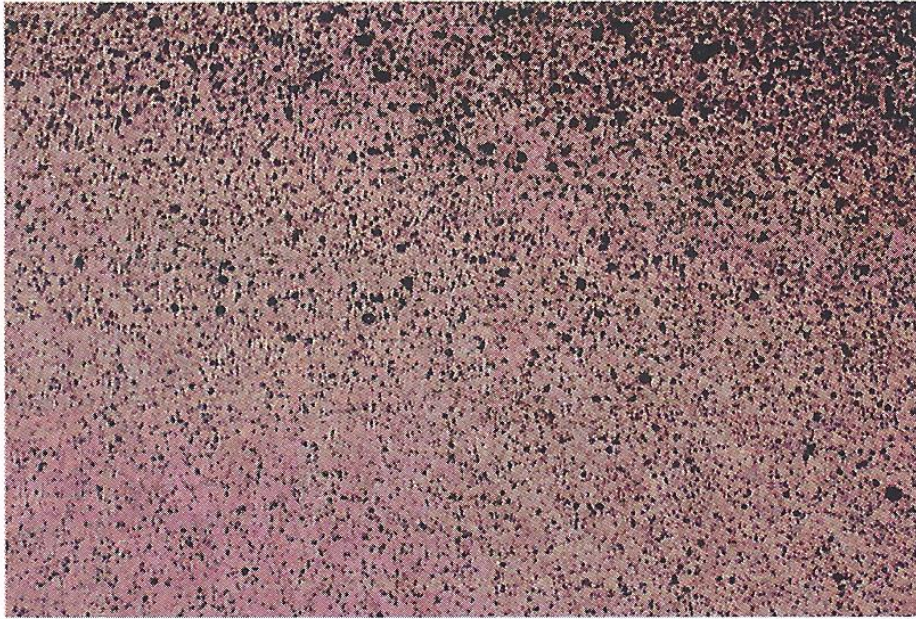
**Description:** Small particles of paint adhering to the surface of a previous dry coat, generally adjacent to the area being sprayed. Often appears as a pebbly surface.

**Probable Causes:** Particles of wet paint falling outside the spray pattern as misapplication to an adjacent surface. Spray application under windy conditions.

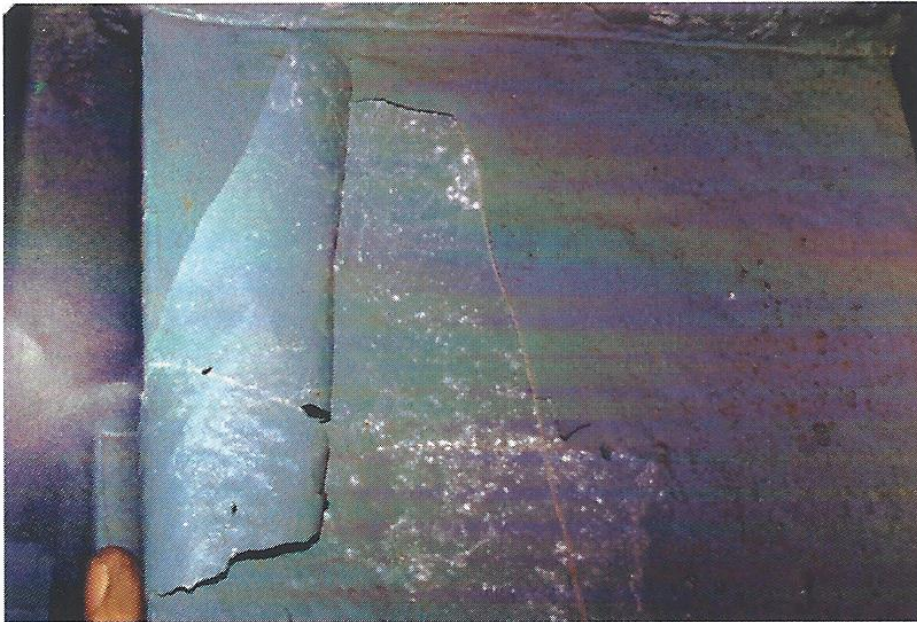
**Prevention:** Spray paint under suitable environmental conditions. Adjust spray pattern to minimise overspray.

**Repair:** Before curing or drying, remove by dry brushing followed by solvent wipe. After curing, abrade and apply a further coat.

## OVERSPRAY



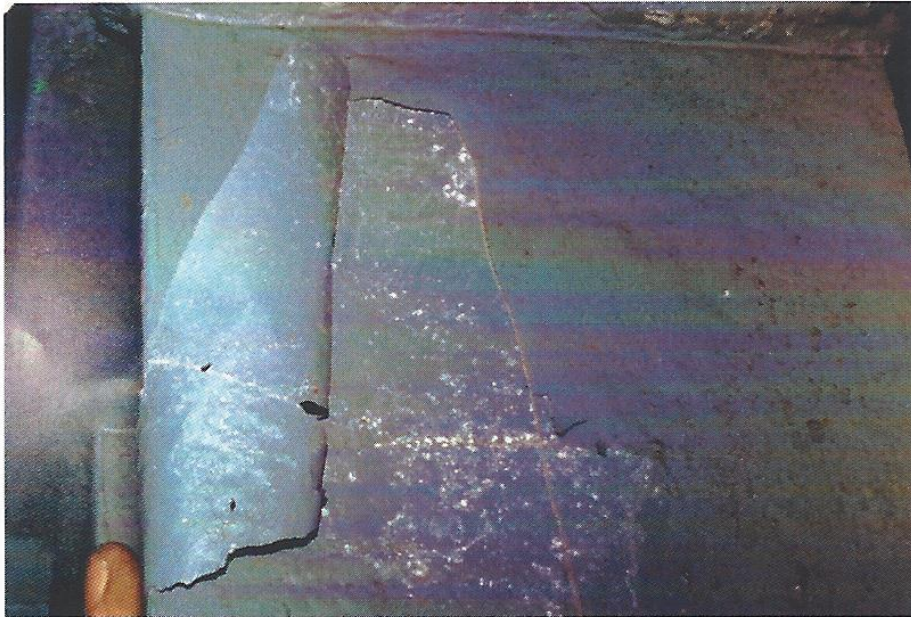
### PEELING



Other examples are shown on the following page

- Description:** Similar to flaking, although peeling tends to be associated with soft and pliable fresh 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



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**PEELING**



### PINHOLES



Other examples are shown on the following page

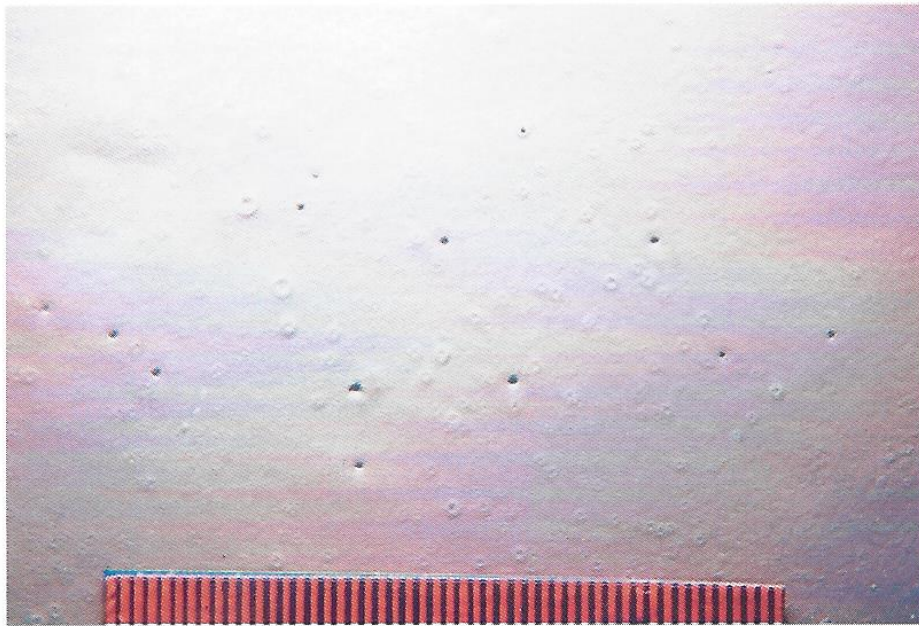
**Description:** The formation of minute holes in the wet paint film during application and drying, due to air or gas bubbles which burst, giving rise to small craters or holes which fail to coalesce before the film has set.

**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. 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. Apply a mist coat.

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

## PINHOLES



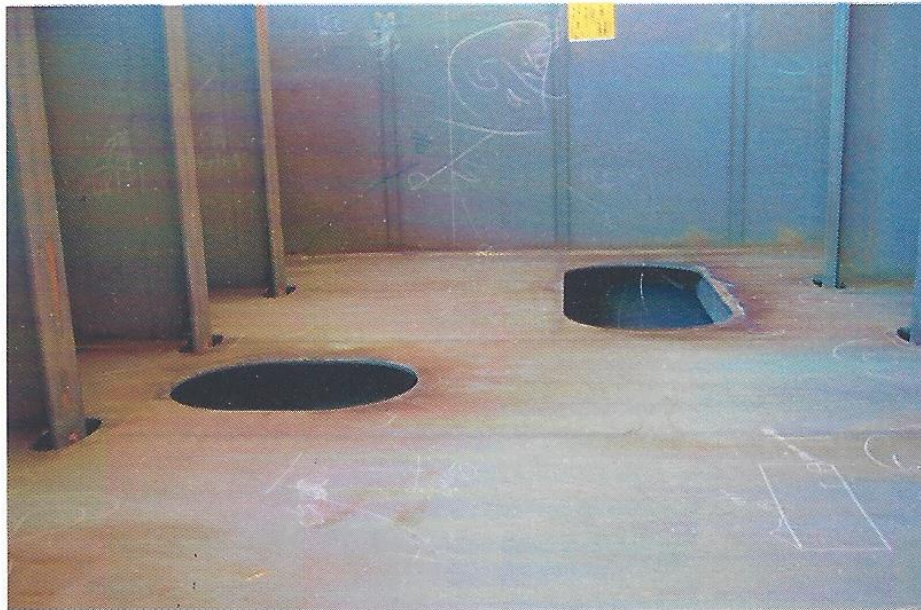
## PRIMER DEGRADATION



Other examples are shown on the following page

- Description:** Deterioration of a shopprimer during weathering in the form of rust rashing and salt formation in the case of zinc silicate primers.
- Probable Causes:** Low film thickness, excessive exposure periods and harsh environmental conditions.
- Prevention:** Ensure that an even, adequate film thickness is applied and the exposure period is suitable for the environmental conditions.
- Repair:** Depending on the extent, the surface is either prepared by mechanical cleaning (small areas) or blast cleaning (large areas) prior to application of the coating system.

## PRIMER DEGRADATION



## RAIN DAMAGE



Other examples are shown on the following page

**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.

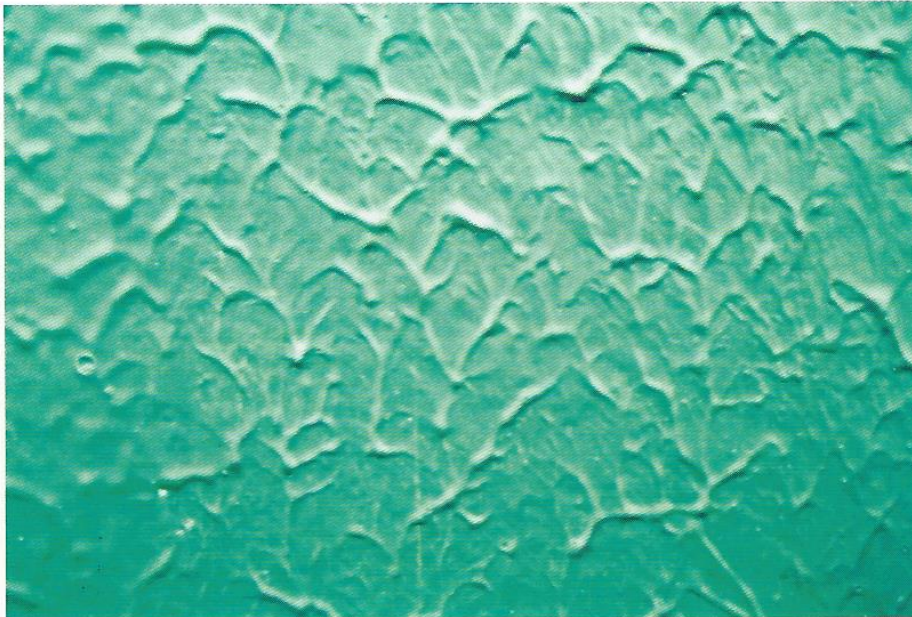
**Prevention:** Allow coating (where practicable) to surface harden prior to exposure to rain or heavy condensation.

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

## RAIN DAMAGE



## RIPPLED COATING



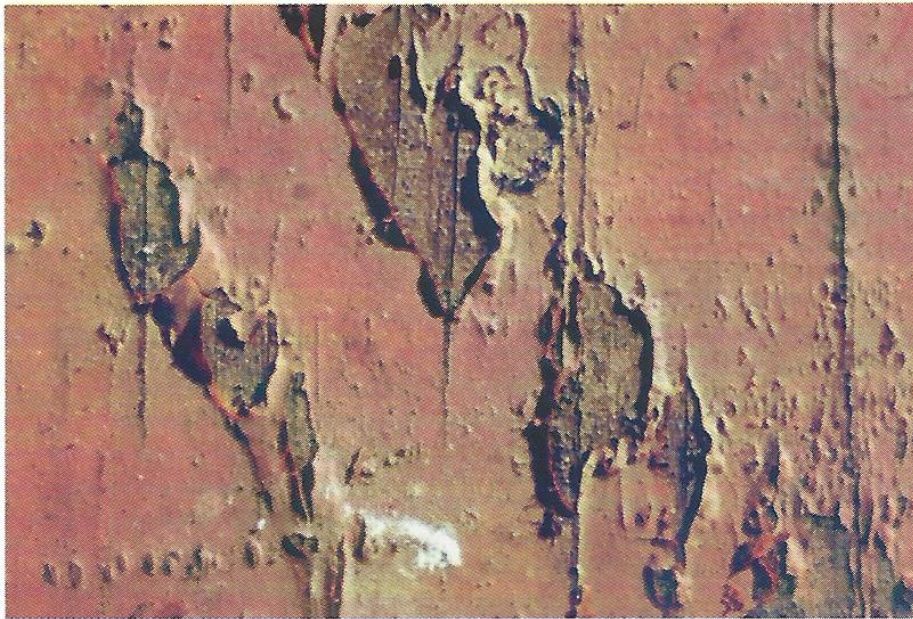
**Description:** A rippled effect on the surface of the paint.

**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)



Other examples are shown on the following page

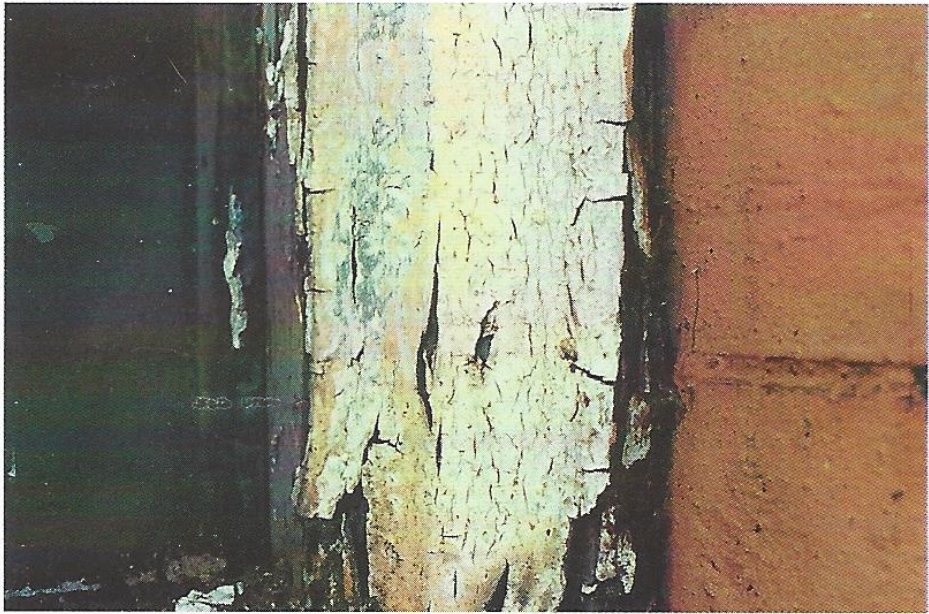
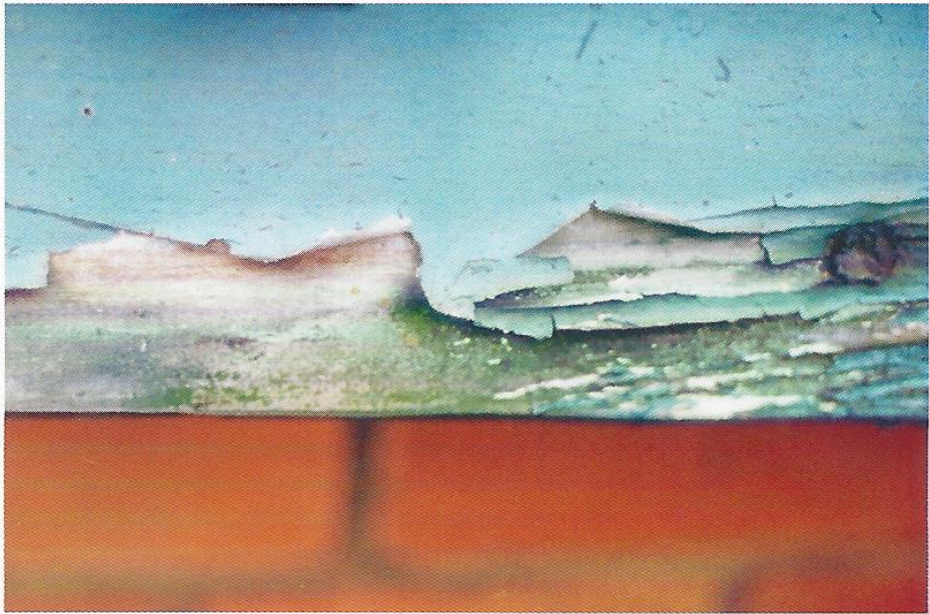
**Description:** Damp and rotten wood exposed by splitting, flaking and cracking of paint.

**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.

**ROT  
(wood)**



## RUST JACKING



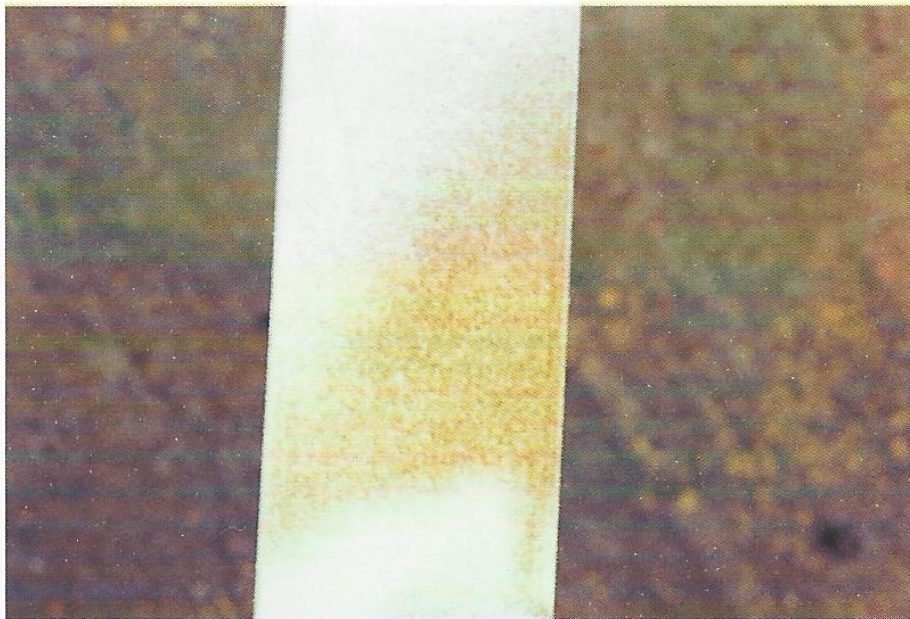
**Description:** Formation of layers of rust scale that expand, increase in volume and force the mating surfaces apart.

**Probable Causes:** Penetration of moisture between mating surfaces through defects in the coating system.

**Prevention:** Edges of mating surfaces to be adequately coated and gaps to be sealed.

**Repair:** All corrosion products to be removed prior to the area being fresh water washed, recoated and gaps sealed.

### **RUST RASHING to Thermal Spray Coating**



**Description:** Spots of ferrous oxide develop within the pores of a sprayed metal coating similar to rust rashing of a paint film.

**Probable Causes:** A phenomenon which can develop on aluminium thermal sprayed coatings soon after application as moisture is absorbed into the metal coating and reacts with the ferrous substrate.

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

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

## RUST RASHING



Other examples are shown on the following page

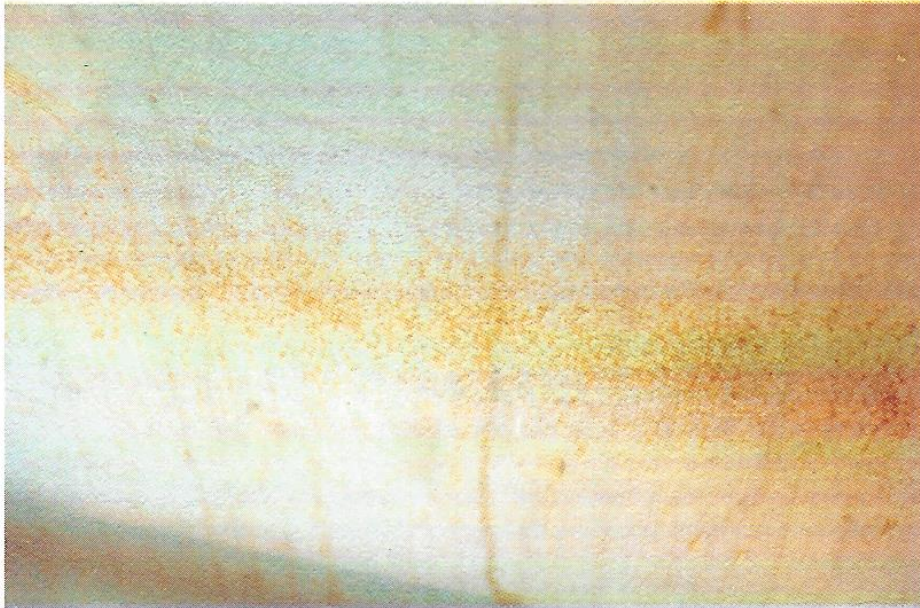
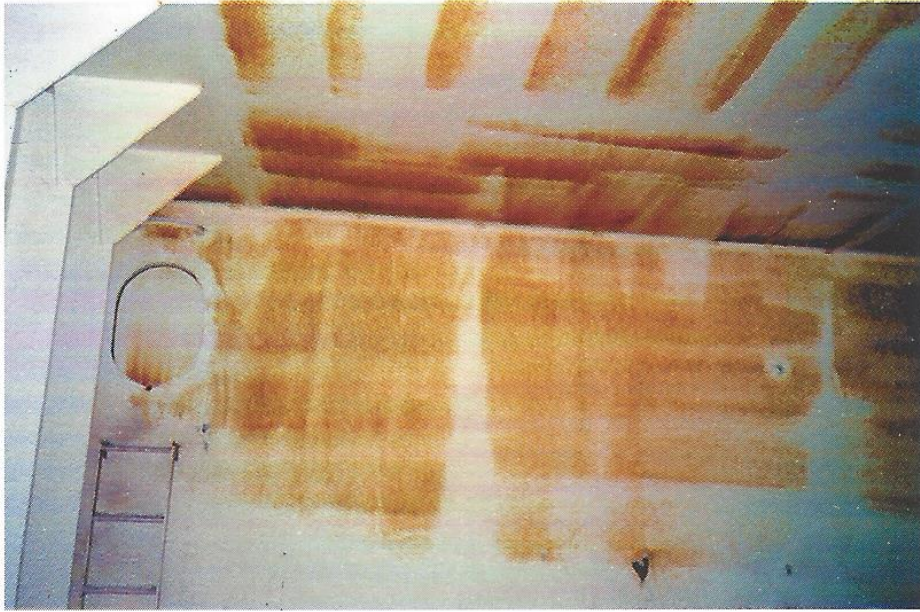
**Description:** Fine spots of rust which appear on a paint film, often a thin primer coat. The initial spots rapidly spread over the surface resulting in a film of rust through which the individual spots are difficult to discern. Also from holidays.

