ABSTRACT: The present invention relates to methods, particularly suited for the coil-coating industry, for continuously covering and permanently bonding a heat stable plastic foam to a metal web traveling at comparatively high speeds of up to 300 feet per minute through coil-baking ovens having ambient atmospheres above 400° F. The metal web may be an unwound coil of steel or aluminum, and the foam may be expanded polyvinyl chloride. The foam-covered metal coil product of the invention, which may include a plastic film laminated thereto, is suited for postforming by stamping, bending, crimping, roll forming, or the like.
FOAM-COVERED COIL AND METHODS OF MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

The coil coating industry is a fast-growing industry which is little more than 30 years old. The first continuous coil-coating line was developed in 1936 to prepaint steel strips for the venetian blind industry. From the original single coating line, the industry has grown to approximately 60 companies, operating more than 100 coating lines, and actively engaged in coating over a million tons of coil (upwards of 4 billion square feet) per year. The precise nature of individual coil-coating lines varies. However, all are high speed, heavy duty installations representing significant capital investments (often well over one million dollars per line). The industry today is represented as a group by the National Coil Coaters Association.

Coil-coating lines have been able to precoat or prepaint metal strip with conventional solution vinyls, alkyd-aminos, acrylics and the like applied in very thin wet film thicknesses, i.e., 1-4 mils, and to precoat strip with organosols and plastisols at somewhat higher wet film thicknesses, i.e., 3-15 mils. Nevertheless, commercially acceptable foam-covered coil has heretofore not been continuously produced at high speeds and on a continuous basis by coil-coating lines.

The plastisol technique for making foamed vinyls on a continuous basis at low speeds and comparatively moderate temperatures (in contrast to the speeds and temperatures of coil coating lines) is well established art. Several million pounds of foam, produced by known plastisol technology are consumed yearly by the textile, artificial leather, and flooring industries among others, in a wide variety of laminated structures. However, as mentioned hereinabove, a commercially successful, continuously produced, vinyl foam laminate having a sheet metal substrate has heretofore not been produced by the coil coating industry. Accordingly, the present invention is directed to the provision of a new and improved foam technology to enable "coil coaters" to manufacture foam-covered metal coil on their existing lines and utilizing conventional coil-coating equipment.

As is known to the art, a vinyl plastisol is a finely divided polyvinyl chloride or polyvinyl chloride copolymer resin which has been dispersed in a plasticizer or combination of plasticizers to form a fluid paste to which various modifiers may be added to enhance heat stability and to improve rheological properties. Upon raising the temperature of the vinyl compound in the range of 300°-400°F, the vinyl resin and plasticizer become homogeneous. This transition is characterized as "fusin." Thereafter and upon cooling, this thermoplastic mass becomes a highly cohesive plastic.

To convert a conventional vinyl plastisol to an expandable plastisol, a "blowing agent," i.e., a chemical compound which decomposes and releases a gas when heated, is added thereto. The decomposition of the blowing agent, if "triggered" at the proper time during the fusion of the plastisol by a "stabilizer-activator" (i.e., a chemical compound which has a stabilizing effect on the PVC resin as well as an activating effect on the blowing agent) will result in the formation of a uniform cellular foamed product of varying density, tensile strength and resilience. The temperature at which the blowing agent decomposes and the rate of gas release is determined by the type and concentration of blowing agent, its particle size and the stabilizer-activator type and concentration.

More specifically, the formation of commercially acceptable vinyl foam with small, uniform proper cell size and smooth surface in the textile, flooring and allied arts is achieved by coordinating the timing of gas release with the timing of plastisol fusion. That is to say, it has been determined that the chemical reaction should not decompose before sufficient hot strength or fusion has been developed in the plastisol to entrap the escaping gas. The effect of proper timing on the foam appearance is the establishment of a smooth surface and a uniform small cell size. Conversely, coarse cells, rough surface, and/or greatly reduced plastisol expansion are often the result of improper timing or poor heat transfer due to improper oven design.

When the blowing agent has decomposed at too low a temperature for all the gas to be retained by the plastisol, (i.e., before adequate fusion or before the development of sufficient "hot strength") a condition characterized as "preblow" is said to have occurred. Preblow may be caused by inadequate fusion of the plastisol composition at the time of gas release or the premature activation of the blowing agent by the stabilizer-activator. It has been one practice in the foam industry to eliminate "preblow" by the use of relatively low molecular weight vinyl, in which case fusion occurs at a lower temperature and the gas is trapped. However, the use of low molecular weight vinyl resin produces foam with reduced physical properties. That is to say, high molecular weight vinyl resins produce foams with better tensile strength, elongation, tear strength, and less compression set than foams produced from low molecular weight resins. Furthermore, the common use of low molecular weight dispersion grade vinyl for making foam in the textile and flooring fields makes oven residence time critical. When the plastisol is maintained in the oven beyond the minimum time required to expand it into acceptable foam, the gas trapped in the cellular structure expands the cell walls beyond their elastic limit. Such overbaking results in a weakened or collapsed foam with significantly reduced physical characteristics.

