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AN ENGINEERED APPROACH TO LININGS AND COATINGS

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1. SUMMARY

Thermoset linings and coatings with a service life in excess of 15 years are available. To achieve a successful installation a comprehensive engineered approach should be taken. To be successful a lining or coating must withstand chemical attack, have low permeability to protect the substrate, withstand other service conditions such as mechanical and thermodynamic parameters, be on a properly designed and prepared substrate and be installed properly. Quality control at all stages is very important.

2. INTRODUCTION

Investment in industrial plant often requires a plant life in excess of 15 years. There are obvious benefits to the investor if all components of the plant can perform equally, i.e. the linings and coatings last for the plant life. With for example tank internals, buried pipelines or sub-sea items it is very difficult to get at to repair or replace linings and coatings. If they fail, the pipeline or tank will fail thereafter.

This paper looks at the use of reinforced, chemical-resistant thermoset lining and coating systems in severe industrial environments. Thermoset resins most commonly used are polyesters reinforced with strands, glass flakes, and spherical particles such as silica. Thermoset resins are characterized by a good chemical resistance, by being able to be formulated to give a wide range of physical characteristics and by being monolithic, i.e. jointless.

3. ENGINEERED APPROACH

Successful systems are not formulated by the numbers. Rather the lining or coating vendor puts together a likely system and puts it to the test. The systems often contain difference layers with different functions and so are not uniform throughout. Testing is done in both the laboratory and in the field. By far the best laboratory test is the Atlas cell test using ASTM C-868 which provides the nearest possible simulation of a field environment. As the lining or coating emerges successfully, the results of field tests and field installations are gathered. Only then can the lining vendor offer the system and the purchaser buy the system with confidence. But that is only the start.

To achieve a successful installation, it is most important to look at all the engineering parameters pertaining to the particular situation. If a comprehensive engineered approach is taken, then a thermoset lining or coating system can be installed to give the plant life that is required.

To be successful a lining or coating must:

1. Withstand chemical attack
2. Stop the corrosive fluids reaching the substrate
3. Withstand other service conditions such as mechanical and thermodynamic parameters
4. Be on a properly designed and prepared substrate
5. Be installed correctly.

4. SUCCESS CRITERIA NO 1 – WITHSTAND CHEMICAL ATTACK

A thorough knowledge of the chemistry is essential. While clients often consider their chemical formulations or make-up of their chemical waste to be strictly confidential information, it is most important they divulge sufficient information to the lining vendor. What the client may think to be sufficient information may not necessarily be sufficient for the lining contractor. A thorough description of the chemistry with all chemical additions, pH ranges, temperature ranges and any likely upset conditions is essential.

A few percent of solvent, the presence of chlorine or sodium hypochlorite, the cleaning solutions used, the presence of hydrogen sulphide gas and the likelihood of strange by-products are examples of situations that need exploring. Chemicals such as hydrofluosilicic acid that attack glass require special attention.

Corrosion charts published by the thermoset resin manufacturers are good guides in selecting the thermoset resin but they cannot be used without hesitation. For example, resin manufacturers say their vinyl ester resins will withstand 18 percent sodium hypochlorite to 82ºC, but in practice the maximum service temperature is about 37ºC.

Thorough chemical testing over many years plus monitoring of actual installations is the only way to develop chemical resistance data. Chemical resistance is often related to temperature so temperatures during testing must be recorded. The vendor that describes his system as "resistant to sulphuric acid" is either not telling the whole story or doesn't know the whole story.

5. SUCCESS CRITERIA NO 2 – RESIST PERMEATION

For the corrosion and degradation of the substrate to occur, the chemicals in the liquid or gaseous environment need to reach the substrate. So for a lining or coating to be successful, it must resist permeation of the chemical ions.

All linings and coatings are permeable to some degree. The permeability of a thermoset resin can be altered dramatically by the addition of fillers and flakes. These fillers and flakes cause the path of the permeating chemicals to be dramatically lengthened because the chemicals must pass around the fillers or flakes. Table 1 gives permeability figures for typical lining and coating systems.

Table 1
Relative Permeance of Various Lining and Coating Systems

SYSTEM	THICKNESS (mm)	RELATIVE PERMEANCE
Flakeglass Polyester Lining - trowel applied	1.8	1
Silica Filled Epoxy – trowel applied	1.6	3.1
Flakeglass Polyester Coating – spray applied	0.89	5.3
Fibreglas Mat Laminate – epoxy or polyester	2.2	10.6
Flake Filled Coating – spray applied	0.51	12.8
Flake Filled Coal Tar Epoxy – 2 coats	0.41	13.2
Flake Filled Epoxy Coating – spray applied	0.25	18.3
Clear Polyester Coating – no pigments or fillers	3.3	13.9
Neoprene Coating	2.5	103.8
High Build Epoxy Coating – 2 coats	0.23	196.5
Polyester Urethane Coating – 1 coat	0.05	853

Note 1: Permeance is the water vapour transmission rate per ASTM E-96 procedure "E" of the lining or coating at the stated thickness.
Note 2: The relative permeance of a flakeglass polyester lining trowel applied arbitrarily assigned at 1.

Note the table shows a high build epoxy coating is 196.5 times as permeable as a flakeglass polyester lining trowel applied.

A major driving force for permeation is temperature, so it is at the temperatures above ambient that the engineer must be extra careful to select linings and coatings with low permeability. Chemicals with small molecules such as hydrochloric acid are able to permeate through linings and coatings more quickly than chemicals with larger molecules so once again proper knowledge of the service conditions is essential.

