Maximizing the Life of Tank Linings

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A protective lining forms a barrier between the substrate and the cargo of the tank, with the aim of preventing substrate corrosion, maintaining product purity, and decreasing erosion. It can also improve the ease of decontaminating and cleaning the tank. In mild steel tanks, a lining allows a reactive or corrosive cargo to be stored in a vessel that, if unprotected, would be attacked by the cargo.

For a lining to be successful, it must do the following:

- insulate the cargo from the reactive substrate,
- prevent or minimize the permeation of any element of the cargo or another electrolyte through the coating film to the substrate/lining interface,
- resist corrosion products that may develop from or on the substrate,
- form a full and continuous film with a high level of integrity and low levels of moisture vapor transmission, and
- display excellent adhesion and cohesion.

Although the time to failure varies widely, most tank linings fail. While failure cannot be avoided completely, premature failure can be minimized. This article will outline crucial steps for maximizing the life of a protective lining in carbon steel tanks and vessels that hold aggressive chemicals. These steps address important factors often overlooked when specifying, applying, and inspecting new or replacement linings. The choice of lining type is obviously crucial but is beyond the scope of this article.

Service Environment

The specifier must accurately and comprehensively define the environment in which the lining is expected to serve.

Tank Content

First, the tank content must be described fully, including the following aspects:

- liquid or solid nature, including what it might be diluted with;
- the concentration;
- the temperature;
- the fill level; and
- the cyclic process that might be involved (which may include changes in fill level, concentration, and cycle time, as well as temperature).

Understanding the cyclic process to which a tank is subject involves evaluating exactly what sequence of activity will occur in the tank. (The plant operations staff can provide this information for a relining job, while the design engineer should be consulted for lining of new process vessels.)

For instance, in a condensate/boiler feed tank, the vessel could be filled with cold water and have boiler treatment chemicals added; it may then have elevated temperature condensate added into (or worse, onto) the tank surface as the boiler water recycles. The tank may then reach an operating level of 115-125 F (46-52 C) with the boiler's normal draw-off and condensate return. When the night or weekend boiler load changes, tanks of this type have been known to rise to 195-205 F (90-96 C). The frequency and mode of adding boiler treatment chemical must also be considered. Is it, for instance, continuously added in a metering system, or is it shock-dosed every week (given a high dosage in a short time), which will indicate an elevated peak in chemical concentration?

When determining the contents of the tank, one must often consider the pH and the type of acid or alkali. Differing types of acid or alkali can have a vastly different effect on the durability of the lining. If the tank is to contain an aggressive chemical, then its solvency, its effect on the film due to its hydroscopic nature, or other film effects should be determined. If there are mixes of chemicals, their effects can be difficult to determine. The cumulative effects of combinations can be unpredictable without accurate analysis of these conditions.

Outage Demands

Another aspect of service environment is the plant shutdown or outage demands on the coating. Is it necessary, for example, to allow for a clean-out process that could involve steam cleaning, high pressure waterjetting, or alkaline or acidic rinsing? It is common practice in the petrochemical industry to steam out tanks by filling them partially with water and then running live steam or condensate into the vessel until it

When a tank is to be relined, its history and the performance of linings in similar environments can be invaluable.
Photos courtesy of the author.

overflows. This type of service could destroy a lining that was designed to withstand many harsh chemicals but was not designed for or capable of withstanding this combination of cleaning processes.

In another instance, the concentration of a tank cargo may rise significantly during the process sequence because of evaporation of some of the water, which could increase the aggressiveness of the cargo.

Temperature and Temperature Gradient

The temperature and temperature gradient across the tank structure, including the lining, must also be evaluated. Organic coatings have a coefficient of thermal expansion significantly greater than most steel substrates. The extent of this thermal expansion changes whether the tank is thermally insulated or not. In certain instances, the stress from the differing thermal expansion rates is enough to exceed the bond strength between the lining and the substrate or between individual layers in the lining. Thick films are particularly susceptible to cracking from thermal expansion. Failures often occur at a localized overbuilding of the lining.