**Probable Causes:** Low film thickness often in combination with a high surface profile.

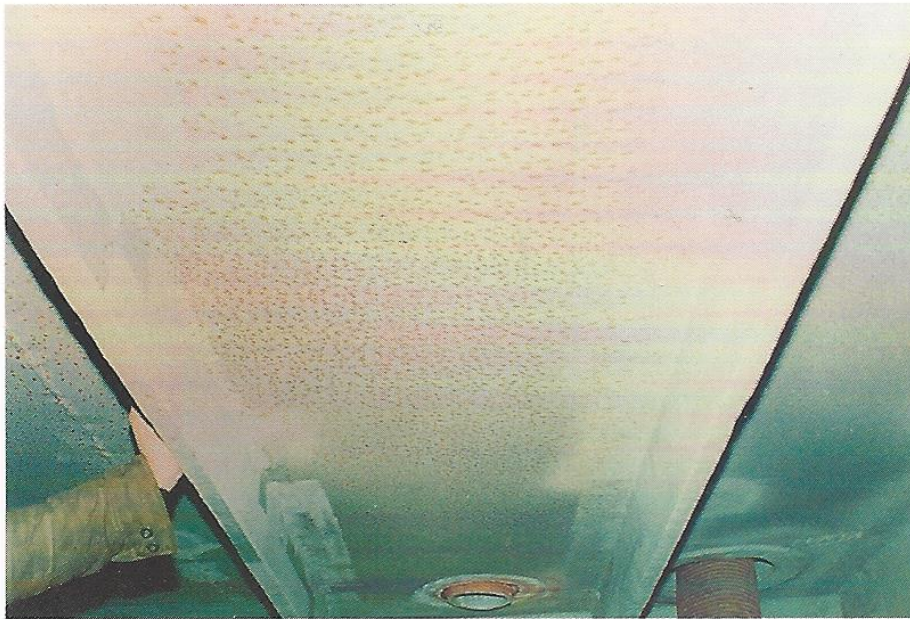
**Prevention:** Ensure that an adequate thickness of a primer coat is applied to cover the surface profile and check that the surface profile is not too large.

**Repair:** Clean rust rashing locations, wire brush and fresh water wash. Large areas may require blast cleaning.

## RUST RASHING



### RUST SPOTTING



Other examples are shown on the following pages

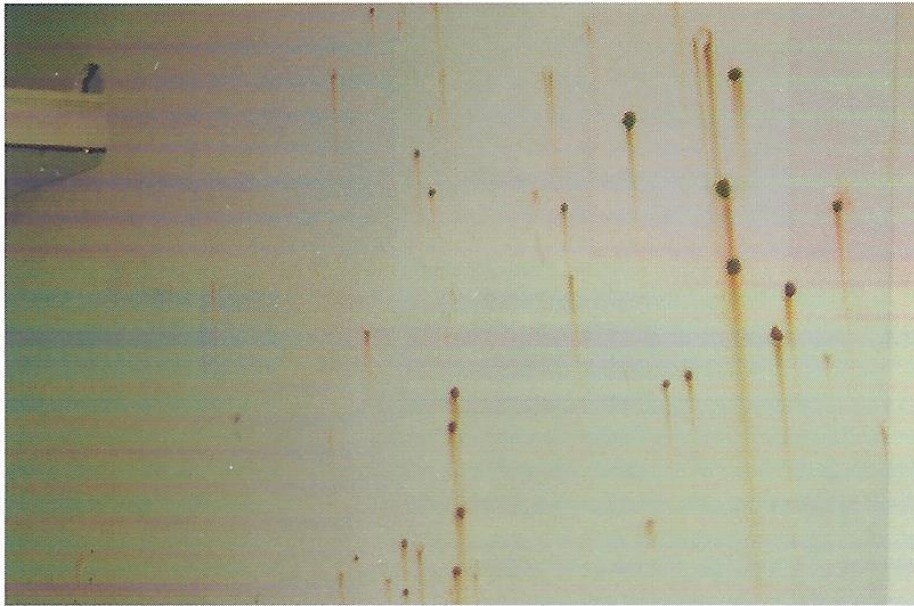
**Description:** Individual spots of rust which appear on a paint film and frequently start as localised spotting but rapidly increase in density.

**Probable Causes:** Low film thickness (more likely creating rust rashing), voids and holidays (more likely creating rust rashing), but also defects in the steel such as laminations and inclusions. 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:** Ensure that an adequate thickness of a primer coat is applied to cover 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 after removal of all foreign debris. Apply spot repair or recoat overall.

## RUST SPOTTING



### RUST STAINING



Other examples are shown on the following page

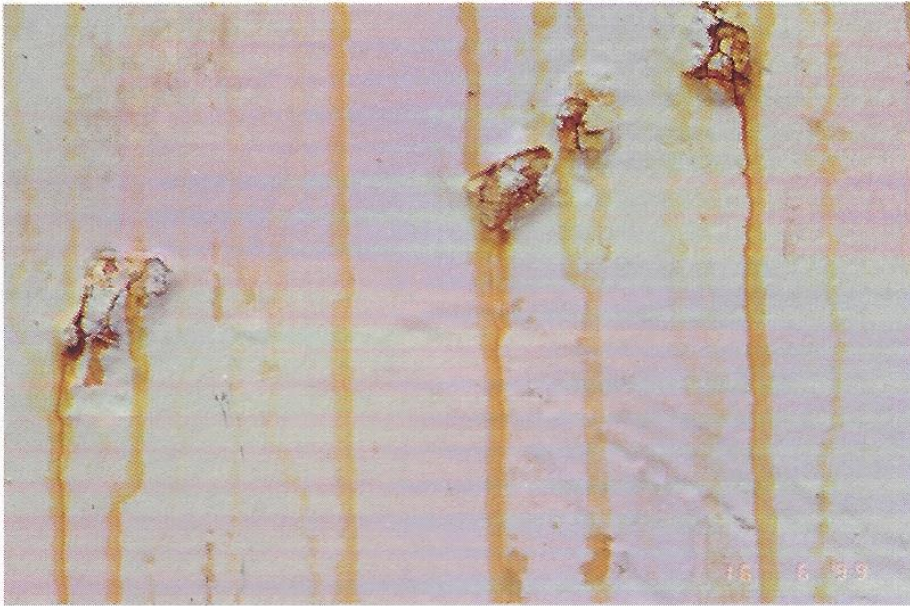
**Description:** A light staining on the surface of the paint caused by the precipitation of ferrous oxide from adjacent exposed steel.

**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.

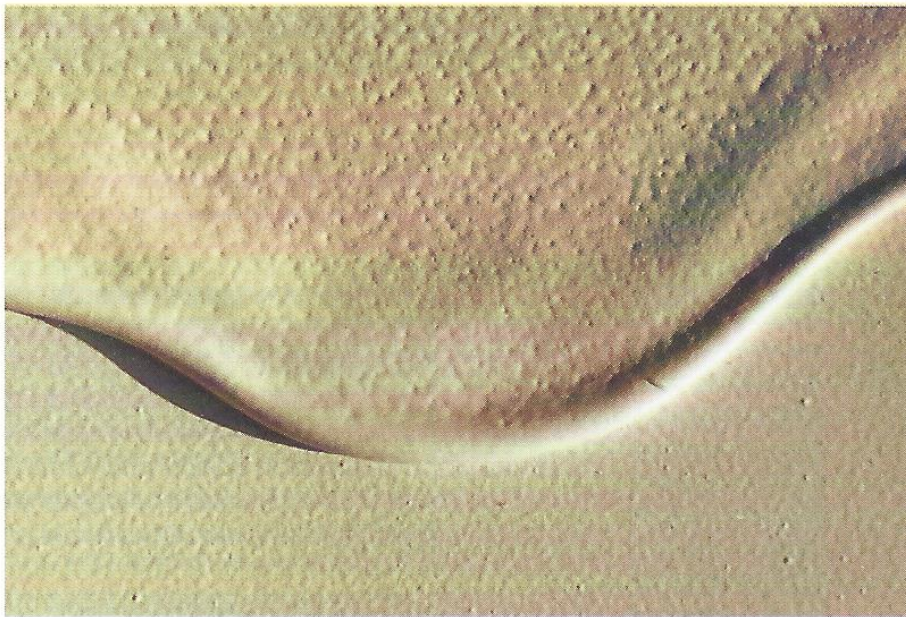
**Prevention:** Adequate design and suitable maintenance.

**Repair:** Remove staining with a rust remover and apply a cosmetic coating, as necessary.

## RUST STAINING



### **SAGS** also described as curtains



Other examples are shown on the following page

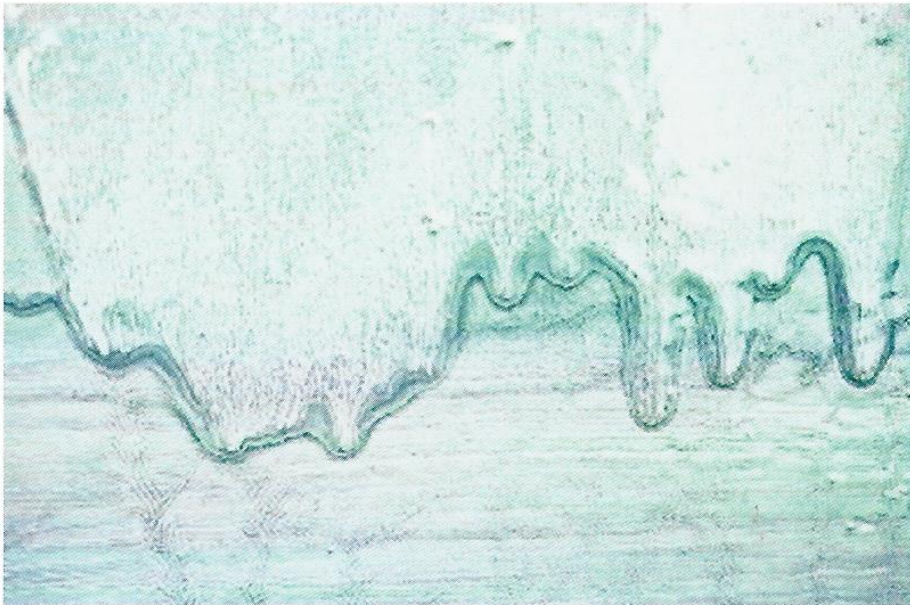
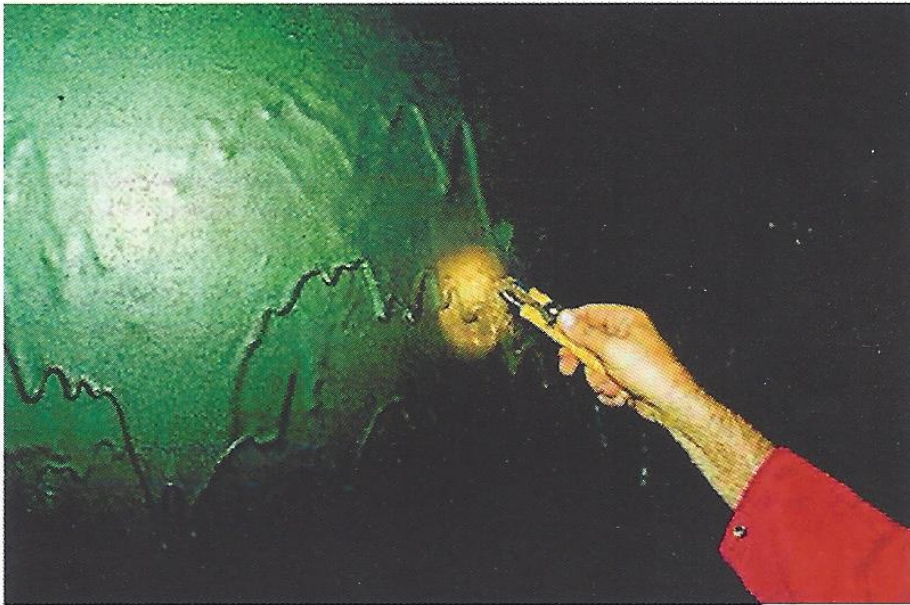
**Description:** Sags are the downward movement of a coat of paint which appear soon after application and before setting that results in an uneven area with a thick lower edge. They are usually apparent on local areas of a vertical surface and in severe situations may be described as curtains.

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

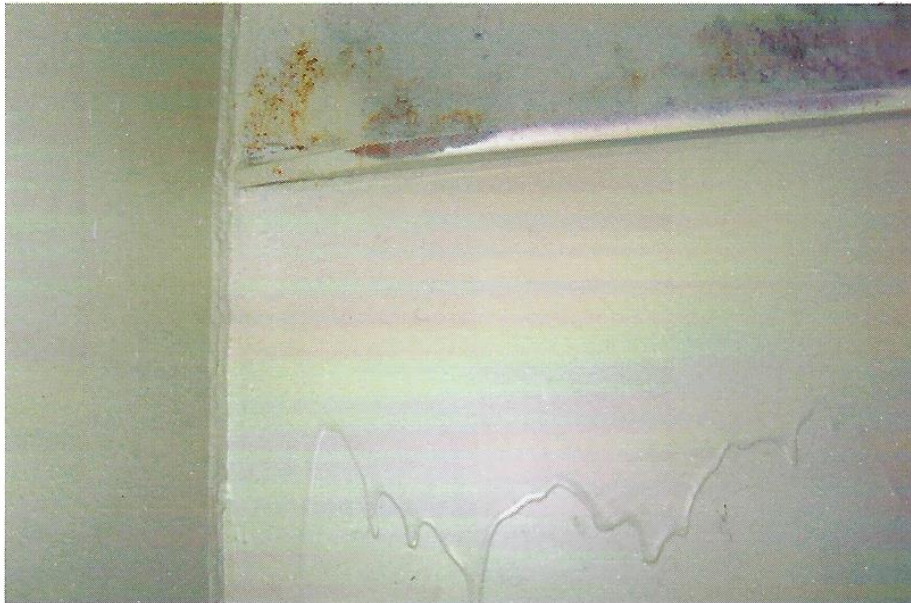
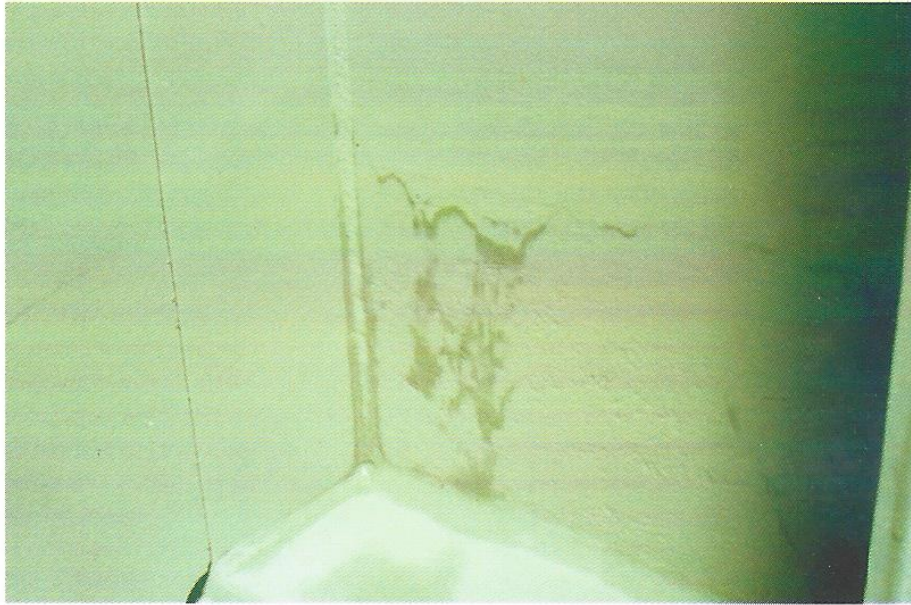
**Prevention:** Use correct application techniques with suitably formulated products.

**Repair:** While the paint is still wet, brush out runs and sags although this may not result in an acceptable appearance. When the paint has dried, abrade and clean defective areas and apply overall coat or spot repair as necessary.

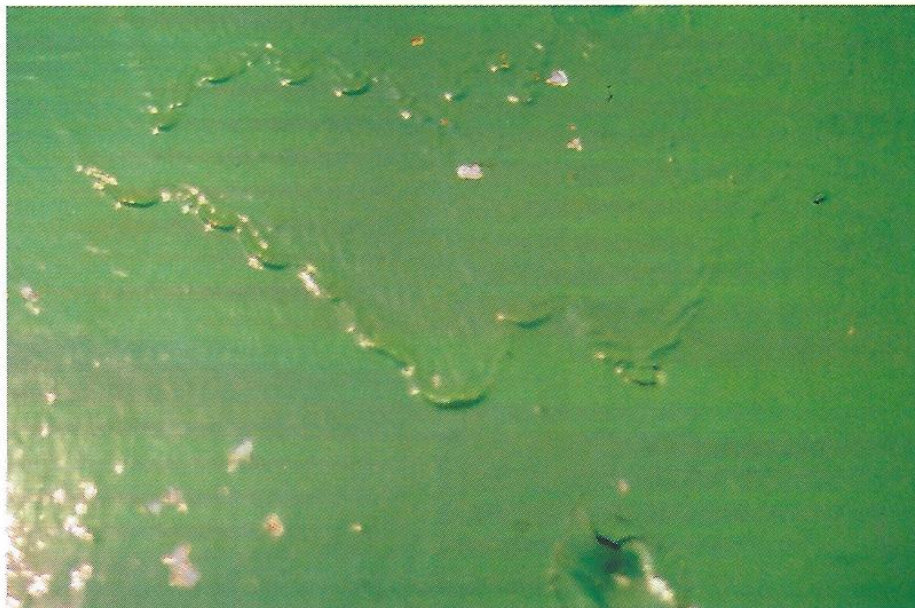
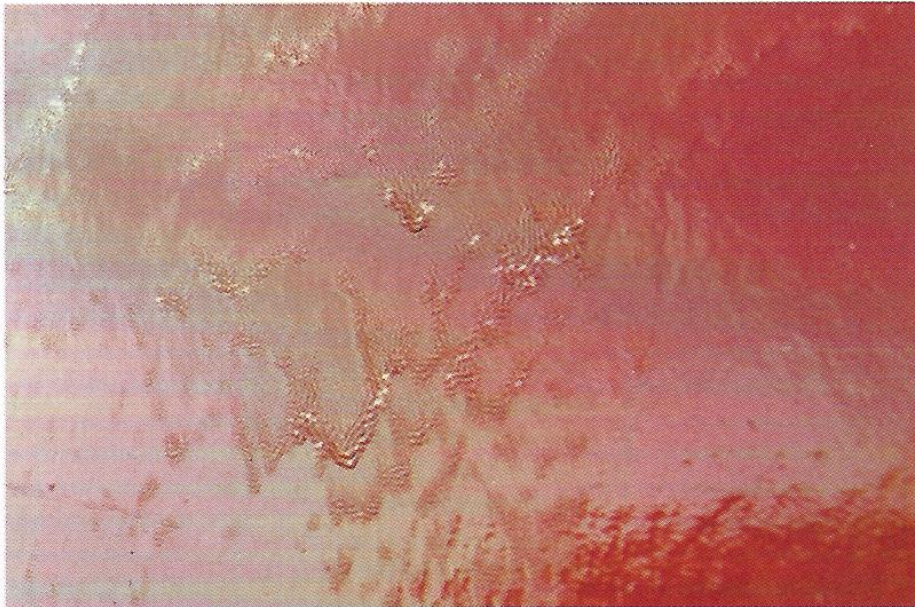
**SAGS**  
also described as curtains



**SAGS**  
also described as curtains



**SAGS**  
also described as curtains



### SALTS



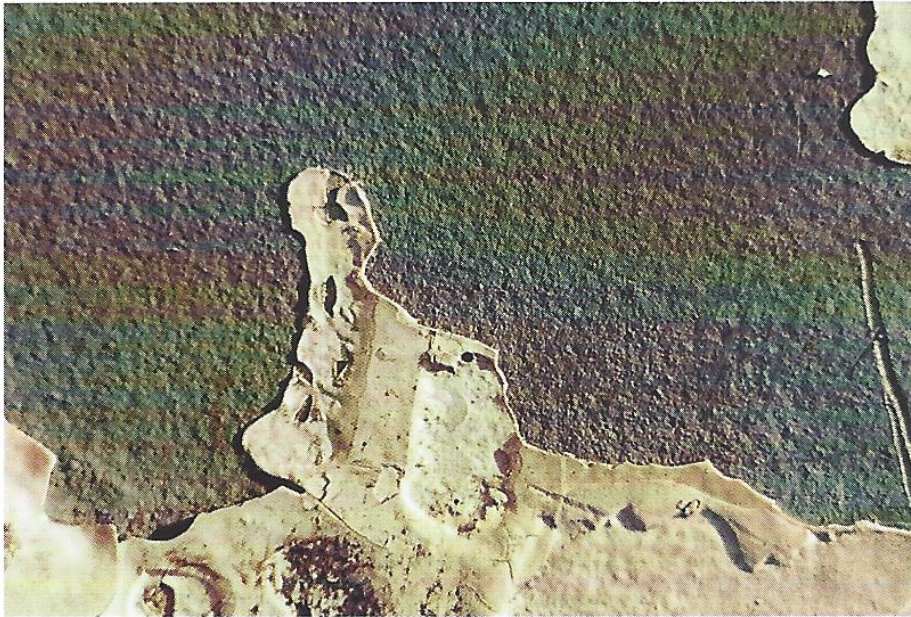
**Description:** Contamination in the form of a salt.

**Probable Causes:** Deposition from a coastal salt laden environment, environmental pollution or weathering of zinc primers.

**Prevention:** Protect items from exposure during treatment and fresh water wash between coats if positive tests for salts are obtained.

**Repair:** If salts are detected fresh water wash prior to coating application.

## SAPONIFICATION



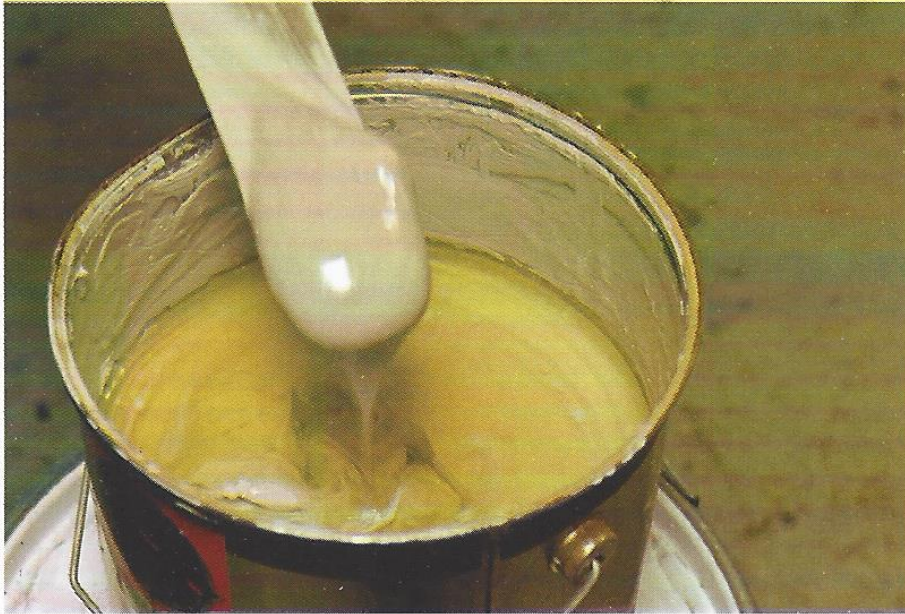
**Description:** The coating appears to be soft and sticky. Can be in sporadic isolated spots or as an overall effect.

**Probable Causes:** The formation of a soap by the reaction between a fatty acid ester and an alkali. Decomposition of the binder component of alkyd and oil based coatings by alkali and moisture from a substrate such as concrete or cementitious renders. Can also occur on zinc substrates.

**Prevention:** Use correct coating specifications and materials.

**Repair:** Remove all soft coatings where saponification has occurred, abrade, clean and reapply undercoat/topcoat using non-saponifiable materials.

### SETTLEMENT



**Description:** The sedimentation of the solid constituents comprising pigments and extenders from the binder and solvent whilst standing in a container. Settlement which occurs after mixing and during application can result in different shades and performance in different areas.

**Probable Causes:** Old stock, heavily pigmented paint and incorrect formulation 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:** If a variation in shade is produced, abrade and reapply ensuring uniform mixing before and during application.

