100% Solids Liquid Sprayable Coatings

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Introduction:

This paper covers a series of environmentally compliant liquid coatings, with a primary emphasis on the first commercially available 100% solids liquid sprayable baking coating. The application and performance characteristics of this technology, along with companion compliant coatings materials developed to fulfill other coatings technology niches will be discussed. Given the focus of this conference, the availability of these materials provides significant economic advantages for the liquid coatings end-user who is facing regulatory pressures and needs to consider alternatives for compliance which provide required levels of performance while addressing existing and proposed regulations on VOC's, HAPs content, and SARA 313 reportable constituent issues, while at the same time not requiring full-scale equipment conversions.

Virtually the entire industrial coatings-related community [raw material suppliers, chemicals and coatings manufacturers, and end users] have watched with great interest the development of (and the lack of uniform enforcement of) the Clean Air Act of 1990 and its Amendments. While there once appeared that there would be wide-spread general enforcement of these regulations across industry segments and geographies, certainly the record to date has been one of localized limited activity, most typically the result of specific incidents or local (state level) interest. The initial implications of the regulations, however, have prompted re-alignments in technology development by suppliers to the coatings industry, and the ensuing years have seen some distinctly different formulation approaches taken to providing the end users of paints and coatings with environmentally friendly alternatives. This conference has been organized to focus on those liquid compliance coatings technologies which are commercially available or under advanced development, and to identify which can provide end users the technology they need to maintain their requirements for product performance while addressing current or proposed environmental regulations without the necessity for add-on control equipment (incinerators, thermal oxidizers, etc.) or wholesale conversion of existing application equipment.

Several years ago, certainly before a significant pretense of regulatory pressure began to emerge, one of the first major compliance alternatives to conventional solvent-borne liquid coatings came in the introduction of powder coatings. While capable of providing an option in many situations, a conversion to powder from liquid always requires rather considerable equipment expense, often in the range of hundreds of thousands of dollars. While it provides an escape from the VOC issue, the use of powder coatings leaves the end user to

CHART ONE: Comparative Features And Benefits Summary Chart

Product Features	TioTech 20	TioTech 21	Powder	Solv. Hi Solids	Water Hi Solids
Differentials In Solids As Supplied	100%	87-94%solids	100% solids	60-65%solids	50-55% solids
Differentials In First Pass Transfer Efficiency	90%	85%	55%	85%	85%
Specific Product Attributes					
Low cost/AccCpplied Film Build (0.5-1.0 mils DFT)	yes	yes	no	yes	yes
Potential 75% Reduction In Heated Make-Up Air Requirements	yes	no	yes	no	no
No Additional Application Or Cure Equipment Investment	no	yes	no	yes	no (st. steel)
Faster Line Speed (No "Flash Off" Zone Needed)	yes	no	yes	no	no
Minimal Waste Disposal Cost	yes	yes	yes	no	no
No Product Capacity Limits Due To Current VOC Allowables	yes	yes	yes	no	no
Color Changes In Less Than Two Minutes	yes	yes	no	yes	yes
Reduced Need For Explosion-Proof Equipment	yes	no	yes	no	no
Reduced Need For Extensive Fire Sprinkler Systems	yes	no	yes	no	no
Multiple Color Overspray Is Recyclable	yes	no	no	no	no
No Need For Separate Paint Room/Reduced Manpower Costs	yes	no	yes	no	no
Lower Shipping Costs With No Solvent Or Water Shipped	yes	no	yes	no	no
No Need For Special Weather Formulas/Solvent Purchases	yes	yes	yes	no	no
Lower Scrap Rates Due To Accurate Wet Film Measurement	yes	yes	no	yes	yes
No Need For Refrigerated/Humidity Controlled Storage Area	yes	yes	no	yes	no
Excellent Film Control Due To Lack Of "Fines"	yes	yes	no	yes	yes
No Solvent Or Co-Solvent, Eliminates LEL/LFL Concerns	yes	no	yes	no	no
Overspray/Plant Contaminated Material Is Filterable	yes	yes	no	no	no
Meets All Existing/Proposed Environmental Rules On Emissions	yes	yes	yes	no	no
Number of "Yes" Issues	18	11	11	6	[illegible]

