Tank linings work

Introduction

Selecting the right lining system for the internal side of a tank is not enough to ensure protection to the chemical stored and/or transported at specific operating conditions. Surface preparation and paint system application are also critical; Product Data Sheet (PDS) and Hempel's specifications shall be followed. This Technical Guideline provides additional guidance to successfully undertake the tank lining work.

For consulting the most adequate lining system for your case please always review the online version of Hempel's Chemical Protection Guide, which contains the most updated information.

Safety

Use adequate personal safety equipment and follow sound procedures. Apply only in well ventilated areas. Observe safety labels on packaging and paint containers and consult Hempel's Safety Data Sheets (SDS) for the products to be applied.

Scope

The scope of this Technical Guideline is to provide guidance on how to carry out the whole tank lining work for New Build as well as Maintenance and Repair in the Protective and Marine industries.

This Technical Guideline is not applicable to Thermal Spray Metal coating.

Typical tank linings include:
- Hempadur 15500
- Hempadur 15600
- Hempadur 15460
- Hempadur 85671
- Hempadur Anti-Static 85170
- Hempaline Defend 400
- Hempaline Defend 630
- Hempaline Defend 640
- Hempaline Defend 740
- Galvosil 15700

Rigging of work site and considerations prior to steel work and surface preparation

General considerations
Tanks must be structurally sound.

For the duration of the coating job the tank should be regarded as an "off-limit-area" for all people not involved in the coating job.

All utility supplies (electricity, compressed air, fresh air etc.) should be arranged in an orderly and proper manner.

Suitable storage facilities, preferably with temperature regulation, should be arranged for equipment, spare parts, abrasives and coating materials in order to have them available and ready for use when needed. Paints shall be kept within the temperature range indicated in the related PDS and SDS.

All hot work on both the internal and external side of the tank shall be completed before the surface preparation process begins.

Both during and after coating work, a high standard of cleanliness is necessary. A shelter should be erected over the tank entrance to stop contamination area entering the tank. Anyone entering the tank should wear clothes that are free from oil, grease, and other contaminants. Footwear should be clean or clean shoe covers must be used.

After the final inspection/approval, the tank is to be closed and the entrance locked. Any further access should be authorized and logged.

Staging
Staging must provide safe and good access to all surfaces without rearranging the scaffold during the work progress.

It should have as few contact points to the tank surface as possible. When free standing staging is used, all contact between scaffolding poles and steel surfaces should be point contact only.

Staging poles and working platforms should be placed between minimum 15 cm and maximum 30 cm distance from the surface to provide suitable workspaces for all subsequent operations.

Open ends of staging poles should be plugged or capped to make sure that residues of abrasives or other materials do not remain in the scaffolding poles.

It is recommended that the platforms consist of gratings to ease cleaning and ventilation. If boards are used, they should be new, without defects and/or contamination.

Ladders should be of good quality and used according to maker's recommendations.

Before use, scaffolding should be inspected and approved by the contractor's supervisor and/or safety officer. This should be done regularly; once every week may be recommended. Staging not inspected or approved should not be used until the adequate corrective measures are taken and approval for use is granted.
It is recommended that the contractor keeps a record of the inspections which should be available for a potential inspection.

Protective paper sheets beneath permanent ladders, ladder platforms and lower staging will assist in protection against contamination of the top of the tank.

The staging should not be removed before final inspection.

Damage of paint film must be avoided whenever possible. However, any damaged spots should be repaired simultaneously when dismantling of the staging according to the procedure for repair of small areas.

Handling of items not to be coated
Items not to be blasted and coated which cannot be removed, for instance heating coils or instrumentation equipment, should be protected against over-blast and over-spray by covering/wrapping.

During abrasive blasting process the best protection is offered by a wrapping in heavy duty rubber or plastic with all overlaps and joints on the underside of the coils. This helps to prevent dust and blast media collecting in the wrapping.

During paint application the covering should be of a material such as an absorbent paper that will prevent paint flakes contaminating the freshly applied paint on the top of the tank. Using plastic is not recommended.

Lighting
Lighting in the tank is vital for safety reasons, as well as to ensure that a good standard of the coating work is obtained.

Illuminance should be considered sufficient if it allows the reading of at normal text page, like the present, at a distance of 30 cm.

At the individual work site the general lighting should be supported by powerful handheld flood lights.

All lightning and power supply should be of explosion proof, low voltage design and in accordance with local regulations.

