Fusion Bond Epoxy in Three-layer Coatings

Application and processing guidelines

Fusion Bond Epoxy (FBE) coatings provide high quality protection to pipelines used for the transportation of oil, gas, slurry and water. The advantages of using Fusion Bond Epoxy coatings in a three-layer coating system can be gained through controlled plant application and the use of compatible adhesive coatings to bond the layers in the coating system.

The expertise in coating operations combined with good quality control will have a significant effect on achieving an optimum coating performance.

The critical stages to be controlled, monitored and observed are:

1. Pre-abrasive cleaning preparation
2. Abrasive cleaning
3. Final cleaning and final inspection
4. Surface conditioning
5. Pipe preheating
6. FBE coating application
7. Intercoat time
8. Post treatment
9. Final inspection and quality control
10. Coating repair procedures
11. Pipe handling

1. Pre-abrasive Cleaning Preparation

Proper attention given to the pre-cleaning and preparation of the uncoated pipe prior to the abrasive cleaning operation has a considerable effect on the ultimate quality of the surface cleanliness. A poor preparation has an adverse effect on the cleaning process and cost efficiency.

The basic elements of a pre-cleaning are:

   a) Removal of surface contaminants.
   b) Elimination of mill scale (on new pipe).
   c) Exclusion of frost or moisture.

An uncoated pipe is often covered with contaminants such as salts, soil, grease, oil, organic coating residues and mill treatments. It is highly desirable and recommended to remove as much as possible of these contaminants prior to the first abrasive cleaning operation. Failure to do so may lead to excessive abrasive media contamination, which can greatly impair production efficiencies and, to a great extent, cause deficiencies to the performance of subsequently applied coatings.
Deeply embedded salts and certain organic contaminants, if not completely removed, can cause bond failures and film forming deficiencies.

In certain circumstances, it might be necessary to remove snow and ice from inside and outside the pipe. This is best accomplished in an area with overhead or bottom heating devices. Alternatively, the pipe can be immersed in hot water (75°C - 85°C) for 3 to 5 minutes, which effectively removes salts and dirt from the surface and preheats the pipe uniformly.

The best way to pre-clean the pipe depends on the type and degree of contamination. Salts and soil can be removed effectively only with fresh water (preferably high pressure water, 1000-2000 PSI), while organic contaminants require a hydrocarbon solvent such as Xylene or mineral spirits. Wire brushes are effective in removing loose scale and dirt.

The next important stage of the preparation is to preheat the pipe, preferably by impinging flame burners to loosen mill scale (if present), remove frost and moisture, burn off organic matter, and condition the pipe surface for easier abrasive cleaning. The pipe temperature should be between 65°C and 82°C. Excessive skin heating must be avoided.

Electrical induction heating is also adequate for preheating.

2. Abrasive Cleaning

The purpose of the abrasive cleaning is to obtain a clean, uncontaminated surface, having a slight angular anchor with an average profile depth between 50 and 100 microns. The surface cleanliness should meet a minimum of Near White Blast quality as described under any of the following specifications:

- SSPC – SP10
- NACE No. 2
- SA 2 1/2

This can be achieved most effectively with centrifugal type blasting equipment, using steel shot and steel grit as the abrasive media, in two cleaning chambers separated by an ‘inspection and grinding’ station. The abrasive shot should not be larger than size S-330 and the grit not coarser than size G-18.

To obtain an optimum cleaning, the following sequence of operations is recommended

a) The pre-cleaned and preheated pipe enters the first cleaning chamber. An abrasive medium of S-280 should be used on pipes still having mill scale. If the pipe surface is mostly corroded, it is recommended to use only a steel grit size G-25 or G-40. In other circumstances a combination of shot and grit may be desirable.

b) The first cleaning step will establish the basic cleanliness and anchor patterns. It will also uncover any defects in the pipe, such as slivers, burrs, laminations, scabs and gouges. Disc grinding or other suitable methods should be sufficient to correct these defects. The pipe should be rejected, at this stage, if it shows serious defects.
c) To obtain an adequate cleanliness and anchor pattern, a second abrasive cleaning process may be required. This can be completed by using a steel grit of medium size G-25 or G-40 with a hardness of 50 to 60 Rockwell C for X65 steel. For best performance, only a light blasting is usually necessary.

d) Abrasive residues should be removed from the interior of the pipe with compressed air or other suitable means.

When only one abrasive cleaning unit is available, it is recommended to use a blend of S-280 shot size and G-25 abrasive grit size in the ratio of 50:50 to obtain good results (when used as a blend, the shot and grit must be of similar hardness, otherwise ‘grinding’ will take place resulting in excessive fines, or in grit particles rounding).