deal with the issues of difficult control of thin films, lack of quick or easy color changing without extensive dedicated equipment, the unavailability of blending systems which can make short runs of custom colors effective, the tendency to build thick films on cut edges, and all of the other characteristics which are typical of powder coatings technologies. As environmental pressures increased, on the liquid side, the initial compliance alternative was water-borne coatings. The technical definition of water-borne materials does not equate to a lack of solvent, and in many cases, while solvent levels are lowered in water-borne formulations, they may not be lowered to a point that they will not be the subject of the first round of serious control requirements. Utilizing a partial introduction of water as a diluent in these materials, resulting in a VOC level which is still in the vicinity of 3.0 pounds per gallon, does not provide a meaningful alternative. Keep in mind, there are many excellent conventional high solids solvent-borne materials available today which routinely are capable of providing VOC levels in the 2.5 pounds per gallon range. In all fairness, however, there are a number of water-borne materials available in a variety of resin technologies for application on metals and plastics which are both water-borne and zero VOC. A drawback shared by all of these water-borne materials is the requirement for equipment modifications including grounding and isolation of equipment for electrostatic application, the use of stainless steel fittings to avoid premature corrosion and system failure, and a tendency for the overspray of these materials to be somewhat more difficult to clean up due to a tendency to remain tacky for an extended period of time on booth walls, conveyor hooks, filter sections, etc. As a result, in many regions, the disposal of waste materials including water-borne coatings residue is becoming increasingly expensive and difficult to arrange.

An alternative approach to the concept of compliance in liquid coatings was taken, however, in considering looking at systems for which the vehicle could be the basic resin itself, rather than either solvent or water. This novel approach, which at first blush might appear to be almost a chemical oxymoron, was intended to develop materials which could be described as 100% solids, liquid, sprayable coatings. While many may have considered the potential for creating materials of this sort, the technical persistence and innovation which have made this possible are the result of an extensive evaluation of formulation alternatives, the willingness to consider unique combinations of materials and their processing, and an essential understanding of the breakthroughs necessary to make this successful. Significant re-engineering of existing technologies on this level is not accomplished by attempting to "tweak" conventional high solids coatings. Those materials, while very competent in their current state, rely on the presence of a level of solvents in order to maintain their stability, and do not lend themselves to this kind of modification.

As the effort for commercialization of a material of this sort came toward success, certain characteristics of this emerging technology became better defined. In the absence of conventional diluents, it is not surprising that these materials are typically higher in viscosity than their traditional counterparts. As compared to a traditional material which might exhibit a viscosity of 500 centipoises, the first iterations of this new technology emerged at levels above 10,000 centipoises. Over time, subsequent revisions of this basic chemistry have lowered package viscosity to levels below 6,000 centipoises at room temperature, still somewhat thicker than traditional materials. For purposes of comparison, this approaches the room temperature viscosity of pure maple syrup.

Material viscosities at this level can generate some understandable concerns in fluid handling. In a traditional material with this sort of consistency, it would be virtually impossible to move the material through fluid lines or application equipment with any realistic level of control. In these formulations, however, an inherent understanding of their thixotropy (the property of highly viscous materials to become more fluid as they are heated, shaken, stirred, etc.) is necessary. The unique response of these materials to the mechanical influences of agitation, shear and temperature translate to the development of excellent fluid management and spray application characteristics. On high speed rotary atomizers (disks, bells, etc.) typically operating at 35,000 rpm or higher, application at either room temperature or very slightly elevated temperatures (less than 110F.) results in an ability to apply controllable thin films with excellent coverage, electrostatic wrap, flow and levelling. The advantage of utilizing heat in the range of 100-110F. is the assurance of uniform fluid flow rates year-round due to uniform material temperature regardless of changes in ambient plant environment. As heat is introduced to the coating, the addition of every twenty degrees Fahrenheit sees an associated reduction in viscosity of fifty percent. Keep in mind that conventional solvent-borne materials, which are much lower in initial application viscosity, undergo evaporation of the solvent as they travel through the air from the application equipment to the part being painted, resulting in a material which arrives at the part fairly high in viscosity, and one which (therefore) does not exhibit sags or runs. The materials which are the focus of this presentation react to the shear created by the rotary atomizers by lowering their viscosity in flight, but then regain their viscosity on the part, similarly preventing sags or runs. These coatings, given their solvent-free make-up, maintain essentially all of the electrostatic charge to which they are introduced, resulting in outstanding first pass transfer efficiencies (routinely measured at numbers above ninety percent when applied on high-speed rotary atomizers) and associated excellent wrap properties as they are applied. This combination of characteristics provides a material which typically requires significantly less reinforcement or touch-up than more conventional solids materials. In addition, if there is a desire to apply these materials to embossed metal surfaces, the rheology of the coatings can be modified to provide a coating which will coat the coined or embossed surface uniformly, with excellent sag control on the flat surfaces of the pattern and "hang" on the edges of the valleys, without material flowing away from the edges and/or filling the pattern. The cosmetic results of this sort of application rival any of the more conventional solids liquid materials which have been used for some time, and exceed the capabilities of powder coatings in applications on embossed surfaces.