Ventilation, relative humidity and temperature
Sufficient equipment for ventilation, dehumidification, heating and insulation should be available to maintain the conditions specified for the coating system irrespective of variations in outer climatic conditions.

The tank shall be kept free of condensation during all the tank lining work.

Steel temperature must be minimum 3°C/5°F above the dew point of the surrounding air.

Good ventilation is generally obtained by blowing clean dry air into the upper and middle regions and establishing suction outlets at the bottom of the tank. Possible areas with stagnant air must be ventilated by added spot ventilation.

To prevent introduction and reintroduction of dust, solvent vapours, etc. a light overpressure can be maintained in the tank and care should be taken to keep separation of the in- and outlet ducts in the ventilation system.

Specific guidance about ventilation, relative humidity and temperature conditions during blasting as well as during application, drying and curing are provided in coming sections.

Steel work prior to surface preparation

Parties may decide to establish a common reference for the different steel surface finish grade and surface preparation work before work is initiated, for example on a "mock-up" including all relevant welds, edges, openings, construction details, etc.

Condition of steel prior to surface preparation
Rust Grade B according to ISO 8501-1:2007 is the maximum accepted for raw steel. Areas with Rust Grade C should be kept at a minimum and will call for extra attention both during surface preparation and paint application. Note that non-corroded steel may show impressions from the hot-rolling very similar to the appearance of corroded pits in Rust Grade D steel.

Any parts of cast iron must have a non-porous surface.

Welds, cut edges and other surface imperfections must be prepared preferably by grinding according to ISO 8501-3, grade P3, “very thorough preparation”. To facilitate the observation of pores and pinholes in welding seams it is recommended to pre-blast welds prior to inspection of the steel work
After preparation the welds shall be free of all welding spatter and welding slag, undercuts, visible pores and end craters. Further, the weld profile must be fully dressed, i.e., smooth, see ISO 8501-3, descriptions 1.1-1.6.

Edges, whether rolled, flame cut or the result of punching, shearing, sawing, drilling or similar shall be rounded to a radius not less than 2 mm or as a minimum being chamfered by three succeeding passes leaving no knife edges or whiskers, see ISO 8501-3, descriptions 2.1-2.3. Rolled profiles etc. from steel mills are normally acceptably rounded.

Surfaces shall generally be free of rolled-in extraneous matter, grooves, indentations, pits and craters, visible shelling and laminations. Removal shall be by grinding and in severe cases levelling by welding (see ISO 8501-3, descriptions 3.1-3.6). Some steel defects may only become visible after abrasive blasting. After removal the affected area must be re-blasted to the specified standard.

All hot work like welding and flame cutting on the outer side of a tank must be finished before the tank is released for abrasive blasting and painting. Alternatively, effective control should secure that the temperature of the coated side of the steel plates does not exceed 120 °C at any time.

Most of the above work is carried out by disk grinder, while grinding in corners and small openings shall be carried out using a high-speed drill. The conical stone is also recommended for cleaning local steel imperfections deeper than approximately 3 mm. Such irregularities cannot be ground down to a smooth surface, but must be filled up by welding.

Sufficient time should be allowed at the steel survey so that any repair work can be carried out immediately. The same procedure can be used for areas discovered during the blasting process. If certain small defective areas cannot be remedied immediately, these areas should be taped off for later repair and their positions noted.

Chemical contamination including soluble salts
Various types of harmful chemical contamination can be present on the steel surface:

Water soluble salts shall be removed by high pressure fresh water hosing until the concentration is below 5 µg/cm² (50 mg/m^2). Lower concentration may be specified for certain uses and products, such as potable water. Please follow the instructions in the Product Data Sheet (PDS) and Hempel’s specification. Control for contamination of soluble salts shall be carried out according to ISO 8502-9.

Welding smoke along manual welding seams containing alkaline salts shall be checked preferably as water soluble salts or – for non-exposed welds - with pH indicator paper in a zone of 2-8 cm on both sides of the weld. If pH is above 9 or the soluble salt concentration is above 5 µg/cm² (50 mg/m^2) the area shall be high pressure fresh water washed.

Oil and grease shall be removed completely by washing with emulsifier followed by high pressure freshwater hosing. Minor spots of oil/grease may be cleaned with thinner and plenty of clean rags - avoid smearing out the contamination. Cleaning must be continued until oil or grease is no longer visible on the rag.

Anti-spatter agents should generally be avoided, but when applied they must be water soluble and free of oils or silicone. All residues must be removed by high pressure freshwater cleaning.