Effects of Dissimilar Materials

Another often overlooked effect is caused by dissimilar metals in the tank. It may be easy to assume that the tank is all carbon steel. Further investigation, however, often reveals that flange bolts, float sensing equipment, or other mechanical or electromechanical devices are made of a dissimilar metal, such as copper or stainless steel, that could markedly affect the ability of the lining to survive. In some cases, the design or specification for these items may need to be amended. Examples are stainless steel bolts, stainless steel agitators, and copper- or zinc-coated components for temperature sensing or fill height determination.

Gross failures of tank linings and entire tanks have been caused by the inappropriate use of dissimilar metals. In one example with which the author was involved, a mild steel tank with an epoxy coating system was fitted with a large stainless steel impeller. In less than 6 months, the tank was perforated with corrosion. Small areas that were poorly coated or inaccessible in the mild steel tank shell were forced to be very active anode sites because of the large surface area of stainless steel acting as a cathode. A similar failure occurred on an elevated temperature, boiler feed water tank that had a large copper coil as the inlet pipe and stainless steel items fitted to the tank along with galvanized components. If possible, it is worth changing the construction materials in these conditions or insulating the electrical connection between the dissimilar metals.

Tank History

Most of the considerations above are relevant if the tank is new or going into a new process where there is no history. If the tank is being relined or if a new tank was constructed to replace an existing tank, then a thorough investigation of the previous service environment of the tank or the experience of other users of tanks in the same environment is very useful.

Assuming the present lining is to be removed and replaced and the process is to remain substantially unchanged, the existing lining and its manufacturer must be fully and accurately identified. Additional details such as its age, composition, and history, including whether the lining was recoated or repaired through its life, will give a good indication of its effectiveness. Obviously, its original and subsequent suitability should be addressed. If, however, the lining has performed well for at least 10 years, or failed because of mechanical damage or a change in process, then the lining and its application procedure may be considered satisfactory. Full analysis of a failed or deteriorated lining can be made by a reputable coating consultant, a knowledgeable coating manufacturer, or a coating testing laboratory.

It is a good idea to learn if there has been other satisfactory use in similar exposures by other users. Plants with similar processes, similar chemistry, and similar tank lining services can be canvassed about the success of the lining types they have used. If the process has been undertaken in another environment, useful history can often be extrapolated for the planned project. If the planned service has not been undertaken before, it is valuable to select candidate lining materials and prepare a number of test panels. Panels can be immersed, or partly immersed in the chemical and, given sufficient time for the evaluation and confirmation, important comparative data about the various candidate options can be gleaned.

If a coating has failed in a particular service, it is a mistake to automatically replace it with the same material unless other factors have caused the early breakdown. If the only data available are from accelerated immersion exposures, treat these test results cautiously. Such testing may give some indication of performance and expected coating life, but there can be shortcomings in the extrapolation of short accelerated exposure times.

Service Environment and Lining Recommendations

When seeking a confirmed recommendation from a coating manufacturer or coating consultant, always ensure that they have all the exposure data such as chemicals, pH and concentration, temperature, pressure, and any cyclic nature of the operation. Even at the expense of some proprietary information being forwarded to these people, it is very important that they are fully aware of every factor that could have an implication for the lining's service life. When seeking recommendations from these sources, insist on a written specification with a summary of the environment that the lining is to withstand. This can have significant benefits if there is a failure.

Once the service environment and candidate linings are determined, comparative exposure testing is worthwhile if time allows. Relining plans should always be done enough in advance so that compatibility testing or side-by-side comparability testing can be undertaken before the work is scheduled. Assuming that the system options can be narrowed down to a few candidate materials, it is important not to evaluate their merits on price alone. Other important selection factors are the reputation of the manufacturer, the performance history of each lining, and the ability of the chosen system to be repaired and maintained. If one of the candidate materials, once it has been in service, is extremely hard to repair or needs subsequent coats, another lining may be a better investment.

Linings must be able to withstand conditions during service outages as well as during immersion service.

The ease and versatility of application should also be considered. Linings that can be applied with conventional or airless spray equipment may have advantages compared to linings requiring specialist or plural component application equipment. Such equipment may be difficult to maneuver or operate and, in unskilled hands, may not yield the desired film properties.

Surface Preparation

The highest level of surface preparation possible is strongly recommended in all tank lining work. The mechanical condition of the tank must be addressed as part of the evaluation of the tank for surface preparation.