CHART TWO: First Pass Transfer Efficiency Numbers By Application Method

Application Equipment	Transfer Efficiency On Small Targets	Transfer Efficiency On Large Targets	Definitions:
Conventional Air	15%	40%	Large Targets:
Conventional Air Assisted Airless	30%	60%	Doors, partitions,
Conventional Airless	20%	50%	desks, shelving, etc.
Conventional HVLP	30%	45%	
Electrostatic Air	40%	65%	Small Targets:
Electrostatic Air Assisted Airless	45%	75%	Wire goods, tubular
Electrostatic Airless	45%	75%	furniture, hardware,
Rotary Atomizers-H. S. Disks	85%	95%	etc.
Rotary Atomizers-H.S. Bells	80%	90%	

The coatings developed in this work truly represent a unique chemistry. In performance, they resemble most closely the properties and characteristics of a modified polyester film. These are one-pack materials which cross-link with heat to form a film. In line with the commitment to provide materials with optimum environmental responsibility, these formulations contain no heavy metals, do not contain materials on the HAPs inventory, have no SARA 313 reportables and have no VOC's as supplied.

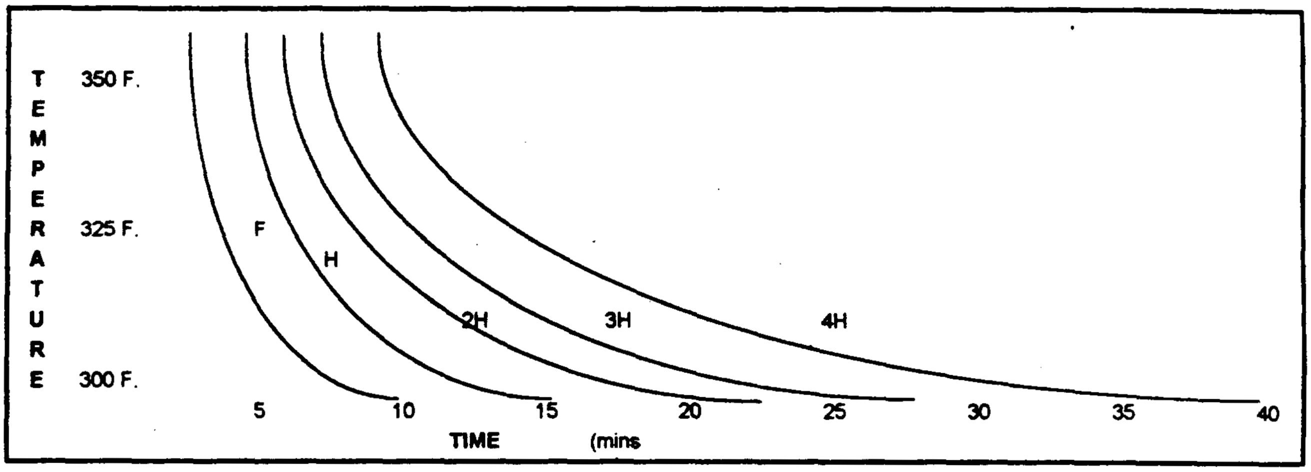
On the subject of VOC's, however, some clarification of this issue is required. While the individual components of these coatings when compiled into the finished material are of a nature that no VOC's are reportable in the initial package, if one runs either ASTM method D-2369 or EPA Test Method 24 on these products, some volatiles are given off. In these test methods, about 0.3 grams of coating is placed in an analytical testing pan and weighed. It is then heated to 110C. for one hour, and re-weighed to determine the degree of weight loss. The weight loss represents what are identified as volatiles. The 100% solids version of this chemistry, when evaluated with these test methods, shows a material loss which calculates to approximately 0.8 pounds per gallon VOC's. What has volatilized during the test are low molecular weight organic materials. These are not conventional solvents being removed from the formulation, these are formulated materials whose components in the lowest molecular weight region are being given off. It should be noted, this same phenomenon with a measurable loss of volatile contents occurs in the cure of powder coatings, again despite the complete lack of conventional solvents in their formulation.