Water used for all washing and cleaning operations shall be fresh water with a maximum salt content of 20 ppm.

Checkpoints for surface prior to surface preparation
The steel work phase should be concluded with a joint inspection declaring the surface fit for surface preparation. This statement should further rest on the parties written approvals based on documented inspections of each check point. Alternatively, non-conformance reports shall be circulated.

Check point	Method	Phase / Frequency	Criteria	Action
Welds: Spatter and slag, undercuts, pores, end craters and profile	Visual as per ISO 8501-3	Before blasting	ISO 8501-3, grade P3 Description 1.1 to 1.6	Removal by grinding. Pores to be punched open. Profile dressed by grinding
Sharp edges	Visual	Before blasting	ISO 8501-3, grade P3 Description 2.1 to 2.3	Rounded or three pass grinding
Steel surface, generally	Visual	Before blasting	ISO 8501-3, grade P3 Description 3.1 to 3.6	Removal of defects by grinding or other appropriate methods
Welding smoke	pH-paper	Before blasting	pH less than 9	Wash welding zones
Oil and grease	Visual. Solvent cleaning with light coloured cloth for spot check	Before blasting or on suspicion	No residues visible on light coloured solvent cleaning cloth	Wash with solvent or emulsifier and high pressure freshwater cleaning
Soluble salts	ISO 8502-9 (conductivity)	Before blasting	Max. 50 mg/m²	High pressure, fresh water Cleaning
Anti-spatter agents	Visual	Before blasting	No detectable amount is accepted	High pressure, freshwater cleaning

Table 1. Checkpoints for surface prior to surface preparation

Surface preparation

The performance of tank coating systems depends on achieving the specified degree of surface preparation.

Chemical and physical cleanliness are considered of equal importance. The purpose of preparation is therefore to create a clean surface with a sharp, dense roughness profile fit for the specified coating.

Surface preparation shall be carried out by abrasive blasting. Mechanical and power tooling should only be carried out on specific cases and after consultation with Hempel.

Compressed air equipment for abrasive blasting
During blasting, compressed air equipment should provide and maintain a minimum pressure of 700 kPa (equal to 7 bar or 100 psi) at the blast nozzle. The air supply can be tested according to ASTM D4285 and should be dry and free of oil.

Blast media
Blast media must provide the specified blasting results, without leaving "smeared out" particles or excessive amounts of abrasive residues on the surface.

Blasting abrasives shall be sharp, dry, clean, free of contaminants and of the right size to provide the specified cleanliness and surface profile.

Mineral grit is recommended; abrasive material containing free silica (such as silica sand) shall not be used. Metallic grit abrasive according to for example ISO 11124, parts 1-5 and ISO 11125, parts 1-8 are acceptable when kept free of water soluble matter, oil, grease and other foreign matter. The amount of ferrous oxide (Fe_2O_3) or cuprous oxide (CuO) shall not be higher than 2% in weight. Cast iron or malleable iron shot shall not be used.

Recycling of abrasive is not recommended to avoid accumulation of contaminants.

Each delivery of blast media should be supplied with a certificate, for example according to ISO 11126, parts 1-10 and ISO 11127, parts 1-8. The moisture content for material delivered in bags or bulk shall not exceed 0.5 % (in weight).

Blast media supplied on site without certificates shall be tested in accordance with Hempel's instructions stated in Hempel’s “Coating Reference Handbook” concerning:

Property	Acceptance criteria
Soluble salt level (mineral and metallic): *As per ISO 11127-6:* *As per ASTM D4940-10:*	Conductivity[1]: Maximum 25 mS/m – 250 µS/cm Maximum 45 mS/m – 450 µS/cm
Oil and grease	Contamination not accepted
Hardness and grain size distribution	Must provide the specified degree of cleanliness and surface profile

Notes:
[1] ISO 11127-6 and ASTM D4940-10 apply different methods for extracting water soluble salts. Accordingly, conductivity values are not comparable.

Table 2. Tests for blast media without certificates

Ventilation, relative humidity and temperature during blasting
Steel temperature must be minimum 3°C/5°F above the dew point of the surrounding air.

Relative humidity of the air (RH) as well as the steel temperature during and after blasting is of importance for preventing re-rusting. A chemically clean steel surface will stay free of corrosion if RH is below 50 %. In case of exposure to normally occurring salts, fine dust, soot particles, etc. a maximum limit of 40 % RH will still keep the surface from corroding. Should re-rusting occur under these conditions it is a strong indication of the presence of water soluble substances, which should be removed due their very harmful impact on the service life of the coating.
According to the above mentioned, the relative humidity should be below 50%, preferably 40%.