## SKINNING



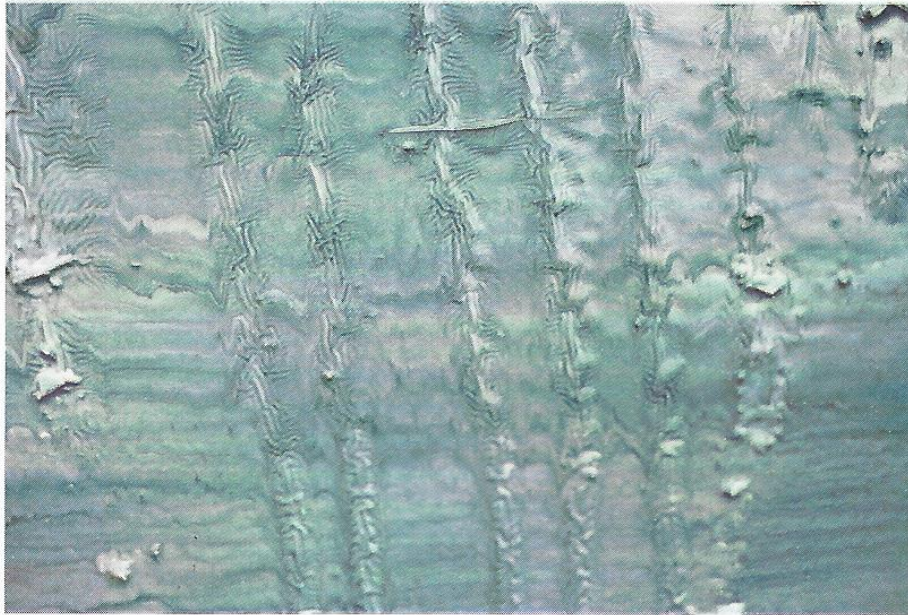
**Description:** Formation of a layer of skin on the paint surface in a container.

**Probable Causes:** Absence of anti-skinning agent, use of non airtight container, hot storage conditions. Often occurs in part used cans.

**Prevention:** Use airtight container and store according to data sheet.

**Repair:** Remove layer of skin and mix until homogeneous.

### SOLVENT LIFTING



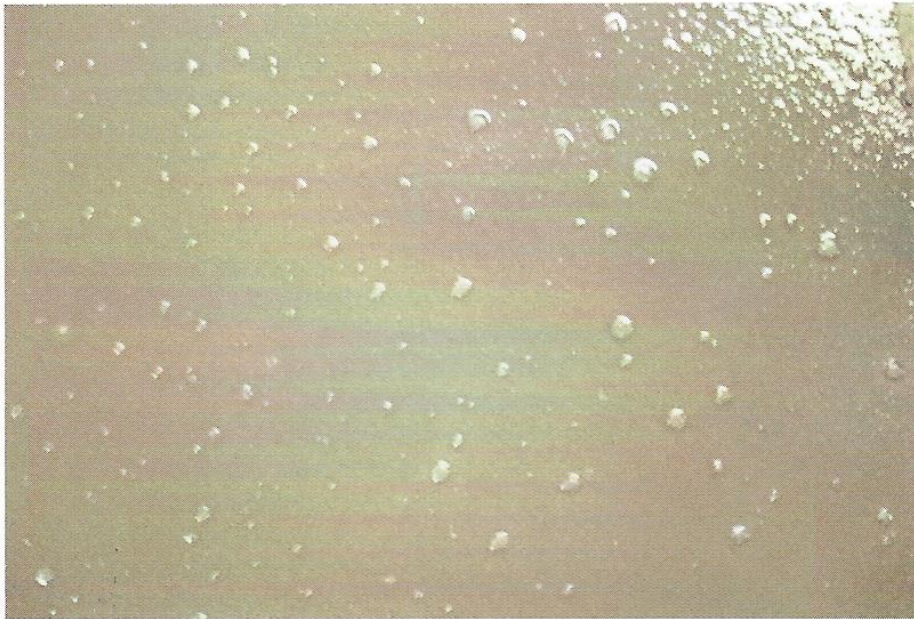
**Description:** Eruption of the surface of the paint film. Wrinkling and blistering which leads to a weak surface and ultimate coating breakdown.

**Probable Causes:** Incompatible paint systems used. Topcoats with a strong solvent blend can react with 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 POPPING



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

**Probable Causes:** Incorrect solvent blends, porous surfaces and incorrect environmental conditions. High surface temperature.

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

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

### STAINING



Other examples are shown on the following page

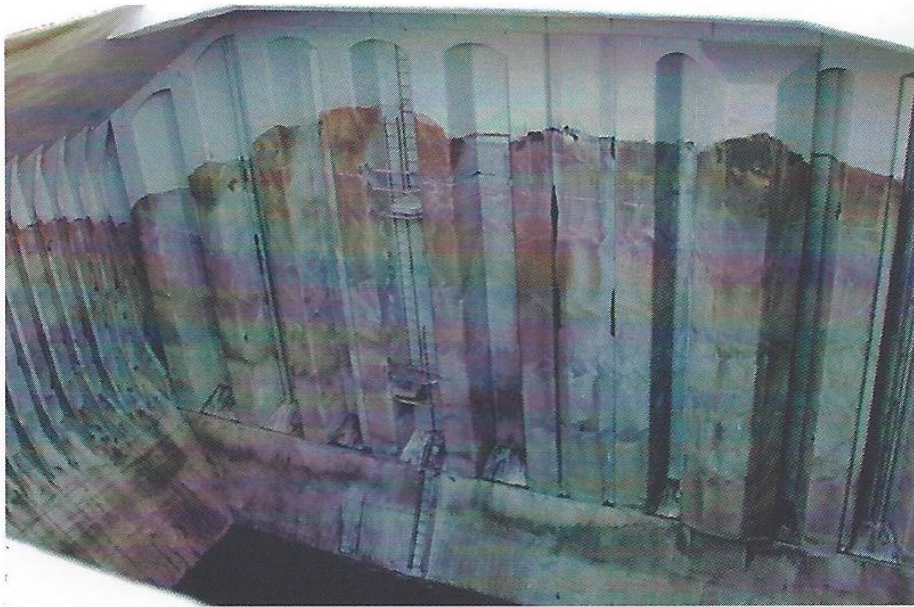
**Description:** Discolouration of a coating system.

**Probable Causes:** Contact with a solid or liquid that imparts a discolouration or stain to the coating.

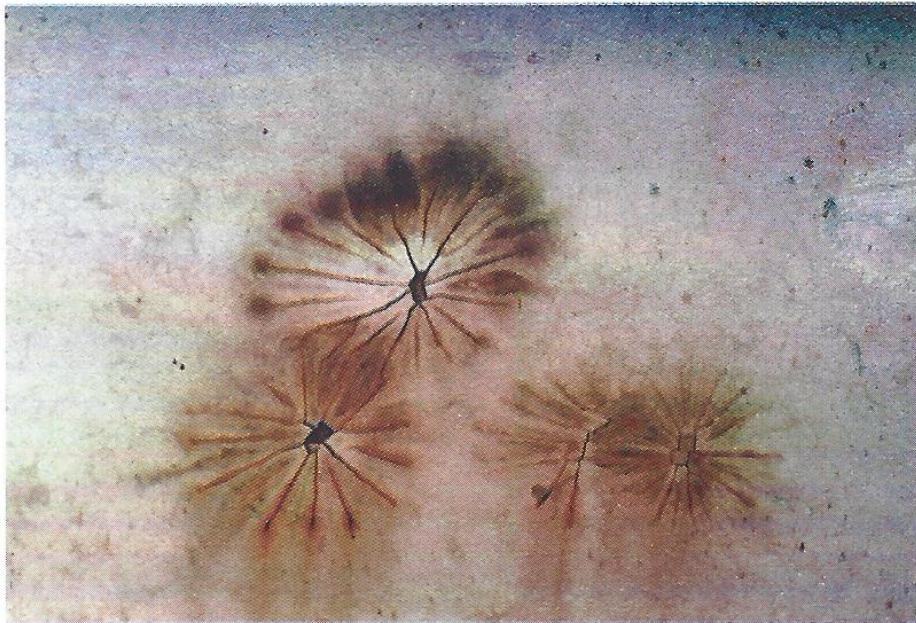
**Prevention:** Avoid contact with solids and liquids that are prone to cause staining or use dark coloured coatings where any staining would not be so apparent.

**Repair:** If the stains are on the surface they may be removed by washing with water or chemical cleaning agents. If the stains have penetrated the coating, abrading after washing may be required prior to recoating.

**STAINING**



## STRESS CRACKING



Other examples are shown on the following pages

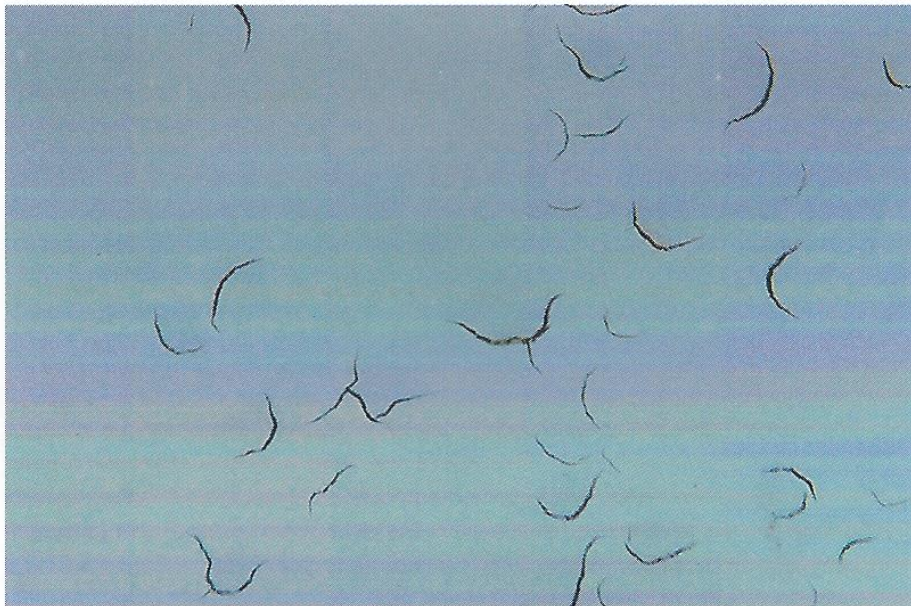
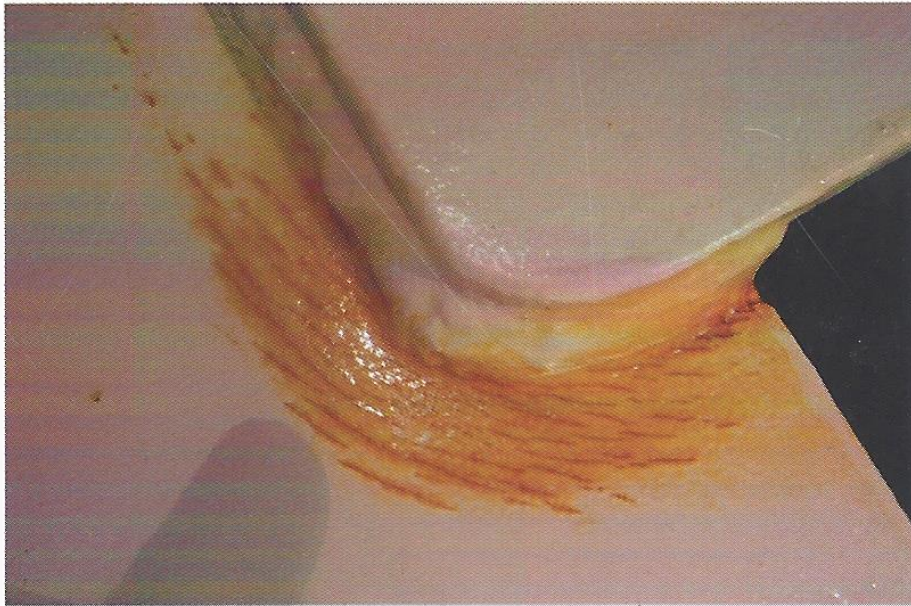
**Description:** Paint coatings with visible cracks which may penetrate down to the substrate.

**Probable Causes:** Stress cracking can be attributed to surface movement, ageing, absorption and desorption of moisture, thermal cycling and general lack of flexibility of the coating. The thicker the paint film the greater the possibility that cracking might occur. Often occurs around welds and changes in section.

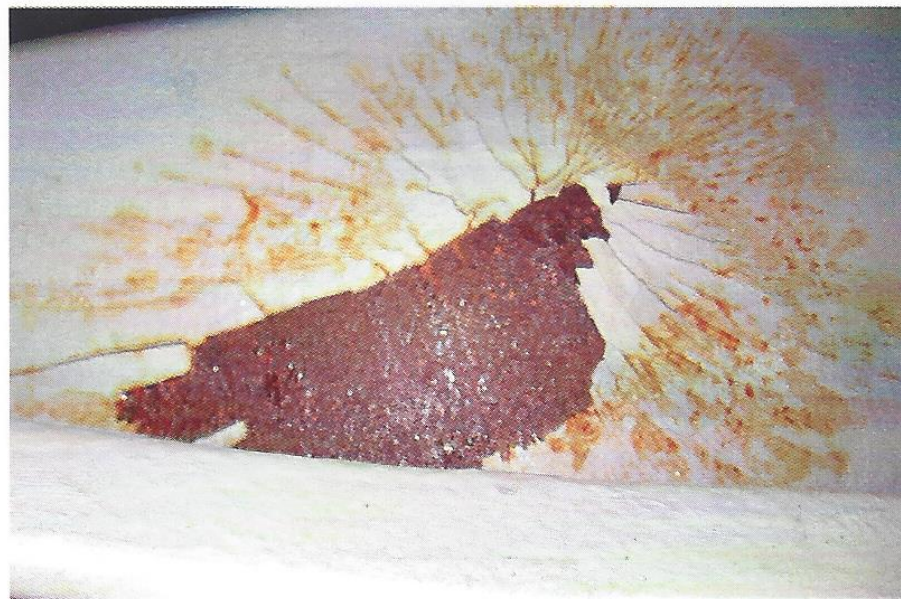
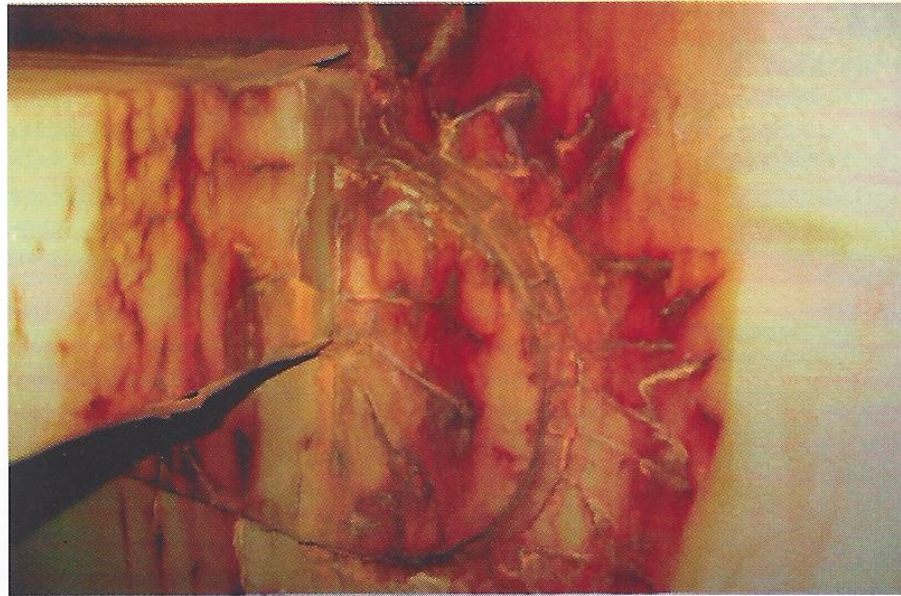
**Prevention:** Use correct coating systems, application techniques and dry film thicknesses or use a more flexible coating system.

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

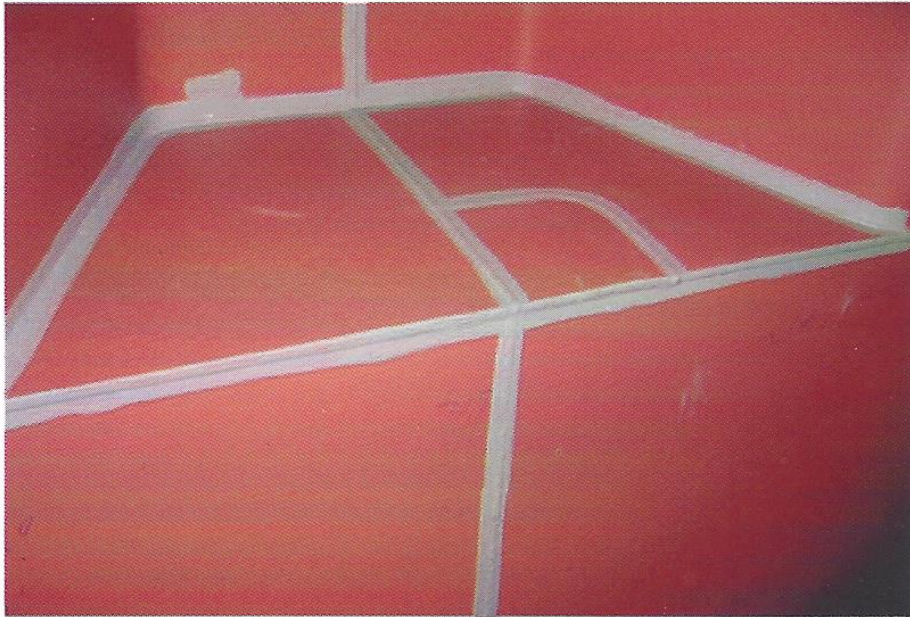
## STRESS CRACKING



## STRESS CRACKING



## STRIPE COATS



Other examples are shown on the following page

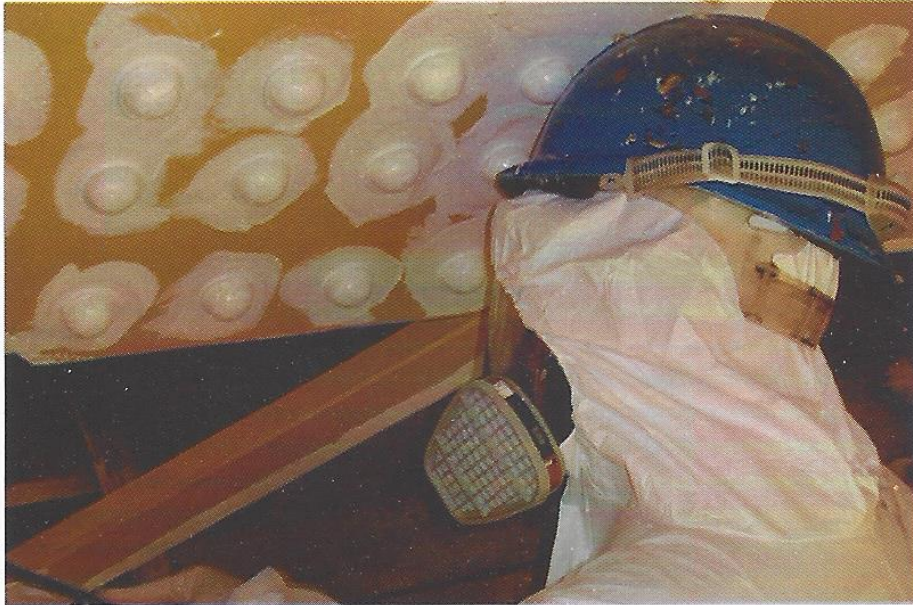
**Description:** Although not a defect the absence of stripe coats can lead to premature breakdown. A coat of paint applied by brush or roller to edges, welds, pits and other difficult to spray areas prior to application of the next full coat.

**Probable Causes:** Breakdown can occur from areas not stripe coated due to the tendency of a coating to flow away from an edge resulting in low film thickness. (The third photograph illustrates an area of poor stripe coating)

**Prevention:** Ensure adequate stripe coating is carried out prior to application of each full coat.

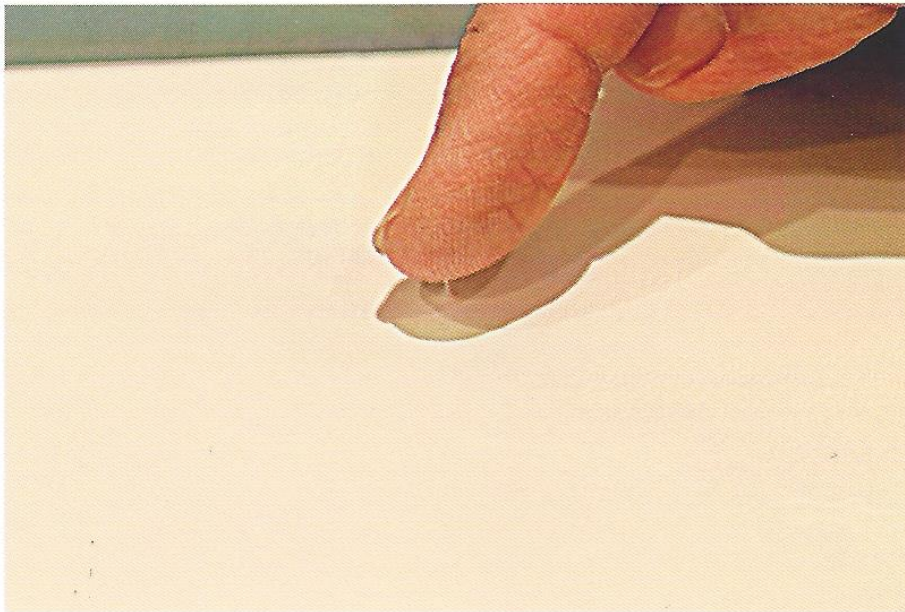
**Repair:** Apply additional stripe coats to areas with missing stripe coats or with inadequate film thickness.

**STRIPE COATS**



Inadequate stripe coating

### TACKINESS



Other examples are shown on the following page

**Description:** Degree of stickiness remaining in the film. Although beyond the wet and liquid stage, the paint film remains as a tacky and soft surface. Sometimes only apparent on touching the coating.

**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.

### UNDERCURED COATING



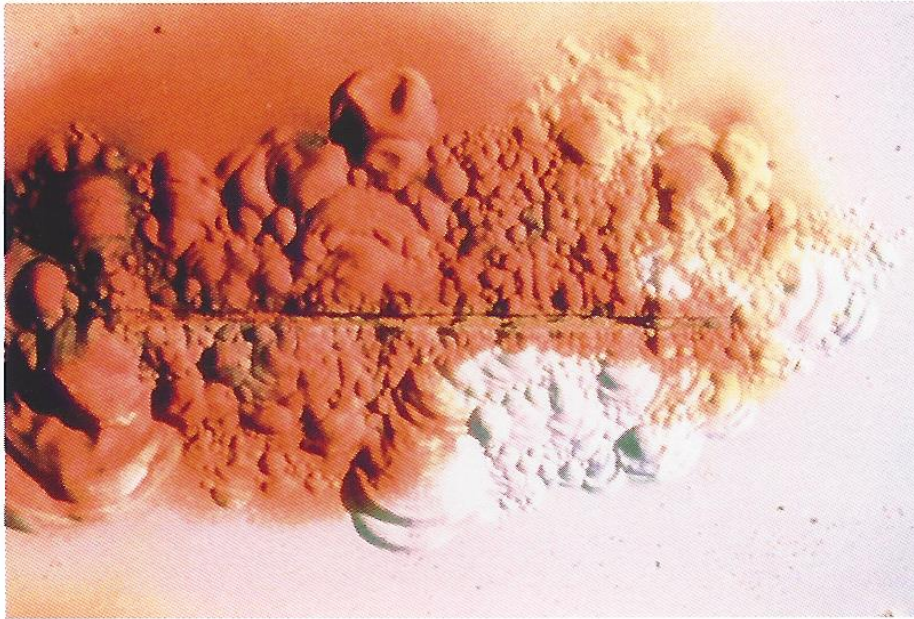
**Description:** A coating that is soft or tacky and easily deformed.

**Probable Causes:** Insufficient drying/curing time, curing in adverse environmental conditions, poor mixing of 2-pack coatings.

**Prevention:** Ensure that the manufacturers' technical data sheet is followed and that the coating is fully cured before being placed in service.