Other characteristics of these materials deserve attention as well:

Gloss: typical formulations can be provided at gloss levels between 20% and 90% when read on a 60 degree gloss meter. If one attempts to formulate materials much below 20%, the additions of the necessary flattener to achieve a true matte finish can have a dramatic effect on increasing the viscosity and render the material very difficult to manage.

Pencil Hardness: Depending on the length of the cure cycle at a stated temperature, significant differences in pencil hardness can be observed. For instance, in conventional convection cure ovens at a 325F. cure temperature, a pencil hardness of "F" is measured after 6 minutes of exposure, while a pencil hardness of "4H" is measured after 14 minutes at the same temperature. At a 350F. cure temperature, a four minute cure cycle will provide an "F" pencil hardness, while a nine minute exposure will provide a "4H" pencil hardness. In the high heat conditions present in a coil coating oven (30 seconds or so at a peak metal temperature of 435-450 F.), H-2H pencil hardness is accomplished within these typical cure parameters. Keep in mind, cure can begin very quickly as no solvent has to be removed from the film prior to beginning the cross-linking process. The attached graph summarizes this relationship between time, temperature and pencil hardness in a conventional convection oven.

CHART THREE: Cure Characteristics (Time Versus Temperature)



Exterior Weathering: when these coatings are placed on traditional exterior exposure without the use of a primer, the films do not yellow, crack, craze, blister, pit or delaminate. However, the films do exhibit some loss of gloss and develop a level of chalking. Currently, in order to pass more stringent exterior exposure requirements, materials that meet these needs require the application of a companion environmentally compliant primer. A conversion of this product to a single-coat technology is in its final stages of development, but all work to date indicates that as a two-coat system, these chemistries will provide excellent weathering characteristics for a wide range of applications. This is not to indicate that in this current state they will be able to match the exterior exposure performance of traditional PVDF films with ceramic pigmentation, which remain the benchmark of high-performance exterior exposure. It is the intention of the research effort underway to be able to provide this weatherable material in a single package, single-coat material.

Corrosion Resistance: in typical salt spray and humidity testing, these materials demonstrate the range of performance one would typically associate with their more conventional counterparts (1/8" maximum creep from scribe at 500 hours over Bonderite 1000/Parcolene 60 treated cold rolled steel). As with more conventional solids materials, this performance can be dramatically affected by the selection of pretreatment processes which are utilized prior to their application. As indicated previously, the use of an associated primer, or the use of two coats of this material, will also enhance properties related to corrosion resistance.

Hiding Properties: these materials will provide excellent hiding at and below 0.5 mils dry film thicknesses, depending on the color being applied and the shape and contour of the parts being painted. In addition, the combination of hiding properties and electrostatic wrap discussed earlier typically allows the end user to enjoy a significant improvement in overall film requirements versus appearance when compared either to more conventional solids liquid materials or to powder coatings. It is very difficult to control powder coatings consistently at films under 2.5 mils, while this material can be easily maintained at less than 0.5 mils if desired. It should be noted that in order to obtain optimum performance from the liquid materials, typical dry film thicknesses are in the range of 0.8-1.0 mils.

Flammability: this material, in its 100% solids version, does not have a measurable flash point. As you start to heat it much past 200F., the coating begins to cure. As a result, it is rated as a Class III-B combustible for purposes of transportation and storage, the same classification as powder coatings.

Settling: Referring back to the discussion of thixotropy, these materials do not settle in the traditional fashion. Therefore, continuous agitation is not required as it would be with a more traditional material. As a result, the normal paint kitchen set-up with timed agitation, etc., is not required, and this material can, in fact, be stored immediately next to the spray booth, shortening supply lines and reducing the necessary circulation equipment.

Required Minimum Air-Flow: the application of any coatings requires some level of air to be moved past the operators and through the spray area. These materials, like powder coatings, do not require the same levels of air make-up or flow as more conventional materials, which can generate a variety of process benefits. Not only does the lesser use of air reduce the cost of heating air and controlling the paint room environment, the physical reduction in air-flow through the spray area can lessen the potential for dust and dirt contamination to be blown onto the applied but uncured film. In addition, the sizing of new equipment to comply with insurance regulations on operator safety becomes less complex when this material is utilized exclusively.

Reclaim of Overspray: in a clean room environment, overspray can be captured and recycled with no loss of properties as there is no solvent being lost which needs to be reconstituted. If dust or other contaminants are a problem, the material may need to be filtered prior to re-use. In addition, if there is a suitable application for a blended color, all of the overspray can be collected in a single holding tank, blended together under simple agitation to create a single color, with complete compatibility, and re-applied as needed. The capability to collect overspray and to re-use it either by itself or in conjunction with companion materials in a blend is not shared with powder coatings, where the only reclaim option is to isolate all materials individually, and to assure that there has been no cross-contamination of either the equipment or the coating in order for it to be re-used.