Vinyl foam in sheet form (unsupported or fabric-backed) has been continuously produced from plastisols at relatively low speeds (less than 75 f.p.m.) and at relatively low temperatures (375°-450°), in comparison with the typical speeds (75-300 f.p.m.) and temperatures (greater than 450°) encountered on commercial coil-coating production lines. Among the ovens used successfully in the production of conventional sheet foam, is an oven manufactured by the Dawson Engineering Co., Canton, Mass. The Dawson oven utilizes nozzles issuing high-velocity air (moving approximately 5,000 feet per minute at 400°F) uniformly distributed in a straight line above and below a traveling web, high-velocity air travels only a short, uniform distance uniform distance (less than 6 inches) before striking the plastisol. In significant contrast, the oven for plastisol lane has parallel planes of nozzles disposed approximately 24-36 inches distance from the nozzle to web surface. More specifically, since coil is unsupported in the oven and travels therethrough as a catenary, nozzle to coil distances are not uniform in the oven, resulting in nonuniform heat transfer. Understandably, the efficiency of the Dawson oven, i.e., rate of heat transfer, is quite high and easily predictable because of the proximity of the high velocity, hot air intakes to the plastisol surface and the uniform, equidistant displacement of nozzles from the plastisol. Needless to say, heat transfer conditions in the ovens normally used to manufacture foam from plastisols are quite different from those heat transfer conditions which are present in coil ovens.

Conventional sheet vinyl foam-vinyl film laminations have been produced in the textile, flooring and related arts by coating a vinyl plastisol or organosol on embossed release paper and allowing the plastisol to gel. Thereafter, an expandable vinyl plastisol is coated on the gelled plastisol or organosol and the two layers are then baked. During the baking cycle, the expandable plastisol expands and the plastisol gel coat fuses, producing an embossed vinyl sheet which may be subsequently stripped from the release paper. An alternate method of producing foam-film laminates involves calendering a film formula containing a chemical blowing agent, usually azobisisformamide at calendaring temperatures below the decomposition temperature of azobisisformamide. Simultaneously, another vinyl film is brought in contact with the film containing the chemical blowing agent and the assembly is expanded. Of course, variations of these methods are possible. However, the end product is almost a
skinned vinyl foam laminate to be used in the textile, flooring or related industries and which will herein be referred to as a "partial laminate."

SUMMARY OF THE INVENTION

The preferred embodiment of the invention provides metal coil coaters with its ability to apply a layer of expandable liquid plastic, i.e., plastic foam, to rapidly traveling metal webs in the normal cycles in which metal finishing steps are performed while utilizing available reverse roll coating equipment normally employed for the application of industrial finishes, such as paints and lacquers, to metal coils.

In accordance with the principles of the present invention, vinyl foam-coated metal may be produced on a continuous basis by forming and permanent, by painting the foam in situ on a traveling metal web, after the metal has undergone cleaning and chemical pretreatment. More specifically, typical coil-coating operations (for applying paints, lacquers) are yet up on a production line basis and include reverse roll coaters and high temperature baking ovens (above 400°F.) through which the metal coils, usually ranging in width from a few inches up to 60 inches in thickness from 0.006 to 0.06 inch i.e., 16 gage down to nominal 32 gage, travel at speeds of up to approximately 300 feet per minute.

As an important aspect of the present invention, readily available equipment heretofore used for the application and baking of standard industrial finishes (such as reverse roll coaters and industrial coil-baking ovens) are utilized to apply a thick liquid coating of expandable plastic (5 to 20 times greater than conventional wet film thicknesses) and to subsequently "blow" or "expand" the same within the very short intervals and at the extremely elevated temperatures employed in the coating of metal coil with available coil coatings. Thus the process of the present invention may be advantageously and easily employed in conjunction with more conventional coil-coating operations. For example, a traveling web of steel or aluminum may be painted on one side while being coated with an expandable polyvinyl chloride plastisol on the other side before being passed through a coil oven in which the paint film is cured and reduced in thickness while the polyvinyl chloride plastisol is converted or blown into a cellular product having a final thickness several times that of its original thickness. As a more specific aspect of the invention the expandable plastic foam has an extremely fine and uniform cell structure, low density, uniform color, smooth and tough skin, and excellent heat stability at temperatures encountered in coil-coating ovens (greater than 400°F.).

The foam-coated metal structure of the preferred embodiment of the invention may be laminated with a printed and/or lightly embossed plastic film or it may be subsequently reworked for similar decorative efforts, without laminating, by directly mechanically embossing by hot or cold roll techniques and/or printing on the foam surface. The lamination is effected by a new and improved method in which a heat activatable adhesive is applied directly to the foam surface by roller-coating techniques. Thereafter, the coated foam is passed through an oven to drive off the volatiles and to activate the adhesive before the plastic film is joined therewith. In some applications, where an especially strong bond is required, the plastic film itself, as well as the foam, may be coated with a heat activatable adhesive.

Printing inks may be applied by rotogravure or other suitable means on the foam coated metal before or after expansion of the plastisol coating. For example, in order to print the unexpanded plastic, it is initially fused at a temperature below the decomposition temperature of the blowing agent to provide a smooth, defect-free surface having the characteristics of ordinary vinyl film, which surface may, of course, be easily printed. Thereafter, the fused and printed plastisol may be expanded without sacrificing print definition. If desired, an "embossed" effect may be achieved by printing the fused but unexpanded plastisol with special inhibiting inks known to the art and described in more detail in U.S. Pat's No. 3,293,108 and No. 3,293,094. The inhibiting inks locally affect the decomposition temperature of the blowing agent. When the plastisol is subsequently subjected to curing conditions, the plastisol will be differentially blown or expanded to provide a chemically "embossed" effect.

