

Aug. 14, 1945.

C. E. McMANUS ET AL

2,382,432

METHOD AND APPARATUS FOR DEPOSITING VAPORIZED METAL COATINGS

Filed Aug. 2, 1940

4 Sheets-Sheet 1

Fig. 1.

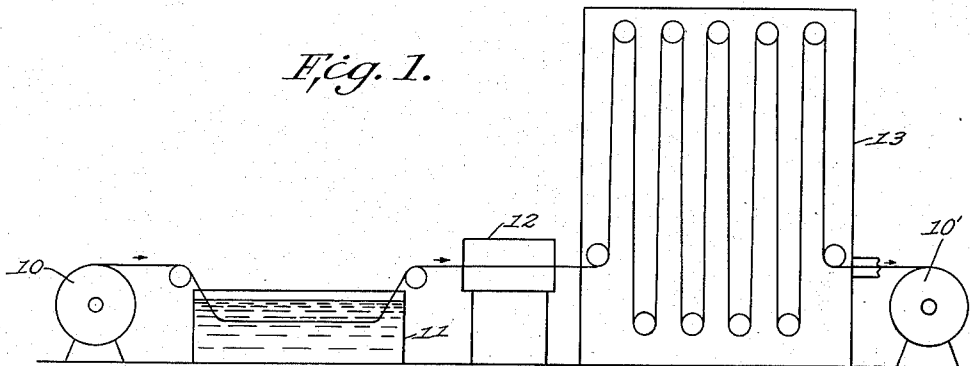


Fig. 3.

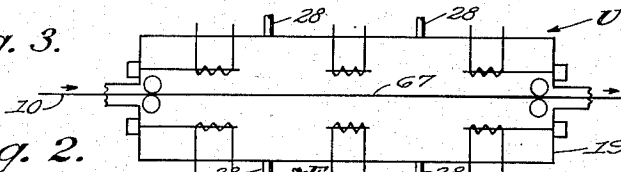


Fig. 2.

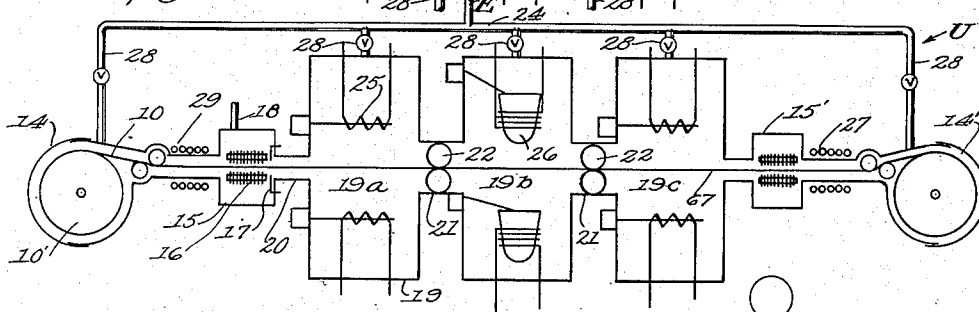


Fig. 4.

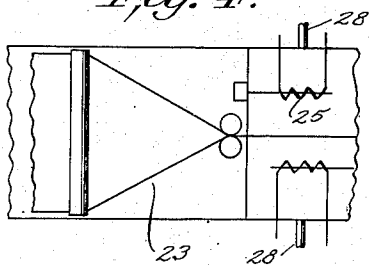
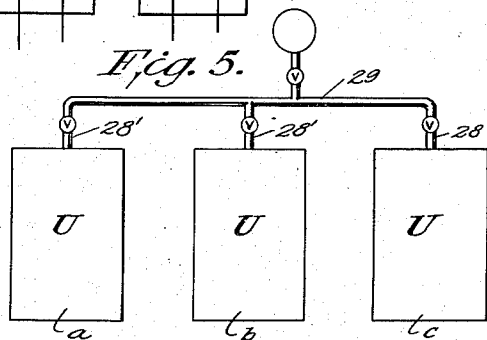


Fig. 5.



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Fig. 6.

