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RUST CORROSION PITTING: PAINT PREPARATIONS IN NEW  
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**TITLE:** RUST, CORROSION, PITTING: PAINT  
PREPARATIONS IN NEW CONSTRUCTIONS AND  
IN THE REPAIR AND MAINTENANCE OF SHIPS

ROST, KORROSION, LOCHFRASS: ANTRICHS-  
VORBEREITUNGEN BEI NEUBAU UND INSTANDSETZUNG  
- HALTUNG VON SCHIFFEN

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## RUST, CORROSION, PITTING: PAINT PREPARATIONS IN NEW CONSTRUCTIONS AND IN THE REPAIR AND MAINTENANCE OF SHIPS

[Author not identified; Rost, Korrosion, Lochfrass; Soldat und Technik, No. 4, 1983; pp. 196-198; German]

Every paint, whether above or under water, whether interior or exterior, /196\* serves primarily to protect the material under it. That task can be performed reliably by the paint only when all the preconditions necessary for a prescribed paint application meeting the preparation instructions of the paint manufacturer are fulfilled. That presumes some basic knowledge which even military personnel should have.

### Principles of Corrosion of Steel

**Rust:** Rust is a compound of iron, oxygen, and hydrogen (ferric hydroxide,  $\text{Fe}(\text{OH})_3$ ). According to the electrochemical rust theory, iron, following its high solution pressure, that is its tendency to pass into solution, passes ions into solution in an available liquid with the formation of hydrogen. This produces  $\text{Fe}(\text{OH})_2$ , therefore still no rust. In the second phase, this  $\text{Fe}(\text{OH})_2$  is changed by water and oxygen into non-water-soluble  $\text{Fe}(\text{OH})_3$ , rust. Accordingly, iron does not rust in air free of water or water free of oxygen. The rusting process proceeds more quickly if, for example, acids, certain salt solutions, or stray electrical currents are operating concurrently.

**Corrosion:** With this term we mean the destruction of a solid body which proceeds from unintentional chemical or electrochemical attacks of the surface. We differentiate between general uniform corrosion, that is a uniform erosion of the material, localized corrosion (pitting), which appears as deep erosion in locally limited points, intercrystalline corrosion within the grain structure of the material, which reduces the mechanical properties of the material, crack corrosion in the cracks between contact surfaces of metals which produces surface pits, for example, in riveted and fished joints, and stress corrosion which results from uniform mechanical stress simultaneous chemical attack.

### Pitting Resulting from Speed

Pitting is mainly an electrochemical process which is caused by local regions of an anodic (+) nature, favorable water conditions, and unprotected metal surfaces.

The corrosion of ship bottoms by pitting occurs most heavily where there are stagnant conditions or eddies (rivet heads, weld seams, among others). They start from the fact that, with unprotected metal surfaces in rather high speed ranges, anodic (+) regions with weak metal ion concentrations form and, in the lower speed ranges, cathodic (-) regions with unlimited ion concentrations form. As a consequence, an electrical current flows from the anode to the cathode, and corrosion results on the cathode, since the metal is being eroded there by electrolysis.

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\*Numbers in right margins indicate pagination in the original text.

Any eddy current which leads to a partial loss of the protective paint can possibly be dangerous, because still other circumstances may be present which excite the flow of current to the anodic regions and thereby again activate the corrosion potential. A frequent example for the formation of eddy currents is the propeller region. The currents flowing here from the steel hull of the ship to the bronze screw concentrate at damaged points in the paint and additionally increase the potential of the currents generated by differences in speed and by eddying.

From the foregoing it appears that the eddying resulting from rather small irregularities on the skin is more or less harmless and leads only to minor local corrosion. The appearance of such corrosion points should of course be a warning sign, and rust spots which occur should be treated immediately and thoroughly, because corrosion over a wider area can be triggered by the addition of other moments. Especially weld points should be worked clean and be free of excess material. Weld beads and rivet heads complicate the painting problem in that case, because the paint has the tendency to flow off high points. It will always be advisable to paint over those points carefully with the brush.