Ventilation during abrasive blasting should be balanced between the needs for visibility and low RH. It may, as an example, be necessary to increase suction from the tank to compensate for air admission during blasting. It is important to fully utilise the ventilation capacity by arranging the flow in such a way that it flushes the work surface even if it means moving the inlet and outlet points according to the blasting progress.

Abrasive blasting procedure
A reference area should be blasted and jointly inspected by all parties for acceptance of degree of cleaning and roughness profile before starting the main blasting process.

The steel surface must be abrasive blast cleaned according to ISO 8501-1:2007, Sa 2½ - Sa 3. This demand is to be understood as Sa 3 at the moment of abrasive blasting, but giving allowance for a slight reduction to minimum Sa 2½ at the moment of paint application.

The surface profile must conform to the requirements stated in the Product Data Sheet (PDS) of the relevant the product.

Irrespective of condition all shop primer shall be fully removed. To facilitate the blasting process shop primers should have a colour contrasting to blasted steel.
The exception to the above is cargo oil tanks of crude oil tankers. In this case, please consult the most updated version of IMO PSPC MSC.288(87) for details on how to proceed.

All marking (paint) must be removed.

All scallop edges, lightening holes and internal surfaces of hatch coaming, back or return edges are to be considered. Areas on bottom covered by scaffolding support tubes shall be kept in mind in the blasting schedule.

Already coated areas, such as upper part of the tank, may be protected against over-blast damage by masking off from approximately half a metre from the uncoated zone.

At completion of blasting or a blasting shift, the area should be cleaned and quality checked. This includes blasting profile, level of chloride contamination and removal of grit adhering to steel surfaces. Results should be recorded in the daily inspection reports.

After completion of blasting all dust and abrasives of all surfaces, staging, tank fittings, etc. must be removed. The final cleaning must be vacuum cleaning.

Checkpoints for abrasive blasting procedure
During inspection of abrasive blast cleaning, special care shall be taken to check areas with difficult access. This shall be done using good lighting and mirrors. The same is valid for the final check of the cleaning for dust and debris; these contaminants can hide in all sorts

of cavities, recesses and joints in the tank and the staging. For this reason, the staging should be carefully cleaned and the ventilation run at full capacity before the final cleaning is inspected.

When checking ambient conditions special care should be taken to record the full variation (hot and cold areas) of the steel temperature caused by, for example, day/night rhythm, orientation to the sun, water level, inlet of heating etc.

Check point	Method	Phase / Frequency	Criteria	Action
Wrappings	Visual	Before start of blasting	Correctly mounted	Re-rigging or special cleaning procedures
Remove "blast wrapping"	Visual	After approval of blasting	Removed	Remove
Degree of cleaning	ISO 8501-1:2007	By completion of rough cleaning	Sa 2½ - Sa 3 No pitting	Reblasting
Roughness profile	Rugotest No. 3 ISO 8503-1	20-30 spots picked at random representing the tank	Conform requirements in the PDS of the relevant coating	Reblasting by other procedure or media
Rough cleaning	Visual	Full area by completion	Shall allow full inspection of blasting	Recleaning
Final cleaning	Visual. Dust tape test (ISO 8502-3)	Full area by completion	No dust	Recleaning by vacuum cleaner
Oil and grease	Visual. Solvent cleaning with light coloured cloth for spot check.	Before blasting or on suspicion	No residues visible on light coloured solvent cleaning cloth	Wash with solvent or emulsifier and high pressure freshwater cleaning
Laminations	Visual	By completion of rough cleaning	Not acceptable	Grinding and reblast/ rough grinding
Ambient conditions[(1)]	Dry bulb temperature Wet bulb temperature Relative humidity Steel temperature Dew point	2-3 times/shift. By changes in outdoor conditions. Steel temp. at areas with extreme temp.	RH 40-50 % Steel temp. depending on product and 3°C above the dew point	Improve conditions or stop blasting work

Notes:
[(1)]A calibrated capacitative humidity gauge can be used. Measurement close to the specified criteria shall be double checked using a calibrated sling psychrometer

Table 3. Checkpoints for abrasive blasting procedure

Paint mixing and application

Paint mixing
Homogenization, mixing and dilution shall be done just prior to application.
Homogenization and mixing of open paint containers shall take place in a well-ventilated place, away from sparks and open flame. If a thickened layer has formed in a newly opened can, the paint shall not be used

All paint components shall be homogenized in the original container and proper dispersion of the pigment settled at the bottom shall be checked. If there is any difficulty in homogenizing the pigment, the paint shall not be used. In the case of paints of two or more components, previously homogenized components shall be mixed in accordance with methods and ratio in the Product Data Sheet (PDS) of the relevant product. Thinning shall also be in accordance with PDS and Hempel's instructions.