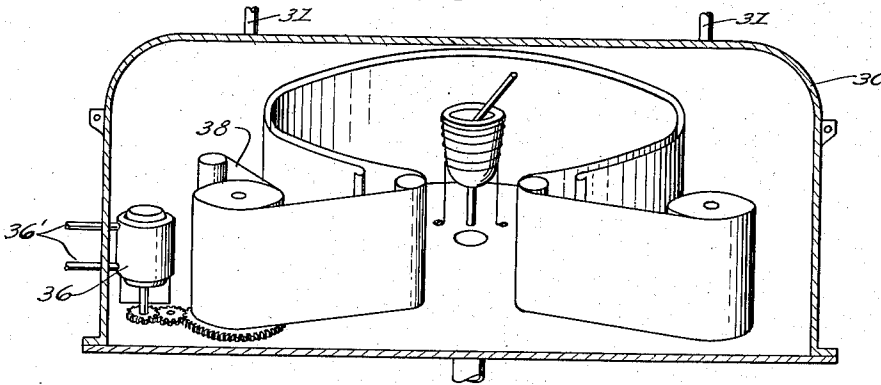
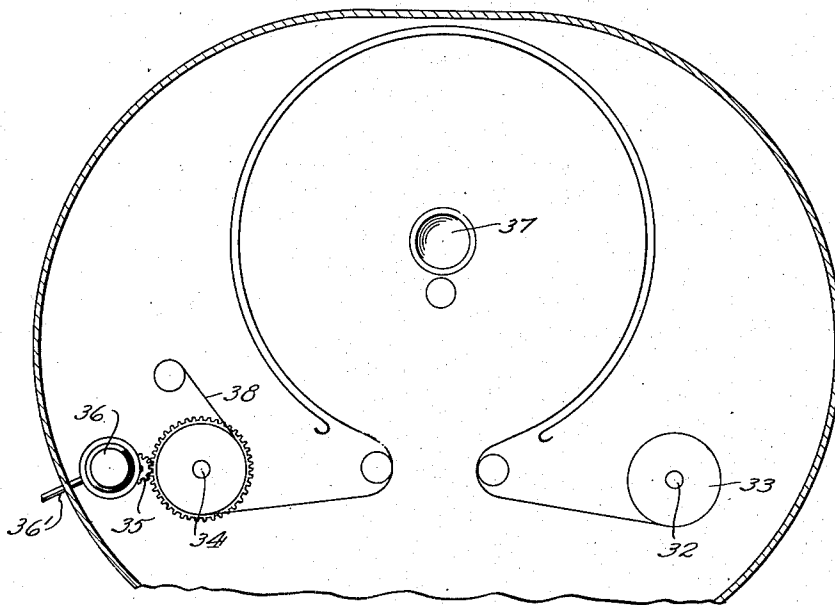


Fig. 7.



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Fig. 8.

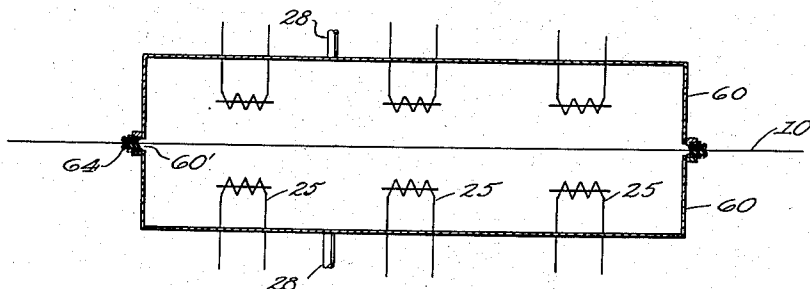
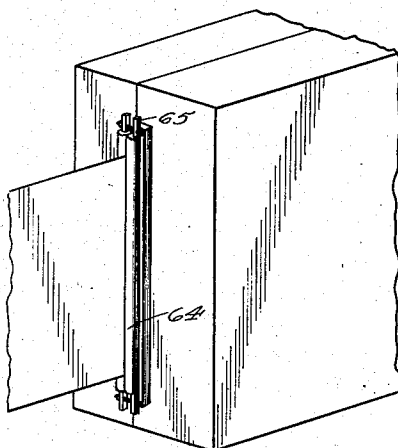
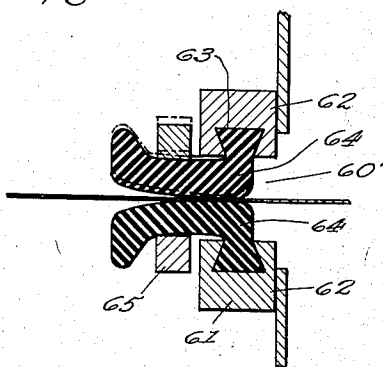