If desired, in lieu of laminating a separate film to the foam for protection, a rough skin may be formed on the plastic foam by coating the unexpanded plastisol with a transparent coating and then baking the unexpanded and clear coated plastic.

An alternate embodiment of the present invention provides metal coil coaters with techniques for combining a preformed foam or foam-film laminate with metal coil at high speeds and on a continuous basis. As will be appreciated, all of the methods of this invention enable, for the first time, a coil coater to produce foam-covered coil on existing production lines and in commercially feasible, optimally short cycle times.

The new foam covered metal coil material may be used in the manufacture of a wide variety of articles, including interior or motor vehicle components, insulated siding, cushioned metal furniture, and the like.

DESCRIPTION OF DRAWINGS

For a more complete understanding of the present invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a schematic representation of a typical tandem coil-coating production line set up for the practice of the preferred embodiment of the present invention;

FIG. 2 is an enlarged, fragmentary, cross-sectional representation of a foam-covered metal embodying the principles of the invention and including an layer of primer and a plastic film superimposed upon the foam;

FIG. 3 is a foam-covered metal in which the foam is adhered to the metal substrate without primer and a plastic film is superimposed upon the form;

FIG. 4 is a foam-covered, primed metal substrate embodying the principles of the invention;

FIG. 5 is a foam-covered, unprimed metal substrate embodying the principles of the invention;

FIG. 6 is an embossed foam-covered metal substrate embodying the principles of the invention; and

FIG. 7 is a metal coil substrate covered with a fused but unexpanded expandable plastisol.

DETAILED DESCRIPTION OF INVENTION

Referring now to FIG. 1, the preferred method of the present invention may be practiced on any conventional coil-coating line which includes at least one reverse roll coater 10, such as is conventionally employed to apply wet coatings of common industrial finishes, and at least one coil oven 11, such as is employed to cure common industrial finishes on metal coil. Specifically, a typical coil-coating production line is set up to prepaint or to finish, on a continuous basis, coiled webs of metal ranging in width from about 6—60 inches and in thickness from about 0.006—0.060 inch, e.g., 16 gage to nominal 32 gage steel. Such a line may be a "tandem line," i.e., it may include two coating stations and two ovens.

As shown, a coil 12 of metal to be finished, typically steel or aluminum, but in some instances galvanized steel, brass, copper, or magnesium, is uncoiled and the web 13 is directed through an entry accumulator 14. The accumulator provides sufficient lineal web storage to allow the leading end of a fresh coil to be spliced into the trailing end of the coil 12 without process interruption, thus permitting continuous operation of the line. From the entry accumulator, the web is directed through surface preparation stages of the line where it is sequentially subjected to the action of a caustic cleaning bath 15, abrasive brushes 16, a hot water rinse 17, baths 18—20, for pretreatment solutions, such as iron phosphate or zinc phosphate for steel coil and chrome conversion solutions for
aluminum coil or steel coil, a cold water rinse 21, an acid rinse 22, a dryer and cooler 23. As will be understood, in some cases, the pretreatment may be somewhat varied or even omitted, if the metal coil is absolutely clean and uncontaminated.

Thereafter and in accordance with the preferred method of the invention, the top side of the prepared web is coated by the coating apparatus 10, usually a reverse roll coater, although any coater capable of applying a coating will be equally efficacious, with a 0.6—1.5 mil wet layer of primer 24. A suitable primer for the practice of the invention comprises a coating having approximately equal amounts of phenolic, such as that marketed under the trade designation BK5-2620 by Union Carbide Corp., and a solution-type vinyl, such as marketed under the trade designation VMCH by the Union Carbide Corp. Other known primers based on a variety of readily available resins and polymers may also be satisfactory. The prime coat must have excellent adhesion to the substrate and not delaminate after the highly plastizied vinyl plastisol is baked. The primer-coated metal coil is then directed through a first coil oven 11, which is of the gas-fired convection type (approximately 30—180 feet long) having parallel planes of hot air nozzles or slits directed at the top and bottom sides of the coil, these nozzles or slits are approximately 24—36 inches from the coil. The primer is baked to a 0.2—0.5 mil dry film in the coil oven 11 at temperatures ranging from approximately 500°—800°F. (most coil ovens having multiple heating zones maintained at graduated highly elevated temperatures). The exact speed of the web (which may range from 50—300 feet per minute) and the length of the oven will determine the time the primer will remain in the oven. For example, a web traveling at 150 feet per minute will provide 40 seconds of baking time in a 100 foot oven. Metal temperature for the primer should be in excess of 450° for optimum results.

Upon leaving the first coil oven 11, the primed web 13 is subjected to the sequential action of an air cooler 25, a quench bath 26, and a blower 27 to effect cooling and drying. Thereafter, the primed metal web is directed through a second coater 30, which may be 88 to the coater 10 and which is, in any event, at least capable of applying a viscous liquid. An approximate 10—100 mil wet layer of a new and improved expandable vinyl chloride plastisol 31 is applied to the primed surface by the coater 30. The precise wet thickness of a given vinyl chloride plastisol coating which in some applications may be about 5 mils, will determine the subsequent finished thickness of the film layer and the approximate oven temperatures required for baking, as will be understood. For example, a 15 mil wet vinyl plastisol coating provides approximately a 1/16-inch layer of vinyl foam having a 20 pound per cubic foot density, while a 45 mil wet plastisol coating provides approximately a 5/16-inch layer of foam having the same density. Of course, extremely thin wet coats (about 5 mils) can be blown at comparatively low oven temperatures (approximately 300° F.), and a change in formulation resulting in a change in foam density will change the "blow ratio" (expanded thickness to wet thickness). The lower the density, the greater the "blow rate".