A lining failure inside a cement sludge tank caused by poor site preparation and poor coating of the field welds.

Mechanical Condition of the Tank

The condition of the welds and the plate edges, the presence of weld spatter and the general continuity of the surface, and the radius of guillotined or gas-cut (flame-cut) edges must be satisfactory to ensure the adhesion and integrity of the lining system to be applied. The condition of the surface itself, whether new or being relined, must be assessed, particularly for the presence of oil, grease, or soluble salts. All of these items quickly attack tank linings.

Condition of Existing Lining

For relining projects where the existing lining has not completely deteriorated, it is worthwhile to evaluate the life expectancy of the existing lining system until full removal is required. If there is only localized damage (blistering and minor pitting), the lining does not necessarily need to be fully removed. It may be better to evaluate the threat to the substrate's integrity and, if the substrate is not at risk, leave the existing lining in service for as long as possible. When the substrate's integrity is at risk, however, a full coating removal and replacement should be planned.

In the author's experience, spot repair with localized blast on the deteriorated areas has sometimes caused massive failure by blistering in areas adjacent to the repair areas, due to overblast damage. Previously sound coating has suffered pinprick damage from the abrasive stream impinging on non-target surfaces. Even if microscopic at first, this damage has opened a path through the old coating that allows the transmission of water vapor or electrolyte to the substrate, causing blisters. In some instances, where 50 percent to 80 percent of a tank surface has been spot blasted or spot and sweep blasted, the anniversary inspection showed massive damage on all surfaces adjacent to the spot blast zones.

Spot blasting should be considered only if less than 10 percent of the tank surface requires repair. For damage above 10 percent, it is preferable to delay recoating until more of the residual value of the lining has been consumed, when a full blast can then be planned. The incremental cost of extending to a full blast is generally not excessive and can certainly be more attractive when weighed against durability and cost per year of service.

If spot blasting and repair are considered essential, then workers must fully and adequately mask the areas adjacent to the zone of repair so that there is no threat of damage to sound areas. This can be done by taping insertion rubber, rubber sheeting, tarpaulins, or heavy cardboard sheet around the repair zone to confine or restrict any threat of overblast damage.

Sequence for Surface Preparation

Pre-job planning should include developing a sequence for surface preparation. Relining projects may call for a blast/wash/blast sequence to remove or lower the soluble salt levels that may be underneath the film or to allow the mechanical condition of the tank to be checked thoroughly, especially at welds, plate edges, and other areas difficult to protect. A double blast sequence is highly recommended for tank lining or relining projects. It allows the old lining to be fully removed for tank inspection, but it also allows greater productivity per day once the second or final whip blast (Brush-Off Blast, SSPC-SP 7) is under way.

Typical production blasting rates for removing an old lining inside a tank can be between a quarter and a third of the rate at which a whip blast of a previously cleaned surface can be completed. Therefore, larger areas can be lined after a single day's reblast production. This means fewer joints in the lining, less contamination from denatured coating or abrasive, and less chance of overblast damage while maintaining production rates than if the first coat is applied immediately after the first blast.

A blast holding primer that is compatible with the lining system should also be considered. This primer generally allows faster lining of blasted surfaces with quicker drying. Holding the blast with a primer also minimizes the chance of damaging a slower drying, full thickness lining that has been applied to an adjacent surface during the previous shift or day. The use of a blast holding primer also saves the multiple mixing and wasting of high build material that would be needed to coat the limited day's production from a single blast process, thereby reducing the potential for errors in mix ratio. It can also allow for the use of a more economical abrasive for the initial blast, one that might not generate the required surface profile but could be changed for the final blast when significantly less abrasive is needed to achieve the profile specified. Before the second blast, the surface should be fully checked for soluble salts and oil or grease. Detection kits for each are commercially available.

Climate Control

The specifier should consider humidity and climate control, ventilation, and air circulation inside the tank during surface preparation and coating application. Dehumidification equipment will help to hold the blast. Ventilation removes dust to give the blast and spray operator good visibility and to avoid the possibility of contaminating the newly applied wet lining. Both dehumidification and ventilation equipment must be designed for the tank size, volume, and configuration, or they will be ineffective.