Fig. 10.

Fig. 9.



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Fig. 11.

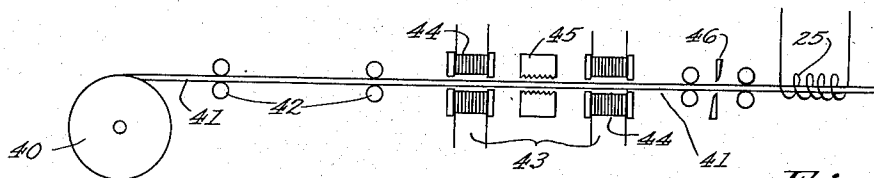


Fig. 15.



Fig. 16.

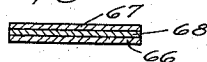


Fig. 12.

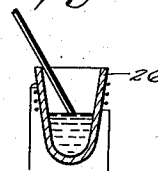


Fig. 13.

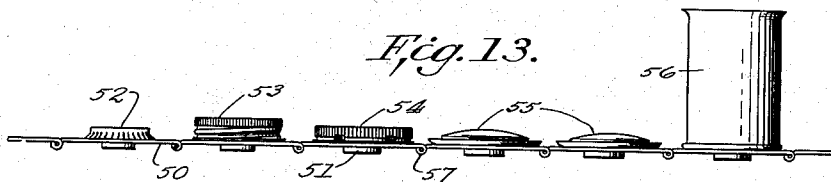
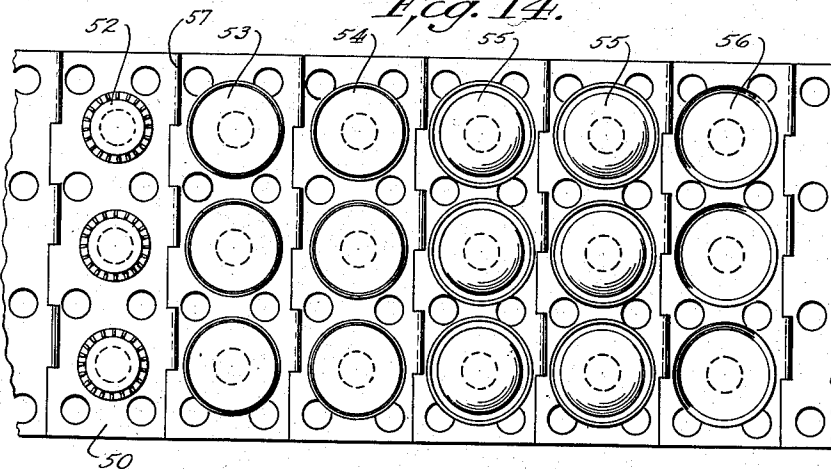


Fig. 14.



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UNITED STATES PATENT OFFICE

2,382,432

METHOD AND APPARATUS FOR DEPOSITING
VAPORIZED METAL COATINGS

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Md., a corporation of New York

Application August 2, 1940, Serial No. 349,646

7 Claims. (Cl. 117-107)

The present invention relates to a method of coating with metallic vapors, and is particularly concerned with a novel product such as steel sheet or black iron having a coating of aluminum bonded thereto and articles formed therefrom.

The method of the invention includes the coating of a base which may be a continuous strip or length of material, as well as preformed articles, to produce on the base a permanently adherent surface film which is deposited or precipitated from an atmosphere of the vaporized coating metal. This coating can be determined as being produced from the metallic vapor by metallographic examination and X-ray diffraction studies.