As an important aspect of the invention, the new polyvinyl chloride plastisol 31 is extremely heat stable in oven atmospheres of 300°—800° F. and is expandable in short durations, i.e., less than 2 minutes residence time, at these temperatures into a layer of foam which is permanently adhered to the primed metal surface and which has a fine and uniform cell size. Ideally, a fixed expandable plastisol formulation will be expandable at a substantially constant "blow ratio" through a predetermined range of temperatures and through a predetermined range of residence time to provide the coil coater with some latitude in selecting a precise cycle time. The latitude afforded the coater enables the expandable plastisols of the invention to be used and cured in conjunction with common paints and lacquers. Moreover, with sufficient latitude, a single plastisol composition may be used on a variety of metals as well as on different gages of the same metal.

After being coated with the selected expandable vinyl plastisol, the coated metal web is passed through a second coil oven 31 which is similar to the first oven in that the hot air nozzles or slits are parallel and approximately 24—36 inches from the coil. As was the case in the first oven 11, the web 13 will have a short residence, e.g., 20 seconds to 2 minutes, in a gas-fired-atmosphere of approximately 500°—800°F. Of course, exact residence time is a function of line speed and oven length. At thy stage in the process, the intense heat will cause the blowing agent to decompose, releasing gas simultaneously or just after the fusion process. The stabilizer-activator, in addition to lowering the decomposition temperature of the chemical blowing agent, also prevents chemical breakdown, degradation, and discoloration of the PVC resin during its expansion into foam 32 and in the subsequent service of the finished product. The specific thickness of the foam 32 is, of course, dependent upon the wet thickness and the specific composition of the plastisol 31. The fine and uniform cell structure of the foam 32 will be determined in a large measure by the choice of liquid plasticizer, PVC resin, and stabilizer-activator, as well as the coil oven parameters, as mentioned hereinabove.

The foam-coated web, upon exiting from the coil oven 31, is subjected to the actions of an air cooler 33, a water bath 34, and an air dryer 35, to cool and dry it. It is highly important that the foam be adequately cooled before it is contacted by any hard surface, such as a direction-changing roll 42, squeeze 41, coil-tracking mechanism, or the like. If the foam is inadequately or insufficiently cooled, pressure or contact with a hard surface will cause its collapse. Finally, the cooled foam-covered strip is wound into a coil 40. When foam thicknesses greater than one-eighth inch are desired, available coil-cooling facilities may be inadequate to sufficiently cool the expanded plastisol. Accordingly as an important, specific aspect of the invention, the preferred design (approximately over 40 mils wet) plastisol coating may be fused but not expanded and thereafter cooled and wound. The heavy, unexpanded but fused plastisol 32' (FIG. 7) may be cooled with existing coil-cooling facilities, rolled up, and eventually shipped to a fabricator. At a later time, either before or after fabrication into a finished or semifinished product, the unexpanded vinyl plastic coated metal is subjected to an oven temperature above 350° F. for a short interval to effect expansion of the plastisol. Cooling of relatively thick "post expanded" foam (approximately 1/2 to 1 inch) to handleable temperatures by the fabricator may often be more easily accomplished by the fabricator than by the coil coater due to the increased air cooling times afforded by the comparatively low conveyor line speeds generally employed in the metal working industries.

The new and improved expandable vinyl plastisol employed in the practice of the invention generally comprises polyvinyl chloride resin (PVC), 40—125 parts of liquid plasticizer per 100 parts of PVC, 0.25—10 parts chemical blowing agent per 100 parts of PVC, and 1—10 parts of stabilizer-activator per 100 parts of PVC.

The polyvinyl chloride resins contemplated by the invention are the homopolymers of vinyl chloride, copolymers and/or interpolymer of at least 70 percent by weight of vinyl chloride and up to about 30 percent by weight of one or more other vinyl monomers copolymerizable with vinyl chloride. For the purpose of this invention, the vinyl monomers which may be included in addition to the essential vinyl chloride in the polyvinyl chloride resins are those monomers having a CH2=O group.

Contemplated liquid plasticizers are the alkyl and alkoxy alkyl esters of dicarboxylic acids or the esters of a polyhydric alcohol and a monobasic acid, and they include such materials as dibutyl phthlate, dioctyl phthlate, dibutyl sebacate, di-nonyl phthlate, di-(2-ethyl hexyl) phthlate, di-(2-ethyl hexyl) adipate, glyceryl stearate, cetyl alcohol, and the like. Specifically, and in accordance with the invention, the plasticizer system for the PVC should include a few parts of a highly solvating plasticizer such as alkyl-aryl phosphate or
butyl-benzyl phthalate to ensure the evolution of a fine and uniform cell structure in the cured plastic foam. Reactive monomers may be used as a partial or total replacement for the conventional plasticizers where a more rigid foam is desired.

The blowing agents employed in the new and improved expandable plastisol are preferably chemical blowing agents (those compounds which decompose at elevated temperatures and evolve gases). The most preferred blowing agents for the practice of the invention are azoformamidobenzyl (azidocarbonamide), azobisobutyronitrile, and diazoaminobenzene. In addition to the aforementioned azo-compounds, the N-nitroso compounds, the sufnonyl hydrizides, the sulfonf sulfuric semicarbazides, and the other like compounds commonly employed as chemical blowing agents may be used. Moreover, it should be understood that in certain applications, when found desirable or necessary, mechanical blowing agents may be employed in lieu of the aforementioned chemical agents.

