

# Aspects of salt concentration on prepared substrates



Fig. 1: Heavily corroded steel plate before (left) and after (right) UHP water jetting

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urface contamination by dissolved salts has always been an issue for the corrosion protection industry. It was, however, the replacement of lead-bearing paints ( $Pb_3O_4$ ) by other paint types due to environmental concerns that caused the industry to take a closer look at salts with respect to coating performance. A unique property of lead compounds is the capability of binding up soluble salts. Other coating compounds do not have this capability, and it was for that reason that salt contamination became an issue in surface preparation and coating.

Dissolved salts can affect coatings in all industries. Salts can come from chemical processes, cooling towers, agricultural processes, and other land-based industries. For vessels, offshore structures, and waterfront constructions, the sea is a major source of salt contamination, and it is in vessels, where problems with premature coating failure can be particularly challenging. This article reviews recent literature on salt contamination, identifies commonly used methods of removing soluble salts before coating application, and describes a study on the effectiveness of using ultra-high-pressure water jetting with abrasive on a heavily corroded steel plate taken from a vessel (that had been at sea since 1977).

## REVIEW OF LITERATURE ON SALT CONTAMINATION

Chloride content on the substrate significantly influences the performance of coating systems. Rust development under the paint film and osmotic blistering are commonly observed at an early stage in paint coatings applied over contaminated steel substrates. This is verified in detail by Solz (1) and

more recently by Mitschke (2) and Kaiser and Schütz (3). In a very recent investigation, Richards (4) showed that the amount of dissolved NaCl on the substrate determines the time for flash rusting. At a level of 31 µg/cm<sup>2</sup>, for example, flash rust appeared after 30 minutes, whereas, at a level of 5.3 µg/cm<sup>2</sup>, flash rust appeared after 20 hours. These results verify the earlier statement made by Solz (1).

The major assessment criterion for salt content is the safe or permissible, respectively, salt level that prevents under-rusting or blistering of the applied coating system. Different values are available in the literature; some were summarised by Momber (5). More detailed demands that consider coating DFT and coating material are provided by Appleman (6) and Morcillo and Simancas (7). However, a trend to very low specific concentration values in the range of 2 to 3 µg/cm<sup>2</sup> can be noted. The most recent IMO Draft (8) prescribes chloride levels less than 3 µg/cm<sup>2</sup>. It is for that reason that cer-

**Table 1: Surface Preparation Method Parameters**

Parameter	Method UHP	UHPAB
Operating pressure in MPa	200 (water)	150 (water); 8 (air)
Nozzle diameter in mm	6 x 0.3	19
Water consumption in l/min	10	10
Abrasive consumption in kg/min	–	12

tain authors (9) recommend the washing of contaminated substrates with deionised water before coating.

Surface preparation methods have different capabilities of removing dissolved salts. Mechanical methods, namely wire brushing and needle gunning, perform very bad. Dry grit blasting performs better and it has often been reported that UHP has the highest capability of reducing dissolved salts from steel substrates (see Allen (10) and Fosgren and Applegren (11) for more details). However, observations made by the author show that UHP has at least a limiting capability for removing heavy rust from corroded substrates. This issue, illustrated in Fig. 1, becomes evident if

the rust is very flaky and appears in layers. Although UHP may wash dissolved substrates away at places, it cannot remove the rust down to bare steel and one could expect a certain amount of salts trapped in closed pores and flaws. A method which can remove even heavy rust completely and can, at the same time, wash dissolved salts off the structure, may be of benefit in such situations.

### EXPERIMENTAL

The author used ultra-high pressure abrasive blasting (referred to as UHPAB) for the preparation of a number of heavily corroded steel samples. The specimens were cut from the forepeak of the vessel "Seawheel Rhine," which was in service from 1977. They were partly structured with HP profiles. The original coating (an inert coating with 500 microns DFT) was completely deteriorated. A total of five plates was blasted and assessed.