#### Pitting Resulting from Stray Electrical Currents

Currents generated on shore which are to be supplied to a floating ship are frequently sources of stray currents. There is always the danger that they will break out of their own wires, be carried through the underwater body of the ship into the water, and flow on to the shore. At the point where the electrical current leaves the ship, a considerable loss of metal occurs owing to the electrolytic effect. According to Faraday's law of electrolysis, one ampere removes nine kilograms of iron in one year. The ship is exposed to that danger mainly during welding on board, especially if return circuits are not provided in adequate number and conductivity. Partial currents leave the ship at points at which the paint is thin or where the paint has been mechanically damaged. If those regions are relatively small, then very considerable damage can occur, even if, generally considered, the metal loss from the electrolytic action is not very great. An important indication of existing corrosion which has been caused by the flow of current from the anode to the cathode is that the sea water is broken down into its component parts of hydrogen and oxygen ( $H_2O$ ). The salt residue, which consists mainly of calcium carbonate and magnesium hydroxide, is deposited on the cathode. Since in most cases with a direct current the welding is done with reverse polarity (the ship being the anode in the weld current flow), the salt residues concentrate on the ship, on the rivet heads preferentially, the water line, and at points on the skin which were especially exposed to the heat during the welding in the interior of the ship. If such salt crystals can be located, the cathodic region which causes the formation of corrosion on the anode can be determined.

Damage of that type can be prevented by providing adequate return circuits of the lowest possible resistance which will not cause the returning weld current to break out. It is recommended always to provide three return circuits (forward, amidships, after) and to connect lines to ships lying abreast, ahead or astern. Besides a well conducting connection to the ship hull, care must be taken that the return circuits have a sufficiently large

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cross section. In regions with great tidal differences, care must further be taken that the return lines do not sag too much and thereby come into contact with the water. In that case, the current from the ship can flow through the water and penetrate through damage in the insulation into the line and thus reach the shore.

#### Pitting Due to Galvanic Currents

When two different metals are in electrical contact in an electrolyte, as for example water, then an electrolytic current flows from the anodic metal to the cathodic through the electrolyte. The corrosion resulting thereby on the anode is designated as galvanic corrosion and is very well known to all ship's officers and shipbuilders. One of the best known examples is the corrosion phenomena at the stern of a ship which is caused by the presence of the bronze ship's screw.

Basically, galvanic corrosion is caused by the potential difference between two different metals. Experience has taught that the use of two widely different metals in the contact series must be avoided. There are tables which report the metals and alloys by their potential in seawater. Those tables indicate the possible appearance of corrosion and at the same time show what metals are attacked or protected when they are in electrical contact with each other.

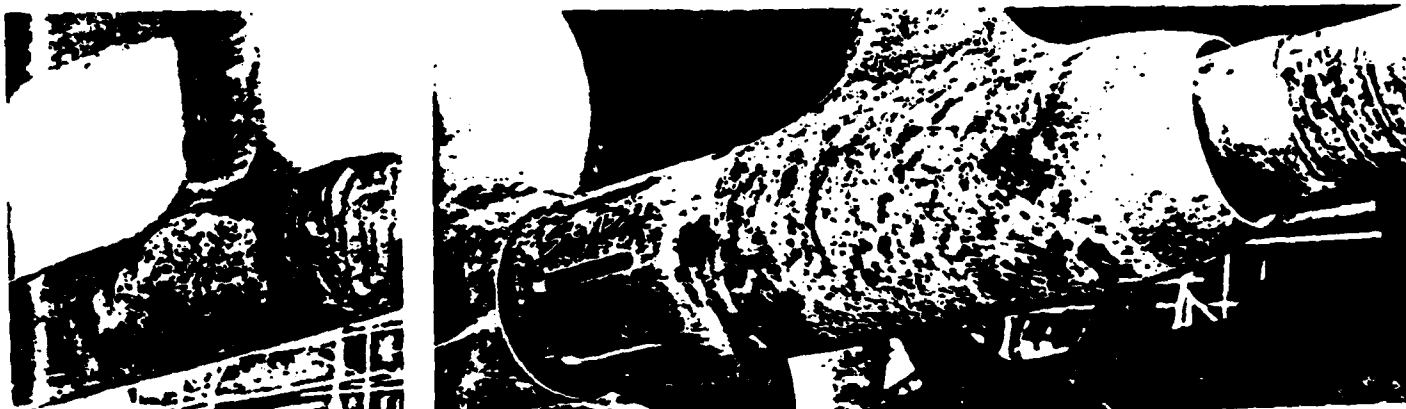
A more base metal has the tendency to pass into solution in the presence of a precious metal. The electrolytic series of the metals from the most base (Mg) to the most precious (Au) are:

Mg-Al-Mn-Zn-Cr-Fe-Cd-Co-Ni-Sn-Pb-Cu-Ag-Pt-Au.