Shelf Life: there are no particular differences in the storage of this material as compared to a high-quality conventional coating. It is warranted for storage in unopened containers for twelve months from the date of manufacture, and only requires normal cautions in its handling. After the twelve month period, we do reserve the right to evaluate the material to assure that nothing unusual has been done with the coating in the interim.

With this information as a background, what about those end users who face a desire to find a compromise between remaining with conventional high solids materials and current application equipment and going to 100% solids material, and the potential for having to install equipment modifications (which may range from merely the installation of line heaters to the use of larger feed lines and fluid handling equipment to adapt to the higher viscosity of the full-strength materials or the transition to state of the art application equipment)? In these cases, there is a product option available which provides a significant reduction in VOC's while allowing the continued use of existing application equipment.

CHART FOUR: Comparative VOC's Chart

Category of Comparison	Conv. Solids	Conv. High Solids	Ultra-High Solids-No. 1	Ultra-High Solids-No. 2	Ultra-High Solids-No. 3
VOC Levels/Gallon	4.0 lbs.	2.8 lbs.	1.5 lbs.	1.0 lbs.	0.5 lbs.
Approximate Volume Solids	40%	60%	77.50%	85%	92.50%
Sq. Ft./Gal. @ 1.0 mil (theoretical)	640	960	1240	1360	1480
Sq. Ft./Gal @ 50% First Pass Tr. Eff.	320	480	620	680	740
Gallons To Cover 1.0MM Sq. Ft. @ 1.0 Mil	3,125	2,083	1,613	1,470	1,351
VOC's On 1.0MM Sq. Ft @ 1.0 Mil	12,500 lbs.	5,832 lbs.	2,419 lbs.	1,470 lbs.	676 lbs.
% VOC's Vs. 40% Vol. Solids Coating	100%	46%	19%	12%	5%

Based on 1.0MM sq. ft. at 1.0 mil dry film

This second family of materials is created by taking the 100% solids coating and introducing a small amount of non-HAPs solvents to create a significantly less viscous material (the impact on viscosity of low levels of diluent is remarkable). As summarized on Chart Two, the resulting coating has all of the properties of its 100% solids counterpart, but in a package which allows easier application on existing manual or automatic spray equipment. The amount of dilution can be monitored, depending upon equipment requirements, to provide a material which ranges in calculated VOC's from just over 1.0 pound per gallon to approximately 2.5 pounds per gallon (including cure by-products), or 0.5 to 1.5 pounds per gallon as supplied.. An option this material provides, in addition to being essentially a "plug-in" process change, is a mechanism whereby a significant reduction in VOC's can be implemented almost immediately, as a demonstration of a significant commitment to environmental compliance without having to make a large initial capital investment in advance. While many of the issues relating to equipment changes can be eliminated by the choice of the super high solids materials, keep in mind that this option with its use of solvent brings back into play the need to store this material like its more conventional counterparts and to maintain a higher level of booth air make-up and exhaust than the more compliant material.

CHART FIVE: Typical Physical Properties

	TioTech 20	TioTech 21
Weight Per Gallon:	9.4 to 14.0 pounds	9.0 to 13.5 pounds
Weight Solids:	100%	84% to 96%
Volume Solids:	100%	80% to 93%
Theoretical Coverage At One Mil Dry Film Thickness:	1600 square feet	1280-1488 square feet
Color/Gloss:	Matched To Standard	Matched To Standard
Flash Point:	Greater than 200F.	Greater than 100F.
Shelf Life:	Twelve Months	Twelve Months
Pencil Hardness:	H - 4H	H - 4H
Stain Resistant To:	All Standard Stains	All Standard Stains
Adhesion to Cold-Rolled Steel:	100% cross-hatch	100% cross-hatch
Mar Resistance:	Excellent	Excellent
Flexibility:	Pass 1/8" mandrel	Pass 1/8" mandrel
Direct Impact:	Pass 120 inch-pounds	Pass 120 inch-pounds
Salt Spray (500 Hours):	1/8" creep	1/8" creep
Solvent Resistance: 200 MEK Double Rubs	no apparent effect	no apparent effect
Solvent Resistance: 200 Xylene Double Rubs	no apparent effect	no apparent effect
Automotive Fluid Resistance:	no apparent effect	no apparent effect
(after 16 hours immersion):	no apparent effect	no apparent effect
	no apparent effect	no apparent effect
	no apparent effect	no apparent effect
Taber Abrasion: 500 cycles/500 grams/CS10 wheels	0.02 grams	0.02 grams
Tested On Bonderite 1000/Parcolene 60 Substrate		

