Surface Preparation

Ensuring coating performance before paint application

Introduction

The single most important function that can influence paint performance is the quality of surface preparation. For optimum service life, the surface must be completely free of all contaminants that might impair performance and should be treated as such to assure good and permanent adhesion of the paint system. The quality of surface preparation has a direct relation with the lifetime of a coating system. Even when using surface tolerant paints, it cannot be emphasized enough that better surface preparation always result in reduced risk of early coating breakdown, improved durability and longer service life of the coating system.

Steel preparation, removal of sharp edges, dealing with pitting rough welds and so on, are not part of this document but should be taken into consideration as part of good painting practices.

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Surface cleaning, primary and secondary preparation

Surface preparation consists of primary surface preparation and secondary surface preparation.

The primary surface preparation aims to remove mill scale, rust, corrosion products, and foreign matter from a (new) steel surface prior to application of a shop primer or primer.

The secondary surface preparation aims to remove rust and foreign matter, if any, from a steel surface that has been already coated with a shop-primer or paint, prior to application of a full anti-corrosive system. All rust, rust scale, heavy chalking, or deteriorated coatings must be removed by a combination of solvent or detergent washing, hand or power tool cleaning or abrasive blasting. Glossy areas of sound previous coatings need not be removed, but should be (mechanically) abraded or brush blasted to create a surface profile to increase coating adhesion. Some specifications may require removal of shop-primer to bear metal by abrasive blasting as secondary surface preparation.

Prior to use any of method of surface preparation, it is essential to remove all soluble salts, oil, grease, drilling and cutting compounds and other surface contaminants. Perhaps the most common method of cleaning off oil and grease type contaminants is by solvent-washing, followed by wiping dry with clean rags. The wiping clean is critical, because if this is not carried out thoroughly the result of solvent washing will simply spread the contamination over a wider area. This moving around of the contaminants (towards the edges of the cleaned area) can result in reduced paint adhesion and lifting of the subsequent coating system. Proprietary emulsions, degreasing compounds and steam cleaning are also commonly used. Recommended procedures are described in International Standard ISO 8504 and SSPC-SP1.

Removal of soluble salts is discussed in the high pressure fresh water cleaning chapter below.

High pressure fresh water cleaning

High pressure fresh water cleaning (HPFWC) is always necessary to remove salts, fouling, any loose paint and other contaminants before further surface preparation. In a dry dock project, it is advisable that fresh water cleaning is done immediately after in-docking as any fouling (organisms such as algae- and shell fouling) is more easily removed when it is has not dried up completely. A water pressure of 500 bar (approx. 7000 psi) is typically used from removal surface contamination and fouling.

For heavily contaminated (rusted) steel, a second wash may be required after rust is removed by an abrasive technique to bring down the soluble salt contamination on the surface to acceptable levels. As indicated by the name of this chapter, it is important that (clean) fresh water is used to prevent the water being a cause of contaminants such as soluble salts.

Soluble salts

Checking for water soluble salts using techniques such as the Brestle Test (ISO 8502-6 and 8502-9) mainly work on the increase in conductivity of water having had time to extract soluble matter from the surface.

This conductivity is then converted and expressed as a certain weight of salt on the surface in µg/cm² or mg/m². Depending on the conversion factor this may be an equivalent in sodium chloride or a specific mix of salts. Note that is not possible to find the type of salts on a surface, so a model calculation like this cannot be avoided.

Different international or industry standards may set different limits for allowed results of the soluble salt test, ensure to double check the limits and conversion factors for the specific type of salt when this is part of a project requirement. IMO PSPC states 50mg/m² (expressed as sodium chloride). Norsok M501 for instance states a stricter 20mg/m² as maximum soluble salt level.

Besides the contamination already on the surface, care should be taken not to introduce soluble salts during the surface preparation. See the abrasive blast-cleaning chapter below.