Heating the tank in cooler weather will also help in most cases with the quality of the tank lining. Care must be exercised, however, to ensure that the well established cold wall effect of high internal temperatures and a low substrate temperature does not lead to blistering and damage.

Abrasive Selection

The type and size of abrasive are important to the work. The abrasive should produce the profile shape and height required to ensure acceptable lining adhesion to the substrate. Abrasives should be chosen with characteristics that minimize shattering and, more important, minimize embedment into the substrate. Many of the heavy angular grits, particularly chilled iron or steel grit, can damage a lining if they are used as the final abrasive. Minute pieces of these metallic abrasives can fracture and become embedded in the substrate. The abrasives and the tank substrate are often dissimilar metals. Embedded abrasives can therefore set up a corrosion cell. They can also remain as protrusions as well as embedments that the lining cannot encapsulate and fully cover. A non-metallic abrasive that is low dusting and low fragmenting is preferred for tank lining. It should be graded to provide even cleaning and to produce an even profile shape and height.

There is much debate about profile requirements. The most crucial element is the profile shape rather than the height. Because the profile height is a measurable item, too many specifiers and inspectors concentrate on the specified height. Beyond a certain point, the profile height has less of an effect on adhesion than does the shape of the surface roughness generated. The most effective abrasive is one that produces a uniform, jagged tooth with the greatest increase in effective surface area but with a height that is approximately 25 to 30 percent of the final dry film thickness (dft). The maximum profile height is 2.3 to 3 mils (58 to 76 micrometers) for most coatings. Very few organic or inorganic coatings require a profile height above 4 mils (102 micrometers). The most common exceptions are ultra high build materials and thermal spray metallic coatings.

Substrates to be lined should never be blasted with spherical abrasives such as steel or chilled iron shot, or any other abrasive that produces a similar peened shape. Disbonding will result. Zinc silicate coatings, which have a metallurgical as well as a chemical bond to the steel surface, can readily detach from a shotblasted substrate.

Housekeeping

Another part of evaluating surface preparation is determining the method of removal of the spent abrasive and paint waste from the tank interior. Is it to be swept out or removed by vacuuming? Before a lining is applied, the blast cleaned surface should be vacuumed as the final step. Sweeping or air blowing will not fully remove the finely shattered abrasive from within the profile shape. If not removed, the shattered abrasive interferes with the lining's adhesion to the substrate and provides a site for osmotic blistering.

Coating Materials

Getting the Material

Before the project begins, the amount of coating required must be calculated and ordered. The amount can be determined only by accurately measuring or calculating the surface areas involved and allowing for all contingencies. Having the lining on site before surface preparation is complete will also allow the contractor to check batch numbers. Ideally, the lining materials needed for a project or a definable part of a project will come from the same batch.

When lining materials arrive on site, the contractor or inspector should verify that the product specified matches the product received. For multi-pack products, the sizes of all components should match. That is, the part B component should be the correct size ratio for the part A. A number of tank lining failures have been caused by mixing the part A component for a one-gallon (four-liter) kit with the part B for a five-gallon (20-liter) kit or vice versa. For linings that require solvent to be added, the solvent should be the one recommended by the manufacturer, not a local substitution. A more economical solvent may be used to clean out application equipment as long as it is flushed out and there is no chance of it being mixed with the product during application.

Storage

The lining material should be stored on site in a secure and weatherproof location. If the coating work is to be performed outside the normal conditions of temperature, 60 to 75 F (16 to 24 C), then the coating should be stored in a controlled temperature environment. The ideal storage temperature for most protective coatings is between 68 and 75 F (20 and 24 C). In many instances, a heated or cooled storage room with temperature controls will be needed to maintain this range. The consistency of mixing, thinning, application effectiveness, flow, cross-linking, and final cure depend on the lining temperature at the time of mixing. Lining containers should also be stored in a place that will keep them free from contact with water. Because of their chemical resistance, many tank linings are multi-component materials. Often, at least one of the components is sensitive to moisture. If coating containers are left in the open and are allowed to heat and cool through weather cycles, water can be introduced into the coating even through the sealed lids as the unfilled space in the container expands and contracts with temperature. Solvents, too, are very sensitive to contamination with water, particularly because the dished lids of the larger containers or drums can allow water to pond if exposed. Storage under a tarpaulin can be nearly as bad as storing the materials in the open because lining materials can sweat under the tarp.