As an example of the levels of impact this technology can have, in a typical industrial high volume facility, utilizing a conventional (40%) solids material, it would not be unusual to generate 750 tons per year of VOC's. In a transition to high (60%) solids material, this number would drop to approximately 345 tons per year of emissions. However, in a transition to the super high (85%) solids, this number moves down to a level approaching 100 tons per year, and a move to the 100% solids material can lower the number to less than 60 tons per year, with all of these volatiles coming from the resin component, not from any solvents or other traditional organic constituents.

From almost any perspective, the availability of these levels of VOC reduction can allow not only the resolution of virtually any environmental concern tied to emissions, but in this age of regulatory balancing, can provide the opportunity for emission offsets (where these are available) to support the installation of other processes within the manufacturing operation which while not paint-related, may generate measurable VOC's of their own, and thus impact some of the issues related to air permits.

CHART SIX: Comparative Systems Costs - Liquid Vs. Powder Coatings

CONVERSION JUSTIFICATION EXAMPLE	Powder Coatings	TioTech 20
Volume Solids	100%	100%
Potential Material Utilization (with overspray recovery)	95%	95%
Typical Solid Density (both with same "light" color)	14 lbs./gallon	14 lbs./gallon
Typical Quoted Price (Computed Equivalent Price)	$2.50/lb. OR $35.00/gal.	$35.00/gal. OR $2.50/lb.
Dry Film Thickness Applied	1.5 mils	0.75 mils
First Pass Transfer Efficiency	55%	90%
Cost/Square Foot At First Pass Transfer Efficiency	0.0595	0.0182
Cost/Square Foot At Potential Utilization	0.0344	0.0172
Cost Savings Versus Powder:		
Based on first pass efficiency:		69%
Based on potential utilization:		50%
cost per square foot = $/gal. x mils/16.04 x % efficiency		

Example of potential payback justification:

IF powder purchases equal:	$1,000,000 per year
TioTech 20 usage @ 50% savings level would be:	$500,000 per year
Gallons purchased @ $35.00/gallon would be:	14,286 gallons per year
Daily usage @ 52 5-day weeks would be:	55 gallons per day

If the equipment cost to convert to a one drum per day 100% solids liquid spray application is less than $500,000 - the payback would be less than one year.

Therefore:
Converting to a 100% solids liquid would then result in a net operating profit of $500,000 below the line for every future year following the year of installation.

An additional topic which should be mentioned at this point of the conversation is economics. For too long, a myth has surrounded powder coatings that they represent not only the environmental alternative for those confronting some of these issues, but are also the low-cost choice - in reality, once liquid coatings move up to ultra-high solids levels, the economics begin a dramatic shift.

Not surprisingly, when development work of this sort is undertaken, avenues of technology are uncovered which can lead to a variety of additional compliant materials. Among the other variants of the super high/100% solids materials is a companion 100% solids material which can have application as a primer-surfacer in the automotive industry. The automotive exterior coatings market, as you know, typically utilizes a high-build cathodic electrodeposition primer as a foundation over pretreatment and ends up with a color coat or color coat/clear coat combination on top of it. In-between, while the trend had been away from the use of a primer-surfacer to act as a higher dry-film buffer between the primer and color coat, for a variety of reasons ranging from levelling to corrosion resistance to control of color development, greater attention is being given to the use of a barrier coat. In many cases, air permits have been re-written to reflect the absence of this layer, so the availability of a low or no VOC material for this application can be evaluated without having to re-open an air permit modification caused by the consideration of a low solids material of the sort previously utilized. It should be noted that there is currently no intention to consider these materials as automotive exterior body color materials, both due to the issues of cost and of weathering data versus the current chemistries being utilized, and due to the historical dominance and support data tied to the existing suppliers and their materials.