As in the case of pitting due to stray currents, here, too, white salt deposits appear on the cathode from the flow of the current through the seawater. Whenever those white salt deposits occur, one can be sure that galvanic corrosion is occurring, for those deposits are on the cathode, which initiated the corrosion. /197



Figs. 1 to 3: Weld seams and points, where steel surfaces are exposed to mechanical or similar abrasion, are in special need of protection



Figs. 4 and 5: Corrosion on shaft struts



Fig. 6. Corrosion on stern tube

Another important mark of galvanic corrosion is the formation of hydrogen on the cathode and the formation of blisters in the paint, which is caused by the alkaline nature of the cathode products. This blistering impairs the process, for the cathodic region which is exposed to the seawater does not become enlarged. In order to preclude galvanic corrosion, dissimilar metals and unfavorable surface conditions must be avoided. In considering the effect of ununiform surface conditions, the influence of the paint must also be taken into account.

#### Pitting from Mill Scale

Of all forms of galvanic corrosion, the one which is caused by the presence of mill scale (cathode) on the steel (anode), has the worst effects. That is attributable to the fact that the relative surface conditions between anode and cathode are extremely unfavorable, more unfavorable than with any other galvanic complex which finds application in shipbuilding. Despite the destructive effect, the galvanic corrosion which is caused by the presence of mill scale is oftentimes not identified as such, so that this form of corrosion often comes as a surprise. The potential difference between steel and mill scale corresponds approximately to that between steel and copper. The potential difference and uneven surface condition factors acting in

combination can cause serious destruction. There are today only three ways which are generally common and required in building specifications to prevent mill scale corrosion:

--The stimulating cathode (mill scale) must be completely removed by curing, flame or sand blasting;

--Reduction of the mill scale surface by seasoning or mechanical means (sand blasting, rubbing with emery, grinding, etc.) to a dimension resistant to the cathodic influence;

--Application of a paint which prevents bare steel from coming into contact with seawater, or seawater from penetrating to the mill scale.

#### Pitting from Paint Containing Copper

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Marine bottom paints containing copper are an ideal condition for the possible onset of galvanic corrosion. It has been demonstrated that at points where the bare iron showed through, a galvanic effect is present whereby the iron surface acts as an anode and the copper-containing paint as a cathode. It has been proved that the cathodic action of the paint is stronger as its copper content is greater.

The coat of paint between the copper anti-fouling paint and the ship's bottom insulates the copper particles from contact with the steel, and the better that insulation effect, the less the possibility of galvanic corrosion. Ship's paint systems, therefore, consist of one base coat applied on the steel followed by various insulating coats which are supposed to form insulation between the steel and the copper anti-fouling paint. Insulating paints as a rule have no rust-preventing properties. Their main task is to protect the underlying steel against attack by the copper.

#### Conditions for a Proper Coat of Paint

Structures suitable for painting: As far as at all possible, one should strive for smooth surfaces for painting. Sharp edges and inaccessible places from which water cannot flow out should be avoided. Generally, the difficulties in preparation of the substrate and in performing the painting work can be considerably reduced by structural measures. Drain pipes should be arranged such that no water remains, and the water being discharged does not disturb the protective paint. In all constructions, as far as is technically possible the later care, maintenance, and repair should constantly be kept in mind.

#### Preparation of the Surface

The protective action and the durability of anti-corrosion materials as well as the ability to function of the entire system depend decisively on the preparation of the surfaces to be protected. The preparation should therefore be performed especially carefully and skilfully. Basically, any surface prepared for painting should be carefully examined before beginning the work.



## Preparation of Steel Parts

Mill scale, dirt, grease, and especially rust and any other materials disadvantageous for surface treatment should be carefully and completely removed before painting. The performance of those measures is an unconditional prerequisite for the long life and protective action of the paint in order to prevent corrosion phenomena. Semi-finished goods delivered descaled should be checked for freedom from scale.