Mixing the Linings

Once the lining is ready to be mixed, the material should be withdrawn from storage. If temperatures are outside the ideal range noted above, withdrawal should be timed so there will be no delay before mixing. Once the blasted surface is nearly ready to be lined, the selected spray equipment should be assembled and tested. Testing should be carried out using the solvent compatible with the lining. With airless spray, filling and pressurizing the unit will assist in flushing the fluid lines and checking for system leaks.

The order of mixing components is often overlooked. Once both components have been selected, the lower viscosity (less thick) component should be stirred first. This will often be the curing agent or catalyst for the lining. Even though it may appear homogeneous, it should always be stirred or fully dispersed. The lower viscosity component should be stirred first because it will be easier to clean the mixing equipment before use on the more viscous component. The second or heavier bodied material is then stirred without any curing agent. Stirring the second component alone ensures that all elements from within the

Metallic abrasives embedded in a metal substrate can set up a corrosion cell if the metals are dissimilar.

drum are fully blended and that it is at a consistency adequate for spray application. Breaking any lumps from the sides and settlement off the bottom of the container, preferably with a stick before complete power stirring, is the first step.

Once the heavier component is fully dispersed and while it is under agitation, the part B component is added. (Often, more than 1 person is needed to mix the lining.) During the addition of the second component, the product should be under agitation to prevent the chance of solvent shock (shocking the pigment out of the solution by adding too much solvent), which can happen if stirring is not performed uniformly while the components are blended. Some linings require an induction time after all components are fully dispersed. The requirements for an induction time are normally given on the manufacturer's product data sheet.

It is always sound practice to mix the full kit of the multi-component pack rather than try to proportion it by eye. Even with considerable experience, it is very difficult to get an accurate ratio of a multi-pack coating without some method of weighing or volumetrically measuring the constituent components.

If the lining must be thinned for the recommended application method, it should be performed after the induction time. Otherwise, the lining could be overthinned because it heats up during induction and becomes less viscous.

Lining Application

Proper Application Conditions

If the lining is not applied under controlled climatic conditions, then application and subsequent drying and curing should be timed to occur when the conditions will be most suitable. Early morning or late afternoon are often not ideal for application and cure because temperatures and humidity levels change most then. Success depends upon satisfactory air temperatures, substrate temperatures, and conditions of relative humidity and dew point. These conditions need to be maintained throughout the application and initial curing. Condensing moisture or dropping substrate temperature during cure is extremely detrimental to the lining's performance.

Condition of the Equipment

Successful lining application also depends significantly on cleanliness of the equipment, in particular, freedom from oil and water in the compressed air supply and in the paint mixing and fluid lines. Generally speaking, the manufacturer's recommendation for application equipment is a good place to start even though other equipment setups can be successful.

Selecting the Application Sequence

As with surface preparation, the sequence of coating application can have a significant impact on lining performance.

The blast and prime process, as opposed to the blast and full coat or double blast sequence, has advantages for lining application as well as for surface preparation. The need for extreme cleanliness between coats and freedom from contamination during the intercoat interval can also dictate this coating sequence. Because of its fast dry characteristics, a blast holding primer or a low viscosity first coat can prevent dust contamination. Its tolerance for early recoating with a high build lining can improve the overall integrity of the lining. The holding primer also allows welds and corners to be stripe coated before the first high build coat. If the blast holding primer is not used, then when the stripe coating is performed, the areas not coated might not hold the blast long enough for the full coat to be applied. If the holding primer is not used, then it is better to apply the stripe coat after the first full build coat is applied and can be recoated.

Stripe coating is critical. During the conversion of a wet coating into a dry film, the normal internal curing stresses inside a lining have a tendency to pull the drying coating away from edges and sharp corners. Even with the careful rounding of these edges in the mechanical preparation of the tank, some thinning of the dry coating will result. Stripe coating is designed to alleviate this low dft to help provide a uniform minimum dft on all areas of the tank. Areas for stripe coating are edges, corners, and welds, as well as the localized zones where access with the spray equipment is difficult, such as on the backs of angles or on the reverse of stiffeners.