The resultant laminated product exhibits characteristics which enable the coated metal to be formed and shaped, for example, (a) stamped into closure caps, particularly those of the skirted type such as crown, screw and lug caps, (b) pressed or drawn for use in the making of containers, and (c) spun to form articles which are best prepared by such operation, namely bottles, reflectors, and goblets. In fact, the coated metal prepared in accordance with this invention is useful in a wide variety of applications where the base metal, if not protected, would ultimately present an objectionable appearance and in the case of containers, might affect the quality of the contents.

The aluminum coating produced from the vaporized metal is characterized by having a purity greater than that of customary aluminum coatings; in fact, the distillation of the aluminum enhances the purity of the coating so that it is substantially pure.

The coating of a base such as steel, in accordance with this invention, does not result in any impairment of the properties of the steel, i. e., the advantageous properties of the base are substantially unaffected by the coating film. The laminated product does not have a brittle intermediate zone or constituent, i. e., is substantially free of brittle intermetallic iron-aluminum compounds such as are frequently present where steel is coated by dipping in molten aluminum. Hence, the composite product has all the ductility of uncoated steel and is substantially free of brittleness. This allows the coated metal to be employed for many forming operations. For example, in the production of crown caps, as by stamping, there is no evidence of cracking of the coating or the base metal. Furthermore, the flexibility, rigidity and tensile strength of the base metal are not sacrificed and the resulting

product possesses the advantageous properties of both the steel and of the metal coating.

A very important characteristic of the laminated product or coated metal is the galvanic protection afforded by the direct coating of the vaporized metal such as aluminum upon the base metal such as steel or black iron. The steel is rendered rustproof and is prevented from discoloring and may be employed in containers for foods and beverages.

Further attributes of the coated metal are the pleasing brightness and high reflectivity for radiant energy, the coating imparting a mirror-like finish. These qualities of the coated metal make it available for walls in low-cost housing and for various applications where heat and/or light reflectivity is desirable.

Another property of the coated metal is its corrosion resistance. Not only does the aluminum coating protect the iron from corrosion, but it inherently possesses resistance to corrosion and is therefore suitable for many situations where corrosive influences would deleteriously affect the metal base.

The abrasion resistance of the coated metal is satisfactory but the coating may be oxidized and hardened to give enhanced abrasion resistance for certain purposes.

Another important characteristic of the laminated product is the strong and permanent adherency or bonding of the aluminum coating to the metal base which makes the product suitable for the metal working processes as above described. In this connection, by regulated heating of the coated metal, alloying of the two constituents can be controlled; i. e., the diffusion between the atoms of the steel base and the coating, and a substantially integral bond is thereby produced without embrittlement.

The aluminum coated metal may be suitably decorated, printed, dyed, or otherwise colored. It may be subjected to well-known processes of the type used for oxidizing pure aluminum or relatively high aluminum content alloys. By such means an oxidized film is formed on the aluminum which readily permits impregnation by various dyes and offers an excellent base upon which organic finishes may be applied. The oxidized film may be produced under conditions which give it an extraordinary degree of hardness.

It will be appreciated that the aforesaid properties, whereby the coated metal may be worked and possesses the desired resistant qualities and receptivity for decoration, make it ideal for the

manufacture of screw caps, crown caps, and other skirted closures. Likewise, the coated metal is useful for making containers and numerous other fabricated products. In other words, this aluminum coated steel, for example, forms a satisfactory substitute for the customarily employed tin plate.

Another embodiment of the invention consists in applying an organic film such as lacquer, varnish or enamel or an inorganic vitreous enamel to the metal surface, e. g., steel either of a preformed article or a continuous strip, whereby any irregularities or pores therein are effectively sealed and a smooth surface for receiving the vaporized metal coat is provided. Brittle enamels should not be used on continuous sheet metal which is wound in coils. The adherent vaporized coating metal is applied to the organic coating and adheres thereto and forms a film bonded to the base which is characterized by remarkable brilliance due to the uniformity, continuity and smoothness resulting from the presence of the intermediate coating. This improved lustrous or mirror-like finish is comparable to a coating produced directly upon highly polished steel sheet when vaporized aluminum is deposited thereon as a film. For all usual purposes, the product above described, in which the vaporized aluminum is directly deposited upon the steel, is quite satisfactory, and in either the case of the aluminum coated steel or the aluminum coated organic surfaced steel, the properties of the steel are not sacrificed and the properties of aluminum are made available. Should there be any pores or other lack of continuity in the organic film, the metallic film will afford the desired galvanic protection.