**Repair:** Remove coating from the damaged area by abrasion and recoat. Large areas may require blast cleaning.

### UNDERCUTTING



Other examples are shown on the following page

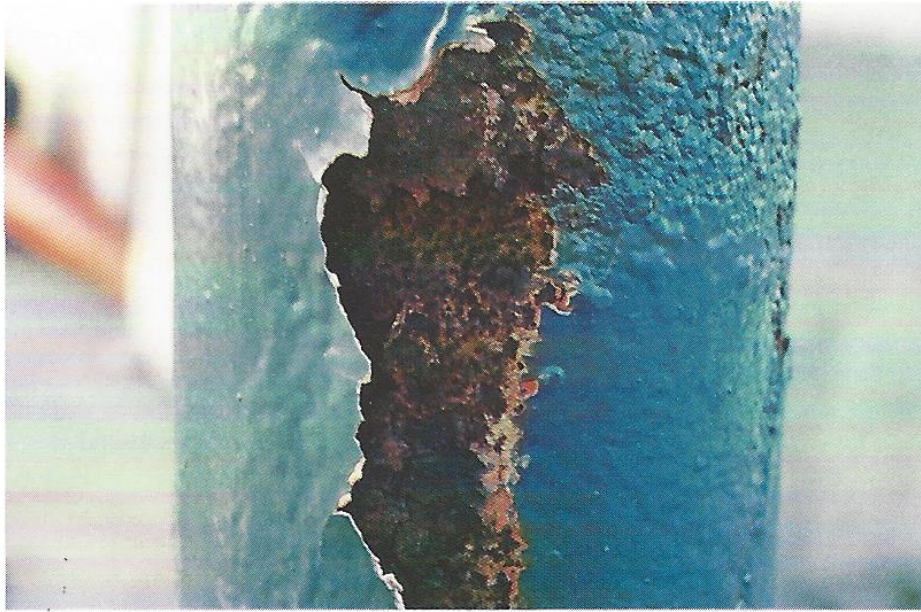
**Description:** Visual corrosion beneath a paint film often called creep. Corrosion travels beneath the paint film and lifts the paint from the substrate. Severe cases can show as blistering, flaking, cracks and exposed rust.

**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.

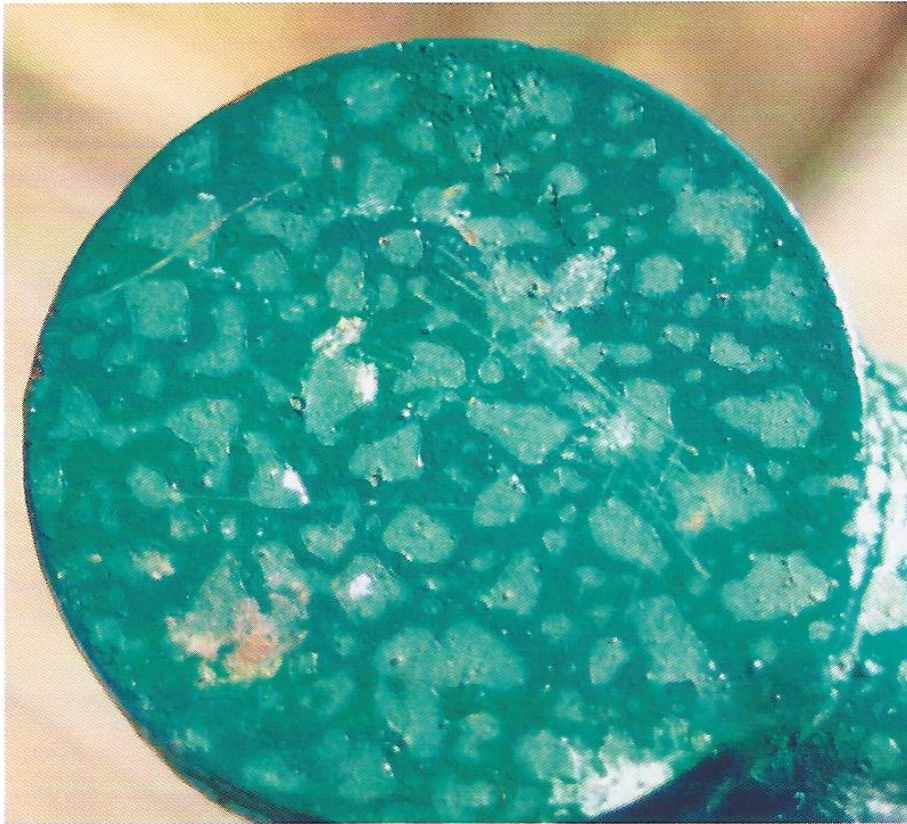
**Prevention:** Use adequate coating specifications and maintenance procedures. Apply a suitably formulated primer.

**Repair:** Spot repair localised areas. Clean areas back to a sound substrate and apply suitable repair coating to manufacturer's recommendations.

## UNDERCUTTING



## WATER SPOTTING



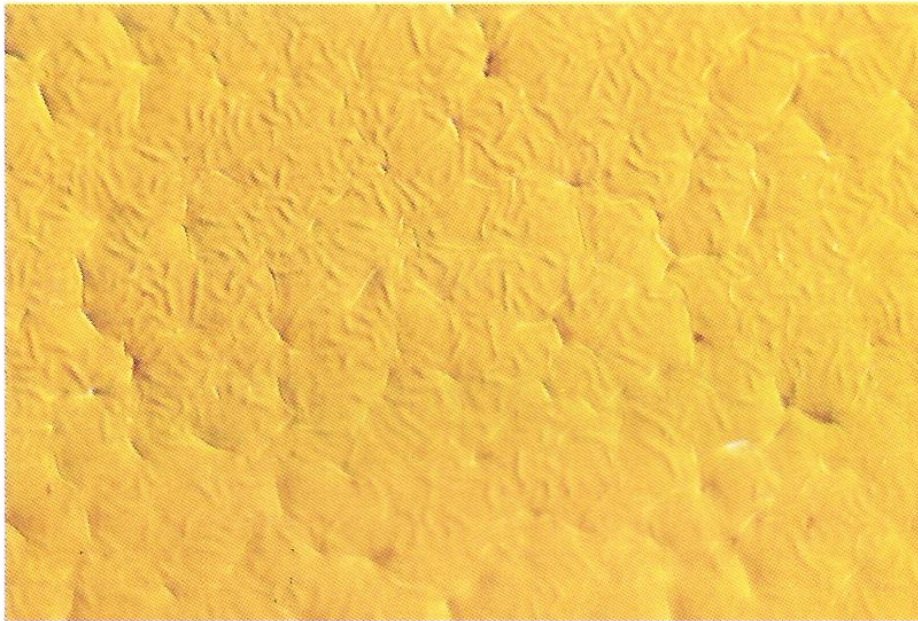
**Description:** The spotty appearance of the paint film caused by drops of water on the surface and which remains after the water has evaporated. The effect may or may not be permanent.

**Probable Causes:** The marks formed by rain drops falling on a wet paint film are prone to leaving permanent marks after evaporation whereas rain drops falling on a freshly dried but hard surface are more likely to be able to be rubbed off although with epoxy coatings it may be more difficult.

**Prevention:** Do not apply paint when rain is forecast.

**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



Other examples are shown on the following pages

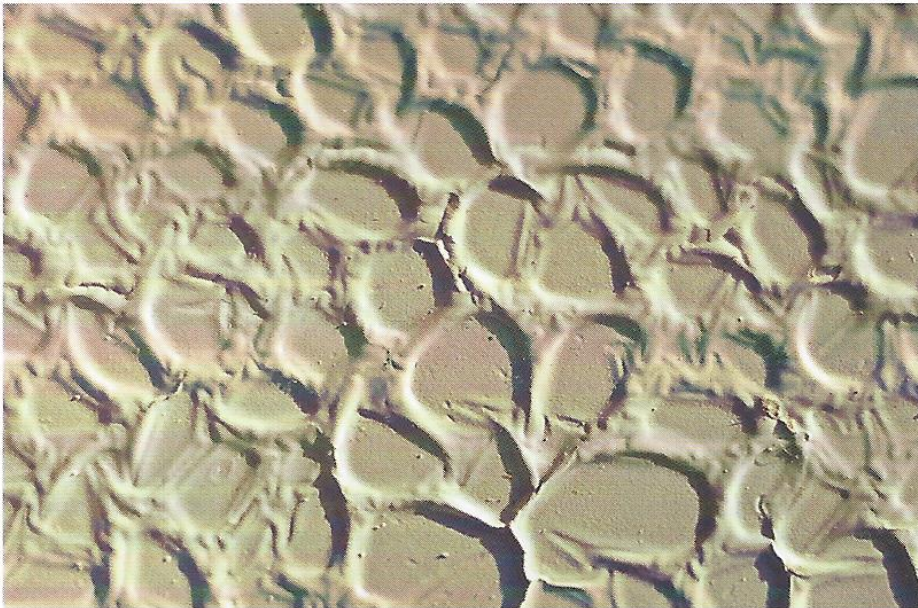
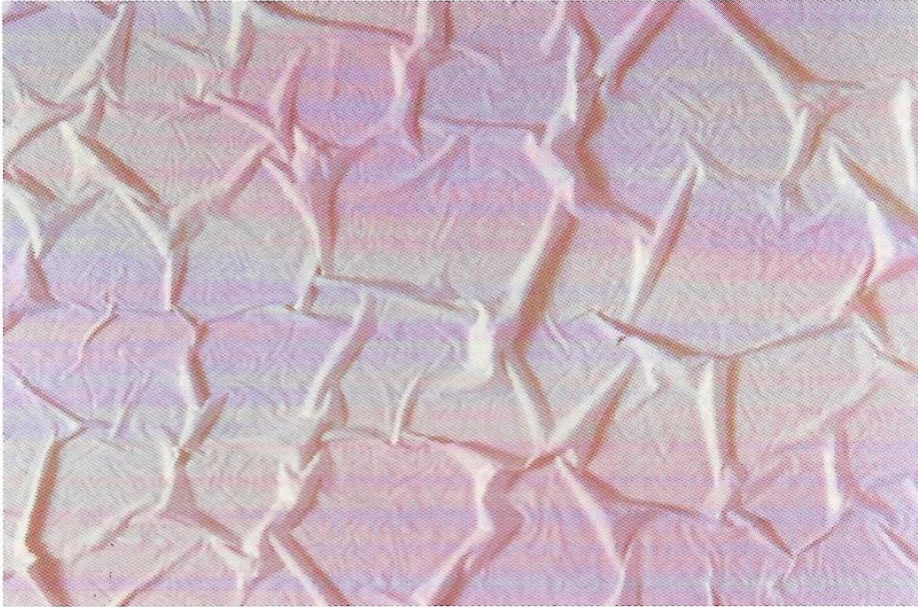
**Description:** The development of wrinkles in the paint film during drying.

**Probable Causes:** Usually due to the initial formation of a surface skin with solvent based paints. Can arise from overcoating before the previous coat has adequately hardened. Over thickness particularly with alkyd coatings.

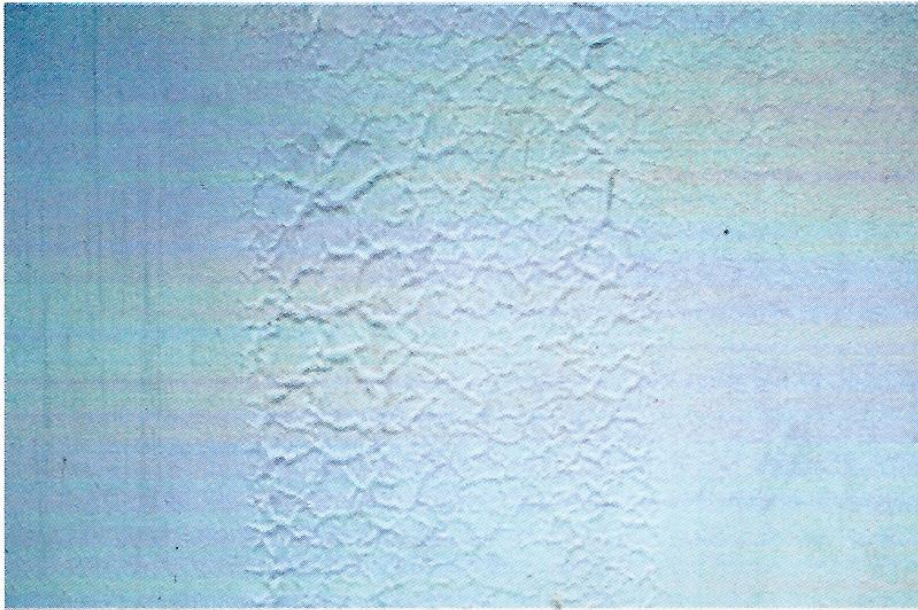
**Prevention:** Use correct coating specification and materials and ensure adequate mixing, application and curing by following the paint suppliers' recommendations.

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

## WRINKLING



## WRINKLING



### ZINC SALTS



Other examples are shown on the following page

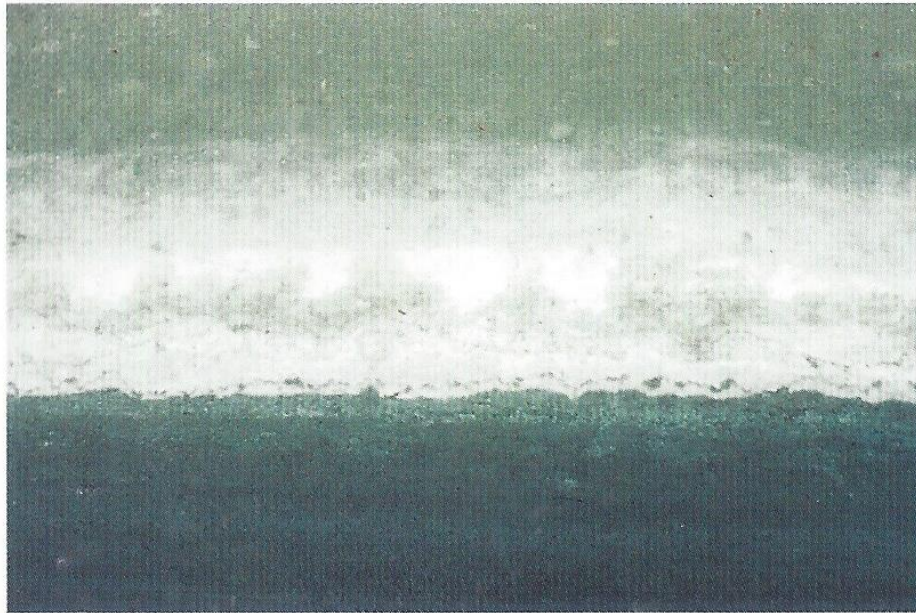
**Description:** The formation of zinc salts on a zinc rich coating or on a galvanised surface during weathering.

**Probable Causes:** Excessive period of weathering or exposure to an aggressive environment before overcoating. Coating application over zinc salts can lead to premature failure. Zinc silicate tank coatings exhibit salt formation in service but is not considered a problem.

**Prevention:** Reduce the weathering period, protect from an aggressive environment or apply an appropriate protective coating system.

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

### ZINC CARBONATES



Fitz's Atlas™ of coating defects

**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 2<sup>TM</sup> of coating defects

5 - MICROSCOPY

**INDEX OF MICROSCOPY**

CONTENTS LIST.....5-1  
MICROSCOPY.....5-2  
BLISTERS.....5-4  
BUBBLES.....5-6  
COHESIVE FAILURE.....5-7  
CONTAMINATION.....5-8  
CRACKING.....5-11  
DELAMINATION.....5-12  
EDGE COVERAGE.....5-14  
EXUDATION.....5-15  
INCLUSIONS.....5-16  
INCOMPATIBILITY.....5-18  
MULTI-COATS.....5-19  
NON-COALESCECED FILM.....5-21  
PINHOLES.....5-22  
SCALE.....5-24  
STAINING.....5-25  
SURFACE PROFILE.....5-26  
UNDER-FILM CORROSION.....5-28  
UNDISPERSED PIGMENT.....5-29  
VOIDS/VACUOLES.....5-30  
WEED/ALGAE FOULING.....5-32

### MICROSCOPY

In the investigation of coating failures and the characterisation of coating defects the first step is a visual examination, often with the aid of a hand held magnifying lens. To assist in establishing the cause and mechanism of failure a more detailed examination of paint flakes collected during the investigation is required. A microscope, which is an instrument that enables (through a combination of lenses) the human eye to see enlarged images of small objects is used for this purpose.

Present day light microscopes can provide magnifications of up to 1,500 times. At these high magnifications, however, the depth of field and working distance become very small. Stereo microscopes use two separate optical paths to provide slightly different viewing angles to each eye, resulting in a three-dimensional image. This arrangement provides a greater working distance, a greater depth of field, and a useful magnification of about 100 times. It is this type of microscope that is used routinely to examine paint flakes. When the stereo microscope is coupled with attachments such as cameras, video cameras and digitizing computers the images observed can be recorded.

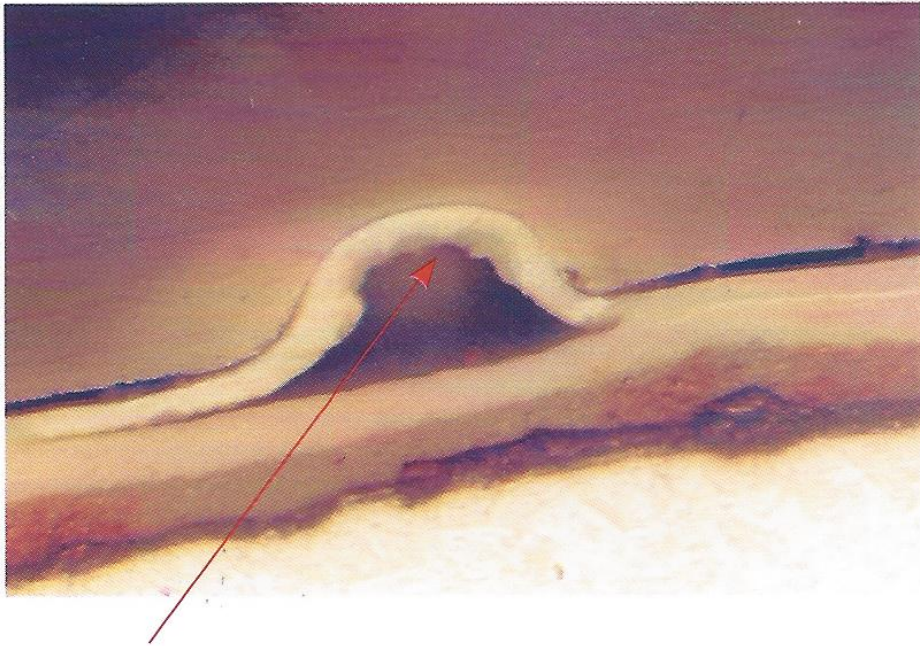
The light microscope, irrespective of the quality of the optics and illumination, is restricted (by the wavelength of light) in the size of object that can be examined. To distinguish smaller objects a type of illumination with a smaller wavelength is required. In an electron microscope electrons are accelerated in a vacuum until their wavelength is very short. Beams of these electrons are focused on a sample and an image is formed on an electron sensitive photographic plate. A particular type of electron microscope, the scanning electron microscope (SEM), produces images of the surface of a sample by scanning it with a high energy beam of electrons in a raster pattern. The SEM has a large depth of field and produces a three dimensional image with a wide range of magnifications from 10 times to about 500,000 times. SEM microscopes are used in paint laboratories to provide detailed images of surface structure. They can, with the use of Energy Dispersive X-Ray analysis (EDX) attachments, also provide information about the elemental composition of the sample.

When the top and bottom surfaces of paint flakes are examined by microscopy for contamination, inclusions and the presence of rust and scale information on the degree of surface preparation can be obtained. When the paint flakes

are examined in cross section the number of coats, their colour and individual coating thicknesses can be determined. Voids, vacuoles and the penetration of rust staining, if present, can also be seen.

Examples of the above defects and others are shown on the following pages.

## BLISTERS



INTERCOAT BLISTER

**Description:** Dome shaped projections or blisters in the dry paint film through local loss of adhesion and lifting of the film from the underlying surface. Many mechanisms can be involved including osmotic gradients associated with soluble salts, soluble pigments, corrosion products, retained solvents and solvents from cargoes. Non-osmotic blistering associated with electro endosmosis, cathodic disbonding, thermal gradients related to cold wall effects and compressive stress.

## BLISTERS

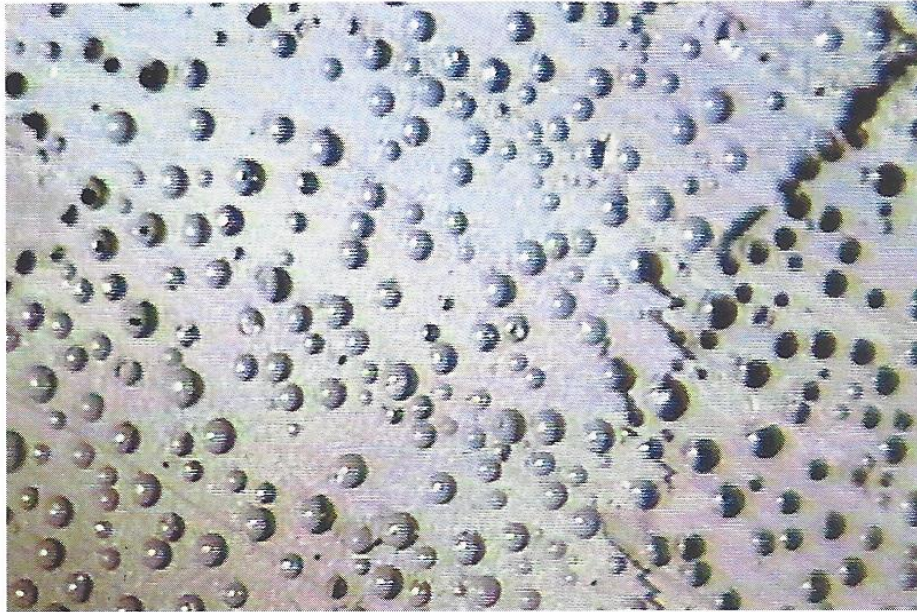


BLISTERED FILM



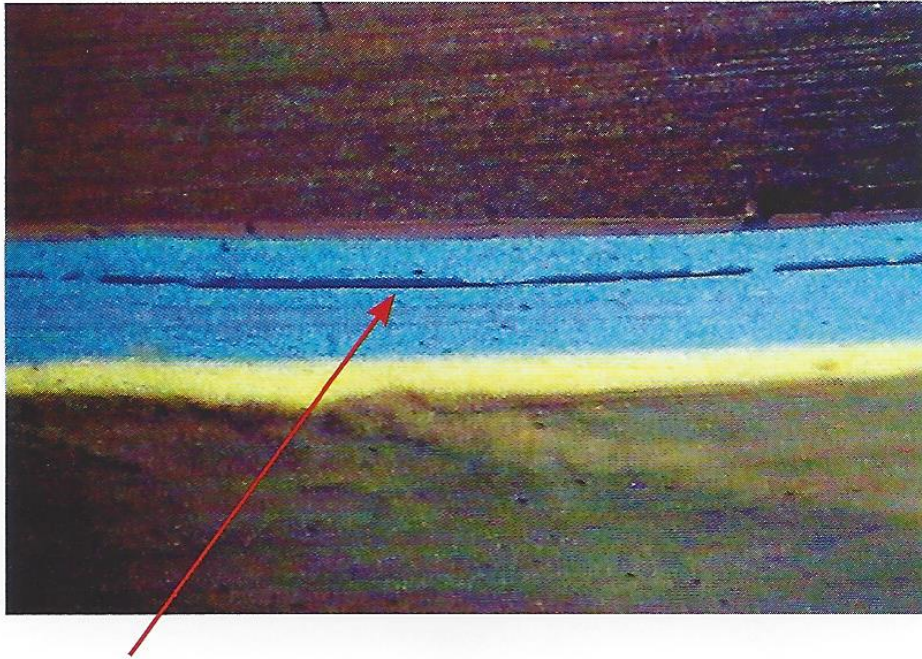
CORROSION PRODUCTS ON THE UNDERSIDE OF A  
BLISTER CAP

## BUBBLES



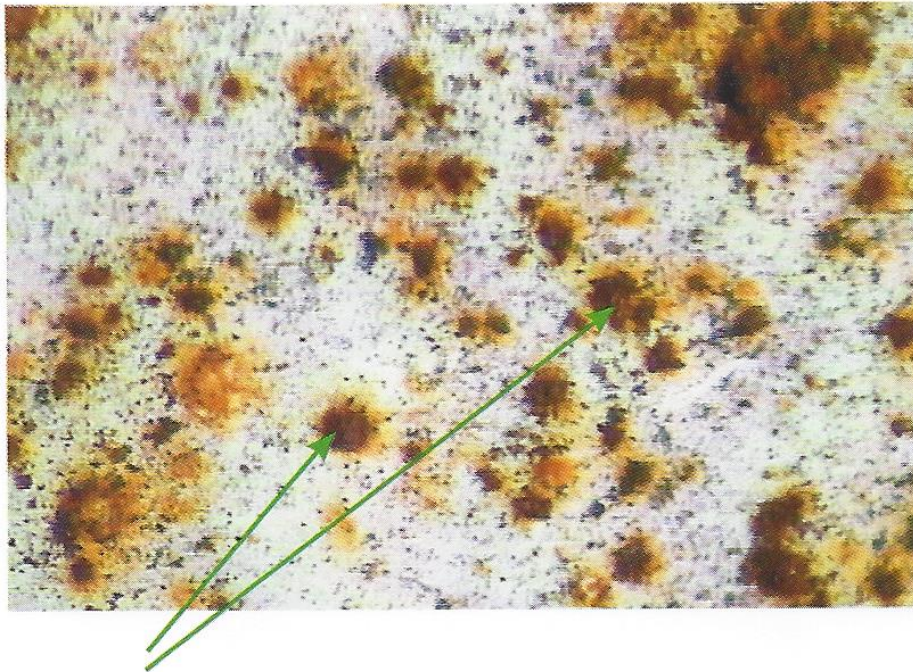
**Description:** Bubbles within a paint film appear as small blisters and can be found in excessively thick paint films where trapped air or solvent within the coating is not released before the surface dries.