Hand tool cleaning

Loosely adhering mill scale, rust and old paint coatings may be removed from steel by hand wire brushing, sanding, scraping and chipping. However, these methods are incomplete, and always leave a layer of tightly adhering rust on the steel surface. Methods for hand tool cleaning are described in SSPC-SP2 and ISO 8504-3.

Hand tool cleaning is very useful when the deployment of power tool is not feasible and economical and the job is localised / small. After cleaning the surface is brushed, swept, dusted and blown off with compressed air to remove all loose matter.

Power tool cleaning

Examples of mechanical tools are rotary wire brushes, sanding disc and needle guns. Power tool cleaning is in general more effective and less laborious than hand tool cleaning for the removal of loosely adhering mill scale, paint and rust. However, power tool cleaning will not remove tightly adhering rust and mill scale. Care should be taken, particularly with power wire brushes, not to polish the metal surface as this will reduce the key for the subsequent paint coating.

Preparation grades with power-tool cleaning are specified according to International Standards method ISO 8504-3 and visual standards are described in ISO 8501-2. Relevant preparation grades are St2-B, C or D and St3-B, C or D. SSPC-SP11 describes the various degrees of surface profile that can be achieved by power tool cleaning.

Blast cleaning

Blast Cleaning is based on the principle of an abrasive jet of particles in a compressed air stream impinging on the surface, removing impurities, mill-scale, rust and old paint. Abrasive blast cleaning is the most thorough and widely used method of surface preparation in the shipbuilding and repair industry. Different degrees of surface cleanliness are possible and depend in part on the surface condition prior to treatment and also to the length of time for which the surface is exposed to the abrasive jet. In addition to cleaning the surface, the abrasive particles will impart a surface roughness to the steel.

Blast cleaning removes rust and mill-scale. However, prior to blasting, steelwork should be degreased and all weld spatter removed. Salts, grease or oil on the surface will appear to be removed by the blasting process, but although not visible, the contamination will still be present as a thin layer. These contaminants will affect the adhesion and performance of subsequent coatings. As an indication for the presence of salts, the conductivity of water that has been used to wash a certain small area of a (blast) cleaned surface can be checked. The Brestle test and soluble salts are discussed in the water washing section of this document.

Furthermore weld seams, metal slivers and sharp edges revealed by the blasting process should be ground down, as paint coatings tend to run away from sharp edges, resulting in thin coatings and reduced protection. Weld spatter is almost impossible to coat evenly, in addition to often being loosely adherent, and it is a common cause of premature coating failure.

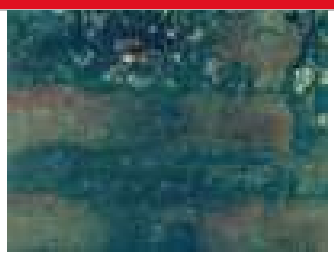
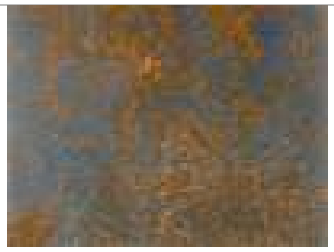
The surface appearance resulting from blast cleaning has been defined by several bodies but the ISO and SSPC standard are most commonly used. The table below gives a summary of the different qualities in surface preparations used by SSPC and ISO standards.

Table 1: descriptions of preparation grades of prepared steel

Description	American SSPC-SP	International ISO-8501
White metal	SSPC - SP 5	Sa 3
Near white metal	SSPC - SP10	Sa 2½
Commercial blast	SSPC - SP 6	Sa 2
Brush-off blast	SSPC - SP 7	Sa 1
Power tool cleaning	SSPC - SP 3	St 3
Hand tool cleaning	SSPC - SP 2	St 2

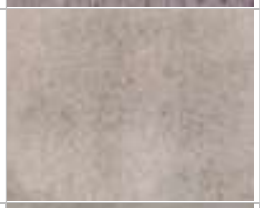
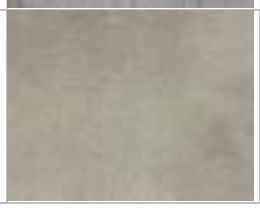
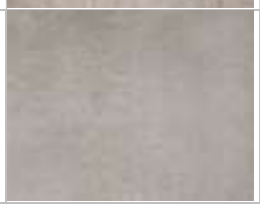
International Standard ISO 8504-2 describes the “Rust grades and preparation grades of uncoated steel substrates after overall removal of previous coatings”. ISO 8501-1 further describes the visual standards.