It has been determined that the selection of the specific stabilizer-activator for use in the plastisol is extremely important and that only certain stabilizer-activators are useful in the practice of the invention.

The heat sensitivity of vinyl is well known and another of the limitations that coil cycles present is the need for a stabilizer which imparts excellent high temperature stability to vinyl thus limiting the possible "activators" which may be practically used for activating the chemical blowing agent. Among those activators which will stabilize vinyl at high temperatures are tri-basic lead sulfate, basic lead sulfate silicate, basic lead carbonate, di-basic lead phosphate, di-basic lead phthalate, dibutyl tin dilaurate and some organotin mercaptides. The common zinc compounds and/or barium, cadmium zinc combinations are excellent activators but do not generally offer as much heat stability.

As discussed hereinabove, the specific proportions of the components of the vinyl plastisol are selected within the recited limits, to provide varying rates of expansion and to provide varying degrees of density, rigidity and resilience, while in all cases maximizing heat stability, minimizing "overblow" (formation of large and nonuniform cells) and "preblow" (premature decomposition of the blowing agent with respect to fusion resulting in reduced blow ratio and rough surface).

The compensation for the difference in heat transfer rates and characteristics that exist between coil-coating bake cycles and conventional foam cycles is one of the important aspects of the invention and represents one of the keys to producing good quality foam on coil lines. Specifically, since line speeds in the coil industry are approximately 75—300 feet per minute, it is necessary to coat, to expand, and to rew ind foam-covered coil at these line speeds of 75 to 300 feet per minute. Therefore, the coil ovens (approximately 100 feet in length and having nozzles or slits 2 to 3 feet from the traveling coil) must be operated at temperatures in excess of 450°F. and as high as 700°F. on heavy gage metal in order to expand the plastisol to practical thickness at high line speeds. Slightly lower temperatures may be used on thinner gage strip since the coil is less of a "heat sink" than heavy gage coil. For example, foam was successfully produced on medium gage metal coil, i.e., 0.035 hot dipped galvanized with 30 mils wet film thickness of applied plastisol, which coil traveled at 75 feet per minute through three oven zones maintained at 600°, 550°, and 550°F., respectively. In this case, metal temperature only reached 425°F. It should be understood that allowable expansion time (determined by line speed) becomes critical, since coil temperature is rising rapidly but never reaching equilibrium with the oven atmosphere. More specifically, with a line speed of 75 feet per minute, the coil is 95°F. hot on entering the coil oven, and in the plastisol, plastisol in which to fully expand. When the decomposition temperature of the chemical blowing agent is reached and passed quickly, the released gas expands the vinyl very rapidly. After full expansion of the vinyl, every additional second in the coil oven leads to some degree of overexpansion which is deleterious. Overexpansion, normally referred to as "overblow" results in the cell collapse, "splitting" tendencies (the likelihood of tearing the metal along an intermediate plane of foam adhered to the metal), and loss of resilience. "Splitting" is evidenced in a finished product in which the foam layer can be easily torn or pulled away from the primed metal, leaving behind an obvious film of foam on the primed metal. This phenomenon indicates that the foam has adhesiobility to the priming, a greatly reduced internal strength or toughness. Of course, in the conventional foam producing industries, temperatures of the magnitude present on coil coating lines are not necessary, and the existence of more uniform rates of temperature rise, the absence of a large heat sink, and proximity of the high velocity air to the plastisol makes controlled gas release a relatively simple matter.

When desired, a plastic film 36 may be laminated to the foam 32 on a second pass through the tandem line to provide a laminated product which may be die cut, crimped, roll formed, drawn, stamped, or otherwise reform into a finished article. In this case, a special solvent-based adhesive 60 is applied at the coating station 30, by reverse or direct roll coater directly on the foam. Thereafter, the foam coated metal with the superimposed adhesive is passed through the oven 31 which drives off substantially all the solvent and "activates" the adhesive. After exiting from the oven, a vinyl film is immediately married to the "heat-activated" adhesive. The resultant laminate is then sequentially subjected to normal laminating roll pressure by rolls 37, cooled, and finally rewound into a coil. As a specific aspect of the invention, a heat activatable adhesive is employed in producing a foam-film laminate. Since the vinyl foam 32, a thermoplastic, will collapse under pressure of the laminating rolls 37 if the internal temperature of the foam is in excess of 250—300°F., the "heat activation temperature" of the opted adhesive must be less than 250°F. Moreover, while the distance the adhesive 60 must travel from the oven to the laminator 37 is short, the adhesive must nevertheless possess a reasonable "open tack time," that is, it must remain in bondable condition.

In addition to reasonable "open tack time" and a heat activation temperature below 250°F., the established bond should be of long term strength. Thus it must resist plasticizer migration which may result in bond failure on aging. Accordingly, as an important aspect of the invention, a polymer is chosen for the adhesive 60, which polymer is of the proper type and of sufficient molecular weight to resist plasticizer migration from either the vinyl film or the vinyl foam.