## COHESIVE FAILURE



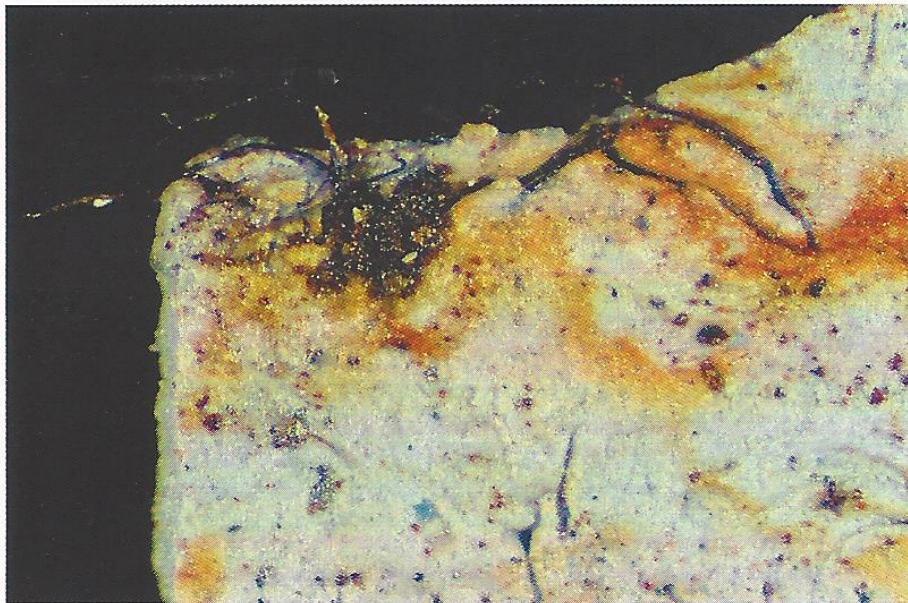
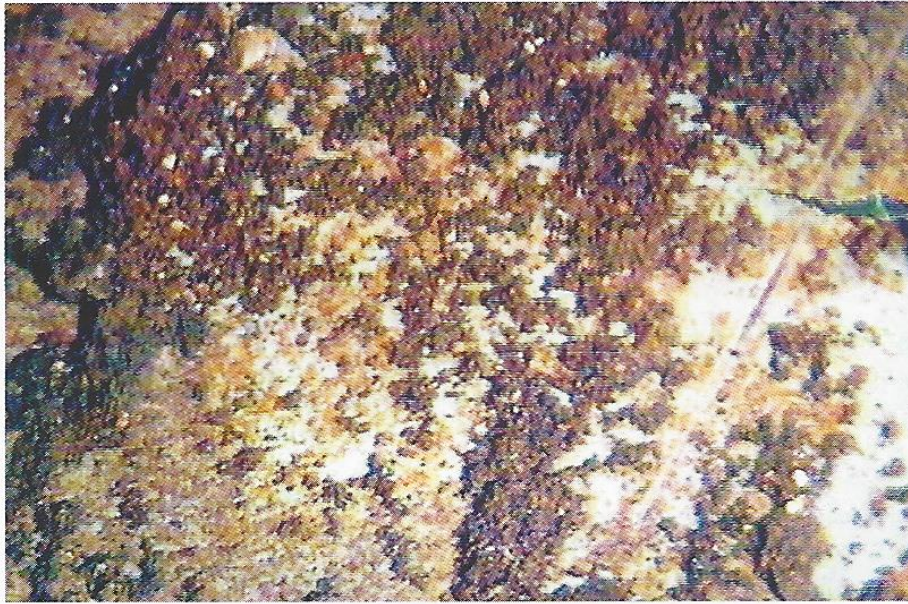
**Description:** A failure within a single coating layer. This failure mode is often seen with inorganic zinc coatings whose cohesive strength is poor and with coatings applied at high dry film thicknesses.

## CONTAMINATION

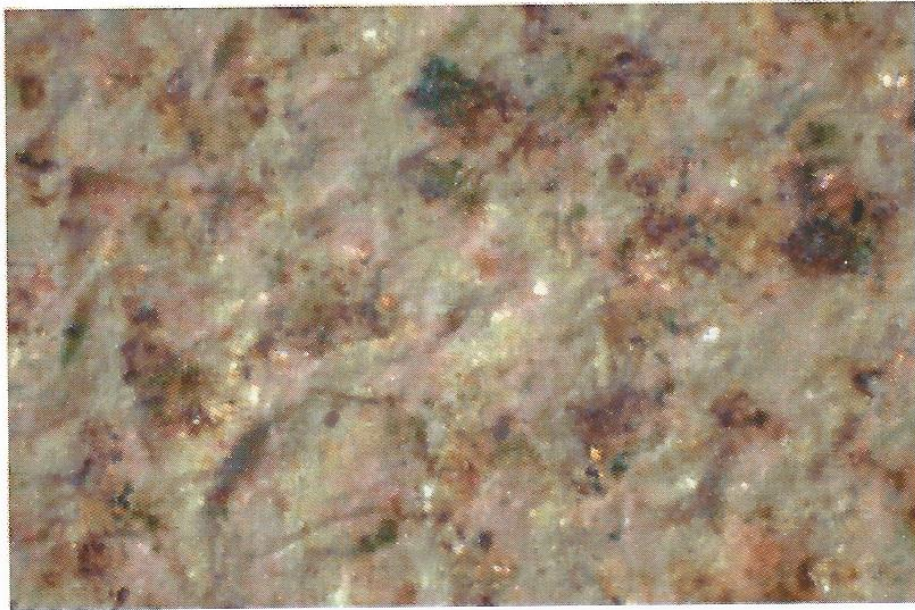


**Description:** The presence of dirt, salts, rust, grinding dust etc. on the steel surface, or the painted surface that can lead to poor adhesion and coating failure.

## CONTAMINATION

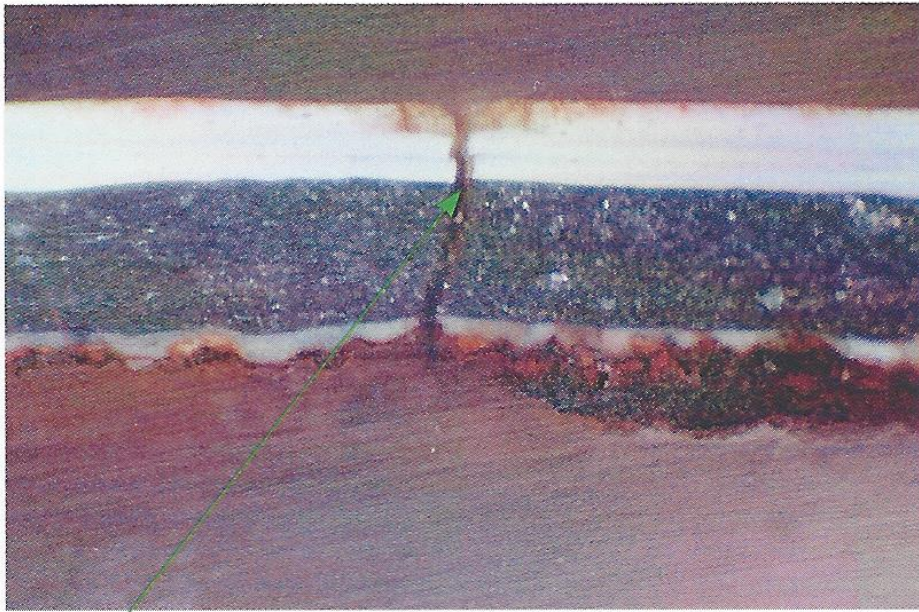


## CONTAMINATION



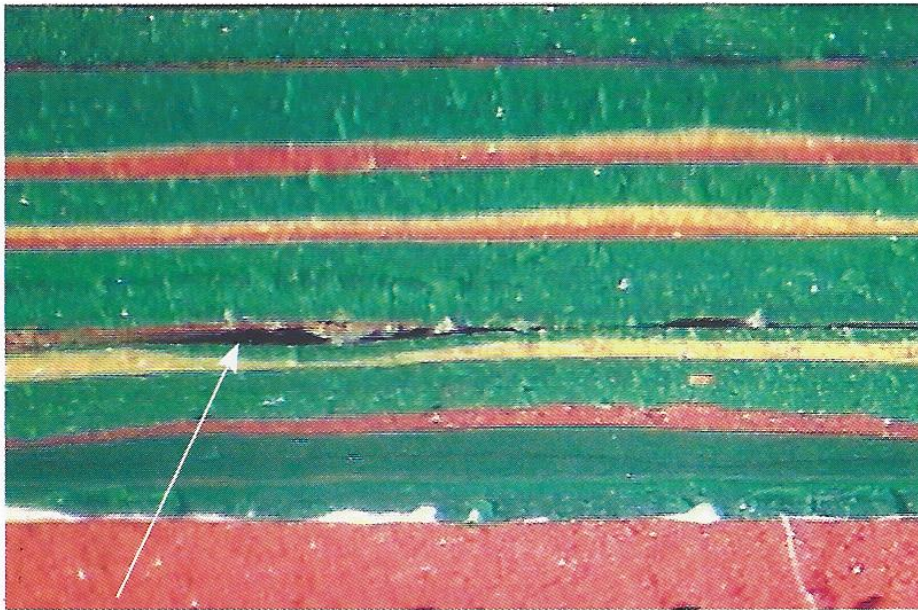
INTERCOAT CONTAMINATION

## CRACKING

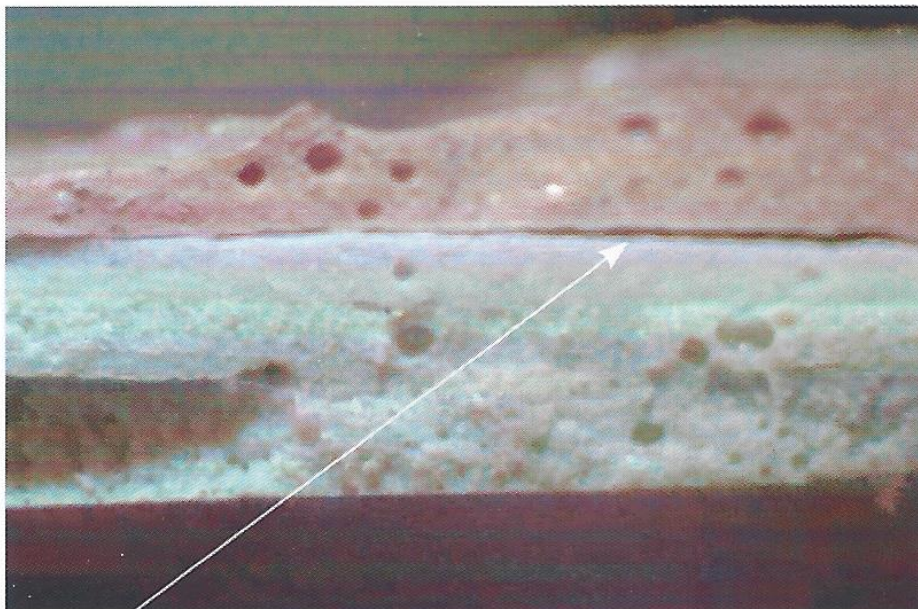


**Description:** The splitting of a dry paint film through at least one coat to form visible cracks which may penetrate down to the substrate. Cracking is generally a stress related failure and can be attributed to surface movement, ageing, absorption and desorption of moisture and general lack of flexibility of the coating. The thicker the paint film the greater the possibility it will crack.

# DELAMINATION

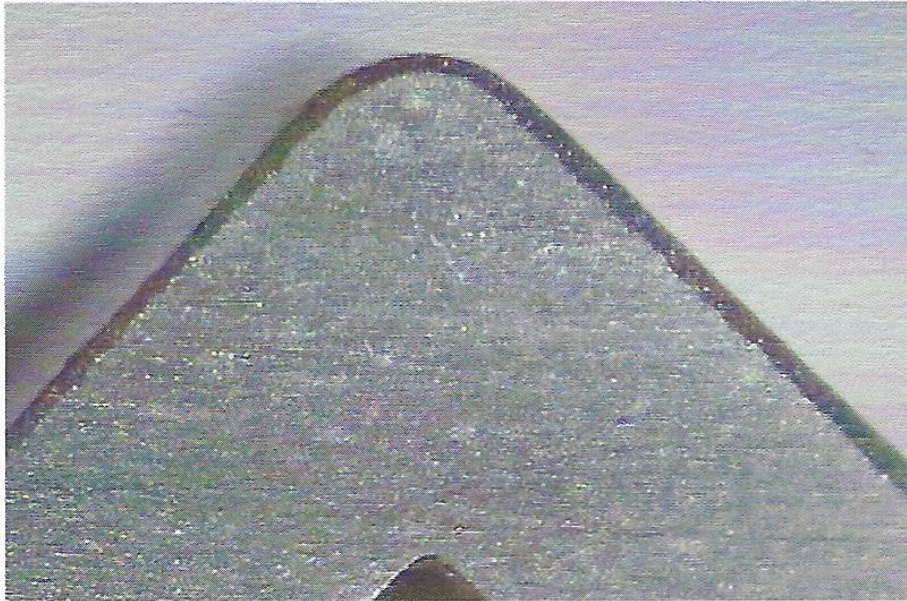


DELAMINATION

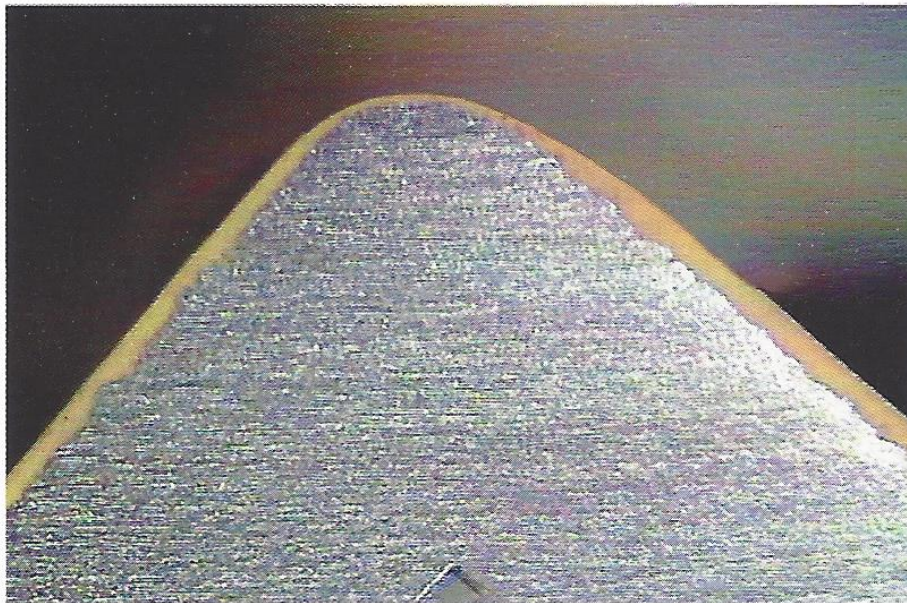


DELAMINATION

## EDGE COVERAGE



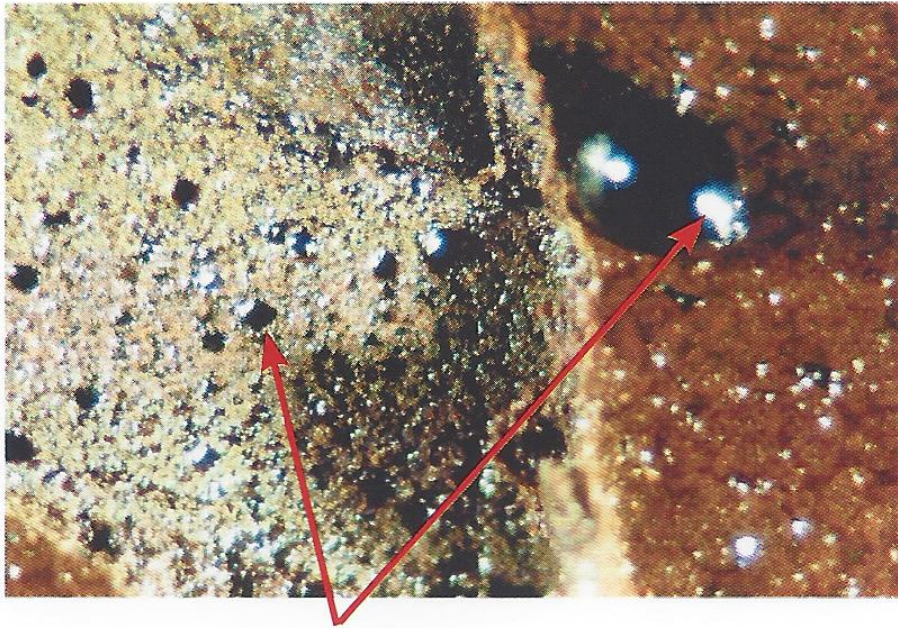
GOOD EDGE COVERAGE



POOR EDGE COVERAGE

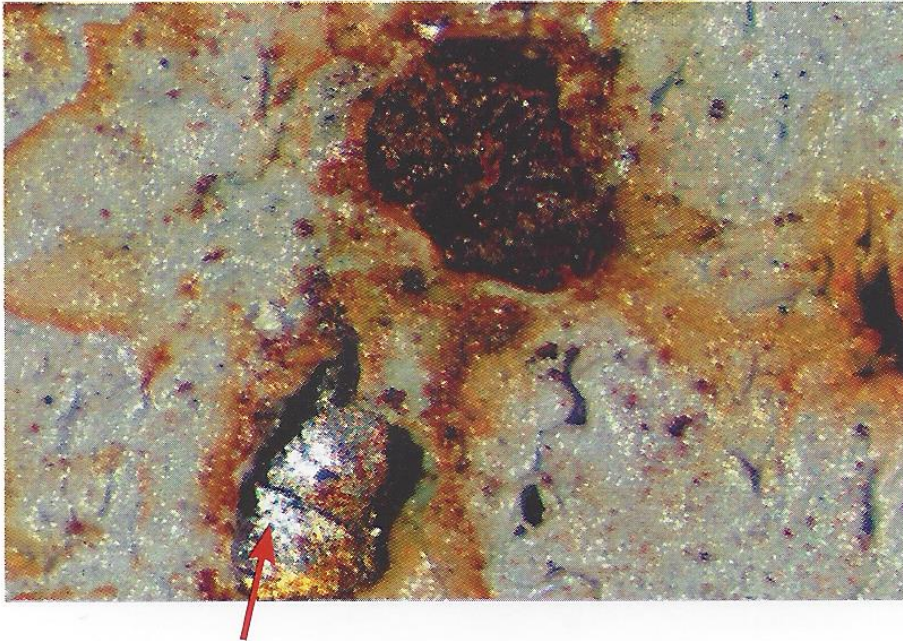
**Description:** Coatings have a natural tendency to flow away from edges necessitating the use of stripe coats to achieve the specified film thickness. They can however be formulated to achieve good edge coverage as illustrated above.

## EXUDATION



**Description:** The appearance of an oil-like film on the surface of the coating after drying. Migration of a component of the coating e.g. plasticizer, additive, or curing agent that remained unreacted. Also seen within the coating due to incompatibility between two or more raw materials.

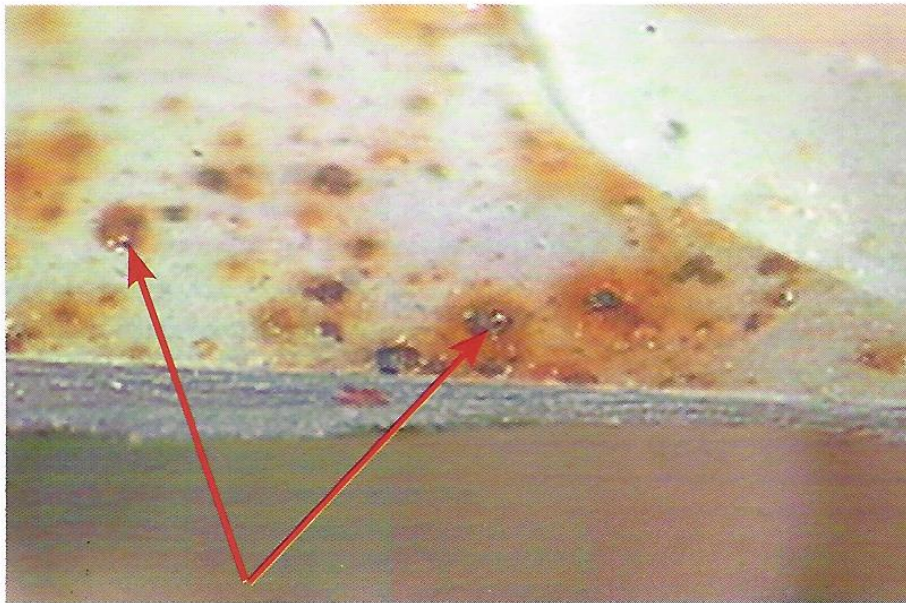
## INCLUSIONS



**Description:** Particles of grit and dust embedded within the coating system or on the surface often from contamination of the wet primer or undercoat with grit from other blast cleaning operations.

Fitz's Atlas 2™ of coating defects

# INCLUSIONS

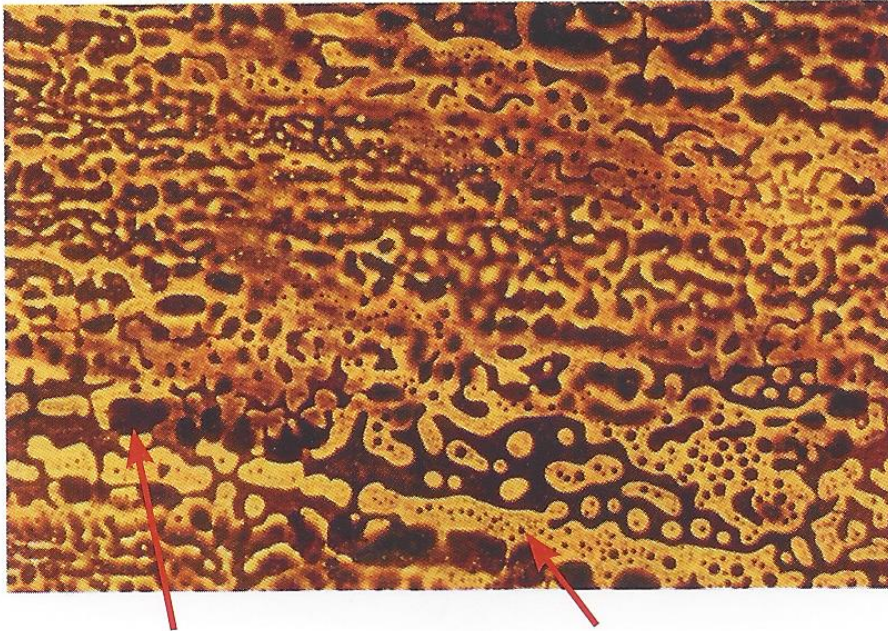


GRIT INCLUSIONS



SHOT INCLUSIONS

## INCOMPATIBILITY



TAR (BLACK)

RESIN (YELLOW)

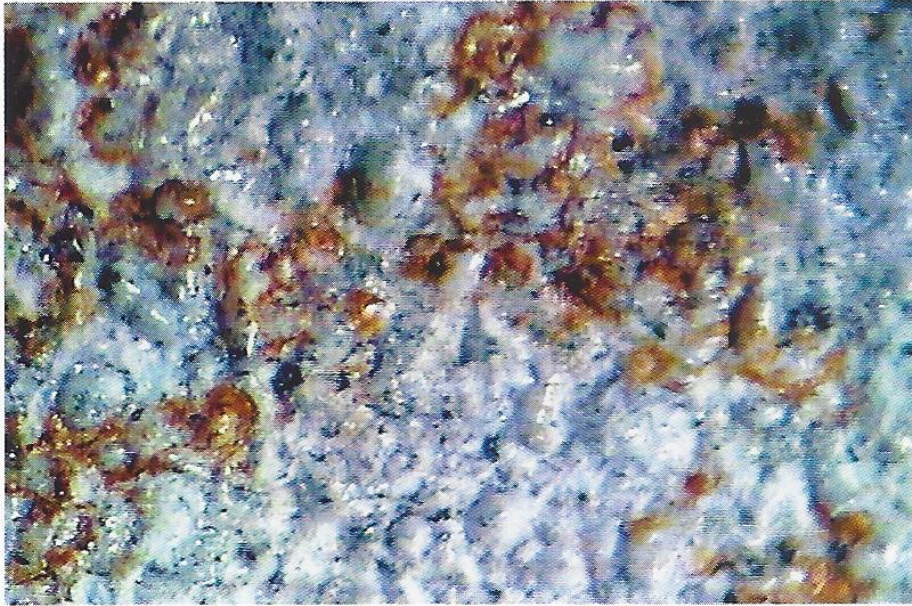
**Description:** Incompatibility between two or more raw materials resulting in separation and a non-homogeneous film.