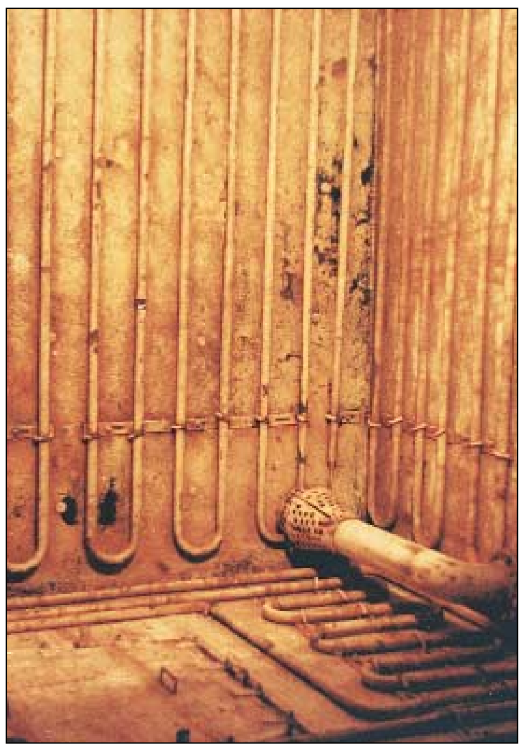
A quick-drying primer is preferred for tank lining application. Once the primer is cured enough to be relined without damage, a stripe coat of the high build should be applied, followed by a full spray application of the same lining. Once the stripe and full coats have dried, with the correct recoat interval, the dft should be checked. This approach allows a high probability of achieving the required dft. If dfts on edges, welds, and corners are still low, then the intermediate film thickness readings will indicate where attention is still required.

Quality Assurance during Lining Operations

The applicators should be advised of the target dfts per coat and the wet film thicknesses required to achieve the dfts. Overbuilding can be as detrimental as underbuilding in tank lining applications, especially because of solvent entrapment and insufficient cure. Both can lead to blistering and coating detachment. An application sequence and the necessary equipment help ensure that the largest possible area of the tank's internal surface can be coated with good access and with an even spray pattern that will give reliable film thicknesses. Attention to welds, edges, and corners dictates that not only should they receive a stripe coat, but they should also receive careful spray attention. They should be sprayed on both sides or on all exposed surfaces. It is not uncommon, when inspecting tank linings, to find uniform film thicknesses on plate surfaces while only 1 side of the welds is lined adequately.

A color contrast should exist between each lining in a system, including the stripe coating, to help measure dfts. Unfortunately, many tank lining materials are manufactured in only 2 colors, for instance, white and buff. However, for the sake of the color contrast, it is often satisfactory to make a partial blend of the two colors and convert it with the correct ratio to give an intermediate shade that will be different enough where the color contrast is required.

Lighting and ventilation are again major issues for coating application. It is



A fish holding tank inside a tuna fishing vessel before relining. The difficulty of access caused by the ammonia refrigerant piping should be considered when preparing a specification for relining.

very difficult to apply a uniform coating thickness if the applicator has minimal visibility or if there are excessive spray mist and solvent fumes inside the tank.

Flameproof or explosion-proof lighting is extremely important in any situation where solvent vapor is present. For adequate ventilation, the air movement should be sufficient to assure that the maximum concentration of vapor does not exceed 10 percent of the lower explosive limit for that vapor.

Cleanliness at all stages of the final surface preparation and coating application is very important. Cleanliness extends to preventing perspiration drips in the tank and preventing dirt or other foreign matter, including abrasive debris, from becoming embedded in the tank lining. Developing a system for access and housekeeping ensures maximum cleanliness at all stages of work.

At all stages of the surface preparation and lining application, the applicator, the supervisor, and the full crew must assume responsibility for ensuring quality. Quality is not as simple as achieving a dft within the specified narrow range. Often, factors such as intercoat cleanliness, observation of the climatic and substrate conditions, and time for curing are not as obvious as dft when the coating system is complete, but can be significantly more important in ensuring the integrity of the lining.

