NEW COATINGS AS COMPONENTS OF ROOFING SYSTEMS

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Coatings have played an important role in the roofing industry for many decades. Dr. G.L. Oliensis received the first patent for cold-applied roof coatings in 1921. Clay-type asphalt emulsions were introduced in the early 1930s. Solvent-based insulation adhesives, a modified form of roofing mastics, gained popularity in the mid-1950s as a result of a substantial fire loss at a General Motors plant in Livonia, Mich.[1] Due to their filler content, these adhesives have greater resistance to flow at high temperatures than hot-mopped bitumen. The '70s saw the use of rubber in many roof coatings and mastics and much greater use of water-based materials.

In more recent times, coatings have been employed as complements to some of the new membranes. They have given the manufacturers and users of these systems options to improve key properties such as weathering and fire-resistance. For example, clay emulsions have been used as coatings in modified bitumen systems to attain Class A fire ratings by UL 790 and ASTM E108 procedures. A variety of both solvent- and water-based products have served as the critical topcoat in spray-applied polyurethane foam systems. The manufacturers of elastomeric single-ply products have relied on coatings for property improvements as well. Prior to the development of fire-retardant formulations, EPDM sheets, for example, were regularly surfaced with Hypalon coatings and embedded sand to achieve fire classifications.

The following functional definitions will be used in this paper in discussing the various materials:

Paint—used for decorative or reflective properties; offers little or no waterproofing performance.

Coating—applied in greater thicknesses than paints; provides waterproofing to the substrate.

Mastic—heavy-bodied material, which can contain substantial amounts of fillers and is usually trowel-applied.

Adhesive—used only for its bonding capabilities. Coatings and mastics may be used as adhesives, but in this paper, other properties would be considered secondary to the bonding characteristics.

Many of the application advantages cold-applied materials offer have been taken for granted over time. Some of these benefits are:

- safe and easy storage, as well as ready transport to the jobsite;
- minimal equipment requirements;
- greater flexibility for the mechanic because, unlike hot systems, cure or set does not take place immediately;
- versatility that allows the products to be used for maintenance along with new, retrofit and replacement roofing applications; and
- greater labor productivity and easier coordination and timing of job stages.

In this paper, we will review some of the new products and systems that have become available. The coatings manufacturers have not been content to have their materials serve merely in an ancillary role for those membrane systems now holding major market share. Many producers are aggressively marketing their coatings as the key components of built-up roofing membranes using both coated and uncoated reinforcements. Additionally, environmental, safety and health concerns have forced a rethinking of the types of coatings being produced as well as the ingredients used in their manufacture.

CHANGES IN COATING FORMULATIONS

Over the last few years, there have been two major factors that have influenced the formulation options open to the manufacturers. The first involves the more stringent regulations that are being imposed on asbestos emissions. Air pollution regulations limiting the amounts and types of allowable solvents represent the second factor.

Because of associated health concerns, the asbestos issue has been in public debate for about 20 years. Although the presence of asbestos in roofing products is still permitted, a number of factors have combined to limit its use. Public opinion on this mineral, especially in light of its previous widespread usage in school buildings, has been an important consideration. Insurance companies, either through very high rates or insurability criteria, have made it very difficult for manufacturers to keep asbestos in their plants and consequently in their products. Trade unions and continued governmental pressures have also led to the restricted use of asbestos.

The State of California has led the way in regulating the use of solvents in coating materials. Typically, other states adopt the California limitations over a period of time. Rule 66 is probably the most well-known of these regulations and has impact on the types and amounts of solvents that could be emitted into the atmosphere. More recently the California Air Resources Board has enacted rules that place greater emphasis on the amounts rather than the types of volatile organic compounds (VOCs) that can be released. Just as they have with Rule 66, other states are expected to adopt the California VOC regulations. Under either restriction, a certain degree of latitude is taken away in the formulation of solvent-based products. This is especially true with the more fluid or less viscous materials such as adhesives and decorative products. Some exemptions, however, have been obtained on the basis that certain coatings are not used solely for waterproofing. One of the results of these restrictions has been a trend toward the use of water-based materials whenever practical.