It has been determined that one family of polymers which are soluble in organic solvents and satisfy the aforementioned criteria are the thermoplastic polyurethanes. These polymers are based on isocyanate-polyl reactions with no unreacted or active isocyanate and require no cure to develop ultimate properties. The high rate of crystallization, outstanding adhesion to polyvinyl chloride materials, and the outstanding resistance to polyvinyl chloride plasticizer migration make them especially well suited for the vinyl foam to vinyl film laminants of the present invention. In the noncrystallized state, thermoplastic polyurethanes are soft and rubbery and possess excellent wetting characteristics as well as a high degree of tack. Moreover, in the crystallized state, they form nontacky flexible films of high physical strength.

Thus, it will be understood that a vinyl foam coated metal, having been prepared on a previous pass through a coil coating line (advantageously, a tandem line) is sent through the coil production line a second time when it is to be laminated. A polyurethane adhesive or other suitable adhesive is then applied at the first or second coating station by direct or reverse roll coater. With the oven temperature of the coil oven set as high as possible but always below the temperature at which foam collapse will ensue, the laminate, the coil oven is then driven off and the adhesive activated in the coil oven. The vinyl film is married to the foam by the heat activated adhesive immediately after exiting from the oven. The resulting
lamine is passed through pressure rolls set at conventional coil-laminating pressure, air-cooled, water-quenched, and rewound.

In the lamination of vinyl film to foam, the specific formulation of the vinyl film may determine the ultimate bond strength. In any event, improved bond strengths may be realized through the application of a heat activatable adhesive to the film itself as well as to the foam. Advantageously, similar adhesive formulations are used for coating the film and coating the foam.

The dual coating of the vinyl film (advantageously at the film manufacturer's plant) and the foam on the coil-coating line (with a suitable adhesive) results in bond strengths greater than the strength of the foam itself, evidenced by foam failure before bond failure in tensile strength tests. Variation in bond strength resulting from differences in film formulation is substantially eliminated. In some applications, the adhesive coated vinyl film may be bonded directly to the foam without coating adhesive thereupon. More specifically, film-foam bonding is possible on the first pass through a tandem line immediately after the expanded foam has exited from the second oven. It should be appreciated that in order to expand the foam the temperature of the foam must exceed approximately 325°F., at which temperature the foam can be collapsed with minimum "finger-tip" pressures. As should be understood, in order not to destroy the foam with the pressure of the laminating roll, sufficient cooling of the foam (to below 250°F.) is necessary after the foam exists from the second oven. This method, although requiring optimum control and special cooling facilities and techniques, is highly efficient since it requires only a single pass through a tandem line. However, when such special cooling facilities are unavailable, foam covered coil may be passed through a tandem line for a second time during which pass the foam is preheated in a comparatively "cool" second oven to a temperature below approximately 250°F. but to a temperature sufficiently high enough to activate the adhesive on the adhesive coated film when it is subsequently married thereto by the laminator.

A typical adhesive for roller coating on foam or film includes the following:

<table>
<thead>
<tr>
<th>Parts by Weight</th>
<th>Polyurethane-Exate 3,740x10</th>
<th>(B.F. Goodrich Co.)</th>
<th>20.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl Ethyl Ketone</td>
<td>40.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyclohexanone</td>
<td>20.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naptha</td>
<td>20.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100.0</td>
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</table>

Other readily available polymers which may be used alone or in combination in the adhesives discussed hereinabove include chlorinated rubber, neoprene or nitrile rubber, post chlorinated PVC, phenolic and modified phenolic resins, acrylic resins, cellulose acetate butyrate, and the like.

In an alternate embodiment of the invention, the laminating step may be omitted, in which case the finished foam-coated web has the structure shown in FIG. 4. As will be understood, the foam may be printed and/or embossed for novel effects instead of laminating vinyl film to the foam (see FIG. 6). More specifically, the foam-coated metal may be printed before or after expansion of the plastisol coating. For example, in order to print the unexpanded plastic, it is initially fused at a temperature below the decomposition temperature of the blowing agent to provide a fused surface having the characteristics of ordindary vinyl film, which surface may, of course, be easily printed. Thereafter, the fused and printed plastisol may be expanded without sacrificing print definition. If desired, a chemically "embossed" effect may be achieved by printing the fused but unexpanded plastisol (see FIG. 7) with special inhibiting inks described in more detail in U.S. Pat. No. 3,293,108 and No. 3,293,094. The inhibiting inks locally affect the decomposition temperature of the blowing agent. When the plastisol is subsequently subject to curing conditions, it will be differentially blown or expanded to provide a chemically "embossed" effect. Moreover, the foam-coated metal may be conventionally mechanically embossed by hot or cold roll techniques.

A similar printed product may be obtained by coating the printed unexpanded foam with a transparent coating and then baking the printed, unexpanded, and clear coated plastic. The resultant product is a tough skinned, printed and/or embossed foam.

As another important aspect of the invention, foam-coated metal coil may be produced on production lines equipped with only one oven and one coater in only one pass. To that end a new self-adhering, expandable plastisol is coated directly upon an unprimed metal surface, and the above described primer coating step is eliminated. In this alternate embodiment of the invention, the self-adherent expandable plastisol generally comprises a suspension of polyvinyl chloride resin in a liquid plasticizer, a chemical blowing agent, a stabilizer-activator, a polyepoxide and/or dipoxide, and a melamine compound containing at least two primary amine groups. More specifically, the resin, plasticizer, and stabilizer-activator are selected from those mentioned hereinabove and are present within the specified limits. The polyepoxide and melamine compounds together are present in amounts ranging from 60-150 parts per 100 parts of PVC resin. More specific examples of polyepoxides and melamines suitable for use in the present invention are set forth at greater length in U.S. Pat. No. 3,278,477, and should be considered to be incorporated herein by reference.