A further product made in accordance with this invention is a foil which may be either of pure aluminum, or comprise a backing of steel of sufficient softness and flexibility coated with a deposit of vaporized aluminum. In some cases where the laminated foil is produced, the thin metal strip is first coated with an organic film such as varnish upon which the thin aluminum coating or layer is deposited. The pure aluminum foil may be produced by depositing the coating upon a suitable non-retentive surface, e. g., steel coated with "Aplezon" oil or stearic acid, wherefrom the foil may be readily stripped off by any suitable means. In general, substances used to make the surface non-retentive must not excessively dilute the metal atmosphere with their own vapors. Foils produced in accordance with this invention are suitable for cap spotting purposes, heat insulation and for electrical condenser foils.

In this connection also, aluminum powder and flakes may be satisfactorily produced in accordance with this invention for use as pigments, in pyrotechnics and other applications, by depositing the vaporized aluminum upon a non-retentive surface, or in a non-adherent form under controlled conditions, i. e., at a reduced pressure representing a less highly exhausted state than that which is required to produce an adherent and continuous film and/or at a temperature of the metal base conducive to production of a spongy or powdery deposit, whereby a discontinuous film or otherwise powdery deposit is formed which may be readily removed. In some cases the deposit so recovered will have the necessary fineness or in any case where a greater degree of fineness is desired, the size of the particles may be reduced in any suitable manner.

In connection with the formation of foils and

powder, we also accomplish this by placing strips or sheets of aluminum or other material having non-retentive surfaces on the walls of the coating chamber, whereby excess vaporized metal which would normally adhere to the wall of the chamber is caused to be collected upon the sheets or strips and may be suitably removed and the foil or powder recovered. If it is not desired to use separate sheets or strips, the walls of the coating chamber itself may be rendered non-retentive so that the aluminum coating may be readily stripped or removed therefrom.

A further embodiment of the invention consists in producing metal coated materials having flexible strip material backings of paper, plastics such as Vinylite or other synthetic resins, chlorinated rubber, zinc foil, etc. by a transfer process in which the coating metal such as an aluminum film is first deposited from the vaporized aluminum upon a non-retentive surface either as a continuous film of foil thickness or as a thin discontinuous film. Thereafter, the flexible backing material to be coated having a suitably adhesive surface is passed over the coating with its adhesive surface in contact with the same so as to pick up and transfer either a continuous film of aluminum to the new backing or a discontinuous film as the case may be. Such laminated materials may be of foil thickness or be of greater thickness as desired. The metallized laminated products produced may be used as foils for cap spotting purposes, packaging, insulating walls, as well as decorative purposes.

As will be appreciated, the products obtained in accordance with the present invention are highly valuable and their production is accomplished by novel methods which are commercially feasible.

An important object of the invention is to provide a method in which a permanent, uniform and coextensive adherency between the coating and the base layer is assured. We have discovered that there are several critical considerations which govern the obtaining of the integrally bonded laminated sheet. For example, it is of particular importance that the metal surface, e. g., of steel, be presented to the metal coating atmosphere in a thoroughly cleaned condition. That is to say, the metal surface should be free not only of extraneous or foreign material, but likewise of rust film. Another critical consideration which we have discovered is that for reliable adherency, the metal should be free of occluded gases, and it is highly important that before the metal sheet or strip is subjected to the coating atmosphere, it be first not only physically and chemically cleaned, but de-gassed as completely as possible.