Mechanical stirrers are used for mixing. During application, this mixing shall be carried out at frequent intervals to ensure the pigment is properly dispersed.

Paints shall not be left in the spray equipment and hoses when the application is stopped or paused in order to avoid blockage.

Paint application
All paint systems shall be applied according to Hempel's specification, PDS and recommendations.

The application shall take place in the presence of the contractor's qualified supervisor/inspector who will be responsible for preparation and application during the project.

Paint of the specified type, with the correct temperature shall be stored on site in an amount relevant to consumption.

Paint application equipment
Paint application shall be carried out with spray equipment. Pumps shall be equipped with clean, high pressure hoses (and filters if needed). All the equipment shall be clean, in good condition and earthened. Spare parts must be readily available to ensure a continuous application. It is recommended to keep a working, spare pump ready in case it is needed.

Brush application shall be restricted to stripe coats, bolted joints, weld areas, edges and all other areas inaccessible for spray application.

Application by roller may be allowed for large areas which cannot be spray applied but after consulting Hempel.

Ventilation, relative humidity and temperature during application, drying and curing
Steel temperature must be minimum 3°C/5°F above the dew point of the surrounding air and in accordance with the Product Data Sheet (PDS) of the relevant product(s).

Ventilation, relative humidity (RH) and temperature during application, drying and curing shall be in accordance with the recommendations in PDS.

Application, drying and curing at temperatures near to the lower limit must be closely monitored using well calibrated electronic temperature gauges. In case of epoxy coatings, any sign of amine-blushing must be removed by (hot) water washing followed by sanding after the coating is cured.

It is important that the air flow is forced to flush the entire coated surface. Possible areas with risk of stagnant air require additional ventilation.

Proper functioning of ventilation and heating installations during night hours should be documented.

The volume of air and the circulation over the coated surface should be capable of removing the evaporating solvents at a rate ensuring drying conditions and keeping their concentration below 10% of Lower Explosive Limit (LEL).

When relevant, the temperature of the inlet air used to increase the steel temperature can be reduced after application of the tank coating. Only sufficient hot air should be supplied to keep the steel temperature of the tank above the dew point and at the temperature needed for drying/curing. Too large a volume of too hot air may lead to surface film drying/curing and hence solvent entrapment.

Holding/blast primer
Surfaces cleaned and prepared for painting shall receive the primer (i.e., first coat of the paint system) before showing signs of oxidation or contamination. If this happens, the surface shall be prepared again.

In some cases, application of the primer before first signs of corrosion occur is not possible, especially in big diameter tanks (>30 metres) placed in humid and hot climates and without adequate relative humidity and temperature control equipment. A holding/blast primer can be applied to provide temporary protection to the freshly blasted steel. It is important that this holding/blast primer is fully compatible with the subsequent lining system. This includes having the same chemical resistance so as not to compromise the performance of the full system.

Caulking
Steel plate overlaps, seams and welds in tank bottoms and walls, the same as the chime area (the joint area between wall and floor plates) should be properly filled in to obtain a smooth, continuous surface to apply the tank lining system on. This step is known as caulking.

The product to be used as caulking material (filler/surfacer) for these areas must have the same chemical resistance as the whole system to make sure the performance is not compromised in these areas.

Please refer to Hempel's Technical Guideline "Caulking of tank bottoms and walls".

Painting procedure
Care must be taken to obtain sufficient Dry Film Thickness (DFT) over edges, openings, rear sides of stiffeners, welding seams etc. Thus, on these areas stripe coating with brush is required.

It is very important to use tips of the correct size and fan angle. A working distance of 30-45cm from the spray gun to the surface shall be aimed at.

To obtain good and steady atomising, the viscosity of the paint must be appropriate and the spray equipment must be sufficient in output pressure and capacity. At high working temperatures, use of extra thinner may be required to avoid dust-spray. However, this can only be added if indicated in the PDS of the relevant product(s) and/or after Hempel's instruction. Solvent free epoxies cannot be thinned.

