THE TREND IN COATINGS FOR DRY KILNS

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INTRODUCTION

A dry kiln is a chamber or compartment within which we wish to maintain a controlled condition of temperature and humidity; heat is supplied, air circulated and saturated gases exhausted to atmosphere. An economic unit should incur minimum maintenance, have low heat loss and saturated vapors only escape at the vents. Good coatings can contribute in all three areas to an economic unit.

The need for the coatings is mainly to protect and prolong the life of equipment and structural components. In effect, protecting an investment in various materials. Indirectly they help to reduce the periods of nonproductive down time. A more subtle aspect now being recognized in the wood industry is the decorative value; projection of a good company image; improvement of employee morale.

These are worthy goals. Yet to achieve value for the effort expended in selecting and applying a coating certain conditions or factors should be considered.

The more important aspects are:

- Environmental factors
- Substrate characteristics
- Coating properties

The economic application of a coating depends not only on a good coating but correct conditions for application, using good equipment, handled by intelligent operators. These conditions have always been pertinent with the 'old' coatings. They are even more applicable with the 'new' or more sophisticated coatings now available. Before we attempt to elaborate on or enumerate some of the new systems, let us take a look at some of these factors in detail.

Use them as a means of attaining a better understanding of what a coating is and can do. Consider the terminology and some of the know-how associated with coatings preparation and their application. In the end this should lead to a better appreciation of the protection/quality/cost relationship.

ENVIRONMENTAL FACTORS

Most of you are familiar with the 'steam bath' rather than 'sauna' conditions within a dry kiln. Some factors important to the consideration of a coating are listed.

HIGH OPERATING TEMPERATURES

Temperatures in the upper structural areas of kilns near fin pipe or direct fired heating ducts are normally 25-30° F. above the indicated or control level. The coating should combat the worst condition.

A HUMID ATMOSPHERE

Although we are drying, water vapor in the air stream is maintained at a fairly high level throughout the kilning cycle. Relative humidities of 75% or greater are not uncommon. The 'dew-point' is a significant term.

AN ACIDIC ENVIRONMENT

Wood acids as well as water are evolved from the various species during seasoning. An acidity or pH 3.5-4.0 can be attained in the kiln condensate; concentration is around 1.0%.

HIGH AIRFLOW MOVEMENT

Coatings tend to wear thin due to the erosive action of impinging airflow. Flexing and vibration of some components can also pose problems.

BATCH OPERATION

Unit raised in temperature fairly rapidly, often with live steam injection and cooled equally quickly via large doorways. This subjects coatings to shock heating and cooling.

SURFACE DEPOSITS

Components of the oleoresinous system of the wood are steam distilled during drying. Gums and rosin can deposit on cool surfaces to act as a protective coating or function as a release agent.

Other factors which often need to be considered are:

LIVE STEAM INJECTION

Apart from any thermal or humidity effect, the frequency of use, number and position of the steam sprays can influence the corrosive atmosphere in local areas of a kiln. Boiler water chemicals entrained in the steam also present problems for kiln coatings.

SPECIAL CONDITIONS

Typical of this category would be the drying of treated lumber. Preservative and fire-retardant treated lumber requires seasoning after impregnation. In some instances, the chemicals involved are water soluble, some leaching or migration to the surface occurs. These chemicals or gaseous products increase the need for good protection and make coating selection more difficult.

SUBSTRATE CHARACTERISTICS

The simplest sub-division of materials normally encountered in dry kiln construction is:

Materials
- Porous ------ Absorbent
- Non-Porous ------ Non-Absorbent

The significance of this division is apparent when you consider coating composition (volatiles and non-volatiles) and thickness (millage).

Factors which affect the adhesion and permanence of coating are:

Surface Texture and Characteristics	A 'rough' surface such as wood or concrete block allows for good ahesion. 'Smooth' poured concrete or sheet metal needs to be etched or profiled to increase adhesion.
	A surface coated with rust, flaking or loosely adhering particles of old coating needs preparation.
	A concrete surface suffering from 'laitance' or a layer of fine dust must be recognized.
	Salts or other chemicals leached ("efflorescence") or exuding from the substrate have an effect on the coating durability and permanence.
	The chemical nature of the substrate can seriously restrict the choice of coating. The wood matrix is acidic, whereas fresh concrete and masonry products are predominately alkaline in reaction. Coating components may react differently on such dissimilar substrates.