**Regardless of the operation type, the following general conditions are important in order to achieve high quality and efficient cleaning:**

a) The centrifugal wheels should have adequate horsepower and be positioned strategically.

b) A good quality abrasive medium should be used and replenished regularly (abrasive must be free of sodium nitrate).

3. **Final Cleaning and Final Inspection**

It is recommended that all abrasive dust is removed. This should be checked occasionally by tightly pressing the surface with adhesive tape, and then examining the tape 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 solution 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. The specification for pipe coating requires a ‘Near White’ metal blast quality. In most cases, a skilled operator can visually recognise the required standard. Visual standards (NACE or Swedish pictorial Standards) should be used in case of doubt.

It is essential to achieve the required anchor pattern. The profile should be angular with no ‘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 Tooke Gauge, Elcometer Surface Profile Gauge or Testex Press-O-Film.

The specified surface cleanliness should subsist at the point of coating application. It is therefore very important that the period between cleaning and coating be kept to the minimum to prevent re-contamination.
4. Surface Conditioning

It is advised to perform a pipe surface treatment to achieve an optimum surface wetting with consequently superior coating adhesion.

A weak phosphoric acid solution in water (10% of 75% concentrated acid) has been found to provide good performance. For best results, it is crucial to remove any free acid by rinsing with water immediately after the treatment. The rinse water should contain no detrimental contaminants and its maximum hardness should be 200 ppm.

Other surface conditioning procedures may prove to be equally satisfactory. For instance, a 5% Oakite 33 or FOX BOND 1099 solution in water provides excellent results. This treatment is mandatory in cases where an uncoated pipe has been undergoing corrosion in the presence of chloride or sulphate ions prior to processing at the coating plant. Such occurrences are common due to exposure to salt-water during the pipe ocean voyage from the steel mill to the coating plant, as well as from stockpiling in the vicinity of salt water or SO₂ atmosphere. In such conditions, the formation of ferrous salts will be retained on the steel surface, particularly in pits, even after normal abrasive cleaning.

To establish the presence of ferrous salts, a potassium ferricyanide or phenanthrolin test can be performed. If optimum performance is desired, pipes showing more than a trace of ferrous salts require to be appropriately treated or must not be coated at all. A proper surface treatment ensures that the pipe surface will remain free of harmful contaminants arising from transportation or coating plant’s operations.

The coating performance can be enhanced by treating the clean pipe surface with a chromate solution prior to the final preheats.

A treatment using Accomet PC, Gardobond 4504, or equal, is particularly effective. A 10% solution in water can be applied by spreading uniformly over the pipe surface. Run off should be kept to the minimum. Waste material should be adequately collected for appropriate disposal, as required by local regulations.

The recommended usage of chromate is 0.3 to 0.7kg of concentrate per 100m² of pipe surface.

5. Pipe Preheating

One of the most important steps to ensure a successful application of the Fusion Bond Epoxy coating is to ensure that the preheat temperature is correct. The steel must reach the appropriate temperature required based on a particular pipe size, line speed, and coating specifications.

The metal temperature should not exceed 275°C, as this may cause metallurgical or surface defects. A strong “bluing” or darkening of the pipe is an indication of excessive heating.
Acceptable heat sources are:

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

A gas fired heating system needs to be well adjusted to prevent deposits from combustion products on the steel surface.

When using induction heating, it is important to use the appropriate frequency to ensure a ‘deep’ heating. However, intense skin heating must be avoided. For best results, it is recommended to maintain a uniform metal temperature at specified levels. The temperature must be controlled at the entrance to the coating chamber. Tempilsticks and infrared pyrometers are satisfactory control tools. They must be calibrated regularly to ensure accuracy.

The correct application temperature depends on the powder type, the line speed, the distance to adhesive application, the adhesive type, the mass of steel and the time to quench.

6. FBE Coating Application

The powder application is best performed by electrostatic spraying. Ideally, a fluidising powder feed and a suitable reclaim system should be used. When the guns are properly set up, there should be relatively little overspray in the powder chamber.

To achieve best results, the most significant details to control are:

a) The pipe must be well grounded throughout the time it is in the coating chamber.

b) Maintain a proper charge on the sprayed powder (normally 50 - 100 KV). Control the amperage at the electrode point and maintain at 150 - 225 microamperes.

c) Position the guns strategically in the coating chamber to provide a uniform powder deposition.

To obtain an optimum advantage from the electrostatic properties and achieve minimum overspray, maintain the guns at an approximate distance of 5 to 10 inches from the surface of the pipe. To some extent, the distance depends on the pressure required to transport the powder uniformly through the line. As a starting point, position the guns at a distance of 8 inches from the pipe, then adjust based on the film thickness requirements, the pipe size and the line speed. The tubes delivering powder should have an appropriate diameter (usually 12 mm or greater), and their length should be as short as practical, with minimum restrictions between the fluidized bed and the guns. Avoid gravity effects on the powder flow through the tubes.