All blasting parameters are listed in Table 1. Drinking water with a specific electric conductivity of 650 µS/cm, a chloride concentration of 130 mg/l, and a sulphate concentration of 17 mg/l was used. The abrasive was clean copper slag with a grain size between 0.5 and 1.5 mm.

Figure 2 shows an example of a sample in original condition (left) and after UHPAB (right). The surface preparation grade corresponded to an Sa 2 1/2 according to ISO 8501-1. Three samples were taken for each plate before and after the surface treatment. The dissolved substances were extracted with



Fig. 2: Heavily corroded steel plate before (left) and after (right) UHPAB water jetting

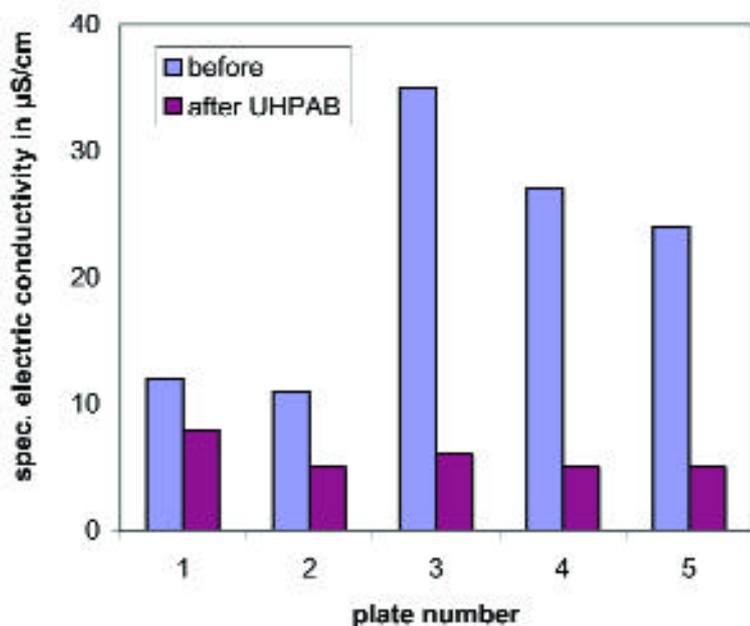


Fig. 3: Results of specific electric conductivity measurements after UHPAB

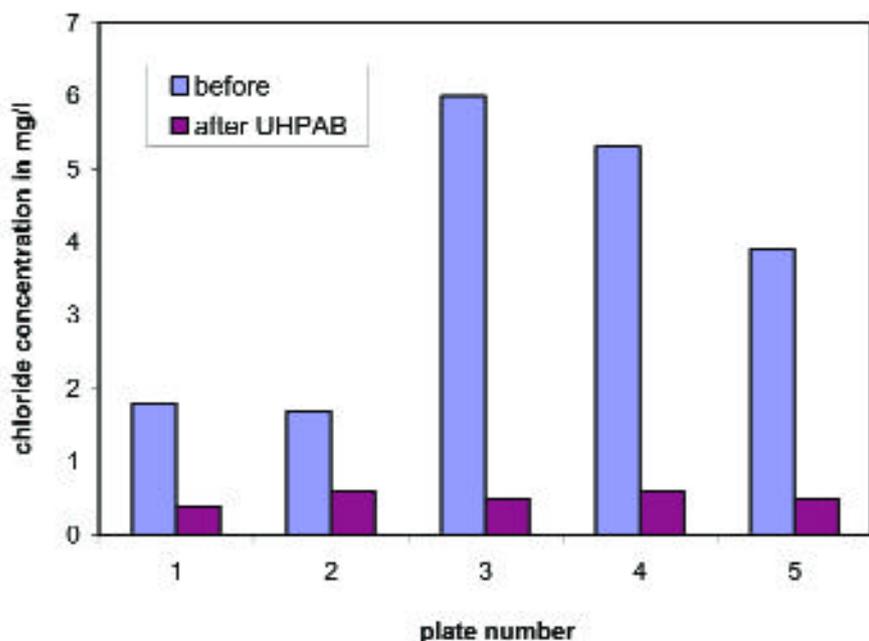


Fig. 4: Results of chloride concentration measurements after UHPAB (ion chromatography)

the Bresle method according to ISO 8502-6. The samples were analysed with an ion chromatograph. Chloride and sulphate concentrations were estimated. The samples were also checked for nitrates, although none were detected on any of the samples. The lower limits of detection for the substances were: 0.2 mg/l for chloride; 0.2 mg/l for nitrate; and 0.1 mg/l for sulphate. The specific electric conductivity was also measured.