COATING MATERIAL PROPERTIES

By definition, 'a coating' is expected to protect, minimize the rate or severity of attack on, or improve the appearance of the item coated. The environment, substrate and cost all bear on the effectiveness of that statement. Some of the significant factors associated with the aggressive conditions in the kiln and the various substrates have been covered. A few of the important features concerning the coating are summarized below:

COATING THICKNESS	This helps confer resistance or a barrier to attack. Quality and cost are closely associated in this aspect. In general the better quality the components, the better the resistance.
VAPOR BARRIER CHARACTERISTICS	The greater the impermeability of the coating the greater the protection. Stop the dilute acid vapor penetration and much kiln corrosion is overcome.
TEMPERATURE STABILITY	Should be capable of resisting maximum conditions without hardening or softening rapidly, slumping or sliding off any surface, drip onto lumber or brush off on clothes.
EASE OF APPLICATION	Well dispersed stable coatings requiring a minimum of mixing before use are the goal. Modern spray equipment is helping to minimize labor and reduce raw material losses in coating work. They can now handle heavy, viscous or thin catalyzed coatings with equal ease. This allows freedom in coating formulation.
ABILITY TO ADHERE	A must for field application when applied to a variety of ill-prepared surfaces.
MISCELLANEOUS	Ability to re-coat any surface faces the formulator. No use producing coatings of excellent durability if the original coat acts as a release agent for any subsequent treatments. Resistance to a variety of conditions are built in e. g. fungus or molds. A few are developed which

resist inquisitive man, be it milled edge of coin, whittling knife blade, or fork lift forks.

This review of the conditions a coating has to withstand causes one to ask, "What is a coating? How is it formulated? What confers the protection?"

Appendix 1 provides a brief description of coating make-up. It indicates the coverage rate to expect from various types of coatings and how to calculate the quantity of material required when the coating thickness is specified.

Protection is conferred by isolating the substrate from the hot, aggressive conditions through the application of a continuous film or skin. The skin and the pigments therein are selected because of their ability to withstand all the conditions. The thickness and impermeability especially the resistance to migration of any kind through the film are important features of a good coating. Some of the resins, rubbers or synthetic polymers now in use as the film forming media are listed in the Appendix 1, as is a brief explanation of permeability to water vapor.

With this more complete background of coating formulation and resistance factors as well as kiln environment we are in a better position to discuss, evaluate and select modern coatings.

Discussion

With all this knowledge of what coatings have to withstand in dry kilns and the vast array of chemicals at the coating formulators command why is the problem still with us. Cost is one factor. Lack of appreciation of all facets of the problem and the need for greater skills in application are others.

A transition has taken place over the last 10 years to a respect for durability and performance; rather than the inexpensive get-by attitude which could be tolerated to a greater extent in times of lower operating temperatures and running costs. A thumbnail sketch of the 'progress' might read.

Asphalt materials were inexpensive and easy to apply using plant labor available at slack periods. The whole kiln was coated, one material used to protect wood, masonry, and metal. Cost was around $1.00-1.50/gal, little time was devoted to surface preparation, coverage was not important.

Next, an adaptation of the old asphalt/bitumen/gilsonite technology to produce matrices capable of resisting higher operating conditions. Mill labor was still available to apply coatings now costing $1.50-2.00 per gal. Coverage of 1 gal/200 sq. ft. was acceptable.

Some embrittlement occurred in these coatings within 1-1 1/2 years at the higher temperatures. Synthetic elastomers or rubbers were next incorporated to increase flexibility, reduce permeability and extend active life. Inert fillers, particularly asbestos also came into prominent use. Cost now around $2.00-2.50 with some guarantee on the product life. Coverage of 1 gal/100 sq. ft. now required.

Various thermoplastic and thermosetting materials were extended with the relatively cheap asphaltic base. Some of these coatings still persist as asphaltic varnishes or coal tar coatings containing epoxy, phenolic, coumarone-indene resins, etc. These coatings probably cost $2.50-3.50 per gallon; more preparation and care was required for fruitful use.

As more demand was placed on durability of the coating to reduce non-productive shut downs and costly maintenance to a minimum, the inexpensive workhorse asphalt gave way to a total resin or synthetic polymer base. By this time mill labor was no longer inexpensive or so readily available; greater skills were also required for proper application.

By communicating the problems involved to large paint companies (and enlightening them on the substantial market therein) interest and attention has been focused on the lowly dry kiln in the last few years.