Testing and Inspection

Even though these items are last in the discussion, they should be included in every stage of the process, from determining the need to line or reline to returning the vessel to service. Whether the inspection is carried out by an independent third party inspector or by the client's own representative, key points include the following.

Pre-Job Meeting

A pre-job meeting that includes the client, the contractor, the inspector, and, possibly, the specifier is vital. All elements of the work should be discussed, particularly the criteria for acceptance and the proposals for the sequence of activities. Correctly conducted, this meeting should clarify the demands of the project for all parties.

One procedure that the author has adopted at the pre-job meeting for tank lining work is preparing a written summary of key specification details for the supervisor. Often this document can be as simple as a one- or two-page summary of the climatic condition limits, the restrictions, the lining system, the interval between coatings, the wet and dry film thicknesses, the solvent type, and any other relevant information such as the inspection acceptance criteria and referenced standards. While the summary does not replace the need for the supervisor to understand the complete project specification, it is valuable for quick reference.

On-Site Inspection

Inspection has many stages. The first inspection of the original condition should include a thorough visual check and rectification, if needed, of all welds and steelwork conditions. Verifying the detection and removal of visible oil, grease, and dirt should receive priority at this same time, too.

Once the first blast is performed, an inspection can provide information about the condition of steelwork and the height and shape of the blast profile. Even though the surface will be reblasted, checking the profile at this time can help to determine if the final surface will meet the specified criteria once the final blast is performed. Additionally, it can provide early indications of possible problems with achieving the specified profile on zones affected by heat, such as welds. On such zones, where metallurgical differences create a harder surface, it is often difficult to achieve the profile specified. In this author's view, many failures around tank welds may be caused by this phenomenon.

After the first blast, the inspector should also look for evidence of oil, grease, dirt, or soluble salt on the steel. These contaminants may have been introduced by blasting or by the workers themselves. Many tank lining failures show evidence of a perfect hand print that was made on the blasted surface before application. Removal of these contaminants may require washing, rinsing, steam cleaning, or solvent wiping. If oil or grease is persistent, then swabbing with a 1:1 mix of methanol and water has proved to be very effective. Steam cleaning between a double blast sequence is recommended for removing soluble salts from steel surfaces.

Inspection after the final blast should include a visual confirmation that the blast, vacuum or final clean, and profile meet the specification. The blast cleanliness achieved, it should be remembered, is the condition evident at the time the lining is applied, not the level when blasting was completed.

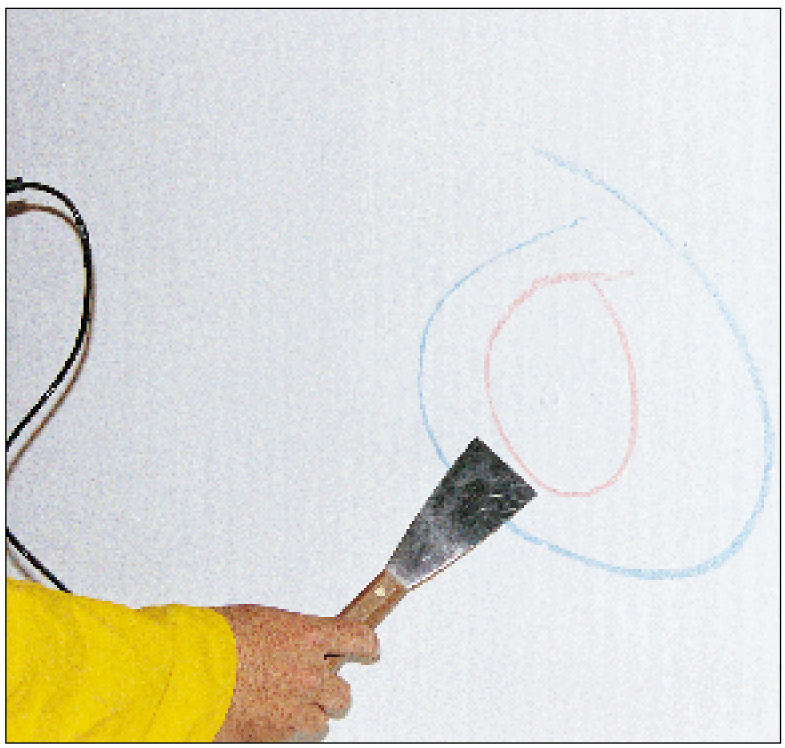
Inspection should also include an observation of the lining mixing, visual confirmation of the components, and recording of the batch numbers and quantities that are prepared. At all stages, the climatic and substrate conditions need to be measured and recorded.