## RESULTS

The results of the conductivity measurements are shown in Fig. 3. Each column represents the average from three measurements. The maximum deviation between the three values was 20% for the blasted surfaces, and it was about 250% for the corroded surfaces. Therefore, salts seemed to be unevenly distributed in the rust. Specific electric conductivity reduced notably after the UHPAB process. The very same result could be noted if chlorides only were considered (Fig. 4).

Figure 5 shows the results of the sulphate measurements. Here, the result was not as explicit as with the chlorides. In some cases, sulphate concentration was slightly higher after UHPAB. However, this result is not definite because the deviations between the individual measurements were in the same range. Sulphate concentration was already low (compared to chloride) before the surface preparation was performed, and with the exception of one case it could not be lowered further.

Figure 6 is a comparison between the results obtained with UHPAB and UHP on one individual plate. Again, the results were averaged. It is clear that both surface preparation methods reduced specific electric conductivity, but

UHPAB was more effective. The most probable reason is that UHP could not remove the rust completely from the substrate as evidenced in Fig. 1. Dissolved substances may still be present in the rust. UHPAB, in contrast, removed rust completely and formed a surface quality comparable to Sa 2<sup>1/2</sup>.

There is some disagreement in the literature over whether there is a distinct relationship between specific electric conductivity and chloride concentration. Some references (12,13) noted a relationship, whereas others (14) did not. The results of our measurements are plotted in Fig. 7. A distinct linear relationship with a coefficient of regression of 0.976 could be noted. If further experimental points from the drinking water measurements were included, this parameter increased up to 0.99. Thus, dissolved chloride ions contributed notably to the specific electric conductivity of the extracted solutions. However, the link was best for the higher concentration values, which were those of the unprepared plates. In those cases, chloride concentrations were one order of magnitude higher than those for sulphates, and this may be one reason for the dominating influence. The results displayed in Fig. 8 do not evidence any relationship between sulphate concentration and specific electron conductivity. The only notable observation was that if sulphate content in the solution was highest, specific electric conductivity was highest as well.

### CONCLUSIONS

UHPAB has the capability of removing dissolved salts very reliably from heavily corroded and contaminated substrates. This is because of the parallel action of high-speed abrasive particles, which remove any rust from the substrate, and

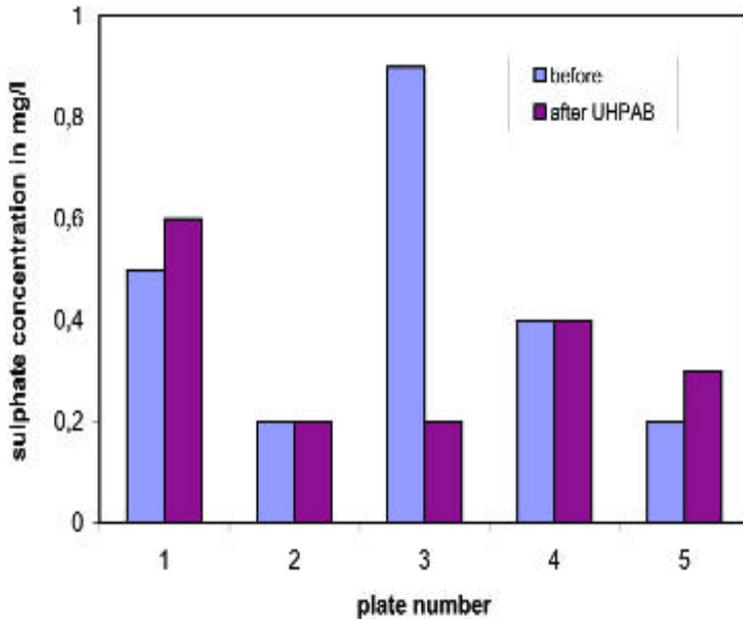


Fig. 5: Results of sulphate concentration measurements after UHPAB (ion chromatography)