Reducing the problem to its simplest terms; it involves avoiding contact between the various kiln components and the hot dilute acid vapors or initially using materials which are resistant to the aggressive conditions.

Cost enters the picture whatever angle you look at it.

Speaking of resistant materials is a good time to enter some constraints to the system. Expecially to the free rein, you think may be given the coating or 'protective barrier' technologist. With modern spaceage technology most wood, masonry or metal components can be well protected by coatings - at a price. A wood wall or roof could be completely protected by attaching a skin of impervious resistant aluminum say .38 cents/sq. ft. plus adhesive, sealant and labor to apply or $1.00/sq. ft. installed.

A masonry system can be faced with a 1/4" composite layer of epoxy cement reinforced with glass fibers, guaranteed for the life of the kiln with no maintenance required - $1.40-1.80/per sq. ft. installed.

The cost constraint is generally the value of replacement with a resistant material or protecting once and for all with a good coating system. When you consider the maintenance expenditure over an active 15-20 year life of a kiln, proper choice of materials or protective systems does deserve some thought.

Acknowledging that cost constraints exist, the technologist seeks to produce inert coatings, of low vapor permeability with a long effective life. Treatment of old structures or existing systems may need a different approach from new material. Shop and field applications may differ. Porous and non-porous surfaces change formulation techniques.

Before we proceed to consider some specific applications we should also differentiate between such terms as moisture resistant, water repellant, and water vapor permeability.

Many materials confer resistance to wetting or moisture. This does not automatically imply that they are impermeable to water vapor. Vapor impermeability is a vital factor in a good kiln coating. At present it is a costly feature to incorporate in coatings. Emulsified coatings may serve as an illustration. Bituminous emulsions offer the advantage of ease of application, freedom from solvent fumes and the convenience of being readily cleaned from tools with water. They may be used at relatively high solids content since the consistency is determined almost entirely by the amount of water.

Emulsions, however, may not always coalesce to form a continuous film so the permeability is higher than solvent solution coatings of the same thickness. Until the coating has coalesced, the film remains water sensitive and may be damaged by water. Since they dry by evaporation of water, drying is likely to be delayed, particularly under conditions of high humidity. These coatings are water repellant, can be applied in thick layers and are inexpensive, however, they provide little long term protection within dry kilns.

Let us consider some specific applications. Metals play a large part in kilns as support or partition materials. They are a good example of a non-porous substrate. Here, rust inhibitive primers are an important subject. There are four main approaches to metal protection.

1. <u>Iron Oxide primers</u>, which provide limited protection. They are often combined with <u>Zinc Chromate</u> - rely on the passivating action of chromate ion.	Generally in Alkyd Vehicle
2. <u>Zinc Dust</u> or <u>Zinc Rich Primers</u>. Their use is based on the sacrificial action of the metal pigment. In some instances the metallic zinc is in a silicate vehicle.	A Rubber base, urethane and polyamide/epoxy resins are common binders.
3. <u>Red lead</u>, <u>lead silico chromate</u>, lead cyanamide and <u>powdered lead</u> based paints.	Tung/phenolic, acrylics epoxy-ester and oil based vehicles are in common use.

4. Anti-corrosive protection based on a <u>conversion reaction;</u> alters rust to a stable iron compound. Acrylics, special alkyds.

These four approaches to corrosion protection have been in use for decades. Linseed, fish and other drying oils or some old style resins have been replaced by modern resin systems. Of the listed procedures, the first three all depended to a large extent on the surface preparation; if it was good they were effective for some time; if poor, they could fail dismally in a short period of time. Under dry kiln conditions a heavy primer coat of 2.5-3.5 mils is the best insurance; the correct coating thickness is dependent on the material profile.

"How to avoid sand blast cleaning or other thorough treatment in the field has been under study for some time."

Powdered lead based paints, incorporating phosphoric acid or other chemicals which passivate a rusty surface, and the conversion type coating are two answers for field treatments. Both can be applied over light, firmly adhering, rust to produce a tightly bonded protective undercoat. A lead based phosphoric acid primer in a modified acrylic resin, and a conversion coating in a special resin have been under evaluation by us in high temperature/humid situations for over a year with good results. They cost $12.00-15.00/gal, coverage rate is 250-300 sq. ft./gal.