Two of the most common errors in adjusting the equipment are to set the guns either too close or too far from the pipe, and use excessive air pressure for powder delivery. Both will result in excessive overspray and inefficient powder deposition. Avoid excessive electrostatic charge, since this may cause back ionization and possible film defects.
An improper adjustment can result in more serious problems relating to gun clogging. This can also result from having the guns too close to the hot surface, or by having partially cured overspray getting into the diffusers. To minimize the problem, a proper design and selection of the diffusers is essential.

The best location of the guns is at the side of the rotating pipe, in a counter clockwise position. This will minimize the detrimental effects of radiant heat, gun clogging and powder reclaim. The guns should also be positioned to provide a steady build up to the required film and to discourage rapid build up of the film on the pipe.

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

All air used in the coating chamber and the supporting systems has to be clean and dry. Moisture can cause deposition problems and coating deficiencies such as craters and pinholes. Serious problems may result from air contamination with oil.

Oil contamination, in addition to causing coating defects, is a major cause of impact fusion, which can lead to a system clogging and erratic spray patterns.

To eliminate oversized particles, a 60 or 80 mesh screen is recommended in recovery systems. To screen virgin powder, a 50 or 60 mesh screen is most appropriate.

It is recommended to use magnetic separators in the powder feed system to help remove metallic contaminants.

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

7. Intercoat Time

In a three-layer coating system the time between the application of the Fusion Bond Epoxy and the adhesive is crucial in order to obtain good peel adhesion values. To optimize the peel strength, it is recommended to apply the adhesive before the epoxy coat gels. This ensures that a sufficient reaction can take place between the chemical groups on the epoxy and the adhesive. If the adhesive is applied too late, the peel strength will be very low and the peel will reveal a smooth coat of epoxy with failure between the adhesive and the epoxy.

If the adhesive is applied in powder form, there is no minimum time before the application of the adhesive. However, in the case of extruded adhesive, the epoxy has to have achieved a level of mobility to support the extruded film without skidding. The other components of the three-layer system can be applied by side extrusion, cross head extrusion or powder spray depending on the final specification for the project.
8. Post Treatment

Before quenching with water, and in order to achieve a film with optimum resistance properties, the coating curing reaction should be allowed to meet the minimum requirement. This minimum requirement depends on the preheating temperature, the pipe size, the steel mass and the three-layer system specification. The specification of the three-layer film affects this phase since the insulation properties of the outer layers will enable the epoxy to continue the curing process after the water quenching has started.

9. Final Inspection and Quality Control

To achieve an optimum three-layer coating, a thorough inspection and coordination of this function with the other application stages is essential. It is far more important to consider inspection as a means of process control rather than to simply pronounce non-specification conditions or rejection. If each processing stage was done correctly, a high quality coating will be only a natural consequence.

Regular quality control tests to be carried out during application include film thickness check, holiday detection (jeeping), peel test and cure test.

The cure of the epoxy layer is usually assessed on a section of the pipe coated without the adhesive layer. Usually this is at the start or the end of the running period. The test should be carried out using the MEK rub test or DSC evaluation of the glass transition temperature.

The peel test is important in assessing the cure and the intercoat adhesion, since in the process control terms provides feedback on the intercoat time (phase 7). Peel test methods may vary depending on the coating specification but in general failures should be within the adhesive film, leaving some adhesive attached to the epoxy and some attached to the outer coat.

It is also recommended to carry out periodic long term tests, to assure that the system is performing to its optimum.

These tests may include:

- Hot water soak.
- Impact test.
- Bend test.
- Cathodic disbondment test.

10. Coating Repair Procedures

In areas where the steel is exposed, it is strongly recommended to use a two-pack 100% solids epoxy repair compound before using a heat shrink sleeve or extruded material to complete the repair.
11. Pipe Handling

Uncoated pipes
Avoid storage of uncoated pipes in direct contact with the ground. Uncoated pipes should be placed on wooden runners. Wooden separators should be placed in the pile as a break, to allow pick-up by forklift trucks.

Coated pipes
Coated pipes should be handled carefully to avoid mechanical damage during stacking, loading, transportation, stringing and lowering.

Three-layer systems provide excellent mechanical resistance properties, but the contact forces of pipe against pipe, or a stone between pipes, can cause puncture damage. The basic requirements are as follows:

- Pad all handling contact points, and use a load spreader beam for pipe lifting.
- Use separators when stacking joints (3/4" thick rubber pads, tire treads or synthetic ropes are suitable).
- Protect the load from stone throws (plywood shielding, fenders or tarpaulins are useful).
- Lift the pipe joints. Do not drag them.
- Avoid slamming the pipes’ ends together.
- Protect beveled ends with suitable caps.