A good example of failure by permeation is the blistering of coal tar epoxies in hot immersion service on steel. The blisters are formed by water vapour pressure and the pressure of corrosion products formed underneath the lining.

To achieve a service life in excess of 10 years, permeation resistance must be considered. Oil companies for example recoat the interior of oil storage tanks every 8 to 10 years. If they considered permeation more closely, this recoating could be stretched out to every 15 years or more. Low permeability and long life are closely associated.

6. SUCCESS CRITERIA NO 3 – WITHSTAND OTHER SERVICE CONDITIONS

Other service conditions that must be considered include:

1. Presence of abrasive particulates
2. Flexing of the substrate e.g. steel tank bottoms or baffles
3. Microcracking or joint movement in concrete substrates
4. Abuse of the lining or coating mechanically by workmen shoveling out solids, engineers using tool boxes
7. Frequent temperature fluctuations
8. Cleaning done by steam cleaning, water blasting, chemicals
9. Presence of hit spots such as steam pipes entering a tank
10. Abuse by heavy traffic such as forklifts
11. Need for smooth or anti-skid finish
12. Need for hygienic pharmaceutical type finish
13. Need for the lining to be conductive (anti-static)

These conditions can only be found out by proper investigation. The engineer must be familiar with the plant operation and know what the client wants. Then the right questions can be asked. And then the lining or coating that gives the desired service characteristics for the desired plant life can be chosen.

7. SUCCESS CRITERIA NO 4 – PROPERLY DESIGNED & PREPARED SUBSTRATE

The two most commonly protected substrates are concrete and steel.

Concrete Substrate

Concrete must have a surface that is sufficiently strong to receive a thermoset material. The thermoset material shrinks as it cures and so has residual stresses. When there are temperature fluctuations in service, because of differences in thermal expansion rates between the thermoset and the concrete, more stresses are generated at the interface. When these stresses at the interface exceed the strength of the concrete surface, the lining delaminates. Or more correctly the concrete fails just below the surface. To have sufficient strength, concrete must be properly formulated, it must have properly graded aggregate, must not be over-vibrated or heavily floated, must not contain additives such as waxes or be contaminated with oil for example.

Construction joints are often a source of failure. When the contractor builds a concrete tank in two pours, the joint between the pours is weak and can separate at some time in the future. This would cause the lining or coating to fail. The problem can be avoided by either eliminating construction joints or by properly preparing them by scabbling and the use of concrete adhesives. Specialised installation techniques must be used to line over joints that could move. Another problem with concrete is that it is porous and so should be water proofed on the other side to stop water getting behind the lining or coating.

Concrete can be prepared for lining or coating by a large number of ways. Any method is acceptable as long as it leaves a clean, dry, porous finish with exposed aggregate.

Steel Substrate

Steel substrates must be designed so they can be lined or coated properly. Weld lumps and splatter must be removed, sharp edges must be rounded, plates that can flex need to be stiffened and inaccessible parts eliminated. Examples of good design include the use of RHS steel stiffeners on the exterior of tank roofs rather than channels inside, weld seams should be continuous, and nozzles in tanks should be large enough to properly prepare and line. The lining or coating vendor should be consulted at the design stage.

Steel is best prepared by blasting with a clean dry abrasive media. Steel grit, slag and sand are commonly used. It is essential that the proper surface preparation is done for the material to be applied. Some materials require only a brush blast, but the longest life linings and coatings need a very clean finish and a deep surface profile. This is easily achieved using the right techniques and the right materials.

8. SUCCESS CRITERIA NO 5 – BE INSTALLED CORRECTLY

A standard specification for installation procedures should always be developed. This must be in a form that can be read, understood and used by the installation crew, the supervising engineer, the client and management. This specification must include all quality assurance steps that are necessary … not too may, not too few … and certainly not unnecessary ones.

The installation crew must be thoroughly familiar with the materials. It greatly assists if the crew foreman knows how the system is formulated and the reasons for the various components. Then in the field, he can make decisions when required to vary from standard procedures based on proper understanding. For example polyesters normally require 2 percent hardener but will be varied between 0.75 and 4 percent at the jobsite depending on a huge range of factors. This becomes the expertise of the supervisor.

Proper surface preparation is very important and has been discussed in the previous section.

The author strongly believes that proper site logging of all steps and quality assurance steps is very important. The author has found the following to be successful:

1. All procedures, specifications and bulletins supplied to installation crew in bound folder with plastic envelope pages. Everything in one folder that can't have pages lost or get dirty.
2. A site log book with all paperwork in one place. This includes special job instructions, estimates, programme, daily job log, quality assurance records etc etc right down to a crew expenses sheet.
3. A camera to log critical stages.

One quality assurance step that should be mentioned is the measurement of humidity and dew point. Humidity is a widely measured and specified parameter but in the author's experience it is the relationship between the dewpoint and the surface temperature that is far more important. If the substrate is at or below the dewpoint of the air, then a film of "dew" will be present on the substrate and this will have an adverse effect on the lining. This situation is very common before 10 o'clock in the morning.

Other quality assurance steps to be taken where appropriate include wet and dry film measurements, high voltage spark-testing for monolithic completeness and degree of cure. The author does not intent to expand on these here.

Lining and coating work is by its very nature a messy and often unpleasant business. It is easy to push it aside and give the work to untrained unskilled workmen and hope they don't complain. Rather the installation crew must be trained, assisted and held in just as high a regard as the manager or salesman who negotiated the job. They hold one of the keys to the job so look after them, care about them and treat then like skilled professionals. And you will get proper results.