Table 2: Initial condition of (new) steel as per ISO 8501

Rust grade	Pictorial example	Description
A		Steel covered completely with adherent mill scale and with, if any, little rust.
B		Steel surface which has begun to rust and from which the mill scale has begun to flake.
C		Steel surface on which the mill scale has rusted away or from which it can be scrapped, but with little pitting visible to the naked eye.
D		Steel surface on which the mill scale has rusted away and on which considerable pitting is visible to the naked eye.

Pictures given here are indicative only, please review the relevant standard documents for comparative standards

Table 3: Pictorial examples of surface preparation according to ISO 8501

Cleaning standard	Initial steel condition (see also table 2).			
	A	B	C	D
St2 Hand tool cleaning	Not applicable			
St3 Power tool cleaning	Not applicable			
Sa1 Brush-off blast	Not applicable			
Sa2 Commercial blast	Not applicable			
Sa2½ Near white metal				
Sa3 White metal				

Pictures given here are indicative only, please review the relevant standard documents for comparative standards.

Type and quality of abrasives

Due to health concerns, the use of sand as an abrasive is now forbidden in many countries. Mineral slag blasting materials generally give faster rates of cleaning and lower health risk (from shattered abrasive) than sand does. Grit also gives more effective cleaning, especially for pitted substrates, and some grades can be recycled.

It is strongly advised to regularly check the quality of abrasive used. Besides particle size and shape (round shot for shop primer lines vs. sharper grit and slag types), a check for contaminants is important. Especially when the abrasive is re-cycled, there is a risk of soluble salts, oil and grease type contaminants being brought onto the surface to be blasted.

The profile height obtained during abrasive blasting is important, to create a "key" for anchoring of paint systems, see paragraph “surface profile” below table 4 on abrasive types, their size and profile heigh guidance.

Table 4: Abrasive types

Type of Abrasive	Mesh Size Max.	Height of Profile
Very fine sand	80	37µm (1.5 mils)
Coarse sand	12	70µm (2.8 mils)
Iron shot	14	90µm (3.6 mils)
Copper slag	1.5-2.0mm size	75-100µm (3-4 mils)
Iron grit No. G16	12	200µm (8.0 mils)

Surface Profile

The profile shape and dimensions will depend not only on the abrasive used but also the air pressure and the technique of blasting (distance and angle from nozzle to the surface). Too low a profile may not provide a sufficient key for coating, while too high a profile may result in uneven coverage of high, sharp peaks possibly leading to premature coating failure, particularly for thin film coatings such as blast or holding primers.

Surface profile indicates the roughness of blast cleaned surface and has no relation to the standard of cleanliness. The profile of roughness obtained during blasting is important and will depend upon the abrasive media, the air pressure, and technique of blasting.

To specify the roughness, a variety of values are used, such as Rz, Rt, and Ra.

R_z = average peak to valley height

R_t = maximum peak to valley height

R_a = average distance to an imaginary centre line which can be drawn between peaks and valleys = C.L.A. = Centre line Average (ISO 3274)

R_z = 4 to 6 times C.L.A. (R_a)

R_z is generally used to describe the required blasting profile on product datasheets. Generally the blasting profile found on datasheets for primer will be a range like 30 to 70µm. The blasting profile should not be too high (not more than one third of the total dry film thickness of the coating system). A high profile can result in early coating breakdown in the form of pin point rusting due to the uneven coverage of high sharp peaks. Too low a profile may not provide a sufficient key of coating resulting in reduced adhesion.