CONSEQUENCES OF FORMULATION CHANGES

Many formulators and users have come to find that asbestos possesses unique and very desirable properties as an ingredient in roof coatings. Some of the functions it serves are:

- acts as reinforcing fiber and improves properties such as strength and abrasion resistance;
- controls viscosity and sag resistance to allow for sprayability, build of film thickness, application on slope, etc.;
- improves weathering and overcomes inadequacies in some of the other formulation ingredients such as, for example, the asphalt; and
- absorbs oils formulated into the coating material thus reducing the possibility of wash-off and staining.

When asbestos's uniqueness as a formulation ingredient is combined with very low cost, it is apparent why the replacement of asbestos has proven to be a difficult task. Problems with the replacement materials have typically become apparent in the areas of sag control and gravel staining. The author's experience indicates that, on average, the non-asbestos coatings and mastics cost about 10 percent more to produce. This cost increase is due not only to more expensive raw materials, but also to longer and more sensitive manufacturing processes. On a positive note, the non-asbestos products are improving in quality and good performing materials are available —although at a higher cost. Based on the many factors that are working against the long-term use of asbestos, it appears that the non-asbestos versions will grow in importance and volume.

Regarding the restrictions being placed on solvent usage, the manufacturers and applicators have more options than are available with asbestos-containing products. Some coatings and mastics already fall within the requirements of the various regulations. Others could be adjusted by relatively straightforward reformulations to be in compliance. Additionally, there are other product options or techniques that can be employed. Water-based or 100 percent solids coatings, for example, can be used in certain applications. Heat-welding and torch application are two alternative installation procedures that obviously do not release any solvent.

The choice of which alternate to use depends on a number of factors. Warm, temperate climates offer the advantage of an extended season for application of water-based products. The colder areas of the country have a very limited time period for the use of water-based materials and must rely on the other alternatives available.

RUBBERIZED COATINGS AND MASTICS

Solvent-based asphaltic products modified with some type of rubber began appearing in about 1970. Through the years, the variety of modifiers has increased and the types of products modified has also expanded. The original products were developed for application on roof edges and flashings. Today rubberized materials are available for essentially all roof situations. The rubber polymers that are most often used for modification are styrene-butadiene-styrene (SBS), butyl, neoprenes, urethanes and, on occasion, EPDMs and Hypalons. Some of the benefits that arise from rubber modification include:

- **Improved tensile strength and elongation.** Even small additions of rubber can increase the tensile strength of asphalt several times. A typical asphalt will have an elongation of 100 to 150 percent at room temperature. If rubber is added to the material, the elongation can be increased into the 1,000 to 2,000 percent range.
- **Greatly improved recovery and fatigue resistance.** Recovery is the ability of a material to return to its original shape after being stretched. Fatigue resistance is its capability to go through repeated extension and compression or bending cycles without failure. Rubber addition to asphalt significantly enhances both these properties. If asphalt is extended to near its ultimate elongation, it will remain in the stretched configuration and demonstrate little or no recovery. Rubber modified asphalt blends, however, can show a 90 to 100 percent recovery and will return very close to the original sample dimensions. Bitumens by themselves have very poor fatigue properties, which decrease even further as the temperature is lowered. When modified with rubber, these same bitumens will see improvements in fatigue resistance of several orders of magnitude.
- **Superior low temperature flexibility.** Asphalts tend to be brittle by nature. The use of rubber as a modifier will significantly upgrade this property. Depending on the amount and type of rubber used, the cold bend temperature of asphalt can be improved by as much as 70 to 80 degrees F.
- **Extension of service temperature range.** As more rubber is added to bitumen, both the high and low temperature service ranges are extended. Cold temperature performance has already been discussed. At high temperatures, rubber modification also makes the asphalt more static or resistant to flow. This allows the material to be used at higher slopes without the need for excessive levels of filler.

The improvements summarized above are certainly worthwhile and of potential interest to the user. To be of real value, however, they must be translatable to substantive advantages in actual roof performance.

It is well understood that roofs are subjected to a variety of forces that create constant movement within the assembly. One of the prime causes is changing temperatures, which result in the expansion and contraction of the many roof components. To highlight the extent of movement, it should be pointed out that at low temperatures (below 30 F) coal tar and asphalt membranes can have coefficients of thermal expansion/contraction higher than many metals. In fact, lack of proper and complete adhesion accounts for a significant portion of BUR roof splits at low temperatures. Because they are unrestrained, the poorly attached BUR membranes are free to undergo these substantial thermal contractions. At higher temperatures, on the other hand, metal flashings and gravel stops show a great deal more movement than the built-up system and components. This, of course, leads to splitting and tearing problems as well. Other factors such as snow loads, equipment vibration and roof traffic are additional contributers to the dynamics of the roofing system, particularly on buildings with flexible roof decks.