Good topcoats for steel are available but like all kiln coatings, the main restriction comes from the temperature/humidity conditions. (Coatings for kilns operating) at or 200-210° F. have as yet a limited choice of tested binders available. The best known are from the epoxy family; epoxy/amine, epoxy/polyamide, epoxy/polysulphide, and the urethanes varnishes are making in-roads in this high temperature/humid environment. Fluoroplastics can also resist these conditions but price still tends to limit their use.

For kilns operating up to 190° F. the conditions are a little less stringent and some alkyds, chlorinated rubbers and Hypalon based coatings have given good service life.

Where higher temperatures pose a problem, say with gas fired systems and hot air distribution or re-cycle ducts, silicone-acrylics (to 500° F.) polyimides (to 700° F.) or silicone resins (to 900° F.) are the main choices open.

These materials range in cost from $10.00-15.00 and are usually pigmented with zinc or aluminum powders.

In the wood or masonry substrates still common to many dry kilns we have absorbent or porous structures. If they are not protected, decay or rotting of the wood and spalling or crumbling of masonry materials due to acid/water action occur.

This comes about by the kiln vapors passing through coatings (permeability) and condensing in the structures at some point as a liquid. It is a dilute acid liquid, which softens, dissolves, or reacts with the various structural materials.

Proper treatments of these materials also constitutes a two or three step procedure. Priming in this case aims at impregnating and sealing the surface layers (1/8" - 1/4" deep). Old style primers were asphalt cut back, coal tar or creosote solution often treated with a drying oil or solvent. Modern primer/sealers often combine a resin (coumarone - indene, phenolic, petroleum resins) flexibilized with a drying oil (tung, linseed or oiticica) in a penetrating solvent (turpentine, pine oil) to obtain a protective effect. Normally the surface layer about 1/8" deep receives the brunt of the water/acid attack. The primer treatment can impregnate this layer with acid resistant materials and confer added resistance. Primer penetration and effectiveness is assisted by applying warm. Tackifiers or adhesion promotes are often added to assist with top coat retention. Where a clear or light colored primer/sealer is required rubberized base materials, fortified by acrylics or other resins in low boiling petroleum solvents are often used. These are film forming primers which also tackify the surface.

Asphalt/Bituminous vehicles have been used as topcoat protect on for many years. These coatings come in many forms; unfilled, fibrated or filled, emulsified and resin or rubber modified.

I dismiss emulsified coatings for dry kilns in the Pacific Northwest as an inexpensive but short sighted investment.

They may serve a useful purpose in low temperature kilns or pre-dryers. They may also serve as the embedding mastic where sheets of aluminum foil are rolled over the coating surface like wallpaper. This treatment carried out successfully on some Eastern region kilns highlights the need for the vapor barrier or film forming components so necessary in a good kiln coating. The light guage foil is impervious to water vapor. If the foil edges are overlapped and sealed properly we have a perfect vapor barrier. In effect a skin of foil within the dry kiln. This approach has been alluded to before. In the constraints mentioned above substitute a plastic layer, a coating of foam or a melamine coated as on plywood, and you have a similar effect.

Many blown or oxidized asphalts initially have good vapor barrier characteristics; proper selection of fillers can enhance this property. Like many materials, however, once the plasticizers or natural oils are driven out by the heat, they tend to crack or craze. A layer of coating may be adhering well be of adequate thickness and appear in good condition. Inspection should always be for signs of the hairline crack stage developing. This is the time to re-coat for continued good protection. A new top coat, if properly applied, will seal or fill these narrow small cracks through a combination of solvent cutting or softening action by and a hot coating. When spalling, flaking or dusting at mortar joints is evident, it is too late for a light overcoat. Cleaning down, priming and filling are then usually required before top coating.

The resin and rubber modifications to asphalt system have been stepped up in recent years. The object is to increase the film forming ability and thereby the impermeability. Scrap rubbers, S.B.R. neoprene and butyl are among the rubbers in frequent use. Some 15-20% of these components is about as much as an asphalt matrix can accept. These more expensive raw materials push the price to $2.50-3.00/gal. Mixtures can be produced with solids contents of 50% and up; at 1 gal/100sq. ft. coverage, a 6-8 mil coat can be applied in one pass. They provide better protection and usually give a longer effective life. The choice of rubber and/or resin is largely governed by the temperature level.