As a rule, it is recommended that the application is started from the lower part of the tank, working upwards to the top. Any dust/dry spray attached to painted surfaces must be removed by very light sand papering between coats or by cautious scraping with a glass or steel

plate Care must be taken in order not to damage the coating. Covering the entire lower staging floor level with tarpaulins will reduce the amount of dust falling from the top of the tank considerably.

It is of special importance that a continuous, properly coalesced and pinhole-free paint film is obtained at application of each coat. An application technique which will ensure good film formation on all surfaces must be adopted in order to avoid pin holing, holidays and excess build up, producing even coats at the recommended film thickness.

Dry spray is not acceptable. Areas in line with the staging boards and around corners of corrugations are especially prone to dry-spray and/or poor film formation. Special care must be taken when spraying these areas.

Irregularities and contamination in the film such as cracking, sagging, dust, dry spray, and abrasive particles shall be remedied.

Minimum and maximum overcoating interval times between coats shall be strictly observed in accordance with the PDS of the relevant product(s). The application of every subsequent coat shall be done after ensuring there are no paint spatters, sagging, inclusions, overspray, etc. on the previous coat/substrate. This can be removed by scraping and/or sandpapering.

The contractor should register the number of drums with each batch number for both base and curing agent used in each coat and in each tank. This information should be reported to owner's and Hempel's representative.

Measurement of film thickness
During application the operators and/or their supervisor should maintain a close monitoring of the wet film thickness (WFT) making sure that the WFT of each coat is kept on level with the specification.

Dry film thickness (DFT) control shall be carried out after the coating has achieved sufficient hardness for light traffic. However, the control must also be made soon enough to make rectification of too low film thickness possible, i.e., within the recoating interval.

The acceptable DFT range is detailed in the specification and/or PDS of the relevant product(s).
DFT stated in the standard specifications is nominal dry film thickness (NDFT). For measurement of the film thickness the following applies:

- Measurements must be carried out using an electromagnetic dry film thickness gauge (ISO 2808) adjusted with calibrated foils placed on a smooth steel substrate.
- The minimum DFT is evaluated according to the "90:10"-rule unless otherwise agreed per specification.
  The "90:10"-rule means that no more than 10% of the total number of measurements must be below the specified DFT and no measurements must be below 90% of the specified DFT.
- Observe the maximum DFT for individual coats.
- Unusually high or low readings that cannot be repeated shall be discarded.
- The following guidelines can be applied for final control of DFT:
  - The number of measurements should on average be one reading per two square meters of painted surface (less on regular surfaces and more on complicated and difficult to apply surfaces).
  - The areas should be selected so that all construction details are represented by the sample.
  - Measurements should be taken to provide a representative profile of the coating thickness, for example distinguishing between open surfaces (smallest dimension larger than 150 mm) and narrow surfaces (smallest dimension less than 150 mm).

Removal of staging and scaffolding

Normally, staging is removed after the upper areas have been painted according to the specification and accepted by all parties concerned. During removal of staging, it is inevitable that damages occur. Destaging damage is always difficult to see from the top of the tank. Consequently, a systematic repair and touch up should be carried out during dismantling of staging. Start from the upper part and finish repair - note especially the fittings - before the next level of staging is removed. Protect the tank entrance area with rubber sheets.

Permanent installations

The tanks are equipped with a number of installations. Some might be coated before mounting, some are made of noble metals and some will be coated on site.

Piping system
In case piping systems such as cargo pipes, stripping lines, pipes for inert gas, pipes for permanently fixed tank washing equipment, couplings, valves, pipe supports, etc. must be coated, they shall be abrasive blasted internally (and/or externally) and coated with the full system before installation. Also, supports for pipes should be abrasive blasted and coated before installation.

On approval by the owner, pipes, supports etc. may be hot dip galvanised, or coated by fusion bonded epoxy, zinc silicate or epoxy or phenolic epoxy tank coating, as appropriate.

Uncoated noble metal
Items of stainless steel, brass or similar should be insulated from the tank surface to prevent the risk of galvanic corrosion.

Spillage of acid pickling liquid or gel for stainless steel passivation must be avoided as the acid may damage the coating.

Fittings for scaffolding
If fittings are made of stainless steel, great care must be taken to obtain a sound paint film on the welding zone, in general at least covering the first 100 mm of the stainless steel to the tank surface. If approved by owner, the fittings may be made of hot dip galvanised steel.