## MULTI-COATS



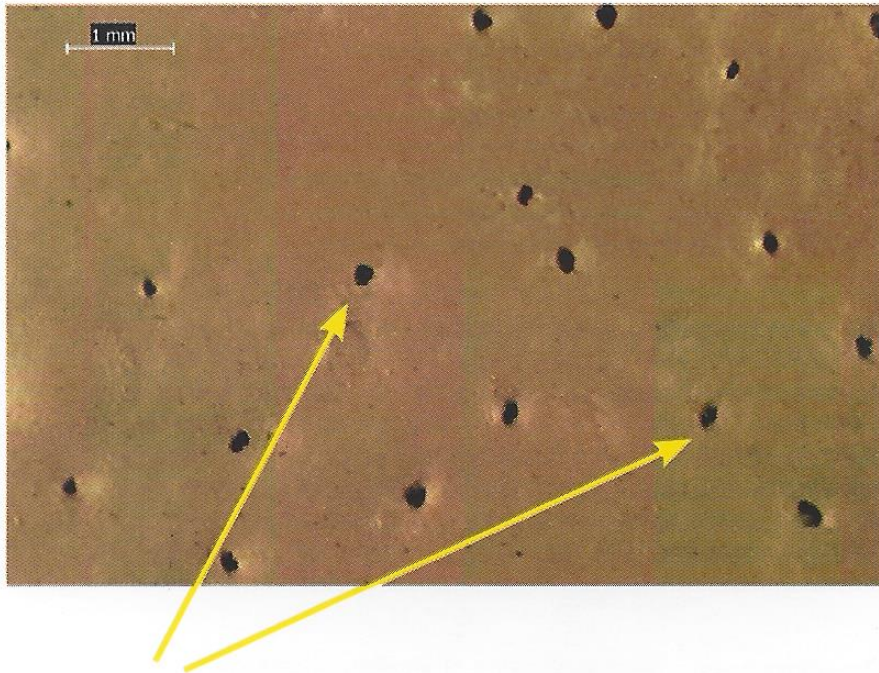
**Description:** The presence of multiple layers of paint that build up over time when existing systems are continually overcoated during years of maintenance.

## NON-COALESCECED FILM



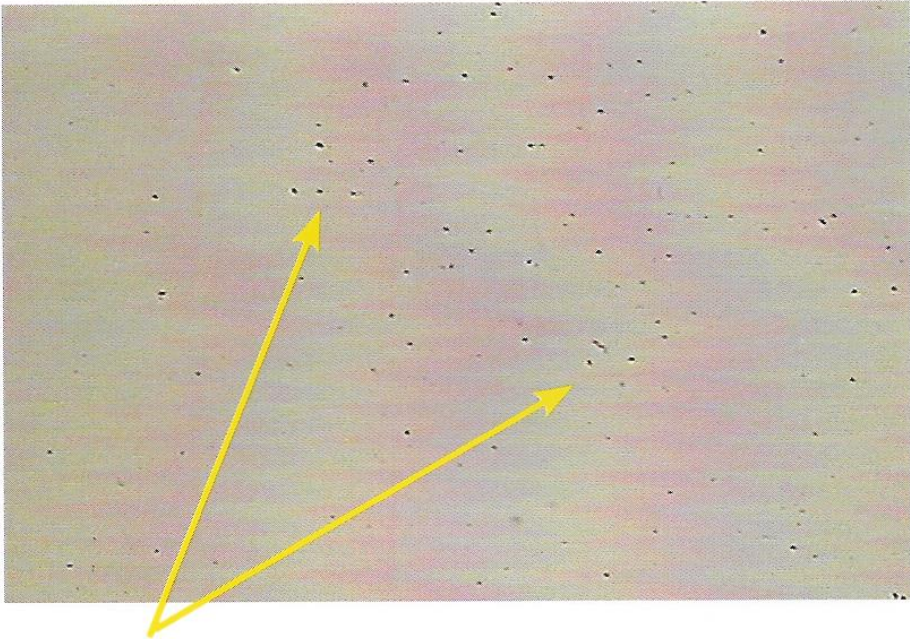
**Description:** After application of emulsion paint, the water evaporates and the resin particles (the binder) coalesce to form a continuous film that will not redissolve in the solvent/water that originally carried it. If the coating is applied at too low temperature coalescence may be hindered and a non-coalesced film produced.

## PINHOLES

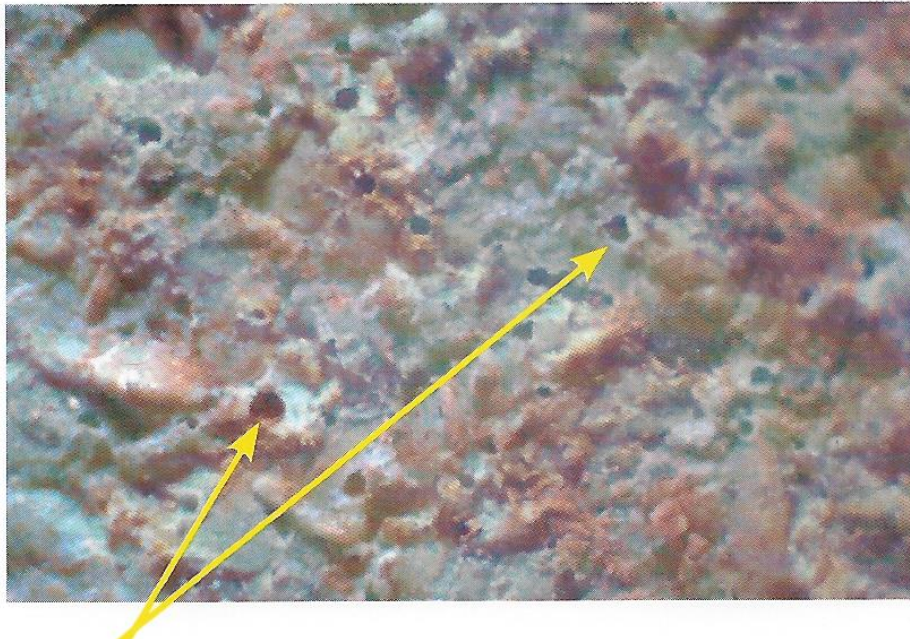


**Description:** The formation of minute holes in the wet paint film during application and drying, due to air or gas bubbles which burst, giving rise to small craters or holes which fail to coalesce before the film has set.

**PINHOLES**

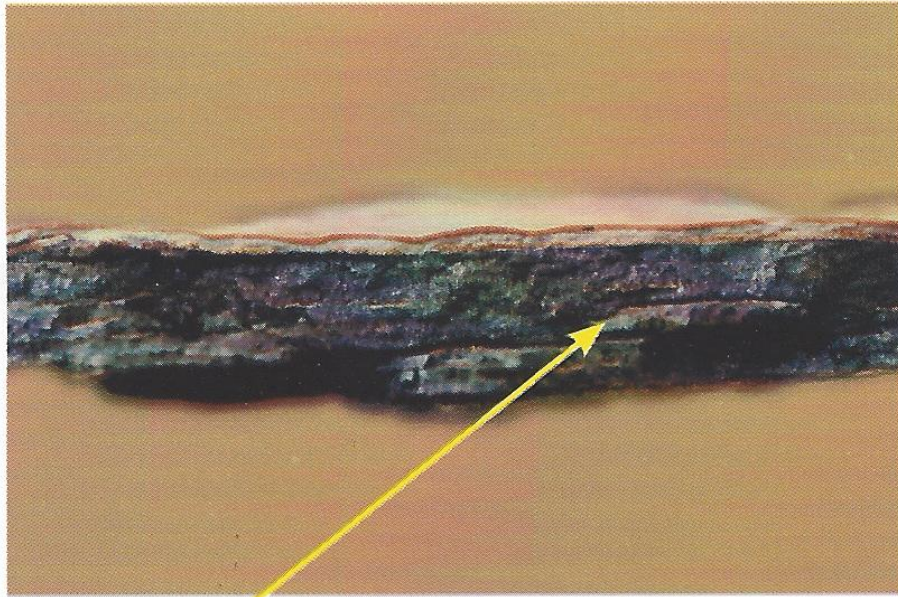


PINHOLES



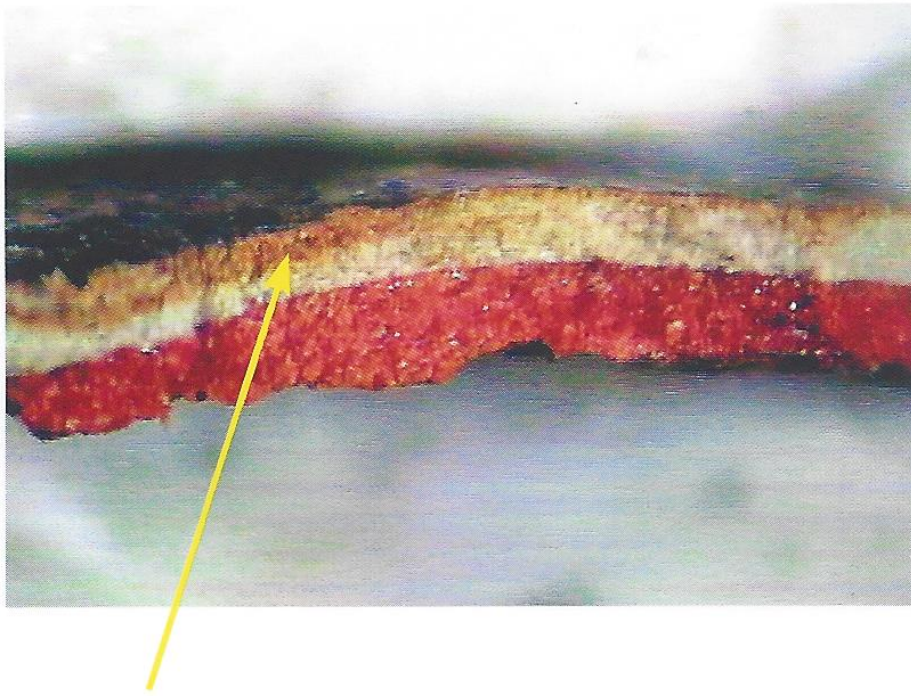
PINHOLES

## SCALE



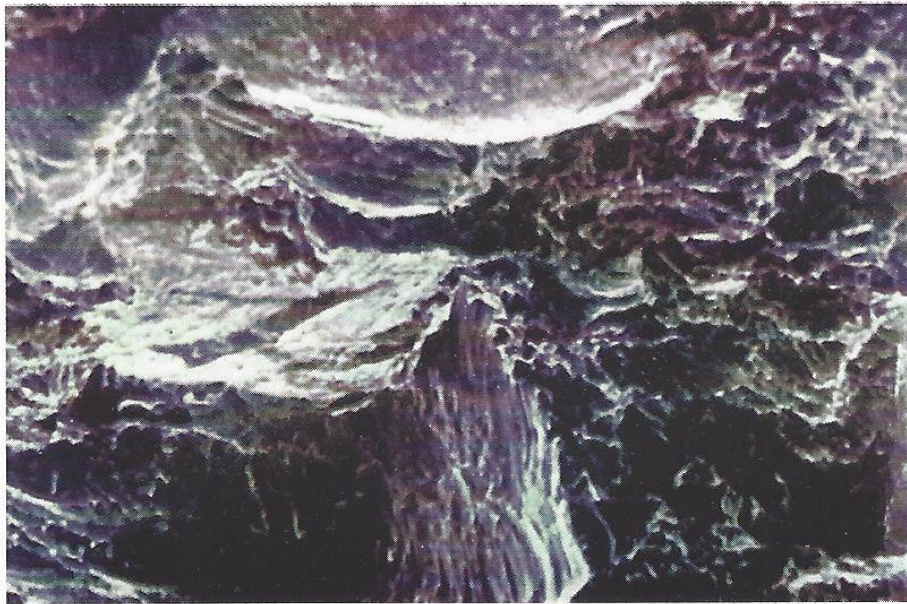
**Description:** Formation of layers of rust scale that expand and increase in volume beneath the coating often by penetration of moisture to the steel substrate through defects in the coating system. Can also be the result of painting over a surface without removing the existing scale.

## STAINING



**Description:** Discolouration of a coating system generally from contact with a solid or liquid that imparts a discolouration or stain to the coating. The staining may only be present on the surface or may penetrate into the coating.

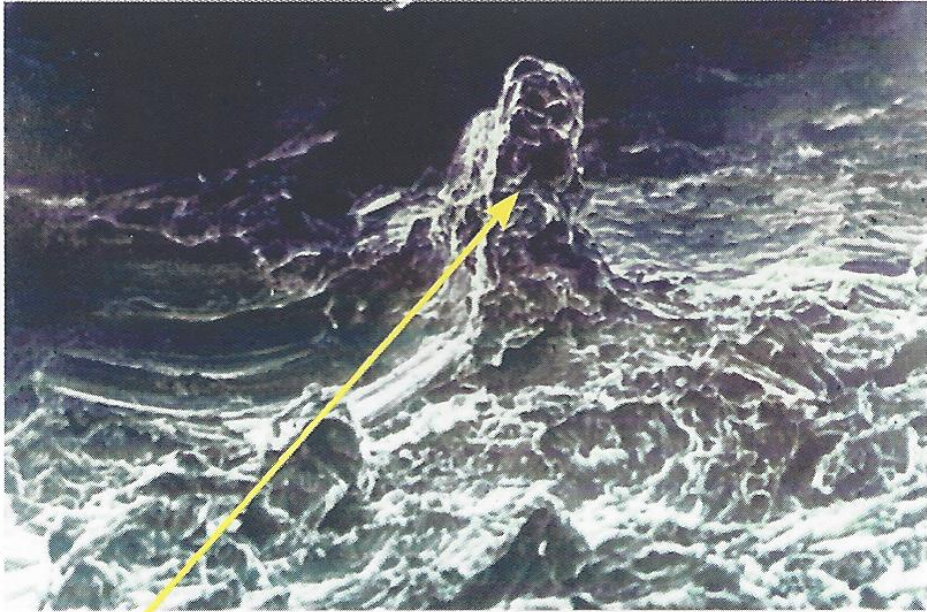
## SURFACE PROFILE



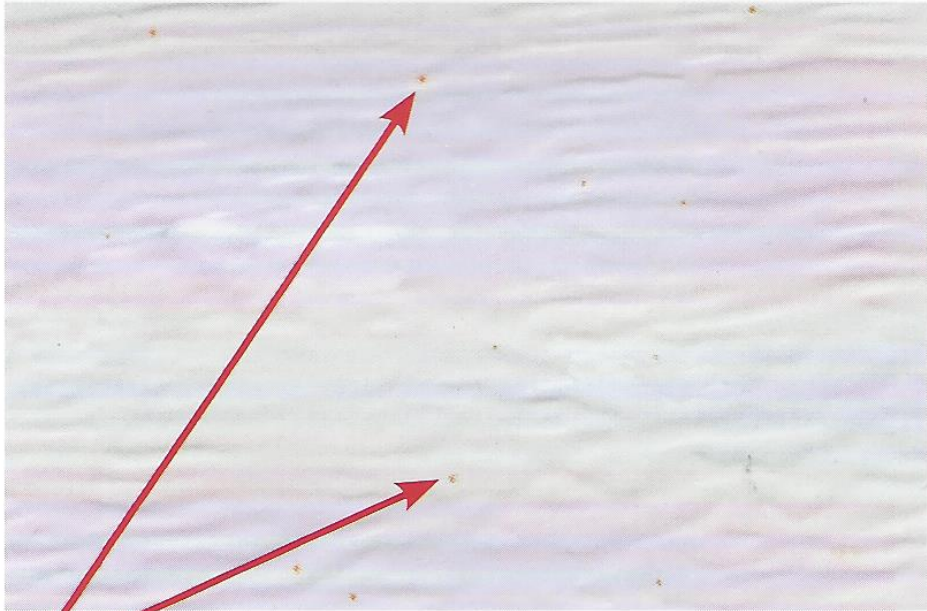
### TYPICAL SURFACE PROFILE

**Description:** The roughness (anchor pattern) imparted to the steel substrate by blast cleaning. Depending on the abrasive type and size the peak to valley height and the peak density can vary. Rogue peaks can be produced that are larger than the average profile and can lead to rust spotting. The photomicrographs of the surface profile are from a scanning electron microscope at approximately 1,000 times magnification.

**SURFACE PROFILE**

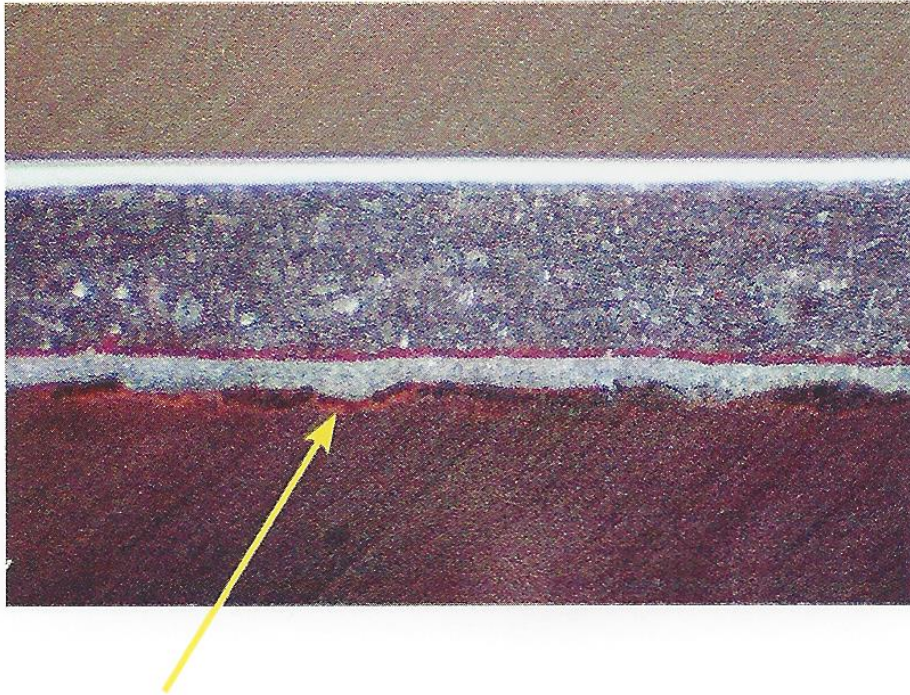


ROGUE PEAK



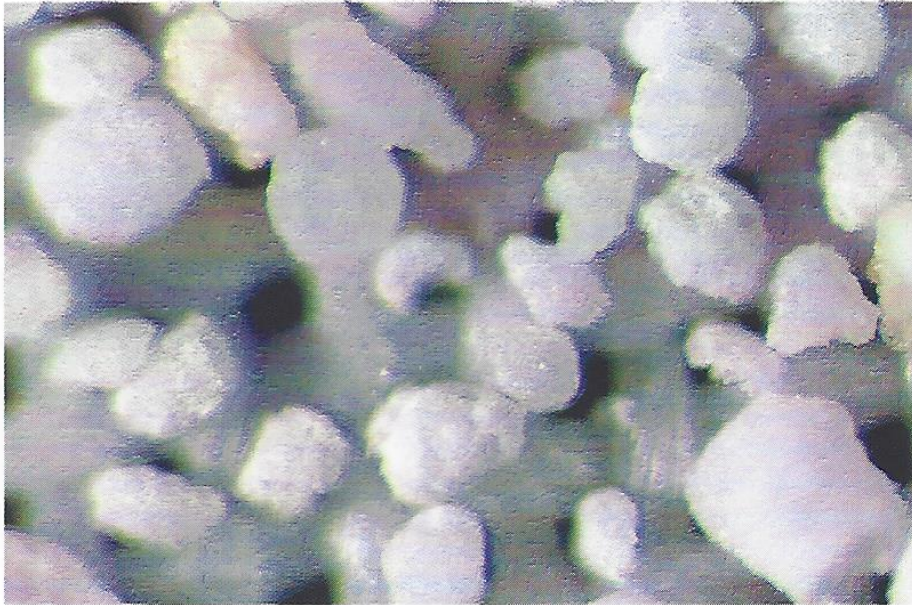
RUST SPOTS

## UNDERFILM CORROSION



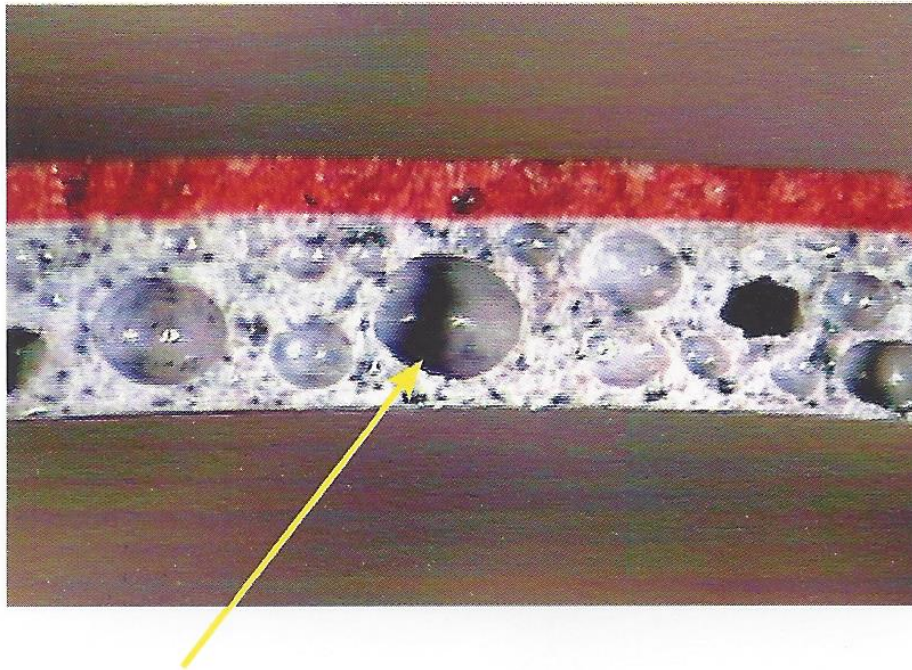
**Description:** The presence of rust beneath the coating system that could be from application to a corroded substrate, rust creep from areas of mechanical damage or penetration of moisture to the steel substrate through defects in the coating system.