Where a more complete or effective form of protection is desired the base material or matrix is made entirely from polymerized rubbers and/or resins. The additive rubbers mentioned have all been tried, also urethane and Hypalon. Many of these have long term durability limitations around 200-210°F. but have been used successfully up to this point. Neoprene/Hypalon is a well known combination for exterior roofing applications which is useful at or below 200° F. in kilns. Neoprene is generally the undercoat and the modified polyetheylene (Hypalon) the topcoat. Moisture curing urethanes have also been tried; again below 200° F. We have under trial some kilns coated with a special polymerised rubber marked under "Elastron." So far this has proved equal to the task at 240-250° F.

These coatings are comparatively expensive, $8.00-10.00 per gal. The volume of solids however, is usually 55% or greater. Many such as the moisture curing urethanes and silicones are 85-95% solids. Coating thicknesses of 20-30 mils are used to provide 3-5 year protection. This deposition of solids or thickness or coating is applied in at least two coats. Coverage is about 75-100 sq. ft./gal. A two coat application is a good procedure for most protection systems. The first coat allows material to flow into the surface irregularities. The second coat can cover any pinholes left or more effectively bridge across the peaks and troughs in a rough surface. It also allows the introduction of a color code system of preventative maintenance. The two coats can be pigmented in contrasting colors, e.g. black undercoat, silver topcoat. When the black undercoat shows through, the silver in places, that is the time to re-seal the surface.

As well as the rubber or synthetic polymers systems we have the expanded foams such as the urethanes or layers of polyester and epoxy resins reinforced with nylon or glass fibers. These have been referred to previously in conjunction with applying an internal 'skin' to the kiln. The skin can be metal or foil, plastic or reinforced resin system. Many systems among the polyesters, epoxies, and synthetic polmers have been developed which will withstand the kiln environment. Some can be applied in the field, others are impregnated or baked to the structural materials before erection.

Most of this work is leading to the isolation or perfection of coatings satisfactory for the protection of dry kiln components. It may also change the approach to dry kiln construction in years to come.

A wall or roof component in a dry kiln is normally composed of three elements:

- Strength
- Insulation
- Resistance

Strength is generally provided by a steel framework assisted or in conjunction with a masonry or wood covering. The insulation may be inherent in the covering materials e.g. layers of wood, thick masonry or concrete, or it may be added as supplemental in the form of fiberglass batts or expanded products such as vermiculite and foamed material. Resistance is to the aggressive kiln environment either in the form of a 'skin' or protective coating.

These three elements are the essential components of most "composites." When the term is used in relation to aerospace technology, it sounds very technical. Yet it is the down to earth parts of the kiln make-up. If good coatings are developed in conjunction with the good insulating materials now available it will allow less expensive wall and roof components to be used. Some examples may help the illustration.

A 1/4" sheet of high density plywood could form the middle skin frame-in of the structural steel support. A resin facing on the inside would be 45% resin solids (phenol, melanine and now acrylics) impregnated in a fibrous material, some 12 mil thick before pressing. If the temperature/humidity conditions were too severe for the resins mentioned, the fluoroplastics could be substituted. With attention to sealing the joints of the plywood sheets, the internal skin would form an impermeable barrier to water vapor/kiln acids. The external side of the plywood could be covered with fiberglass, foamed glass or cellular plastics and coated to provide weather protection and suitable decorative effect.

This is a simple example built up using products familiar to many. A pre-fab kiln panel with aluminum/fiberglass is another, a masonry block wall well sealed on the hot side, filled with vermiculite or other loose filled expanded products could be another. The key item in the system is the coating or layer impervious to acid vapor penetration. Chemically resistant structural materials are generally expensive. If inexpensive substitutes can be produced, good coating may allow their use.

For example, bark components, or other mill waste material could be converted into a lightly pressed board. - Sealed on the hot side with a coating, - apply insulation to the cold side and you have a substitute kiln wall or roof.

It may also solve a solid waste disposal problem and be a step towards total utilization.

Slag or waste material from mines are being bonded into inexpensive blocks - these could serve as wall or roof components.

Waste rubber from tires, another solid waste disposal problem, is being compressed into blocks - can be cemented together with rubber cements into a building form. Sealed and insulated these would form a lasting structure.

With the advances in coating technology, we should keep an open mind. They may allow as to usefully employ many waste or problem materials. Coating cost is not so high in relation to the labor component. Labor is becoming more expensive so why not use it to apply a good product in the first place.