The properties of rubberized coatings and mastics make them well suited to perform under the conditions of movement outlined above. An argument often heard is that roofs do not expand and contract 1,500 percent, so these high elongation values are unnecessary. There are several reasons for building in this "reserve" performance capability. First, materials that are functioning at or near the limits of their performance have a much greater risk of early failure due to fatigue. The greater the difference between the "normal" stress on a material and its ultimate stress capability, the longer the projected performance. Although standard materials perform adequately when the entire roof system is well bonded, rubberized coatings and mastics can provide performance where adhesion is marginal. Second, there is a gradual loss of performance on aging. Properties such as elongation and fatigue resistance decrease with time. The safety factor compounded into the rubberized products allow them to continue to perform despite the natural aging phenomenon. A third factor in support of rubberization of roofing materials is movement at joints. For example, if an insulation joint moves from 1/32 to 1/16 of an inch, there is a 100 percent expansion. Products capable of accepting these levels of elongation can certainly offer longer-term performance benefits.

Some usual applications and the categories of products typically recommended are outlined below:

- **Metal edge flashings and other metal details where high movement is expected.** Mastic materials based on high levels (15 to 25 percent) of SBS, neoprene or other types of polymers are used. Asphalt is used in the formulations to lower cost and for the waterproofing properties it offers. In addition, it acts to improve compatibility and adhesion when the mastics are applied to asphaltic substrates. A reinforcing fabric such as jute, cotton, glass or polyester is usually employed. For best performance, however, it is recommended that a fabric such as polyester, which possesses elongation characteristics and fatigue resistance comparable to the mastic, be used. These materials, alone and with reinforcement, have demonstrated very good performance where straight asphalt and coal tar mastics have failed.
- **Attachment of single-ply sheets to roof surface.** Neoprene and butyl-modified mastics have performed very well in these applications, particularly with EPDM and Hypalon sheet goods. A key to the success of this use is that the mastic matches the highly elastic character of the sheeting material. This application has a good history of success, and the modified mastics perform when other less flexible products fail. Common details where these materials prove useful are flashings, expansion and control joints, tie-ins at built-up/single-ply junctions, etc.
- **Repair of roof splits, tears, blisters and other general maintenance uses.** Mastics with lower polymer amounts (5 to 8 percent) are often used for these situations. Where a split is the result of excessive movement, however, a high rubber content is recommended with a polyester reinforcing fabric. Butyl and SBS are the modifiers most often used in the lower rubber content materials. It is key that the repair material be compatible with the membrane.
- **Topcoats for finishing asphalt built-up membranes, as smooth-surfaced maintenance coatings and as the adhesive or waterproofing component of built-up, cold-applied systems.** These products are used in sprayable viscosities and at a rubber level of about 5 percent. As topcoats for new membranes and in maintenance applications, solvent-based rubberized coatings are used when weather conditions prohibit the use of emulsions. They would also be employed in maintenance situations when thorough cleaning of the surface is not practical. The application of these coatings to construct built-up membranes will be discussed in detail in another section of this paper.

RESATURANT COATINGS

This category of roof coatings has been less affected by the asbestos situation than other products. Only small amounts of fillers are used and their application is limited to lower slopes.

The suppliers of resaturants indicate that the primary benefits of these coatings include:

- lowering the softening point of the aged BUR top pour by permeating oils into the asphalt or tar;
- adding waterproofing material to the surface of the built-up roof;
- providing a means of attaching new gravel; and
- restoring water resistance to dried-out, exposed roofing felts.

The one significant change is that water-based versions are now being offered. These are being recommended by the manufacturers for applications where there is a high sensitivity to coating odors, such as with schools and hospitals. Since these products are emulsion-type materials, they have the limitations of cold weather application and storage as well as potential wash-off if rain occurs shortly after application. For good adhesion, the surface to which they are applied must be cleaner than for the comparable solvent-based products. The water-based resaturants are recommended primarily for treatment of asphalt built-up roofs.

ASPHALT EMULSIONS

As stated earlier, clay-stabilized asphalt emulsions have been available for over 50 years. With the restrictions being imposed on the use of solvents, there has been greater interest in these materials over the last few years. The manufacturers of these products have attempted to improve their already good performance properties in a variety of ways.