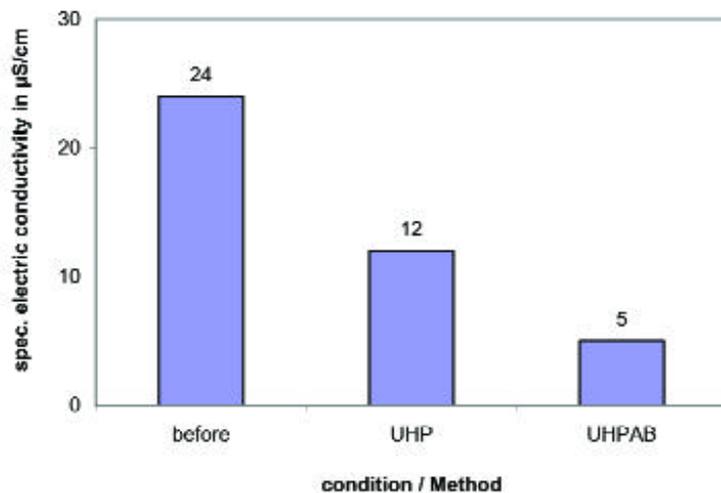


Fig. 6: Results of electric conductivity measurements after UHP and UHPAB

of high-speed water flow, which washes the dissolved substances off the surface structure. If, in site practice, heavily corroded sections of maritime structures must be prepared for recoating, UHP is sometimes not an appropriate method because it has limitations in terms of rust and salt removal. UHPAB or wet

blasting methods should be considered in such situations.

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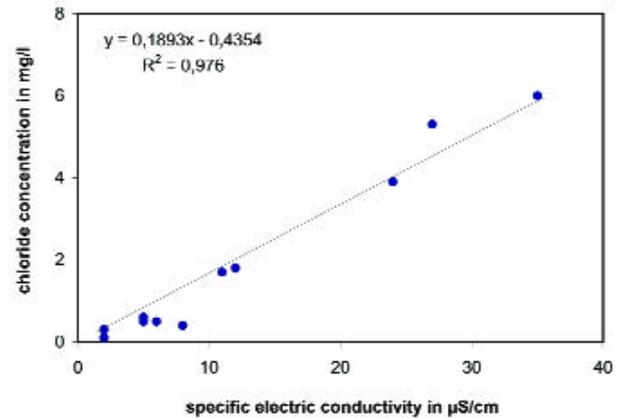


Fig. 7: Relationship between specific electric conductivity and chloride concentration

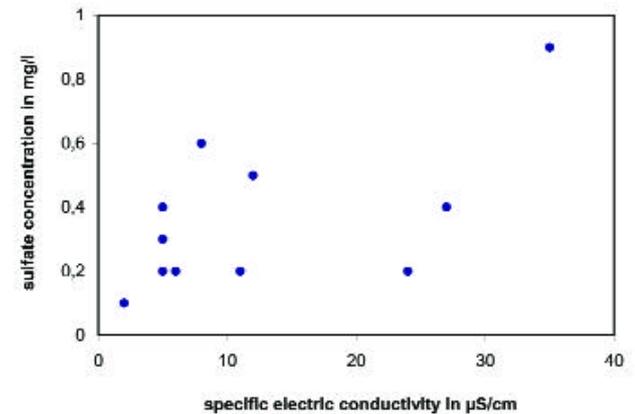


Fig. 8: Relationship between specific electric conductivity and sulphate concentration

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