Equally important, with the foregoing, is the provision of a chamber for accomplishing the coating operation which will permit continuous movement of a continuous strip or sheet to be coated through the same and which will be thoroughly sealed whereby a substantially constant reduced pressure or vacuum is maintained and the vaporized metal in the chamber is prevented from being excessively diluted, or polluted in a manner such as would adversely affect the color or adherence of the film. It may not be objectionable to have, for example, a fractional percent or trace of air, but the presence of an appreciable amount of grease vapor, for instance, may cause the deposit to be blackened, whereas a silvery white film is desired. We use a single chamber or a plurality of interconnected cham-

bers. The connections between the series of chambers are such that the material to be coated may be continuously travelled through the same while maintained under reduced pressure. The conditions in each chamber regarding the vacuum and the density of the vaporized metal may be modified in accordance with the product required.

As will be appreciated, the relative temperatures of the metal base and the metal vapor source within the coating chamber are maintained under conditions to promote rapid precipitation of the metal upon the base strip moving through the chamber to form the coating film, and while in many cases preheating or subsequent heating of the metal will be unnecessary, there are conditions where it may be desirable to either heat or cool the metal under vacuum to a satisfactory operating temperature before deposition.

The method provides for suitably heating the strip under vacuum for the purpose of removing any surface accumulations and occluded gases prior to its entrance into the coating chamber, and also for assuring in certain cases, i. e., aluminum upon steel, that a more adherent coating is obtained, and one which affords an optimum coverage of the base metal. In this connection, in some cases, the temperature of the metal is raised where necessary after the coating operation to further assure the maximum adhesion and/or to improve the continuity of the deposited coating. These heating steps may be accomplished in a protective atmosphere, but are preferably carried out under vacuum.

It may be advantageous, in some cases, in order to promote a better adhesion and continuity, to subject the laminated material to elevated temperature for a predetermined time period and in a non-oxidizing atmosphere preferably under vacuum, followed by a cooling step in a non-oxidizing atmosphere or preferably under vacuum to eliminate the possibility of oxidation.

Also after the coating has been deposited, if the temperature of the laminated metal strip or sheet is so high that it would result in rapid oxidation or discoloration when introduced to the air, it is preferable to cool the coated metal preferably under vacuum, or non-oxidizing influences before it is introduced to the air.

The invention includes a method in which while under vacuum or reduced pressure, in a suitable chamber, the metal strip, for example, of steel is continuously discharged from a roll and passed continuously through various instrumentalities, including the coating chamber. In this connection, in some cases before being introduced to the vacuum chamber, it is preferred to anneal the strip and a continuous annealer may be incorporated in the line, and in addition to accomplishing its accepted function, this heating step will have the further effect of de-gassing the metal herein above mentioned as one of the important preliminary treatments. Likewise, before the strip is introduced as a roll to the vacuum chamber, the cleaning and pickling operations may take place and may precede the annealing operation, if necessary, and, in some cases, a further cleaning and pickling may be resorted to after the anneal, if required, and before the rolls are placed in the vacuum chamber. With relation to the cleaning step, a preferred operation is to subject the strip metal while under reduced pressure in the vacuum chamber to a glow discharge just before it is presented to the vaporized metal for the purpose of removing the last traces

of any physical or chemical contamination. By a "glow discharge," we mean the application of a high difference of potential between the sheet to be coated as one electrode and any suitable type of second electrode such as a carbon pencil type.

As explained above, the coating chamber may comprise a single chamber or a plurality of interconnected chambers all of which are maintained under a reduced pressure including the connections between any series of chambers. In this manner, a different set of conditions may be maintained in each chamber of a series which will enable the formation of multiple coatings upon the metal base, i. e., a built-up coating of any desired thickness, as well as afford increased flexibility of operation. By "flexibility of operation," we mean a method adaptable for meeting the numerous conditions which will be encountered for the successful high production of a continuous strip coated with vaporized metal. For example, the individual chambers may all be maintained under the same conditions so that a strip fed therethrough at constant speed will be provided with a coating of predetermined required thickness. In other cases where a thicker coating is required, the speed of travel of the strip may be retarded with the other conditions maintained constant, so as to assure that the particular predetermined thickness will be uniformly attained. In other cases, the temperature attained by the coated metal strip travelling through one chamber may not be suitable for proper deposition in a succeeding chamber, and, hence, the temperature in the said succeeding chamber may be controlled or intermediate cooling means may be introduced. This intermediate cooling means may be of a positive character, as for example, suitable chilling rolls or cooling coils through which the strip passes from one chamber to the next, or the passage between the chambers may be so constructed that the sheet necessarily undergoes a drop in temperature during its travel by loss of heat through radiation to the walls of the intermediate connection from which the heat may be removed in any suitable manner. In other words, the flexibility afforded by a multiplicity of inter-communicating coating chambers precludes the necessity for repeated coating steps in a single chamber of predetermined size. The present method preferably embodies individual intercommunicating chambers and allows coating with intermediate cooling of a continuously moving strip.