It should be pointed out that the clay-stabilized emulsions are by far the preferred type of product for roofing applications. The other classification of emulsions, referred to as "chemical," does not approach the weathering, fire- or sag-resistance properties of the clay-based materials.

Bentonite is the stabilizing ingredient for the clay emulsions and functions by placing a like electrical charge on the asphalt particles. This charge then causes the minute asphalt droplets to repel each other and leads to a stable, non-settling dispersion. The advantages of the clay emulsions include the following:

- The clay, which is plate-like in nature, coats the surface of the asphalt particles and protects the asphalt from ultraviolet rays and water. In turn, this reduces the rate of oxidation and the loss of volatiles—the two principle mechanisms of asphalt degradation. As a result, clay-stabilized asphalt emulsions age by chalking or erosion, similar to the quality housepaints, which contain titanium dioxide pigments.
- As the emulsion dries, the bentonite forms a three-dimensional network with the asphalt particles enclosed in the honeycomb-like clay "cells." This clay network produces a resistance to flow or slump and allows the emulsion to be used even on verticle inclines. These coatings have excellent utility for flashings and are often used on metal after application of a solvent-based primer.
- The static nature of these materials has caused them to be employed as surface coatings in qualifying roof systems for fire ratings. One of the key factors in obtaining a

"spread-of-flame" fire classification is the prevention of flow of material into the fire source. As the burning area of the test panel is "fed" with more combustibles, the flames intensify and spread even further. The resistance to flow offered by the clay emulsions retards the fueling of the flame source and allows passage of the classifying test.

As already indicated, clay emulsions have found wide usage in flashing and membrane construction, as well as in maintenance applications. Manufacturers, however, have worked to improve the performance of these products. One area in which improvements have been sought is wash-off resistance. The other goal is to upgrade physical properties such as tensile strength, elongation and recovery.

Several directions have been taken to reduce the cure time necessary for the applied emulsion coating to withstand rain or heavy dew. Systems based on chemical asphalt emulsions have been formulated using a co-spray technique, which produces an instant "break" or cure. Another approach that has had good success is the addition of polymeric materials to the clay emulsions. Certain of these formulations have cut the time to achieve wash-off resistance to one-half when compared to the unmodified emulsion. Some work has also been done with a two-coat application in which a fast curing, but expensive, clear topcoat is immediately misted over the asphalt emulsion.

The two-component, "quick-break" product is applied with specially made equipment, which sprays the rubber/asphalt emulsion and the breaker solution simultaneously. This system has been available for many years but has never made a significant impact in the marketplace. Four general reasons are usually mentioned for its lack of market success:

- The equipment needed to apply the system is sensitive and requires constant calibration, as well as an experienced applicator to use it properly.
- Some job problems have been experienced—especially with regard to blistering. An explanation for this involves the cured system's very low permeability. If water is trapped or absorbed by the substrate during the coating process, the rapid cure phenomena will not allow this moisture to escape, thus producing a blister.
- The cost of the system is higher than the clay-stabilized emulsions.
- The weathering is inferior to the clay-based products.

This product is still available in the market. Some success is being observed in the warmer areas of the country, where the weather conditions are favorable for its use. A significant portion of the applications involve foundation waterproofing, which would take good advantage of the low permeability and fast cure this system offers.

Modified versions of the clay emulsions are making more progress in the marketplace. Acrylic, SBS and butyl are some of the polymers that have been used to achieve property upgrades. Among the advantages these one-part materials offer are application techniques identical to the unmodified versions. No new equipment is necessary, and they can be spray- or brush-applied. Acrylic modification, in particular, has proven to be very successful in reducing the time for wash-off resistance.

The third method of achieving rapid resistance to wash-off, misting with a protective top layer, has made little progress because of its cost and the extra cumbersome step required.

The incorporation of polymer modifiers into the clay emulsions has produced materials with substantial property improvements. Significant increases are obtained in the tensile strength, elongation and recovery properties. The added polymers greatly improve the low-temperature performance of these materials as well. The amount of polymer in the cured film is in the range of 5 to 20 percent, depending on the type of modifier and the desired end properties. As low levels of polymer can produce good property improvements, these modified emulsions can also be made available at reasonable costs.

As an example of the general types of improvements that are achievable, below is a nominal property comparison of an unmodified asphalt emulsion and the same emulsion with 20 percent acrylic polymer added.