Bolted installations
Items assembled by bolts and, therefore, not later accessible for painting should before mounting be completely coated according to the specification, at least on the contact faces. Items of stainless steel, brass or similar shall be insulated from the tank surface to prevent the risk of galvanic corrosion. Alternatively hot dip galvanised bolts may be used depending on owner's approval.
Damage caused by mounting of bolted items is to be repaired according to the repair procedures for small areas.

Repairs

All damage to the coating should be repaired as early in the scheme as possible. All repaired areas must be fully cured before the tanks are taken into use.

Repairs shall be carried out using the same coating materials as specified for the main work, following the specification and information in the PDS of the relevant product(s), Hempel's specification and recommendations.

Always mix just the amount of paint needed in order to reduce waste.

Repairs by brush application always require additional number of coats compared to spray application.

Repair process
Before mechanical surface preparation is started the areas to be repaired shall be cleaned for any salts and other contamination.

In order to avoid contamination from the upper part of the tank the area to be repaired should be sealed off with a tent. In case of floating roof tanks, the internal floating roof can be used as a cover.

In floating roof tanks, the underside of the roof shall be cleaned or sweep blasted to remove loose corrosion and other contaminants that may fall down and contaminate the area to be repaired. For protection against rainwater the gap between the floating roof seal and the tank shell shall be waterproof.

The various size of the repair area calls for different methods. In the following sections the procedure has been laid out distinguishing between three sizes:

Small areas
Areas up to approximately A4 size (20x30 cm) or scratches of up to a few millimetres across are considered small areas.

The surface preparation can be executed by sanding or grinding using the criss-cross method to a uniformly clean and rough metal surface, feathering edges of intact coating and slightly roughening the adjacent surface to ensure overlapping with the sound, surrounding area. Remove all dust. Grain size P60 to P80 is recommended for final sanding including overlap zones.

Touch-up with the coating material specified using stippling for the first brush coat. Roller application is not accepted.

This method of repair is only acceptable in view of the risk of excessive damage by vacuum blasting or open nozzle blasting such small areas.

Cracks, in corners or at single sags, may preferably be repaired according to this method.

Medium size areas
Medium sized areas are areas up to 1 m².

Such areas should be prepared by vacuum blasting or by open nozzle blasting (pencil blast) - depending on the extent of the repair. Precautions must be taken against damage from over-blasting.

Degree of surface preparation as of the original specification.

Touch-up as described for small areas, however, spray application with narrow angle nozzles may be used.

Large areas
Areas larger than 1 m² or areas where several small, damaged areas are concentrated. The procedure is basically a repetition of the original specification. Precautions must be taken against damage from over-blasting.

Tank bottoms repair
Repairing of tank bottoms is a special case of repair of large areas.

After some years in service tank bottoms may experience pit corrosion, in particular crude oil tanks. This means a reduction in steel thickness and thus specific repair and maintenance operations are needed to extend the service life of the tank.

Omega pit Open pit

The presence of pits in the steel calls for special procedures utilising thick film solvent free epoxy linings, in many cases as part of a reinforced system. This applies to light, moderately and severely pitted bottoms which are structurally sound. If steel thickness is too low or with holes the weak areas must have the steel replaced; no reinforced scheme can be substitute of this.

Please refer to Hempel's Technical Guideline "Tank bottoms repair".

Repair procedure for inorganic zinc silicates
Repair procedures for inorganic zinc silicates are different from those previously outlined for organic coatings. When repairing inorganic coating, only a single coat 50 to 100 micron (2 to 4 mils) in thickness is involved. The failure of this type of coating is primarily by pinpoint rust forming after a long period of life or use.

Abrasive sweep blasting, as previously described, is the preferred method of preparing the surface. Pressure shall be lower than epoxies in order to avoid microcracking. Using this method, the rust stain from any pinpoint failure is removed, any major failure area can be removed during the blasting process, and the sweep blasting will break up the surface of the existing inorganic zinc or galvanising and allow adhesion of the following coat.

For very small areas of failure, power sanding of an inorganic zinc surface can also be done to remove rust and roughen the surface. A medium to coarse sanding disc should be used which will cut the surface, but not polish it.

Once the surface of the inorganic zinc is prepared, the repair can be done by brush.