## UNDISPERSED PIGMENT



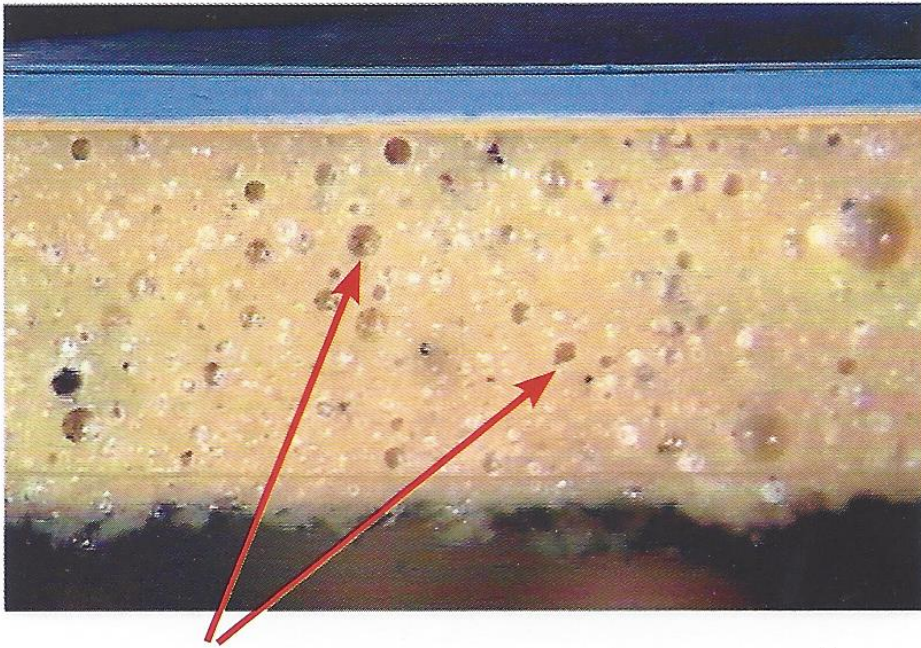
**Description:** Pigment particles that have not been homogeneously dispersed in the binder.

## VOIDS / VACUOLES

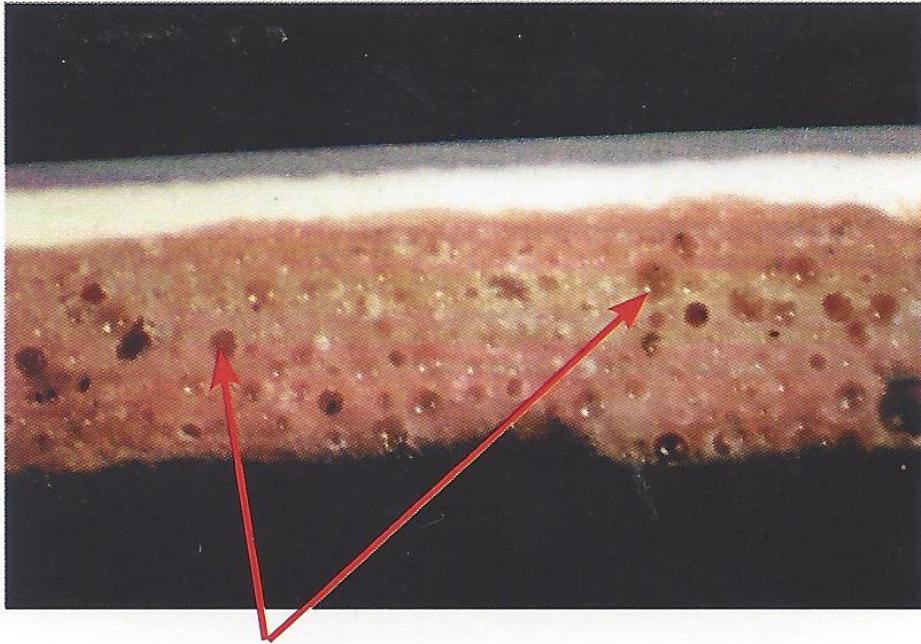


**Description:** Bubbles within the coating often related to air entrainment during mixing, solvent balance, over thickness, application in hot conditions where the surface may dry preferentially and application over a porous substrate. They can vary considerably in size and extent and if excessive can make the coating more permeable and reduce performance life

**VOIDS / VACUOLES**

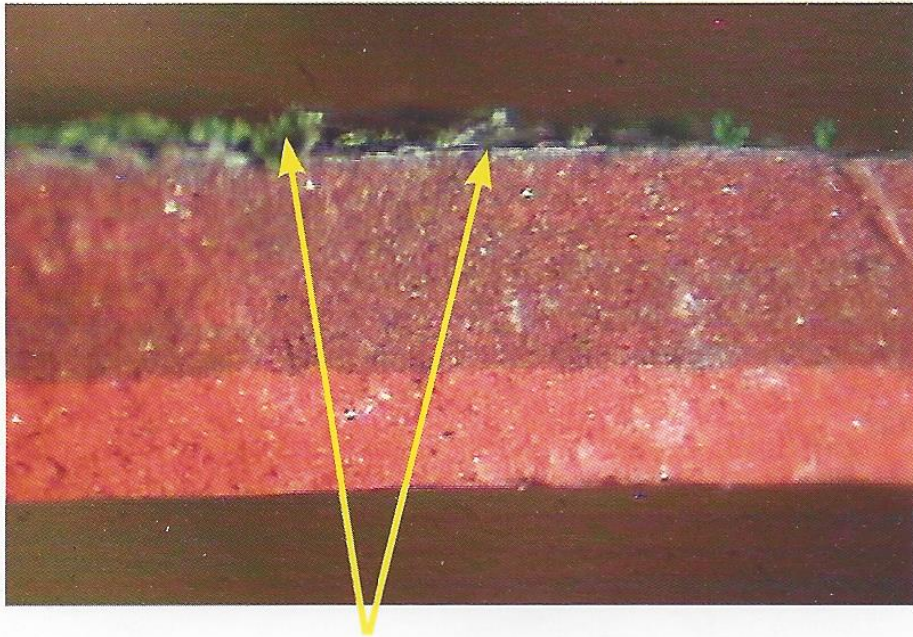


VOIDS/VACUOLES



VOIDS/VACUOLES

## WEED/ALGAE FOULING



**Description:** Green algae (enteromorpha) commonly known as grass is found as fouling on the vertical sides of a vessel hull where there is a high light intensity. It will attach to the paint system on the hull when the biocide activity of the anti-fouling coating is too low or the vessel has been stationary for long periods and its presence can have a deleterious effect on the vessels speed and fuel consumption.

# Fitz's Atlas 2<sup>TM</sup> of coating defects

6 - MARINE FOULING

**INDEX OF MARINE FOULING**

CONTENTS LIST..... 6-1  
MARINE FOULING ..... 6-3  
CLASSIFICATION OF FOULING ..... 6-3  
ANIMAL FOULING ..... 6-5  
FIGURES: Animal fouling ..... 6-7  
    Barnacles ..... 6-8  
    Barnacles – Acorn..... 6-10  
    Barnacles – Gooseneck..... 6-14  
    Hydroid - Tubularia..... 6-16  
    Molluscs ..... 6-17  
    Molluscs and Acorn Barnacles ..... 6-18  
    Polyzoa ..... 6-19  
    Tubeworms..... 6-20  
    Turnicate – Sea Squirt..... 6-21  
PLANT - WEED OR ALGAE FOULING ..... 6-22  
FIGURES: Ectocarpus (brown algae – grass)..... 6-23  
    Ectocarpus and Enteromorpha..... 6-25  
    Enteromorpha (green grass)..... 6-27  
    Rhodophyceae (red algae)..... 6-30  
POLISHING OF ANTI-FOULING COATINGS..... 6-31



**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.

<b>MACROFOULING</b>		<b>MICROFOULING</b>
Animal	Plant	Slimes
Barnacles	Brown Algae	Marine Bacteria
Hydroids	(Ectocarpus)	Diatoms (Plants)
Molluscs	Green Algae	
Polyzoa	(Enteromorpha)	
Tube Worms	Red Algae	
Tunicates	(Rhodophyceae)	

**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

## **Marine Fouling**

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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.

## **Marine Fouling**

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**Hydroids (typically tubularia)** Although plant-like in appearance, hydroids 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

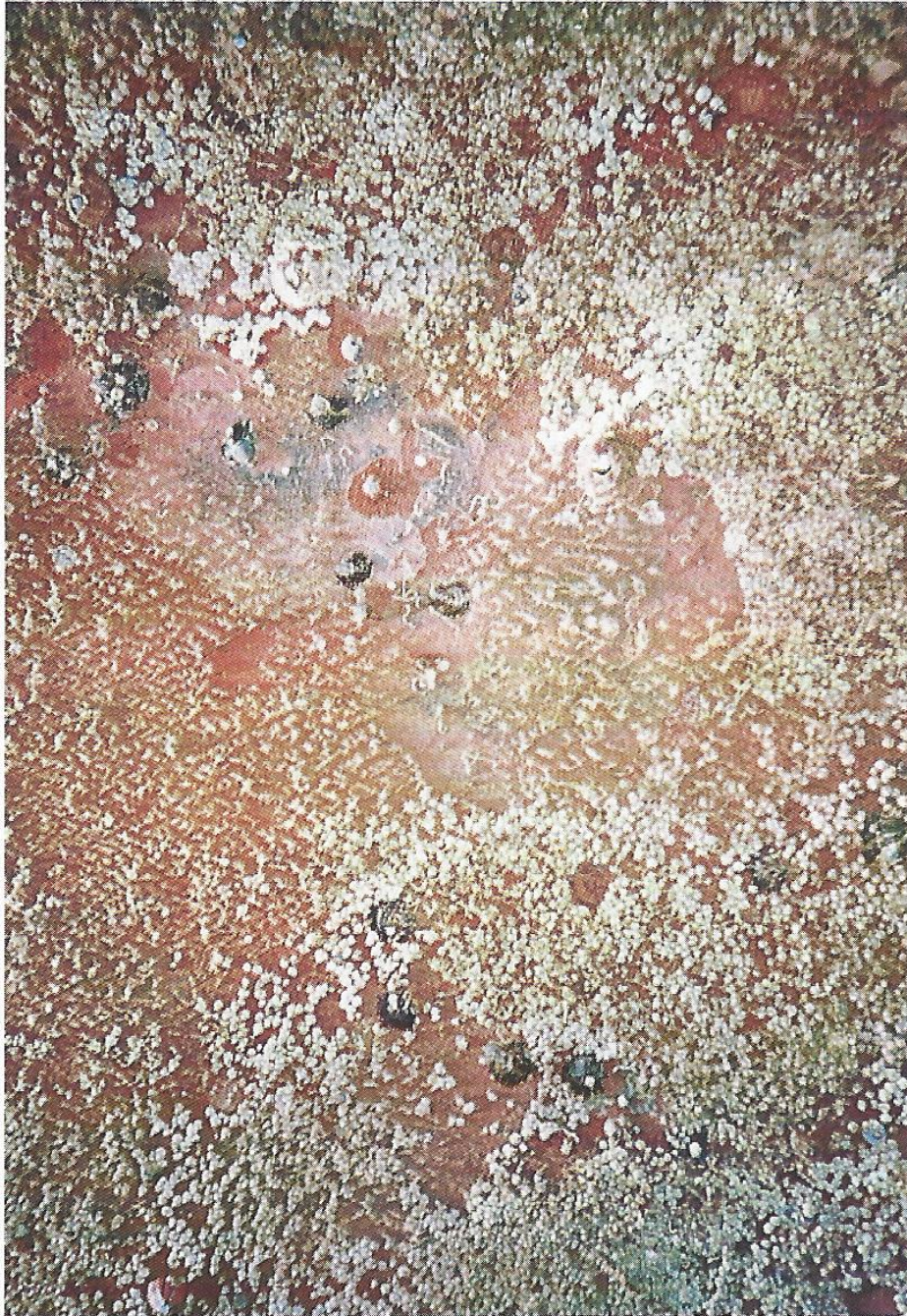


Severe animal fouling to the underwater location of a ship. Fouling can add considerable weight to a ship and increase fuel consumption dramatically.



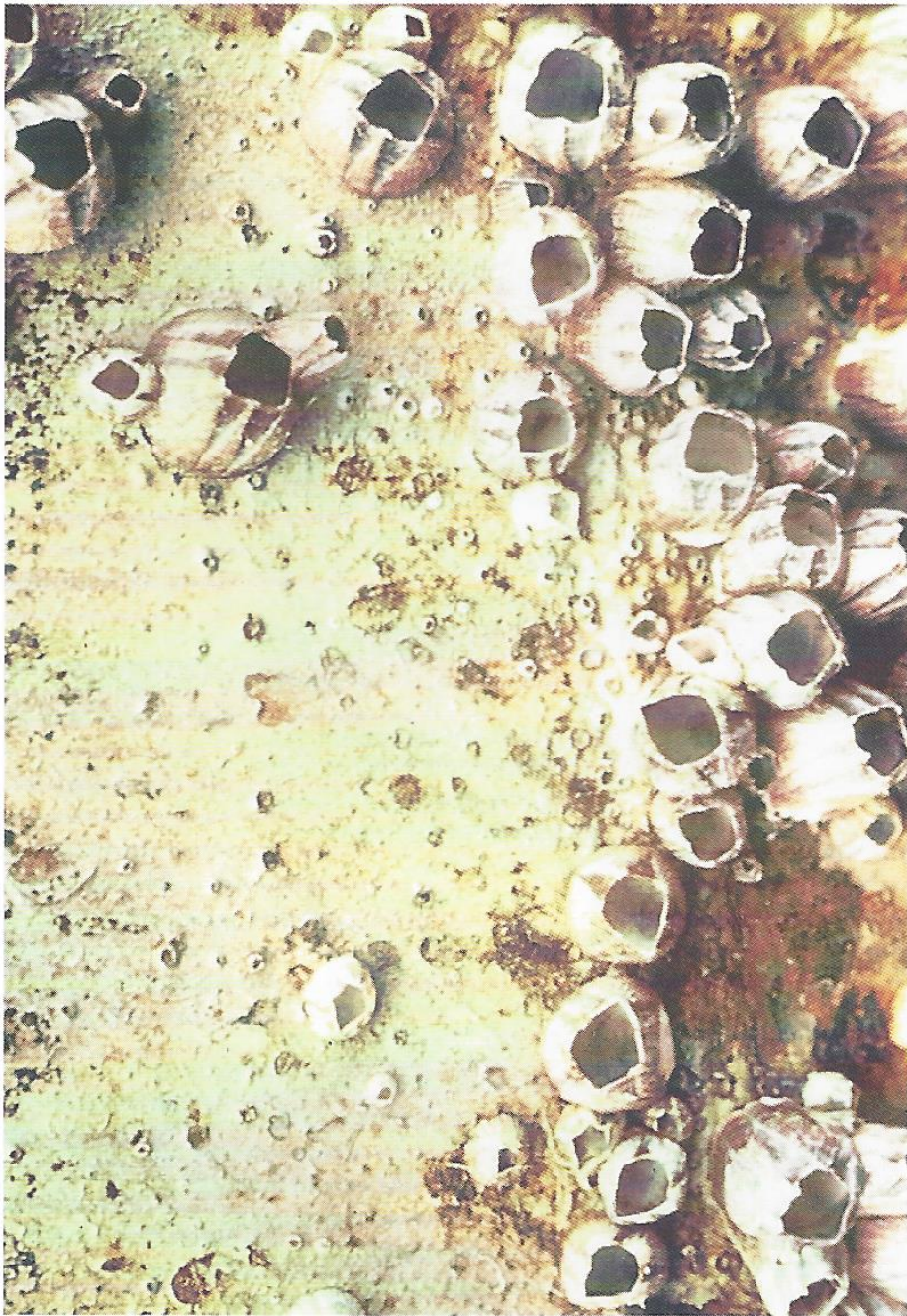
Removal of the fouling by high pressure water washing. Note damage to existing paintwork.

## BARNACLES



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

## BARNACLES



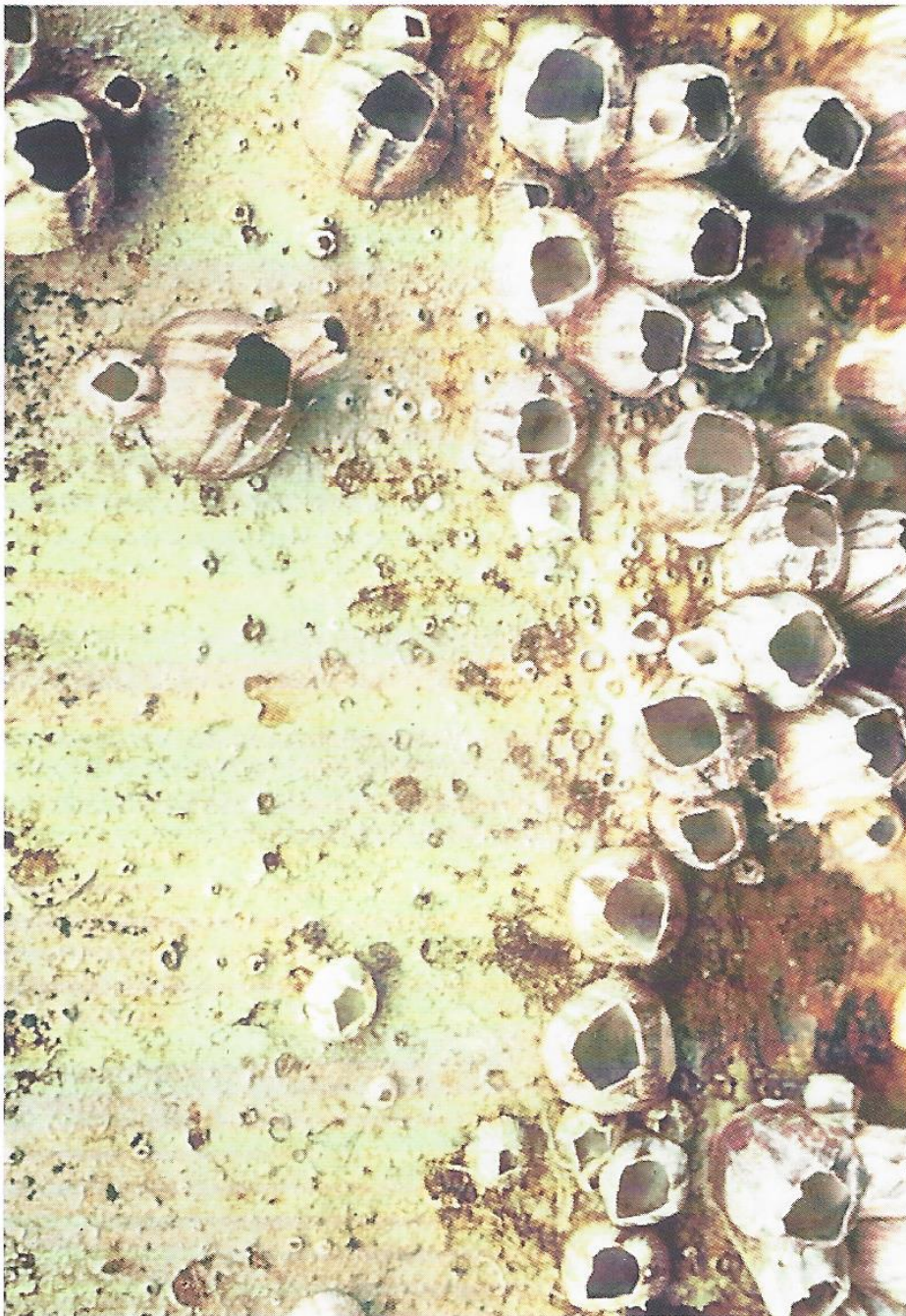
A close-up shot of barnacles. Note the various sizes along with paint damage to the surrounding areas.

**BARNACLES - ACORN**



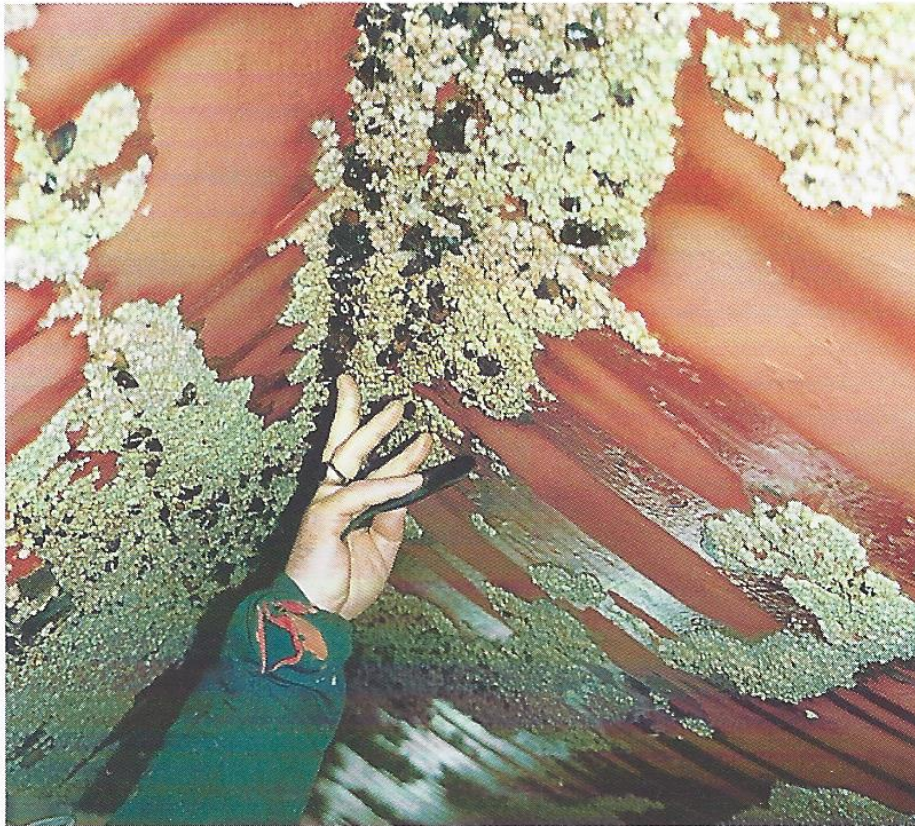
A colony of acorn barnacles. The barnacle larvae can recognise the presence of other barnacles which result in close contact and cross fertilisation.

## BARNACLES



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

## BARNACLES - ACORN



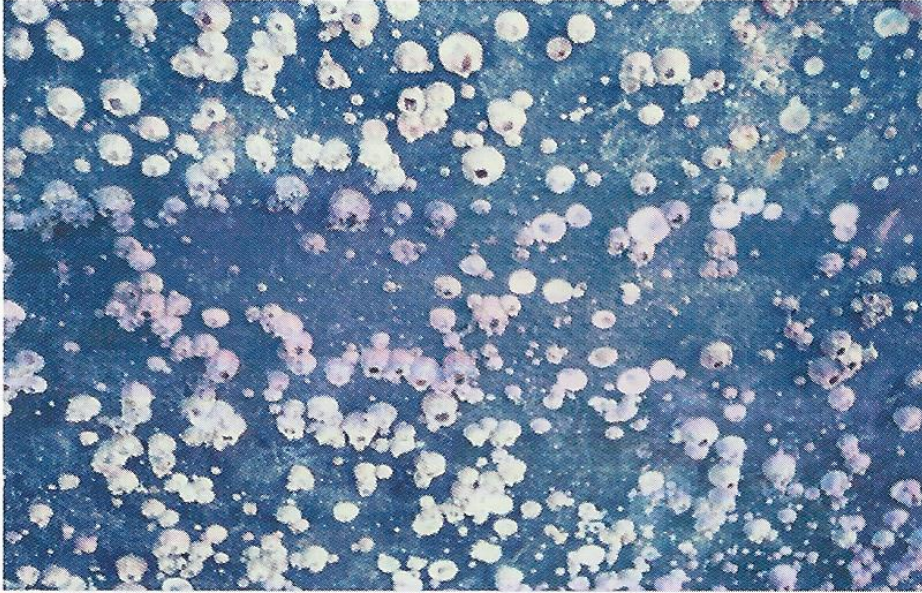
Small acorn barnacles and mussel fouling on the underside of the bilge keel turn of bilge. The shell of the barnacles remains attached to the substrate even when the life of the animal has ended.

## BARNACLES - ACORN



Small scattered acorn barnacles on the bottom shell.