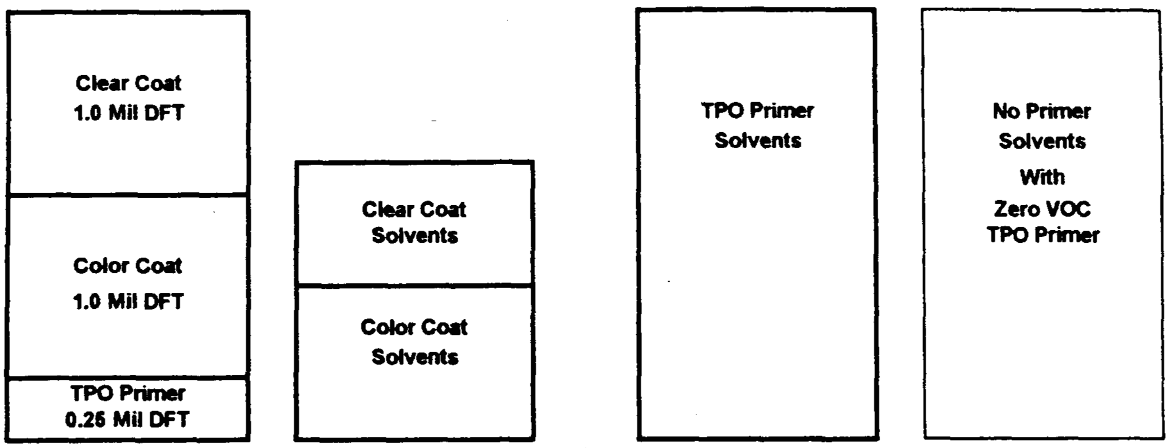
Remaining in the general industrial coatings arena, a material has been developed which is a zero VOC water-borne air dried material for applications on metals, etc. This material formulates at approximately 40% volume solids, has no measurable flash point, and if thinning is required, it can be done with tap water. This material is very forgiving of reasonable levels of surface contaminants, and will demonstrate excellent adhesion over various clean surfaces, with or without subsequent pretreatment. After 24 hours of air drying, or a short period of force drying (30 minutes at 150F or so), this material exhibits reasonable hardness and excellent film flexibility, impact resistance, and other physical properties.

Automotive exterior color coats notwithstanding, there are other applications of great interest in the automotive industry for compliant materials which have resulted from this extensive evaluation of technology. Remaining for the moment on applications for metal substrates, a compliance material has been developed in a zero VOC water-borne material for use as a transit coating for protecting the exterior of the automotive or light truck surface during storage and shipment. Applied as a water-borne solution coating, the material dries to a water-resistant film which while in place is equally resistant to acids (acid rain, airborne contaminants, etc.), and upon arrival at the dealer, is removed in conjunction with the use of an alkaline cleaner solution which is sprayed onto the surface, allowed to remain in contact with the surface for a couple of minutes, and then removed with a pressurized water rinse. Use of a material of this sort is a consideration both as an additional protection for high-end models where every measure of surface enhancement is being taken, and in replacement of the contact film laminates currently in vogue for this sort of protection. The films, while functionally effective, are relatively expensive (typically above $10.00 per vehicle), can be difficult to remove, and create a disposal issue for the dealer which is an additional hurdle. The water-borne solution, while essentially clear, can be dyed slightly (if desired) to be more evident once in use.

Staying with the automotive market, but moving into the growing arena in the use of plastics, an application which has generated extensive VOC levels (and in so doing has limited its development despite considerable customer interest) has been the painting of polypropylene and other olefinic substrates. These materials are of great interest in the automotive market in that they are relatively inexpensive, are completely recyclable into themselves (primary surface uses can be ground up and re-used as a primary surface, not relegated to backers and other non-critical uses due to an inability to provide a smooth surface), and they exhibit good weathering characteristics in their own right. The weakness of these materials relates to the difficulty of obtaining the required adhesion of paints and adhesives on these surfaces. As a result, these materials have typically required an adhesion promoter prior to the application of the color coat. These coatings, typically applied in very thin (0.1-0.2 mils DFT) films, have traditionally been very low solids products (5-6% volume solids is not unusual) containing an associated high level of aggressive coalescent solvents, designed to penetrate the surface of the plastic and to set up adhesion sites for the subsequently applied color coats. It is not unusual for the solvent-borne materials of this type to generate 6.0-7.0 pounds per gallon of VOC's,

CHART SEVEN: Zero VOC TPO Finishing Process

Comparative Solvent Volumes	
Solvent Clear Coat	60% Volume Solids
Solvent Color Coat	50% Volume Solids
Solvent TPO Primer	10% Volume Solids



which can effectively offset any compliance of the subsequent topcoats because of the very high volume of VOC's released in their application. This impact is demonstrated on the attached chart. As you can see, in an operation coating 100,000 square feet of material at 0.2 mils dry film thickness with equipment providing 70% transfer efficiency, more than a ton of VOC's could eliminated per year in the use of a zero VOC adhesion promoter versus a more traditional material. Development work undertaken to provide a material of this sort has resulted in a patented zero VOC waterborne emulsion-type material. This product is applied in equally thin films from a much higher solids material (13% volume solids).