Spot blasting

Spot blasting is localised abrasive cleaning often carried out in ship repair, especially on the outside hull, where patchy corrosion or damage has occurred. It can be used to yield surfaces that are cleaned to Sa 2 or better but often surrounding intact areas are peppered with stray grit.

These areas should be treated as in the inclusion of grit in the final coating system may lead to premature failure of the system. It is therefore required to mark areas to be spot blasted and subsequently mechanically "feather" the damage round the area using rotary disc or sander.

Sweep blasting

Sweep blasting is the treatment of a surface by quickly passing a jet of abrasive across the surface. It is typically used as a tool to get some surface roughness on an existing, firm adhering coating in order to facilitate inter coat adhesion. The level of effectiveness depends on the skill of the operator, the type of surface and particle size of abrasive. In general, a fine grade of abrasive (0,2-0,5 mm) is recommended as larger particle sizes would destroy the existing coating too much.

High Pressure Water jetting

Water jetting or hydro blasting as a surface preparation technique is being used more and more in shipyards. A major advantage of using water pressure as an abrasive is the lower impact on environment and health because less dust is generated than is the case with grit blasting. It also constitutes less of a safety risk caused by sparks and reduces the amount of salt remaining on the surface. As with blast cleaning, prior to hydro blasting, water insoluble foreign matter such as oil and grease must be removed.

Table 5: Definitions and suitable water pressures range

Definition	Pressure (Bar)	Pressure (psi)	Flow rate (l/min)
Low pressure water cleaning	< 68	< 1000	
High pressure water cleaning	68-680	1000 to 10.000	90 - 50
High pressure hydro blasting	680-1700	10.000 to 25.000	50 - 25
Ultra-high pressure hydro blasting	> 1700	> 25.000	Down to 12

High pressure water cleaning is also used to clean a ship from fouling, dirt and salts. However, when we speak about hydro blasting as a surface preparation tool only the definitions high pressure hydro blasting or ultra-high pressure hydro blasting is meant. Please note that Hydro blasting is also referred to as water jetting or hydro jetting but in Transocean documentation only the term hydro blasting is used.

The flow rate determines the reaction force felt by the operator. High flow rates mean strong reaction forces meaning that the operator will be exhausted after some time of cleaning. Lower flow rates mean reduced reaction forces which results in less fatigue for the worker and therefore not only the equipment is easier to handle but also increases productivity. Typical production rates are given in table 6.

Table 6: Relation water pressure, effect of cleaning and production rates

Pressure (bar)	Removal of;	Typical speed (m2/hr)
Up to 500	Fouling, salt and dirt.	300
> 1000	Also loose rust and paint. Firm adherent paint remains.	150 (machine)
> 2000	All coatings. Restores original roughness profile.	5 (handgun) 100 (machine)
> 4000	All coatings. Creates roughness profile.	

The appearance of steel after hydro blasting is different than grit blasting. Hydro blasted surfaces tend to look dull, even before they “flash rust”. The first picture gives a close up of the steel area after hydro blasted at 2000 bar. The rotating nozzle left a circular pattern on the steel. Some gingering of the steel in the form of flash rust is visible too.

In the second picture, steel with active corrosion pitting shows a mottled appearance after hydro blasting. Mottling occurs when the corrosion products are washed out of the pits, leaving a bright patch, and the surrounding areas are left a dull grey, brown to black colour. This pattern is the reverse of that left by abrasive blasting, where anodic pits are often dark, due to corrosion products not being entirely removed, and the surrounding areas are bright.

ISO 8504 describes the different quality grades of preparation in a similar way as the blast-cleaning standard does. From an original condition, 3 grades of cleanliness are described. In addition for each cleanliness grade, 3 levels of flash rusting are defined; L (light), M (medium) and H (heavy).