APPENDIX

COMPOSITION OF A COATING

The terminology used to define the constituents of a coating may simply designate

VEHICLE		BINDER
FILLERS	or	PIGMENTS
THINNERS		SOLVENTS

A modern coating may contain several kinds of constituents which impart desirable and necessary properties. Many of these may modify the chemical resistance of the coating. Some of the possible kinds of constituents are:

- Vehicle
- Solvent or thinner
- Volatile material
- Pigment
- Extender
- Drier
- Catalyst or curing agent
- Flow promoter
- Emulsifier or stabilizer
- Protective colloid
- Preservative
- Anti-foaming agent
- Anti-skinning agent
- Adhesion promoter

COATING THICKNESS

This is often designated as mils (wet) or mils (dry). From a protection point of view, the dry mils is the more important; it indicates the expected thickness of deposited coating solids after evaporation of solvent or other volatiles. Comparison tables may help relate mils to normal dimensions and coating thickness to solids content.

Fractions of an Inch	Equivalent Thickness in Mils
1/64	15.6
1/32	31.25
3/64	46.8
1/16	62.5
3/32	93.75
1/8	125.0
1/4	250.0

Coatings vary in their solids content. Coverage figures over a square of non-absorbent material:

Coverage Gals/100 sq. ft.	% Solids Vol. Basis	Typical Coatings	Coating Thickness Mils (Dry)
1 gal/100 sq ft	25.0%	Primers	4.01
" "	30.0%	Primers	4.8
" "	50.0%	Heavy Bodied Material	8.02
" "	70.0%)	Trowelable Mastics	11.25
" "	75.0%)		12.04
" "	100.0%)		16.05

This last table uses the fact that 1 U.S. gal = 231 cub ins.
1 mil = .001 ins.

$$\text{Thickness} = \frac{\text{Volume}}{\text{Area}}$$

$$\text{Thickness in mils} = \frac{231}{100 \times 144} \times 1000 = 16.05 \text{ mils on 100 sq. ft./gal.}$$

If you wish to calculate the gallons of material required when the film thickness is specified,

$$\text{Gallons required} = \frac{\text{Dry Film Thickness} \times \text{area in sq. in.}}{231 \times \%\ \text{Vol. of Solids}}$$

The porosity or absorbency of a material as well as the surface characteristics affect these calculations.

CLASSIFICATION OF PROTECTIVE MATERIALS

THERMOPLASTIC COATINGS

WAX & GREASE

EMULSIONS -
- Bituminous
- Alkyd Resin

LATEXES -
- Acrylic
- Styrene-Butadiene

BITUMEN -
- Asphalt
- Coal Tar

RUBBER OR RESIN -
- Chlorinated Rubber
- Chlorosulphonated Polyethylene
- Acrylic
- Silicone
- Butyl

POLYMERS -
- Vinyl Chloride
- Vinyl Acetate
- Vinylidene Chloride
- Fluoroplastics

THERMOSETTING COATINGS

ONE-PACKAGE SYSTEMS
- Drying Oil
- Alkyd
- Epoxy - Ester
- Melamines
- Silicone - Alkyd
- Neoprene
- Moisture Cured Urethane
- Oil Modified Urethane
- Polysulphide

TWO-PACKAGE SYSTEMS
- Polyester
- Furan
- Coaltar - Epoxy
- Epoxy
- Urethane
- Polysulphide - Epoxy

CHEMICAL-RESISTANT MORTARS
- Phenolic Resin
- Furan Resin
- Polyester Resin
- Epoxy Resin

PERMEABILITY TO WATER VAPOR

Permeability is a property inherent in a material. We are concerned with water vapor transmission through a coating layer or membrane.

The amount of water which passes through is proportional to:

- Area of the coating exposed
- The differential in vapor pressure across the system
- The time period allowed
- And is inversely proportional to the coating or film thickness

Each of these factors can be expressed in a number of units. This leads to many forms of expressing permeability units based on the formula:

$$\text{Wt. of Water} = \frac{k \times \text{Area Exposed} \times \text{Diff. Vap. Press.} \times \text{Time}}{\text{Coating Thickness}}$$

Where k = Permeability constant (a property inherent in the material).

PERMEABILITY OF VARIOUS ORGANIC FILMS TO WATER VAPOR AT 77-94° F.