## BARNACLES - ACORN



Acorn barnacle colony

## 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



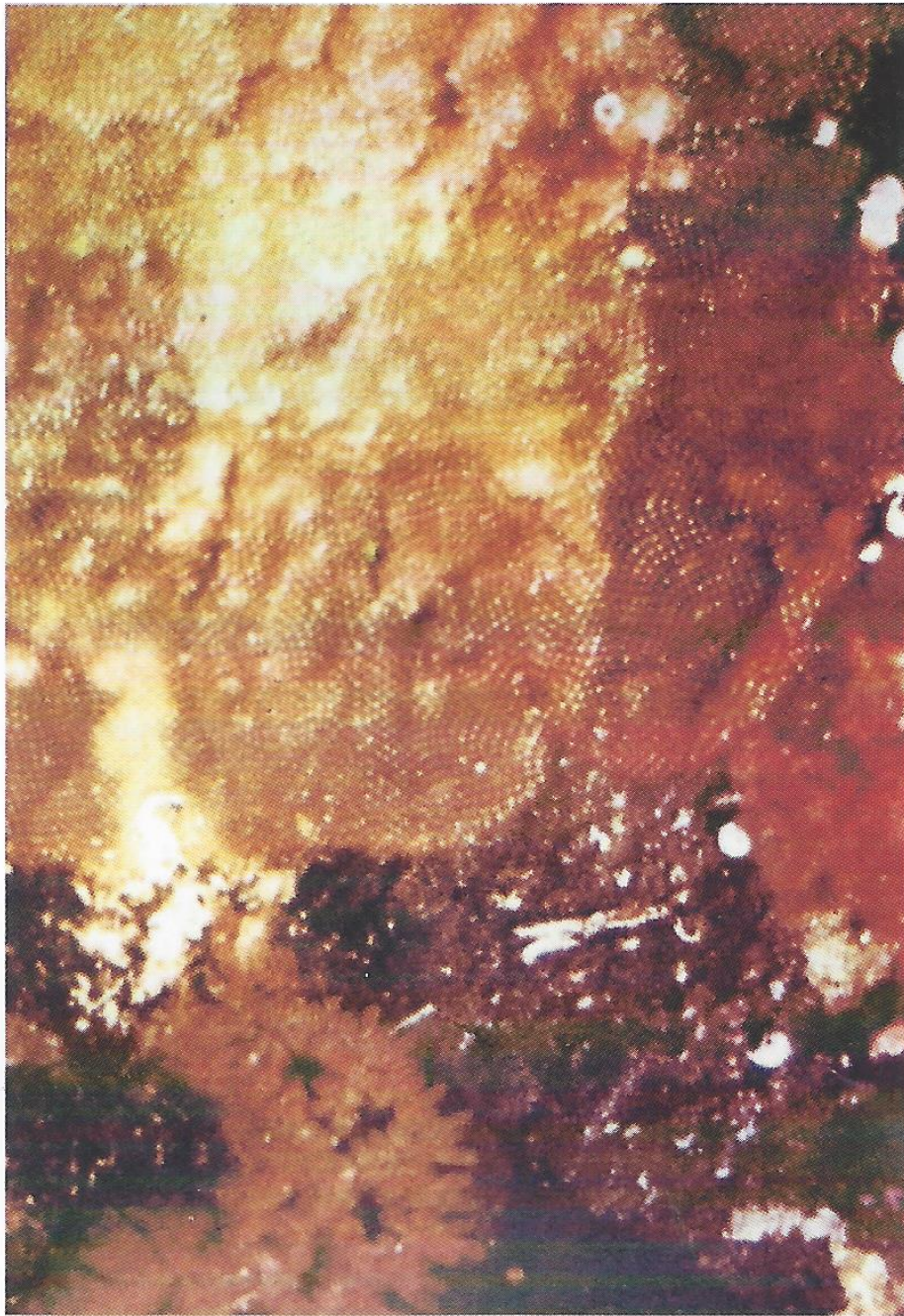
Molluscs - A close-up view of a colony of molluscs

## MOLLUSCS AND ACORN BARNACLES



Molluscs and small acorn barnacles

## 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



ד"ר אהוד גורן, המכון הלאומי לחקר הים

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

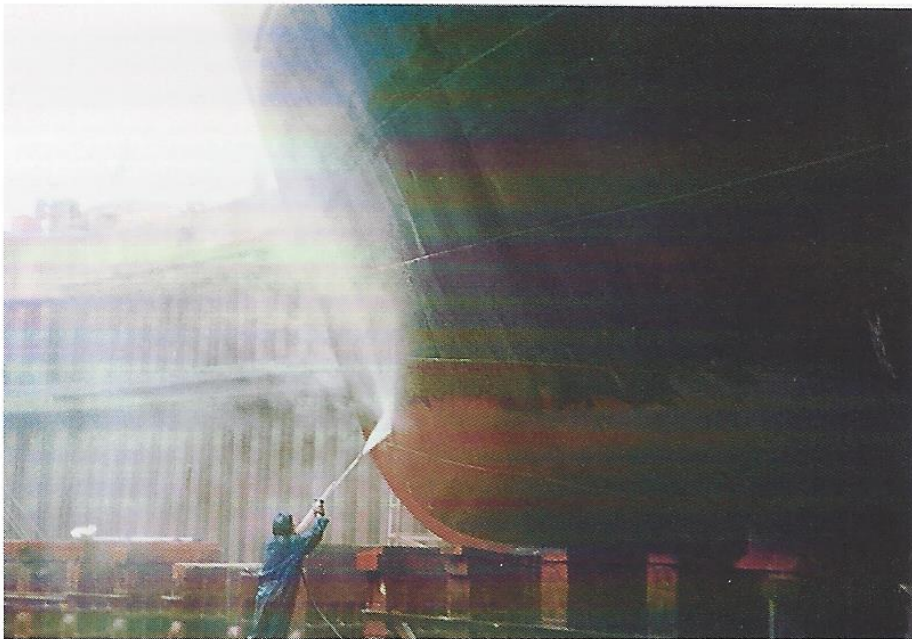


Ectocarpus and Enteromorpha. Most common forms of green and brown grass.

## ENTEROMORPHA (GREEN GRASS)



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

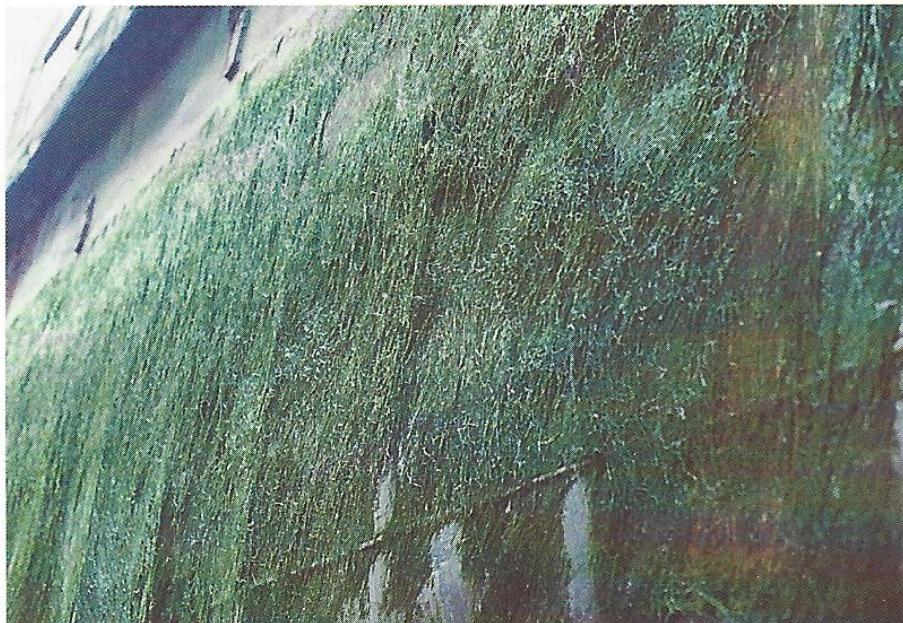


Removal of green algae, exposing sound anti-fouling paint.

**ENTEROMORPHA (GREEN GRASS)**

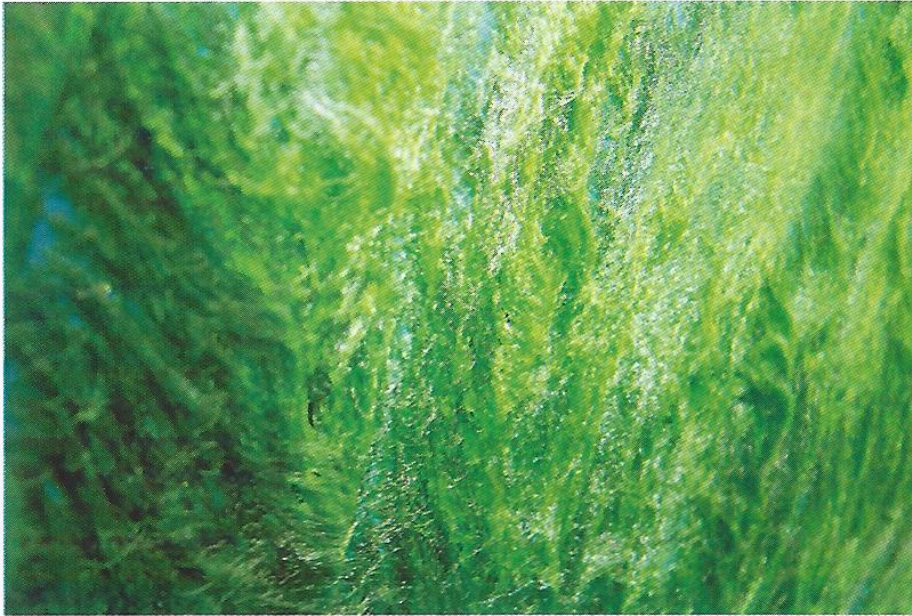


Severe forms of green grass. All green algae are of green grass colour, owing to the predominance of chlorophyll.



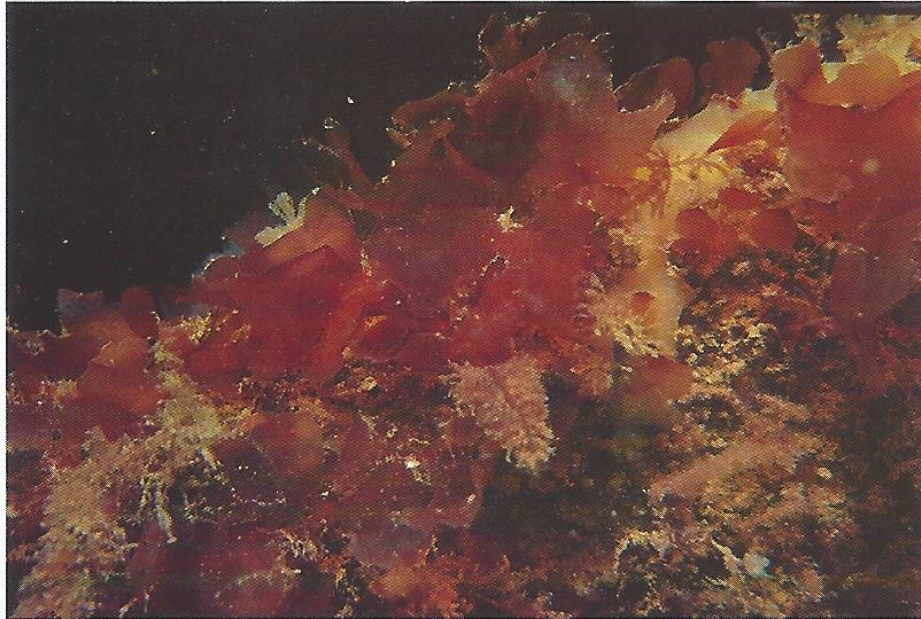
Severe forms of green grass. All green algae are of green grass colour, owing to the predominance of chlorophyll.

## ENTEROMORPHA (GREEN GRASS)



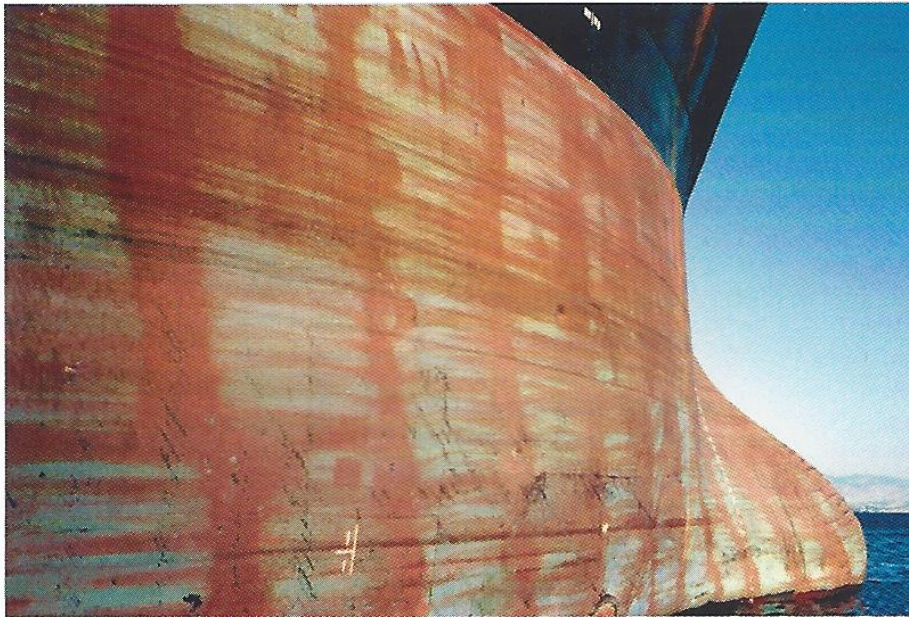
Severe growth of green grass

## RHODOPHYCEA (RED ALGAE)



Rhodophyceae - severe forms of red algae.

## POLISHING OF ANTIFOULING COATINGS



Comment: Self polishing antifouling coatings function by releasing biocides into the water as a result of an hydrolysis reaction with seawater at the surface of the antifouling coating. The polymer system is hydrophobic, restricting the penetration of the water, and hence the reaction only takes place at the surface of the coating. As the biocide is released, the surface layer is depleted of biocides and forms what is known as a leached layer. Movement of the vessel through the water results in the leached layer being polished away exposing fresh antifouling allowing the process to continue. Normally more than one coat of antifouling is applied and the different layers are different colours or shades. The polishing of the antifouling hence reveals the different coloured layers as depicted in the photographs.

## POLISHING OF ANTIFOULING COATINGS



# Fitz's Atlas 2<sup>TM</sup> of coating defects

7 - APPENDICES

## INDEX OF APPENDICES

COATING BREAKDOWN SCALES .....	App-1
BREAKDOWN SCALES (SCATTERED).....	App-2
BREAKDOWN SCALES (LOCALISED) .....	App-4
PAINT COMPATIBILITY CHART .....	App-6
PAINT PROPERTIES CHART.....	App-8
PAINT ARITHMETIC.....	App-11
FORMULAE FOR SURFACE AREAS .....	App-13

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## Appendices

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## 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 Degree of Rusting for Anticorrosive Paint**  
**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.

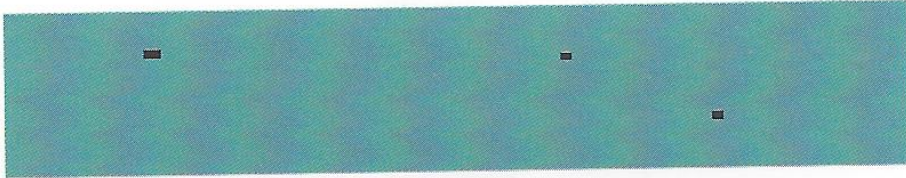
It can be seen that in most cases where 'scattered' failure has taken place it would be uneconomical to attempt a patch repair. Total removal and replacement of the coating system is warranted. However, where the coating has failed in a 'localised' mode, a patch repair can often be economically justified.

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

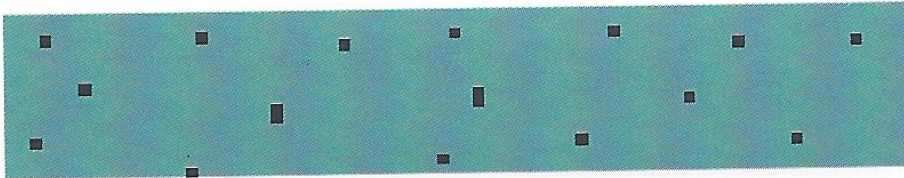
Coating Breakdown Scales courtesy of TCI

## COATING BREAKDOWN (SCATTERED)

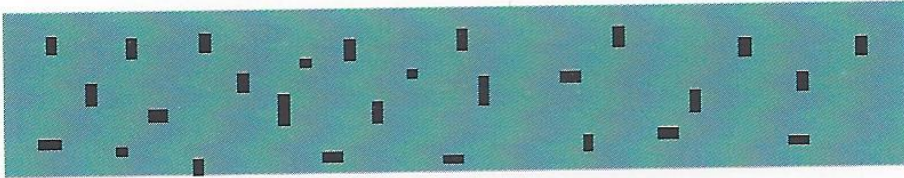
### 0.1% Coating Breakdown



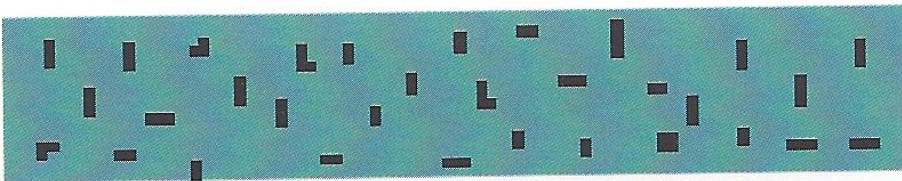
### 1% Scattered



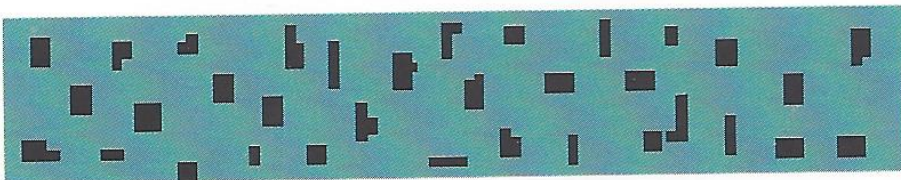
### 3% Scattered



### 5% Scattered



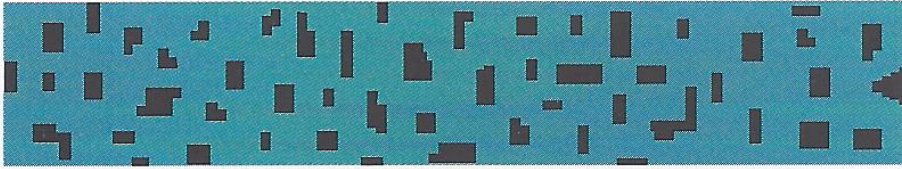
### 10% Scattered



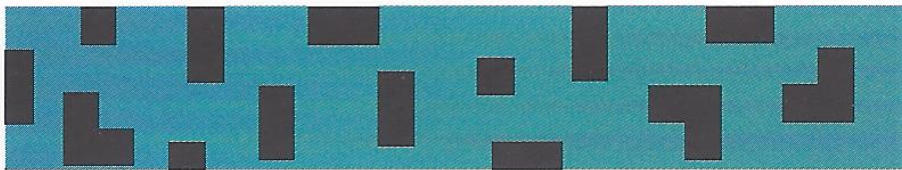
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**COATING BREAKDOWN (SCATTERED)**

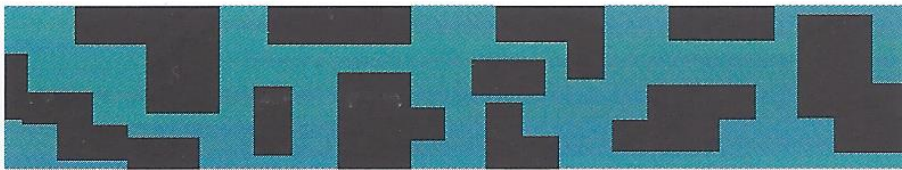
15% Scattered



25% Coating Breakdown



50% Coating Breakdown



90% Coating Breakdown



**COATING BREAKDOWN (LOCALISED)**

**0.3% Coating Breakdown**



**1% Localised**



**3% Localised**



**5% Localised**



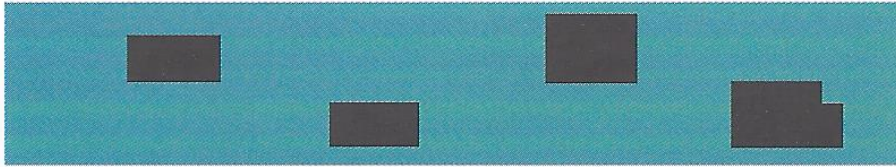
**10% Localised**



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**COATING BREAKDOWN (LOCALISED)**

**15% Localised**



**33% Coating Breakdown**



**75% Coating Breakdown**



**100% Coating Breakdown**



## PAINT COMPATIBILITY CHART

		TOP COAT						
		Acrylated Rubber	Alkyd	Amine Epoxy	Bitumen	Chlor. Rubber	Coal Tar Epoxy	Epoxy Ester
EXISTING TOP COAT	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	

**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 COMPATIBILITY CHART

		TOP COAT						
		Ethyl Silicate	M.C. Urethane	Polyamide Epoxy	Silicone Alkyd	Urethane (2 pack)	Urethane Acrylic	Vinyl
EXISTING TOP COAT	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]

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 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 (solventweld)	Excellent (solventweld)	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
Minimum 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

**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 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 polyimide or amine adduct	Moisture from atmosphere 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

**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 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

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

##### Paint B

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

##### Paint C

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

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.

## Appendices

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.

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

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

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

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

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

Therefore the volume required to cover  $1\text{m}^2$

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

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

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

Therefore the cost per $\text{m}^2$ using;	<b>Paint 1</b> = £4.80 x .25641	= £1.23
	<b>Paint 2</b> = £4.90 x .250	= £1.22
	<b>Paint 3</b> = £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

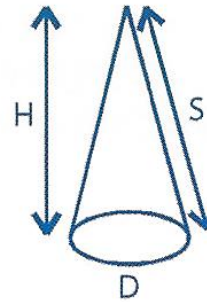
### Abbreviations

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:

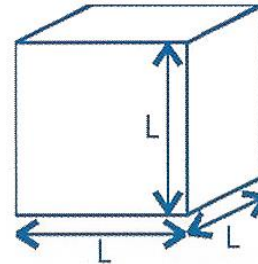
$$A = \frac{\pi \times D \times S}{2}$$



### 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.

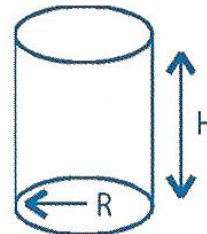
$$A = 6 \times L^2$$



### Cylindrical Tank

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

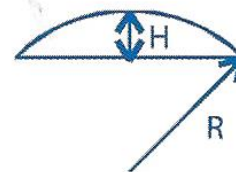
$$A = (2 \times \pi \times R \times H) + 2(\pi \times R^2)$$



### Domed end of Tank

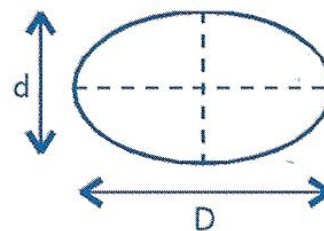
(Height of dome = H)

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



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

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

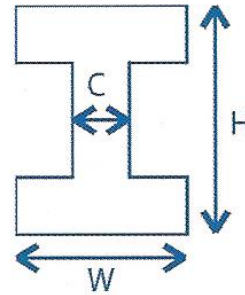


## Appendices

### I Beam

(Plate thickness = C)

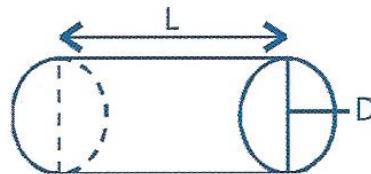
$$A = 2 \times (2W + H - C) \times L$$



### Pipe

The surface area of a pipe is calculated by multiplying the diameter by  $\pi$  and then multiplying by the pipe length.

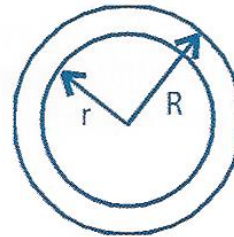
$$A = \pi \times D \times L$$



### Ring

(Outer radius = R, Inner radius = r)

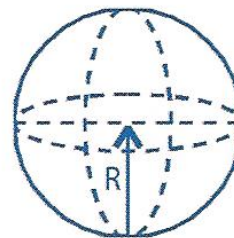
$$A = \pi \times R^2 - \pi \times r^2$$



### Sphere

The surface area of a sphere is calculated by multiplying the square of radius (R) by  $\pi$  by 4.

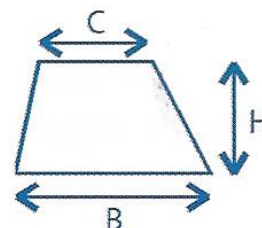
$$A = 4 \times \pi \times R^2$$



### Trapezium

(Parallel sides length = B & C)

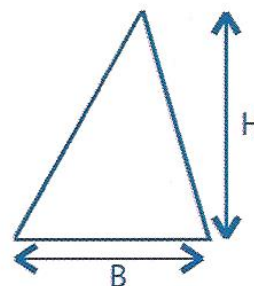
$$A = \frac{(B + C) \times H}{2}$$



### Triangle

(Base length = B)

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



# Fitz's Atlas 2<sup>TM</sup> of coating defects