

Application Guide for Dual-layer Fusion-Bonded Epoxy Coatings

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1.0 Introduction

This document provides guidelines for the factory application of dual-layer Fusion-Bonded Epoxy (FBE) coatings used to protect the external surface of line pipe and fittings.

2.0 General overview

FBE coatings provide high quality corrosion and mechanical protection of pipelines used for the transmission of oil, gas, slurry and water.

Dual-layer FBE coatings are formulated to deliver specific topcoat performance. They can provide anti-slip properties for subsequent concrete weight coating, extra mechanical protection or UV resistance for above-ground pipelines.

The critical steps that must be controlled are:

- 1) Surface preparation and cleanliness
- 2) Blast cleaning
- 3) Cleaning procedure
- 4) Preheating
- 5) Final cleaning and inspection
- 6) Surface conditioning
- 7) FBE coating application
- 8) Post treatment
- 9) Final inspection and quality control
- 10) Repair procedures
- 11) Pipe handling

A review of each step follows.

3.0 Surface preparation and cleanliness

Proper attention to the cleaning and preparation of the steel pipe surface prior to abrasive cleaning has a considerable effect on the eventual quality of finished coating.

The basic elements of pre-cleaning are:

- 1) Removal of surface contaminants
- 2) Loosening of mill scale (on new pipe)
- 3) Removal of frost and moisture

Steel pipe may be contaminated by salts, soil, grease, oil, organic coating residues and mill treatments. It is important that all of these contaminants are removed prior to the first abrasive cleaning step. Failure to remove contaminants may lead to contamination of the abrasive media which will cause poor performance of the subsequently applied coating. Deeply embedded salts and certain organic contaminants will, if not completely removed, cause adhesion failures and film formation problems.

Sometimes, due to environmental conditions, prior removal of snow and ice from the inside and outside the pipe may be necessary. This is best accomplished in a staging area with overhead or bottom heating devices or by immersion of the pipe in hot water (75–85°C / 167-185°F) for 3-5 minutes, which effectively removes surface salts and dirt, and also uniformly preheats the pipe.

The most appropriate way to pre-clean pipe depends on the type and degree of contamination. Salts and soil can be effectively removed with high pressure water (1000–2000 psi), while organic contaminants require a hydrocarbon solvent cleaning such as xylene or mineral spirits. If the oily contamination affects a large area of the pipe then oven burn off, at a temperature of 370-400°C, (698-752°F) may be employed, if the coating specification allows. Wire brushes are effective in removing loose mill scale and dirt.

The next stage is to preheat the pipe, preferably by direct gas flame burners, to loosen mill scale (if present), remove moisture, burn off organic matter and condition the pipe surface for easier abrasive cleaning. The pipe steel temperature is at this stage typically higher than 50°C (112°F). Electrical induction heating is also acceptable for preheating.

4.0 Blast cleaning

The purpose of abrasive blast cleaning is to achieve a clean surface, having an angular surface profile with an average profile depth between 50-100 microns (2-4 mils). The surface cleanliness should meet a minimum of "near white metal" quality as described under any of the following specifications:

SSPC – SP10	NACE No. 2	Sa2½
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This can be achieved most effectively with centrifugal type blasting equipment using steel grit as the abrasive media.

5.0 Cleaning Procedure

If two blast chambers are present, shot may be used in the first chamber for pre-cleaning and grit in the second chamber. It is not recommended to mix shot and grit in the same chamber. Where a single blast unit is in operation, it is recommended to use steel grit only.

The first cleaning step will establish the basic cleanliness. It will also uncover pipe defects such as slivers, burrs, laminations, scabs and gouges. Disc grinding or other suitable methods must be employed to correct these defects. If serious defects exist, the pipe should be rejected at this stage.

The next step is a second abrasive cleaning process using G-25 or G-40 (or as required by the coating specification) steel grit as medium, having a hardness of 50–60 Rockwell C. The main purpose of this step is to achieve the final desired cleanliness and the desired anchor profile. Often only a "light" blasting is necessary for best performance, if the first stage has been performed efficiently.

Regardless of the type of operation, it is important that the centrifugal wheels should have adequate horsepower and be positioned correctly to achieve high quality and efficient cleaning. Abrasive residues should be removed from the interior of the pipe with compressed air or by other suitable means. A good quality abrasive medium should be used and replenished regularly to ensure a balanced working mix.

6.0 Final Cleaning and Inspection

All abrasive dust needs to be removed, usually by vacuum or air knife and the level of cleanliness checked periodically by pressing a clear adhesive tape onto the pipe surface and examining the underside for dirt particles.