Property	Unmodified Asphalt Emulsion	Acrylic-Modified Asphalt Emulsion
Tensile Strength (psi)	40	76
Elongation (%)	60	340
Recovery (%)	10	80
Water Vapor Permeability (perms)	30	16
Wash-off Resistance (hrs)	8	3

LATEX COATINGS

As stated earlier, latex products have moved to a position of greater prominence in the roofing market because of the increased number of solvent emission regulations being adopted. The acrylic materials dominate this market area at the present time. They have been available for some time and have the advantage of lower cost when compared to other polymers. Acrylic latexes are used in a variety of roof coating applications including:

- decorative coatings as alternatives to aluminum products;
- coatings for sprayed-in-place urethane foam; and
- waterproofing and adhesive component for maintenance and membrane applications.

Many manufacturers are attempting to promote other types of polymeric materials into this market. Water-based urethanes and epoxies are just two other polymer categories being offered for roof application. Although some property advantages can be identified with the alternative polymers, as previously stated, the acrylics have a substantial cost advantage, as well as a history of usage.

COLD-APPLIED MEMBRANE SYSTEMS

The first cold-process built-up membranes to have significance in the market were composed of coated organic felts applied with a mineral-filled, solvent-based, asphaltic adhesive. As the built-up roofing industry changed to predominantly glass-based products, these cold-applied systems were also converted to coated felts with glass reinforcement. More recently, systems have been designed using combinations of coated and uncoated polyester mats with either solvent-based or latex coating materials.

The first cold-process built-up roof membranes were introduced at a time when the hot versions totally dominated the roofing market. They were introduced as alternatives to hot and promoted on the basis of offering certain application advantages to the contractor. Some of these are:

- little or no equipment setup, which allows the contractor

to install small roof sections or roofs in areas such as high rises without the use of kettles;
- reduced hazards, especially with regard to fire;
- faster installation, particularly when spray equipment is used; and
- greater flexibility for the installer due to the ability to spray adhesive well ahead of laying felt, elimination of the sensitivity to cooling by low ambient temperature and wind, and the ability to reposition felts before cure takes place.

The trade-offs that are associated with the cold systems are typically a result of the cure times required to achieve full property development. A few of the concerns connected with these systems are:
- Since cure does not take place immediately, there is greater risk of wind blow-off or displacement by very heavy rains for a few days after application.
- Tensile strength properties do not fully develop for months and even years after installation.
- The systems are prone to abuse by foot traffic until some degree of cure is obtained.
- They are higher in material cost than comparable hot-applied asphalt built-up roofs.

The properties of the cold systems parallel those of the hot-applied organic and glass built-up roofs. It has been shown that the *cured* properties of the cold membranes essentially equal those of the hot. In a paper given at an ASTM symposium in 1979, Davis and Krenick[2] reported that even after five years of roof exposure about 5 percent of the adhesive volatiles remained in the system. The NBS tensile strength minimum of 200 pounds per inch[3] was reached when adhesive volatiles reached a level of about 7 percent with the organic systems. The NBS standard was developed for hot BUR systems, but is also generally applied to cold built-up roofs as well.

The move to glass felts in the late 1970s was made to remain competitive with the hot-applied systems. The conversion to glass produced the same benefits as were realized by the hot built-ups—higher tensile strength, more uniform properties in all directions of the membrane and reduced water absorption by the felt.

Cold-process built-up roofing has been used with good success throughout the United States. There is, however, a greater concentration of installations in warmer climates such as the California area.

When problems have occurred with these systems, they have primarily involved blistering with the organic version and ridging or mole runs with the glass. The blisters typically have been developed at the organic felt/felt coating interface and were believed to have been caused by solvent action on points of trapped moisture. The ridging of the glass systems was the result of "growth" of the felt. It was found that if the glass felts were cut in 18- to 20-foot lengths and allowed to relax for about 45 minutes prior to installation, the ridging was eliminated. This step allowed the major portion of the growth to take place prior to installation. Additionally, the shorter lengths of the felt resulted in inconsequential dimensional increases based on proportionality.

A number of less traditional cold-applied membrane systems have been introduced in the last few years. Most of these are based on some form of polyester, although glass and glass/polyester combinations are also being employed. These systems are being applied in two- or three-ply configurations. The coatings used to apply the systems can be solvent-based, rubberized or unrubberized asphalt mastics or acrylic latex materials. With some of these systems, a coated base sheet is used as the first ply. The property advantages of these membranes parallel those of the reinforcing mats or scrims.