Optimum film formation with this material occurs in the presence of heat, as it requires an exposure to 180F. at some point during the process cycle. Interestingly, this exposure to heat can come during the curing of the subsequently applied topcoat, allowing the adhesion promoter and topcoat to be handled in a wet-on-wet application process if there is no existing provision for curing the adhesion promoter by itself. This in no way reduces the properties of the adhesion promoter or the subsequently topcoated material.. Once the adhesion promoter and topcoat are in place, they perform very well in the most aggressive automotive evaluations, including thermal shock and other deployment analysis, which are sufficiently destructive to expose a film weakness very quickly. In those applications which are not topcoated, but rather are intended for the bonding of an adhered companion surface (typically the double-sided tape used to bond body-side moldings, etc.), this material serves as an excellent foundation for the existing adhesives to allow the olefins to compete for these applications which have previously been dominated by the use of PVC. The strength of PVC has been in its superior adhesion, while the weaknesses of PVC have

CHART EIGHT: Zero VOC TPO Primer Description

Weight Per Gallon	8.55 Pounds
Weight Solids	15%
Volume Solids	13%
Recommended Film Thickness	0.2 - 0.4 Mils DFT
Theoretical Coverage @ 0.2 Mils DFT	1043 Sq. Ft./Gallon
Package Viscosity	200 - 400 cps (Brookfield)
Thinner (If Desired)	Tap Water
pH	8.5-9.5
Flash Point	None Measurable
VOC's (Pounds Per Gallon)	Zero

been in exterior weathering (to the point of requiring a clear coat) and in its non-recyclability into an equivalent use. Once the issues relating to the adhesion of the tape to an olefin are resolved, however, with a material of this sort many other design options open up for the end user. In addition to this material being provided in a standard clear formulation, it is also available in a pigmented conductive version, intended to enhance the electrostatic properties of the substrate for subsequent application of color coats. This can be a significant benefit for first pass transfer efficiency on molded or intricately shaped parts, and as such, can provide additional economic incentives to consider a material of this sort.

[It should be stated once again that the chemistry of the adhesion promoter is completely different from any of the other low and no VOC materials discussed in this paper.]

Summary

The issues related to the implementation of these various technologies will vary by region, by industry and by facility. It is becoming clear that the Clean Air Act will be enforced with varying emphasis from region to region, and it is too early to tell whether the tenets of the regulations which call for uniform enforcement across similar industries will materialize. Eventually, however, there can be little doubt that the intentions of the Clean Air Act and its Amendments will be enforced, and that there will be little forgiveness for having ignored its requirements. It is unrealistic to imagine that the conventional high solids (60% or so volume solids) materials in wide-spread use today will meet the requirements of the regulators without the installation of extensive control equipment. For this reason, it is equally unlikely that the liquid coatings manufacturers will spend any measurable portion of their development budgets in the future on making a "better" 60% solids material. Selective development investments in water-borne systems will certainly continue, particularly in the zero VOC water-containing materials where a real contribution can be made to lowering emissions. It will be unlikely that similar levels of investment in product development will be undertaken on a wide-spread basis in powder coatings for some fundamental reasons. There is sizable over-capacity in the North American powder coatings market currently, with over 60 manufacturers of most chemistries. The result of this combination, not surprisingly, is an ongoing commoditization of the powder coatings market as prices are driven down to a level which makes it difficult to justify true product development activities. In addition, there are so few powder coatings manufacturers who are basic in resin manufacture that the bulk of the market is left to pick materials from a common raw material base in which differentiation is almost impossible. There will always be a market for powder coatings, certainly, but the "easy" improvements in this technology have already been realized. The more difficult hurdles confronting powder coatings (mentioned previously) will not readily disappear, and the availability of a viable liquid material which effectively removes these hurdles changes the issues when an end user confronts his options for equipment conversion and process compliance.

The core message of this presentation is quite simply this: for the broad-based requirements of the general industrial coatings marketplace (office furniture-files-partitions, appliances, shelving, tool boxes, commercial and residential metal furniture, electrical component enclosures, and other general metals end uses), liquid materials are available TODAY which provide the optimum blend of performance and compliance, coupled with value economics which allow the end user to achieve all of his needs.