The following methods are common for descaling and derusting:

**Removal of rust by hand and by mechanical devices:** With rather small and hard rust spots, merely remove rust with a hand hammer, a chipping hammer, putty knife, scaler, steel brush, and, if necessary, special tools. With larger surface and hard rather large rust spots, it is recommended to use mechanical tools such as a sledge hammer, rotary impact tools, and steel brushes. Damage and deformations as well as heavy roughness of the substrate should be avoided.

**Sand-blasting Method:** This is used for removal of mill scale and old paint as well as also for general rust removal. This involves blasting the substrate with quartz sand. Abrasive material with the following grain sizes are approved:

Quartz sand: not finer than 0.5 mm  
not larger than 1.5 mm  
optimal particle size 0.5-1 mm

River sand: (Rhine gravel and the like)  
not finer than 0.5 mm  
not larger than 3 mm  
optimal particle size 0.5-2 mm.

The abrasive material must be absolutely dry. The effectiveness is a function of the grain size of the sand and the air pressure at the nozzle. The sand should be of uniform grain size and sharp. Sand containing clay, humus, and salt should not be used for sand blasting. Especially hard rust spots should be derusted by hand. During painting and the hardening time of the paint, sand blasting must be discontinued, owing to the formation of dust. All the blasting work should be performed essentially dust-free. Vacuum blasting machines are preferred for use. The grades "metal bright" and "cloudy" are to be established from case to case according to the requirements on the protective paint. In sand blasting as well as in the following steel grit method, 0.080 mm is the highest permissible roughness. Aim at values of between 0.040 and 0.060 mm.

**Steel Grit Method:** This method is generally used for removing mill scale before installation of the material. The hardness and the grain size of the steel grit should be so selected that no rather large scuffing profiles result. In no case should the steel grit be larger than 1 mm.

**Flame Blasting Method:** The substrate is prepared using torches. Equipment working only with acetylene gas should be used. Basically, this method

is approved only on steel parts with a thickness of 8 mm on up. The de-seamed surfaces should be cleaned with steel brushes. The process should be repeated if necessary until all rust and all residual mill scale are removed and the substrate appears blue-gray after cleaning. The prime coat is applied on the substrate which has a temperature of about 30-90° for best results. It must be able to tolerate those temperatures, however.

**Seasoning and Removal of Mill Scale:** The mill scale is exposed to the elements, and it peels. In the process, wetting of the semi-finished product with pipe or river water without harmful chemical additives is permissible.

**Chemical Method:** Treatment in baths of acid or salt solutions with inhibitors should be used only in those plants which have facilities for thorough rinsing and suitable supervision of proper use.

**Selection of the Method:** The selection is usually left to the building or maintenance yard and its available facilities. However, the shipyard must assume full responsibility for the proper performance of the work. The approval of other treatment methods is basically the responsibility of the competent construction directorate.

**Further Treatment of the Material:** To remove rust and very thick films of rust after erection of a structure, the following derusting methods are optional, whereby the structural parts must not be deformed or damaged:

- All sand blasting methods operating dust-free;
- All powered or mechanical derusting methods using scraping or brush tools;
- All impact and ramming tools are excepted;
- As long as reentrant angles and corners cannot be adequately handled with power tools, hand derusting is called for.

Immediately after derusting, all derusted parts are to be brushed and dusted, but only if more rust or sand does not fall on the surfaces. The derusted and cleaned parts are to be provided with the prescribed anti-rust prime coat immediately after, or at least on the same day as the derusting. Lapped points must be so treated on both sides before assembly. Weld seams and rivets should be especially carefully derusted before painting and then provided with a zinc chromate prime coat, to which the next coat bonds solidly. Proceed accordingly in care and repair work.

#### **Painting and Preservation of Light Metal Parts**

Light metals used in ship and boat building do not need any paint on them for reasons of preservation. If for reasons of appearance and paint is applied, then the parts should first be thoroughly cleaned with special cleaners of the paint factories. During repairs, the damaged places should be smoothed with emery paper and cleaned. "Alu-Wash-Primer" is used for preparing a bonding surface; it roughens, passivates and gives the smooth

light-metal surface good adhesive properties. This is followed by an undercoat with zinc chromate. Paints and varnishes which contain copper, lead, or mercury are unsuited for lighth metals. In any case, the painting recommendations of the manufacturer should be carefully followed. It is recommended to obtain the pigments of a paint system exclusively from one firm so that they will match.

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