It is more difficult to check for oil or organic matter contamination. The use of surface tension measurements, using wetting tension solutions of known values and characteristics, provide the best information. However, for practical purposes observing how well a drop of clean water will wet the surface is a useful indicator.

All pipe coating operations require a "near white metal" blast quality. In most cases, a skilled operator can visually recognize the required standard using visual standards (NACE or Swedish pictorial standards).

It is very important that the required anchor profile is achieved. The profile should be angular but should not have "undercuts" that can result from "over blasting", wrong abrasive or improper positioning of the centrifugal wheels. The profile can be measured by instruments such as an Elcometer Surface Profile Gauge or Testex Press-O-Film.

It is very important that the period between cleaning and coating be kept as short as possible to avoid deterioration of the surface.

7.0 Surface Conditioning

Sometimes it is desirable to use a chemical pre-treatment on the surface of the pipe. This could be for example due to the presence of soluble salts remaining on the steel surface and this has a secondary benefit of washing off dust residues.

A weak phosphoric acid solution in water has been found to perform well. It is highly important and critical to the success of this pre-treatment that remaining acid is removed by thorough water washing immediately following the treatment. The rinse water should be reverse osmosis or de-ionised water.

Acid washing is mandatory if the pipe has been subjected to corrosion attack in the presence of chloride or sulphate ions prior to processing at the coating plant. A common cause of this is salt-water exposure during sea transport of the pipe from the steel mill to the coating plant or from stockpiling near salt water or in an atmosphere containing SO₂ or industrial CO₂. Under these conditions, ferrous salts will form that will be retained on the steel surface, particularly in pits, even after normal abrasive cleaning.

A good test to establish the presence of ferrous salts is by using Potassium Ferricyanide or Phenanthroline tests. The Elcometer SCM400 salt test meter is commonly used for this test.

Any pipe showing presences of ferrous salts must be appropriately treated.

Proper surface treatment ensures that the pipe surface will be free of harmful contaminants arising from transportation or coating plant operations.

Additional coating performance enhancement can be achieved by treating the clean pipe surface with a chromate solution prior to the final preheat.

A chromate solution in water is applied by spreading the solution uniformly over the pipe surface. Spreading of the solution is done with a rubber "squeegee" or brush. If the process is well controlled, there will be no run-off material. It is important that any waste material is collected for appropriate disposal as required by local regulations.

8.0 Preheating

Correct heating of the pipe joint is one of the most important steps in the successful application of fusion-bonded epoxy pipe coatings. The steel must reach the appropriate application temperature recommended by the FBE manufacturer to achieve optimum performance of the FBE coating. The pre-heating temperature can vary according to the grade of material. At no time should the metal temperature exceed 275°C (527°F) as this may cause metallurgical or surface defects. A strong "blueing" or darkening of the pipe surface is one indication of excessive heating.

With the introduction of high grade steels, there may be further restrictions on maximum heating temperature.

Acceptable heat sources are:

- a) Gas-fired radiant heat
- b) Gas-fired direct flame
- c) Electrical induction

It is important that gas-fired heating systems are well adjusted so that products from incomplete combustion are not deposited on the steel surface.

With induction heating it is important that the appropriate frequency is used to ensure "deep" heating. Intense skin heating must be avoided. Multiple induction coils are recommended for stable heating, especially in the case of thick wall pipes.

Uniform metal temperature at the specified levels must be maintained for the best results. The temperature must be controlled at the entrance to the coating chamber. Tempilsticks are most commonly used and can be very effective when used by experienced operators. Infrared Pyrometers are satisfactory control tools, but must be calibrated regularly to ensure their accuracy. When using pipe connectors, the possibility of "cold ends" should be considered.

9.0 FBE coating application

Powder application is best accomplished by electrostatic spraying.

It is important that a fluidizing powder feed and a suitable reclaim system is used. The number of guns in use may vary depending upon the required film thickness and pipe diameter. When the guns are properly set up there should be relatively little overspray in the powder chamber.

The key feature of dual-layer coating application is that a top layer is applied directly over the primary layer, usually during the melt stage of the primary coating. The application is best performed in two separate spray booths situated side by side. This will facilitate the recovery and use of reclaim powder. It may also be possible to install a partition into an existing large spray booth. If powder from both layers is to be recycled there should be two entirely separate reclaim systems. In the case of anti-slip coatings and UV resistant coatings, it may not be economically viable to install a second reclaim system.