	Film Thickness Mils (Dry)	'Perms' Grains Water/Ft^2/Hr. Per In. Hg. Press. Diff.	'Perm-Mil' Grains Water/Ft^2/Hour Per In. Hg. Press. Diff. / Mil Thickness
Oxidized Asphalt	50.0	.017 - .033	.08
Fibrated Cold Applied Coatings (Solvent & Conventional Fillers)	60.0	.048	.28
Fibrated Cold Applied Coatings (Solvent & Fillers to Increase Permeability)	60.0	.475	2.85
Hard Rubber	20.0	.108	.21
Vulcanized Neoprene	34.0	.109	.37
Plasticized Vinyl Chloride	19.0	.286	.54
Polystrene	21.0	.272	.57
Bakelite	22.0	.312	.68
Soft Vulcanized Rubber	14.0	.714	.99

Thickness is not a part of the calculation for 'perm' rating. 'Perm-Mil' rating shows the effect of coating thickness on water vapor permeability.

The permeability of most materials is a function of relative humidity (vapor pressure gradient) and to a lesser extent temperature. Test conditions are important and should be stated.

This chart is purposely made to show a fresh asphalt coating in a good light. The important factor missing, however, is time under operating conditions. Many coatings crack and craze or lose their thermoplasticity. Permeability then increases rapidly. Modern elastomeric or rubberized coatings maintain low 'perm' ratings over a long period of time. This is one significant advance with new coatings.

THERMAL CHARACTERISTICS OF SOME COATING MATERIALS

BASIC RESIN OR POLYMER SYSTEM	MAXIMUM CONTINUOUS DRY SERVICE TEMP. (°F.)
ACRYLIC EMULSION	150° - 180°
ACRYLIC RESINS	250°
ACRYLIC-CHLORINATED RUBBER	210°
ALKYDS	200°
COAL TAR-EPOXY SYSTEM	325°
CHLORINATED POLYETHERS (PENTON)	250° +
CHLORINATED RUBBER	190°
CHLOROSULPHONATED POLYETHYLENE (HYPALON)	230°
ELASTRON RUBBER COATINGS	250°
EPOXY/POLYAMIDE	250°
EPOXY/AMINE ADDUCT	300°
EPOXY-ESTER	200-225°
FLUOROPLASTICS (TFE; FEP; CTFE)	400-500°
NEOPRENE RUBBER	200°
PHENOLIC-OIL VARNISH	250°
PHENOXY	180°
POLYESTER RESIN	200°
POLYSULPHONE	375°

BASIC RESIN OR POLYMER SYSTEM	MAXIMUM CONTINUOUS DRY SERVICE TEMP. (^{o}F.)
POLYSULPHIDE	300^{o}
POLYIMIDE	+400^{o}
SILICONE-ALKYD	350^{o}
SILICONE-ACRYLIC	450-500^{o}
SILICONE	600-700^{o}
URETHANES	225-230^{o}
VINYL CHLORIDE	150^{o}
VINYL FLUORIDE (TEDLAR)	300^{o}

These temperatures are for dry heat conditions. Humidity alters the rating in many instances particularly at high dry bulb temperatures.

The thermal stability of many coating systems are improved by the pigments and fillers used. These figures can be taken as a reasonable upper limit for the various filled resin/polymer systems in current use.

TERMS ASSOCIATED WITH COATINGS

THERMOPLASTIC - Materials may be softened by heat. On cooling they harden without undergoing chemical change. On reheating they will resoften.

THERMOSETTING - Materials, in the process of setting, undergo a chemical reaction which causes molecular crosslinking. The reaction product will not melt. Many thermosetting materials react at ambient temperatures.

SOLUTIONS - Contain resin dissolved in a solvent. The solution may be pigmented as desired for each end use. Some form a hard chemical-resistant film by evaporation of solvent, but others require further curing after solvent evaporation, depending on the kind of resin used.

EMULSIONS - Contain resin dispersed in water and usually pigmented. The cured film may be produced as soon as the water evaporates. However, in addition to evaporation of water from the coating, some resins require curing.

LAITANCE - Is the term applied to the fine cement powder found on all concrete work. This powder does not adhere to the concrete surfaces well and will in turn prevent adhesion of a coating to the surface. It can be removed by acid etching, sand blasting, industrial vacuum cleaner, or by blowing the surface with clean air.

EFFLORESCENCE - Is the phenomenon in which soluble salts have been transported through the concrete or masonry by moisture and deposited on the surface. These salt deposits on the outside walls of dry kilns is a good indication that water vapor is passing through the masonry components.

Masonry products which have effloresced must be carefully prepared, since the salts impair the durability of the paint by preventing adhesion. Acid neutralization followed by water washing is normally the cure.