Since many of these applications include two or more layers of polyester, they can boast of the increased advantages provided by the synthetic mats:
- good tensile strength;
- excellent toughness or strain energy;
- light weight;
- excellent puncture and tear strength;
- very high elongation; and
- very good conformance to irregular surfaces.

The concern with these systems is that when non-coated reinforcements are used, all the waterproofing must be supplied by the coating materials. This places a substantial burden on the applicator for obtaining uniform and complete coverage with the coating or mastic—a very difficult task. Additionally, great care must be exercised to avoid traffic on the uncured membrane as the coating material will be forced down through the uncoated mats, destroying waterproofing properties. This last concern has prompted some of the manufacturers to require a coated sheet as a first layer.

METAL ROOF MAINTENANCE

A new, expanding area for coatings is metal roof and wall maintenance. This discussion will concentrate on the roofing portion of the market.

Millions of square feet of metal roofing have been installed over the last 40 years. These roofs have come in a variety of shapes and sizes; most are well-built, but many have problems in design, materials or workmanship. These roofs are in desperate need of good, sound maintenance coatings/systems to extend their useful service lives in an efficient and economical manner.

The emphasis in the maintenance applications must, to ensure effective treatment, be placed on a systems approach. Very rarely will one application of coating reasonably resolve all the problems associated with fasteners, seams, projections, gutters, deflected panels, pinholes, skylights and rust. When choosing a system to maintain a metal roof, a decision must be made prior to the selection regarding the problems that exist and the extent of treatment necessary. Is it to be a simple "paint job" to control rust and improve aesthetics, or a major overhaul addressing all facets of the roof's problem areas? A simple rule of thumb is: Aesthetics and reflectivity are functions of the coating; waterproofing is usually a function of sealant details and flashing work prior to coating.

Metal buildings have been in use for many years. Consequently, a large variety of materials and methods have been employed (with varying degrees of success) to maintain them. For discussion, the following general types of treatments will be used:
- paints;
- coatings; and
- systems.

Paints have been and continue to be used in an effort to stop rust. They can provide excellent reflectivity and appearance. Alkyd rust paints, zinc oxide primes, one- and two-part epoxies, aluminum pigmented paints, as well as the newer rust conversion materials all offer the same benefits. If rust is the problem, choosing one of these products may be the solution. However, none of these types of treatments will keep water out of the building.

Coatings in the context of metal buildings imply something more. Due to a buildup of thickness and some ability to elongate, a degree of waterproofing capability is inferred. The types of products in this category include urethanes, epoxies and acrylics. Bituminous products, although not specifically designed for metal roof maintenance, are also employed. Coatings such as aluminum-asphalts, rubberized asphalt cutbacks and modified asphalt emulsions have been used. Although more effective waterproofers than paints, these materials provide marginal long-term watertightness to boltheads, joints, projections, etc. They are, however, very capable of improving the aesthetics of a roof, increasing reflectivity and sealing firm rust and stopping its spread.

Systems, on the other hand, provide a multifaceted approach to metal roof maintenance. There are many systems to choose which offer varied products and techniques.

A number of manufacturers supply one basic coating for the field of the roof and "body" up this material for use as a sealant over fasteners and as a mastic over joints and on flashings. Acrylic latex products are a good example of this systems approach. Primers are generally not used and reinforcing membranes may or may not be employed over joints.

Another system uses elastomeric, bituminous coatings such as modified asphalt emulsions or cutbacks (with rust inhibitors added) with flexible, reinforcing polyester membranes. Applied in a three-ply configuration, these systems blanket the entire surface of the roof. Optional surfacing finishes are available, such as granules along with aluminum or white paints. The use of primers varies but is not mandatory with these systems.

A third option in today's marketplace combines special sealants, elastomeric tapes, primers and various coatings. Each problem area is addressed individually, resulting in a complete system that offers waterproofing, reflectivity, rustproofing and aesthetics. These systems offer a wide selection of coatings, colors, finishes and warranties to the customer.

Metal roof maintenance is a growing market. It has generated a great deal of interest, and coatings, systems and techniques are being introduced on a regular basis. At this time, the coatings being offered have been typically used for other applications and are being adapted for metal roof work. It is just a matter of time until the potential of the market is realized and uniquely formulated products will be developed for this end use.