Flash rusting is the result of light oxidation of the steel, which occurs as hydro blasted steel dries off. The appearance changes from a light, ginger colour in to an orange-red dusty layer.

Flash rusting can be prevented by the use of water soluble chemical corrosion inhibitors. These inhibitors may leave a crystalline layer on the steel surface as the water evaporates, which can then lead to a loss of adhesion and osmotic blistering, if coatings are applied over this type of surface. Transocean therefore does not favour the use of corrosion inhibitors. In case inhibitors are used, they must be thoroughly washed off with fresh water before application of the first layer of paint. Transocean has various products available, which are compatible with hydro blasting and some products may even be applied when steel is still damp. In such cases, the level of flash rusting acceptable for recoating is not an issue.

The three mentioned flash rusting categories can be described as follows:

Light Present as a ginger coloured surface staining that will partially discolour the original metallic surface and will not be heavy enough to easily mark objects brushed against it.

Medium Present as a yellowish layer which obscures the original metallic surface and will be heavy enough to mark objects brushed against it.

Heavy Present as red-orange powdery rust that obscures metallic surface and easily marks objects.

Heavy flash rusting is not acceptable for coating application and it may be removed or reduced by brushing with a hard bristle brush, or by washing down with high pressure fresh water cleaning, at pressures above 68 bar (1,000 psi).

Wet slurry blasting

Wet abrasive blasting may be performed with low or high pressure fresh water to which a relative small amount of abrasives is introduced, and in some cases inhibitors are added to prevent flash rusting (however, as a general rule it is recommended not to use inhibitors when cleaning areas are to be immersed during service). This reduces the amount of airborne dust and sand. It is necessary to rinse the surface after blasting to remove sand and debris.

Surface preparation of other metals

Aluminium

The surface should be clean and dry. Any corrosion salts should be removed by light abrasion and water washing. The cleaned surface should then be abraded or very lightly abrasive blasted using low pressure and non-metallic abrasive (e.g. garnet).

Alternatively, the aluminium can be etched by using an acidic solution or etch primer. Transocean Gelclean 0.03 can be used for this purpose. Please consult the technical datasheet and safety precautions before use.

Galvanised steel

The surface should be clean and dry. Degreasing of most galvanised surfaces requires some effort to obtain a clean surface. Any white zinc corrosion products should be removed by high-pressure fresh water washing, or fresh water washing with scrubbing. When using the preferred method of surface preparation, i.e. sweep blasting, it is still advisable to fresh water wash to remove soluble zinc salts. Many coatings based on non-saponifiable polymers can be applied directly to galvanised surfaces prepared in this way.

When sweep blasting is not possible, then an acid etch solution or etch primer should be used to passivate the surface and provide a key for further paint coatings.

When steel has been treated with a passivating treatment immediately after galvanising, then this must either be allowed to weather off over a period of several months exterior exposure or be abraded before application of a coating. In general etch treatments have no effect on fresh materials of this type.

Stainless steel

Stainless steel does not require any particularly specialized surface pre-treatment prior to coating. These surfaces should be free from oil, grease, dirt and other foreign materials by chemical cleaning. The development of a surface profile on stainless steel is highly recommended to assure good coating adhesion. A profile depth of between 1.5 and 3.0 mils is suggested for most coating systems. Because stainless steel is a very hard metal, abrasive blasting is recommended to impart a continuous surface profile.

Surface preparation of concrete

New Concrete

Fresh concrete should be permitted to harden at least for 28 days at 23°C and 50% relative humidity. The moisture content of the concrete / masonry should be less than 6%. All soft or loosely bound surfaces should be cleaned down to a hard substrate. Sweep abrasive blasting is the effective and preferred method to do so. Large cracks or holes should be repaired with a non-shrinking compound. When abrasive blast cleaning is not desired or not feasible, acid etching is an alternative option. In less critical areas where blasting is not practical, wire brushing has to be adopted to remove laitance, followed by treating with dilute hydrochloric acid (10%).