Once lining application has begun, the inspection should include checking wet film thicknesses; confirming that flow, leveling, and atomization are appropriate; and assuring that the first coat is free of pinholes. If deficiencies in lining handling or application cannot be corrected with spray technique, timely adjustments can be made to the application equipment; mixing, thinning, or the temperature of the lining; or other variables.

After the first coat, a full inspection can give valuable guidance to the applicator and the supervisor so that the balance of the application can rectify any non-conformance in the system so far. It is particularly useful to detect and highlight areas that are missed, or those that are high or low in dft. Finding such areas at this point can often save the application of an additional coat if the indications are that the present technique will not achieve the desired final film.

Methods of highlighting non-conformance should be considered. It is not a sound idea to use wax crayons or felt tip pens. Chalk is generally superior, providing the color does not interfere with the subsequent lining. Bright colors have been known to show through the next wet coat.

Chalk marks highlight non-conformance found during inspection.



The inspector should look for sweating on the first coat, particularly with epoxies, which will always be detrimental to adhesion of subsequent coats. The

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1:1 mixture of methylated spirits in water is an effective remedy, and because of the miscibility and easy evaporation of the mixture, residual water is not a problem.

The inspector should also note the need for recoating or repair. If deficiencies are found in any coat, they should be rectified before application continues, particularly if there is a sequence of differing coatings in the lining system. (The argument that applicators will fix up the shortfall with additional finish coat should not be accepted.) Similarly, the inspector should observe the stripe coat methods, discuss the options, and ensure full compliance.

Checking the cure of each coat is important. If accelerated or retarded curing is evident during the inspection of the first coat, the problem is worth investigating. In one instance where a slowly curing first coat was ignored and a finish coat was applied, the lining failed. Investigation revealed that the mix ratio for the first coat was incorrect. Even though the primer was coated with a finish having a correct mix ratio, the tank lining failed because of the poor integrity and inadequate chemical structure of the primer. This failure resulted in a rather expensive removal and replacement procedure that could have been avoided if the warning signs of slow cure had been heeded. If there is doubt about the integrity of any part of the system, it is better not to continue rather than risk the consequences of a non-conforming lining.

Once the system is applied, final checks will include a full dft check, a thorough visual continuity check for missed or thin areas, and verification of a touch-up procedure for any non-conforming zones. Once a satisfactory visual continuity check is completed, the lining must have enough time to cure before the tank is put into service. Unfortunately, the outage time for the tank relining often includes only the minimum time calculated without any allowance for lost time. When only the minimum cure time is allowed, the cure is often compromised because of inspection, rework, or climatic changes that slow cure. If the tank is filled before cure is complete, disastrous failure may result.

Continuity testing with high or low voltage equipment as appropriate for the lining type and thickness should be carried out if specified. Continuity testing, however, can be performed only when the coating is cured and dft has been checked completely. Continuity testing must be performed in accordance with the standard specified. If touch-up is needed, the procedure must be authorized by the lining manufacturer.

Recordkeeping

One of the last stages of inspection is to complete a full and final report, including all achievements, non-conformances and their rectification, full details of the lining used, batch numbers, and climatic and other relevant data. This report will often be the only permanent record of all aspects of the lining project. The report can be extremely useful, whether the coating serves for many years or fails prematurely.

Anniversary Inspection

Frequently, the last duty of the inspector is to perform the anniversary inspection approximately 12 months after the tank is put into service and just before the contractor's maintenance period expires.

Conclusion

To maximize the life of a tank lining system, take the time, plan the work, and stick to the plan. Compared to a poorly planned project with a resulting lining life of only a few years, a properly planned, well executed lining project can add as much as 12 or 15 years to the achievable operating life of the system. **JPCL**