The following important points should be considered:

- a) The pipe must be well grounded during its entire travel through the coating chamber.
- b) The proper charge on the sprayed powder must be maintained (normally 50–100 kV).
- c) The guns should be positioned appropriately in the coating chamber to give a uniform powder deposition.

The guns should be at such a distance from the pipe surface to make optimum use of the electrostatic properties and give minimum overspray. This distance is likely to be 5–10 inches from the pipe surface and is, to some extent, dependent upon the pressure necessary to uniformly transport powder through the line. As a starting point, position the guns at a distance of 8 inches from the pipe. Then adjust according to film thickness requirements, pipe size and line speed.

Powder delivery tubing should be of the appropriate diameter (usually 12 mm or greater) and the

length be as short as practical with minimum restrictions between the guns and fluidized bed. Avoid gravity effects on powder flow through the tubing by careful routing of the supply pipe.

Improper adjustments can also result in the more serious problem of gun clogging. This can also be caused by either the guns being too near the hot surface, or partially cured overspray entering the diffusers. Proper design and selection of diffusers will minimize problems.

The best positioning of the guns is at the side of the rotating pipe with the pipe surface travelling in an upward direction. This will minimize detrimental effects from radiant heat and gun clogging. The deposition rate should be adjusted to give a steady build-up of the required film and not flood the pipe.

A test should be made to measure the necessary powder delivery for a given pipe diameter and speed. This information can be used to determine deposition efficiency and effectiveness of equipment settings.

It is important that all air used in the coating chamber and supporting systems is clean and dry. Moisture can cause both deposition problems and coating deficiencies such as porosity and pinholes. Worse problems will result from air contaminated with oil. In addition to causing coating defects oil contamination is a major cause of impact fusion, which can cause system clogging and erratic spray patterns. Excess porosity can also be caused by a high powder deposition rate.

Excessive electrostatic charge must also be avoided since this may cause back ionisation and possible film defects. Poor positioning may result in spirals or striping on the surface. A 60 or 80 mesh screen is recommended in recovery systems to eliminate oversized particles. For screening virgin powder a 50 or 60 mesh screen is most appropriate. Magnetic separators should be used in the powder feed system to help remove metallic contaminants.

The coating chamber must be equipped with appropriate fire and explosion detection systems.

10.0 Post treatment

To achieve optimum mechanical and protective properties, quenching should occur after the coating is fully cured. The minimum time requirement will depend on the preheat temperature, the pipe diameter and wall thickness. Wetting of the conveying wheels to minimise "tracking" should be done.

11.0 Final inspection and quality control

Thorough inspection and coordination with the other application steps are essential for a quality coating. Inspection should be considered as part of the process control operation and not just a decision point for approving or rejecting coatings. If each processing step is done correctly, a high quality coating is assured.

Regular quality control tests to be carried out during application include film thickness, holiday detection and cure.

Cure of the epoxy layer is usually assessed by MEK rub test for a quick online evaluation and confirmed by DSC evaluation of the glass transition temperature.

Longer term tests should also be carried out periodically to assure that the system is performing optimally. These include, but are not restricted to:

- Hot water soak
- Impact test
- Cathodic disbondment test
- Flexibility test

There may be certain tests required specific to the function of the dual-layer system. For example, roughness tests for anti-slip coatings or gouge tests for coatings providing additional mechanical protection.

12.0 Repair procedures

Where the steel is exposed, it shall be repaired using a two-component 100% solids epoxy repair compound. Melt sticks should not be used.

13.0 Pipe handling

Bare pipe must not be stored in direct contact with the ground. It should be placed on wooden runners or polyethylene covered sand berms. Wooden separators should also be used as a break in the pile to allow forklift trucks to pick-up from the pile.

Careful handling of the coated pipe is essential to avoid mechanical damage during stacking, loading, transportation, stringing and lowering.

The basic requirements are listed below:

- All contact points of handling must be padded and a load spreader beam should be used for pipe lifting.
- Separators must be used when stacking pipe joints ($\frac{3}{4}$ " thick rubber pads, tyre tread, synthetic rope are suitable).
- Pipe joints should always be "lifted" rather than dragged.
- Slamming together pipe ends should be avoided.
- Bevelled ends should be protected with suitable "caps".



Note: The information on this Application Guide is given to the best of the manufacturer's knowledge, based on laboratory testing and practical experience. Jotun Powder Coatings reserves the right, without notice, to alter or change the content of this Application Guide.

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