Old concrete

Remove the surface contaminants like grease, oil, etc., by solvent wiping or by 10% caustic solution. Preferably the surface has to be prepared by light blasting. In case, blasting is not practical, etch the surface to get a good profile by treating white dilute (10%) hydrochloric acid. Remove acid and contaminants by liberal wash with water. Ensure that acid solution does not retain on the surface and joints. Allow the surface to dry thoroughly before applying primer. Any cracks should be cut out and filled with suitable filler prior to painting.

For more details about cleaning concrete refer to ASTM D4259 – Abrading concrete or ASTM D4258 – Surface cleaning of concrete.

In general the first coat on concrete is thinned down to amount up to 25% to facilitate penetration and to enhance adhesive properties.

Wood surfaces

Dirt, grease / oil should be removed by one or more chemical cleaning methods. Knots, nails, holes, cracks etc., should be filled with appropriate filler compound. Scrap off loose adherent coating if any and sand to an even surface, chalky surface should be washed cleanly and dried well before coating.

Table 7: Overview of surface preparation standards used in Transocean documentation

Preparation standard	Reference to SSPC	Description
High pressure fresh water cleaning (pressure 70-700 bar) **HPFWC**	n/a	This method is routinely used on ships in drydock to clean the underwater area of fouling, salts, loose adhering paint and other foreign matter.
Solvent Cleaning **SP-1**	SSPC-SP1	Foreign matter other than oil and grease should be removed by scraping or brushing followed by HPFWC. Removal of oil, grease, dirt, soil, salts and contaminants by cleaning with solvent, alkali, emulsion or steam. After cleaning remove dirt, dust and other contaminants by vacuuming or blowing with clean, dry air.
Thorough Hand- and Power tool cleaning **ISO-St2**	SSPC-SP2	When viewed without magnification, the surface must be free from visible oil, grease and dirt and from poorly adhering mill scale, rust, varnish coating and foreign matter.
Very Thorough Hand- and Power tool cleaning **ISO-St3**	SSPC-SP3	Similar to St2 but the surface must appear very thoroughly treated to give a metallic sheen arising from the steel surface.
Brush off Blast-cleaning: **ISO-Sa1**	SSPC-SP7	When viewed without magnification, the surface must be free from visible oil, grease and dirt and from poorly adhering mill scale, rust, varnish coating and foreign matter.
Thorough Blast-cleaning: **ISO-Sa2**	SSPC-SP6	When viewed without magnification, the surface must be free from visible oil, grease and dirt and from most of the mill scale, rust, varnish coating and foreign matter. Any residual contamination must appear firmly adhering.
Very Thorough Blast-cleaning **ISO-Sa2½**	SSPC-SP10	When viewed without magnification, the surface must be free from visible oil, grease and dirt and from most of the mill scale, rust, varnish coating and foreign matter. Any remaining traces of contamination shall show only as light stains in the form of spots or stripes.
"White metal" Blast-cleaning **ISO-Sa3**	SSPC-SP5	When viewed without magnification, the surface must be free from visible oil, grease and dirt and from mill scale, rust, varnish coating and foreign matter. It shall have an uniform metallic colour.
Hydro jetting **Wa 2**		Loosely adhering mill scale, rust and poorly adhering coatings are removed. Various spots of old coating systems and firmly adhering mill scale is still present. Thin coatings on previously blast-cleaned surfaces are predominantly removed. Before drying a weak sheen arises from the metal surface which disappears during drying due to flash rust formation.
Hydro jetting **Wa 2,5**		As Wa 2. Firmly adhering mill scale is still present. From firmly adhering rust at most thin dark oxide layers and/or slight residues in the roughness valleys are present. From firmly adhering old coatings residual areas having spots with damages, various scattered small spots and residues in the roughness valleys may be present. Thin coatings on previously blast-cleaned surfaces are predominantly removed. Before drying a distinct sheen arises from the metal surface which disappears during drying due to flash rust formation.