Detection of holidays, pinholes and damaged spots: sea water test/high voltage test

Holidays, pinholes and bared/damaged spots shall be detected after full cure of the coating system (dry to handle in case of solvent free coatings) and repaired before the tank is put into service. There are different procedures for this:

- **Seawater test**
  - Fill up the tank with clean seawater for approximately 1 hour.
  - After draining, close the tank for minimum 12 hours (still in wet condition) prior to inspection.
  - Check visually for rust indicating bare spots, pinholes, damages, etc.
  - If any repair must be carried out, wash the tank with freshwater and thoroughly dry all surfaces.
  - If freshwater is used, the test time is double (minimum 24 hours)
  - In case of zinc silicate coatings it should be stressed that small bare spots and small damaged areas usually will not show up by such short-term exposure because of the galvanic protection from the surrounding paint film.

- **High/Low voltage pinhole detection**
  - According to ISO 29601, where specific voltage is indicated depending on dry film thickness.
  - This should only be attempted on coating systems with sufficient dry film thickness and consisting in non-conductive coatings. E.g it is not suitable for zinc silicates and antistatic coatings.

Inspection

The supervision of the tank coating job should contain the following information:

1. Rigging of work site
2. Steel work prior to the surface preparation
3. Surface preparation
4. Paint application
5. Destaging and repair
6. Detection of holidays, pinholes and damaged spots
7. Final acceptance

All stages of the tank coating work are to be logged and systematically recorded, including any problem encountered (paint problems, complaints, ventilation, dehumidification problems, etc). It is recommended that the testing equipment has a calibration certification not older than 12 months.

It is essential that all information relating to the work is passed on to all relevant parties as soon as possible.

Checkpoints during application
Markings during inspections are to be done with an ethanol-based marker and kept as limited as possible. Chalk is not acceptable.

Check point	Method	Phase / Frequency	Criteria	Action
Rigging of work site [(1)]		Before start-up		Re-rig, clean up
Application equipment	Inventory	Before start-up	Pumps, hoses, tips, wet film gauge etc. in order	Additional equipment
Arrangement of application equipment	Visual	Before start-up	Good, shielded mix. and work procedures[(5)]	Rearrange
Ventilation system	.	Before start-up and two times daily until full curing		
Wrapping	Visual	Before start-up	Correctly mounted	Rearrange
Mixing, stirring and paint temperature	Observe procedure & condition record batch & consumption	By start-up and daily	According to data sheet, instructions & specified thickness	Change procedures
Paint storage[(5)]	Ambient conditions	Daily	Data sheet	Change conditions
Application schedule	Record time	At start-up		Re-inspection
Stripe coating[(2)]	Visual (mirror)	After first and second coat	Full coverage	Touch-up and full inspection routine
Individual coats	Visual, (WFT) and DFT[(3)(4)]	Each coat according to section 6.3.	Full coverage Correct film formation Min/max DFT according to specification	Touch up, sanding, correct spray procedures or parameters

Notes:
[(1)] Precaution to avoid ingress of contaminants into the tank should be taken. Used abrasive should be removed from the deck, and all openings into the tank should be protected against ingress of dust and water. Operators entering the tank should change to clean, soft soled shoes or carry clean shoe covers.

[(2)]Special care should be taken on areas with difficult access.

[(3)]WFT should be taken during application by the operator, especially at the beginning of the application. DFT is to be measured as soon as the coating has achieved sufficient hardness for light traffic. Visually the coating shall be uniform in colour, gloss and structure without sagging, spray dust, contamination of dust, grit, debris or paint flakes. Special care should be taken on areas which are difficult to reach or cover by spraying, such as reverse sides, cut outs, corners, edges and welds.

[(4)]DFT must be measured by an electromagnetic gauge according to ISO 2808 The gauge must be calibrated on smooth steel and within the region of the specified film thickness. Calibration foils shall be without any signs of wear and be verified according to a documented procedure.

[(5)]Preferably container with heating/cooling facilities

Table 4. Checkpoints during application

Checkpoints for final inspection

Check point	Method	Phase / Frequency	Criteria	Action
Finish	Visual (mirror)	After completion of area before destaging	Uniform colour, gloss and structure, no sags, swelling, wrinkling, spray dust and contaminants	Removal or sanding and touch up
Imperfections	Visual (mirror)	After completion of area before destaging	Full coverage. No pinholes, holidays and pores; no cracking, blistering, cratering, peeling	Sanding and touch up
Holidays, pinholes and damaged spots	Sea water test/ High voltage detection	After completion	No rusty spots or areas accepted	Repair
Dry film thickness	Electro-magnetical gauge (ISO 2808) according to plan	After completion of area before destaging	According with specification	Grinding, touch up or application of extra coat

Table 5. Checkpoints for final inspection

Taking the coating into service

The tank lining system must be fully cured, referring to information given in relevant PDS.