CONCLUSION

The solvent emissions and asbestos issues have clearly impacted the directions of the coatings manufacturers. The greater part of available R & D time has been spent reacting to or anticipating potential legislation and regulations in these two areas. Water-based and asbestos-free products are here to stay. Certainly there have been some property trade-offs in the process as two important formulation ingredients have had, in one way or another, use restrictions placed upon them. These are continuing issues and they will involve much additional discussion and technical development time.

There also has been a move to greater sophistication in the coatings used in the roofing market. Much of this is in response to the higher technology membrane systems now available and the greater receptivity of the market to try new materials. A number of coatings suppliers have recently entered the membrane market to realize a greater usage of coating per square of roofing. The growth of single-ply is diminishing the inventory of roofing on which the existing types of coatings can be used. Work is also progressing on materials to treat or coat the rapidly growing square footage of single-plies which will need maintenance in the future.

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Material	Standard	Application/Comments
Asphalt Primer	ASTM D41-85	Low-viscosity liquid for use on dry, dusty surfaces to promote good adhesion. Often used on metal and other type surfaces prior to applying emulsions or latex coatings.
Creosote Primer	ASTM D43-73	Tar primer. Applied prior to the use of coal tar products (hot or cold) to ensure good adhesion.
Asphalt Emulsions	ASTM D1227-87	Type I: Clay-stabilized, asbestos-filled. Type II: Chemically stabilized, mineral-filled. Type III: Clay-stabilized, no fillers. Type IV: Clay-stabilized, filled with non-asbestos fibers.
Modified Asphalt Emulsions	Manufacturer's Specifications	Available as one-part or two-part products. Clay- or chemically stabilized. Modifiers can be acrylics, butyls, SBS polymers or neoprenes. Generally superior properties to unmodified emulsions. Useful over modified bitumen sheets.
Asphalt Roof Cement	ASTM D2822-75	Type I: Made with Type I asphalt. Type II: Made with Types II or III asphalt. ASTM D 2822-75 indicates the use of asbestos as a filler. Trowel-grade materials for general flashing and roof work.
Asphalt Roof Cement, Asbestos Free	ASTM D4586-86	Parallels D 2822 but eliminates the use of asbestos filler.
Modified Asphalt Roof Cements	Manufacturer's Specifications	Large number of products available with different levels and types of polymer modifiers. Property upgrades include elongation, fatigue resistance, cold temperature flexibility, etc., compared to unmodified products.
Asphalt Roof Coatings	ASTM D2823-75	Type I: Uses Type I asphalt for self-healing, adhesive and ductility properties. Type II: Made with Types II or III asphalt. D 2823 allows the use of asbestos as a filler and, as a prescriptive specification, is sometimes employed for resaturant coatings.
Asphalt Roof Coatings, Asbestos Free	ASTM D4479-85	Similar to D 2823 but specifies the use of fillers other than asbestos.
Modified Asphalt Roof Coatings	Manufacturer's Specifications	A number of polymer modifiers are used. Difficult to develop a single specification for the variety of products available.
Aluminum-Pigmented Asphalt Roof Coatings	ASTM D2824-85	Type I: Non-fibrated. Type II: Fibrated, contains asbestos fiber. Type III: Fibrated but contains no asbestos fiber.
Asphalt Lap Cement Used with Roll Roofing	ASTM D3019-85	Type I, Grade 1: Brush consistency, no mineral filler, air-blown asphalt. Type I, Grade 2: Brush consistency, no mineral filler, vacuum reduced or steam-refined asphalt. Type II: Asbestos-fibered. Type III: Filled but contains no asbestos.
Coal Tar Coatings	Manufacturer's Specifications	Coal tar versions of asphalt products.
Coal Tar Roof Cement	ASTM D4022-81	General purpose mastic compatible with coal tar roofs.
Liquid-Applied Neoprene and Chlorosulfanated Polyethylene Used in Roofing and Waterproofing	ASTM D3468-85	Neoprene and Hypalon waterproofing coatings Type I, Grade 1: Neoprene solution with no fillers.
Emulsified Asphalt Adhesive for Adhering Roof Insulation	ASTM D3747-79	Type I: Applied at temperatures above 40F. Type II: Applied at temperatures above 20F. Used to adhere preformed roof insulation to steel decks.

Table 1 *Available products with reference standards and typical applications.*