As will be understood, when the self-adherent expandable plastisol is employed, the foam-coated product of the invention will have the cross-sectional configurations shown in FIGS. 3 and 5.

As a further aspect of the invention, the expandable plastosils, whether self-adherent or otherwise, may have pigments, fillers, or other additives incorporated therein. The use of pigments is especially worthwhile when nonlaminated, foam-coated products (FIGS. 4 and 5) are to have decorative end uses. The specific choice of pigment is arbitrary; however, the opted pigment, of course, must not interfere with the expansion rate, stability, blowing characteristics, or rheological properties of the plastisol. The self-adhering foam may be printed, embossed, and/or laminated with vinyl film in the manner described in the preferred two-coat system (primer and plastisol).

As should be understood, the new and improved foam-coating techniques (one coat or two coat) may be performed in conjunction with conventional coil finishing operations such as painting. Thus, for example, and as shown in FIG. 1, a roll coater 51 may apply a primer for baking enamel to the underside of the web 13 before it enters the oven 11 and a second roll coater 52 may apply a baking enamel thereover before the web enters the oven 31. As will be appreciated, the paint primer and enamel will be cured simultaneously with the primer 24 and foam 31 within the normal coil-coating cycle times. In combined painting and foam-coating operations, it is preferable to coat the liquid foam on the top rather than on the underside of the coil.

An alternate method for producing vinyl film-foam-metal laminations in the coil industry involves the use of "partial laminates," i.e., vinyl film laminated to vinyl foam which is available from the foam manufacturer in web form. These "partial laminates" are produced by the vinyl industry by conventional methods such as those discussed hereinabove in "Background of the Invention." In accordance with the invention, a special heat activatable adhesive is applied to the metal coil and/or the vinyl foam. Thereafter, the vinyl film-foam "partial laminate" is married to heated coil as it leaves the
second oven of a tandem line. For a line having only one oven and one coater, this method is especially desirable since it requires only a single pass to produce a film-foam coil laminate, whereas the plastisol-coating technique would require several passes through the coil line. However, this method requires special facilities for supplying the partial laminate to the laminator, since the vinyl film-foam rolls are extremely large and cumbersome.

Following the procedure employed in the preferred method, the special adhesive is applied at a coating station, and the solvent is driven off in an oven while the adhesive is heat activated therein. Upon leaving the oven, the vinyl film-foam partial laminate is married to the strip and pressure applied. After cooling, the laminate goes into the accumulator and thereafter into the windup.

The special adhesive has good adhesion to both metal coil and vinyl foam and is activatable at temperatures between 250°—300° F, so that the foam in contact with the hot metal will not collapse under the lowest pressures at the laminating roll. Suitable special adhesives which are activatable at about 250°—300° F. include the following:

**EXAMPLE I**

<table>
<thead>
<tr>
<th>Adhesive</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Phenoxy&quot; PKHH (Union Carbide)</td>
<td>10</td>
</tr>
<tr>
<td>Thermoplastic epoxy</td>
<td>10</td>
</tr>
<tr>
<td>PKHH 5,740x110 polyurethane</td>
<td>10</td>
</tr>
<tr>
<td>Cyclohexanone</td>
<td>40</td>
</tr>
<tr>
<td>Naptha</td>
<td>40</td>
</tr>
</tbody>
</table>

**EXAMPLE II**

<table>
<thead>
<tr>
<th>Adhesive</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epon 828 (Shell) liquid epoxy</td>
<td>1.7</td>
</tr>
<tr>
<td>Estane 5,740x110 polyurethane</td>
<td>16.6</td>
</tr>
<tr>
<td>Dicydianamide</td>
<td>1.7</td>
</tr>
<tr>
<td>Cyclohexanone</td>
<td>40</td>
</tr>
<tr>
<td>Naptha</td>
<td>40</td>
</tr>
</tbody>
</table>

Other adhesives suitable for this purpose are disclosed in U.S. Pat. No. 2,728,708 and considered to be incorporated by reference herein. It should be understood that the specific methods of covering coil with foam herein illustrated and described are intended as examples and are intended to be representative only, as certain changes and variations may be made therein without departing from the clear teachings of the disclosure. Accordingly, reference should be made to the following appended claims in determining the full scope of the invention.

We claim:

1. A continuous process for applying in situ a heat stable layer of plastic foam and permanently bonding the same to the surface of a rapidly traveling, continuous sheet metal web, comprising the steps of
   a. supplying a wound coil of continuous sheet metal substrate material selected from the group consisting of aluminum, steel, and galvanized steel, and having a thickness of approximately 0.006 inch to 0.060 inch and a width of approximately 6 to 60 inches,
   b. unwinding said coil at speeds of 50 to 300 feet per minute, then directing the unwound web through a liquid-cleaning bath,
   c. water rinsing said web and then subjecting said rinsed web to the action of a pretreatment solution selected from the group consisting of iron phosphate solution; zinc phosphate solution and chromate conversion solution,
   d. drying said cleaned and pretreated web,
   e. directing said web to a first coating station and there priming the upper surface of said unwound coil of sheet metal with a wet layer of liquid resin primer,
   f. baking said liquid prime coating to a dried film thickness of approximately 0.2 to 0.5 mils by forced hot air of approximately 500° F. to 800° F.,
   g. quenching said substrate and baked primer in a water bath to cool said primed substrate and thereafter drying said cooled, primed substrate,
   h. directing said cooled, dried, primed substrate to a second coating station and there applying a coating of expandable plastic to said rapidly moving substrate, said plastisol including 100 parts polyvinyl chloride resin, 40—125 parts plasticizer for said polyvinyl chloride resin, 0.25—10 parts chemical blowing agent for said polyvinyl chloride resin, and 1—10 parts stabilizing activator for the resin-plasticizer-blowing agent combination, said plastisol being curable and expandable in less than 2 minutes at an atmospheric pressure and at elevated ambient temperatures greater than 400° F. and having predetermined gas envolving properties directly correlated to the thermodynamic characteristics of said unwound metal coil substrate,
   i. directing forced heated air having elevated temperatures of approximately 400° F. to 700° F. upon said plastisol coated web for limited durations of approximately 20 seconds to 2 minutes, whereby said plastisol coating may be formed, cured, and permanently bonded to said unwound primed coil substrate, said foam plastic having a fine and uniform cell structure,
   j. thereafter subjecting said web and foamed, cured, and bonded coating to a water bath,
   k. drying said foamed coating and said coil substrate,
   l. squeegeeing the foam coating and then winding said rapidly traveling web at a speed of approximately 50 to 300 feet per minute.

2. The process of claim 1, further characterized in that
   a. said plastisol coated web is subjected to said elevated temperatures of step (i) in two distinct heating stages separated by a cooling stage, the first of which heating stages causes said plastisol to partially cure without expansion and the second of which heating stages causes said partially cured plastisol to expand.

3. The process of claim 2, in which
   a. said partially cured plastisol is printed and clear coated before it is expanded.

4. The process of claim 6, in which
   a. said partially cured plastisol is clear coated before it is expanded.

5. The process of claim 3, in which
   a. an expansion inhibiting ink is employed in said printing step.

6. A wound coil of post-formable multilayered structural sheet metal comprising
   a. a base web of continuous sheet metal coil having a thickness of approximately 0.006 inch to 0.060 inch and width of approximately 6—60 inches providing substantially all the strength and properties of said structural material, said metal selected from the group consisting of steel, aluminum, and galvanized steel,
   b. a prime coat covering one surface of said base web,
   c. a continuous coating on the other surface of the web,
   d. a continuously cast and cured in situ layer of heat stable, foamed polyvinyl chloride plastic permanently bonded to said metal through said prime coat,
   e. said bonded foam layer being obtained by first heating in situ foammable PVC liquid plastic, said plastic including 100 parts polyvinyl chloride resin, 40—125 parts plasticizer for said polyvinyl chloride resin, 0.25—10 parts chemical blowing agent for said polyvinyl chloride resin, and 1—10 parts stabilizing activator for the resin-plasticizer-blowing agent combination.

7. The material of claim 6 in which
   a. said plastic layer is embossed.

8. The material of claim 6 in which
   a. said plastic layer is covered with a clear coating.

9. The material of claim 6 in which
13 a. said other surface coating is paint.

10. A wound coil of post-formable, expandable structural material comprising
a. a base web of metal coil having a thickness of approximately 0.006 to 0.060 inch and a width of approximately 6 to 60 inches, said web providing substantially all the strength properties of said structural material,
b. a nondelaminable prime resin coat of 0.2—0.5 mils on one side and a continuous coating on the other side of said coil,
c. a continuously cast and cured in situ layer of fused, heat stable, expandable PVC plastic permanently bonded through said primer to said metal, said plastic including a blowing agent and having predetermined gas evolving properties directly correlated to the thermodynamic properties of said metal, said plastic including 100 parts polyvinyl chloride resin, 40—125 parts plasticizer for said polyvinyl chloride resin, 0.25—10 parts chemical blowing agent for said polyvinyl chloride resin, and 1—10 parts stabilizing activator for the resin-plasticizer-blowing agent combination,
d. whereby said coil and fused plastic may be subsequently unwound and said plastic may be expanded by heating it to a temperature sufficient to activate said blowing agent.

11. The material of claim 10 in which
a. said plastic is printed with an inhibiting ink and clear coated.

12. The process of claim 1 which further includes the step of a. coating the undersurface of said rapidly moving web with a continuous coating of paint between steps (a) and (i).
CERTIFICATE OF CORRECTION

Patent No. 3,593,848 Dated July 20, 1971

Inventor(s) Arthur H. Landau

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 72, "chemical is" should read --chemical blowing--. Column 2, line 41, after "web" insert --which hot,--.
Column 2, line 42, delete "uniform distance" (second occurrence).
Column 2, line 65, "expends" should read --expands--.
Column 2, line 74, "expended" should read --expanded--.
Column 2, line 75, after "almost" insert --always--.
Column 3, line 17, "hay should read --has--.
Column 3, line 61, insert a period after "therewith"
Column 4, line 15, "thy" should read --the--
Column 4, line 34, "an" should read --a--
Column 4, line 38, "form" should read --foam--
Column 5, line 38, "we" should read --web--
Column 5, line 39, "88" should read --identical--
Column 5, line 56, "expended" should read --expanded--
Column 5, line 58, "rate" should read --ratio--
Column 6, line 9, "thy" should read --this--

Signed and sealed this 11th day of April 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR. ROBERT GOTTSCHALK
Attesting Officer Commissioner of Patents