In addition to the aforesaid advantages accruing from the flexibility of the process, there is the further desirable factor that different metals may be vaporized in the several chambers, and, therefore, built-up coatings of different compositions may be produced on the base metal. For example, aluminum may constitute the first coat upon a metal base of steel followed by the deposition of a silver coating or vice versa. By subsequent heating of such built up coatings, a surface layer composed of a true alloy, e. g., aluminum-silver may be produced with resultant advantageous properties such as increased hardness, resistance to wear or corrosion.

In another embodiment of the invention, the method comprises placing a coil of the strip material or metal base in an exhausted chamber or suitable bell jar together with a reeling instrumentality and continuously feeding a strip from the coil into a vaporized metal atmosphere, e. g., of aluminum maintained in the evacuated cham-

ber, whereby the surface of the strip is coated, and continuously winding up the coated strip at any desired speed within the bell jar as formed, the reduced pressure or vacuum being maintained throughout the operations. When the entire strip has been coated and rewound, the operation is discontinued and the chamber or jar opened to permit removal of the coated coil and then the operation is repeated on another coil.

In some cases either where a single coating chamber is employed or a plurality of interconnected chambers are used, all as above described, instead of the base metal travelling continuously, it may travel intermittently by means of suitable mechanism which will move the material step-by-step into the coating atmosphere and through the apparatus. In this manner, the coating operation will be conducted upon consecutive sections of the strip or sheet while the same are at rest. While we may break the vacuum between successive movements of the strip or sheet, this is not necessary except in cases where permanent sealing means for the coating chamber are not available.

A preferred embodiment of the invention is to arrange the several vacuum chambers or bell jars as the case may be in units, suitably connected to the exhausting means and to each other whereby while one roll of metal is being coated, another unit is having the coated roll removed and a new roll placed in position. The units are so connected that when the coating of a roll in one unit has been completed, the unit containing a roll to be coated is placed in connection with the first unit which is under vacuum so that it may be partially exhausted. Then when the second unit is exhausted, a less amount of work and time is required to bring it to the desired vacuum, while at the same time the vacuum in the first unit has been broken and a coated roll may be removed and a new roll placed in position while the second unit is operating to coat another roll of the strip. This affords a very appreciable economy and permits substantially any number of units to be employed which are suitably connected with each other and to the exhausting means.

In addition to the foregoing features of the invention, we provide heating units which embody means for assuring that the metal to be vaporized will be constantly supplied and constantly vaporized at a substantially uniform and controllable rate. This is advantageous in that it enables constant conditions to be maintained in the coating chamber or chambers and assures the deposition of a continuous uniform film upon the travelling metal strip. Of particular importance, the provision of a continuous supply of the metal to be vaporized is accomplished automatically and, therefore, in such a manner as to not necessitate any loss or interruption of vacuum. In some cases, as where the base metal is intermittently fed as above described, we may substitute intermittently operated heating units to vaporize the metal intermittently in a single or a plurality of chambers. With this embodiment, the automatic vaporizable metal replenishing means above described will be satisfactorily employed.

A further embodiment of the invention comprises the use of electrostatic means within the coating chamber for directing the gaseous metal positively and definitely during the deposition of the same as a film upon the backing. In this connection, equipment such as is embodied in the "Cottrell" precipitator may be advantageously used for this purpose, with the metal backing strip

acting as the electrode upon which precipitation occurs.

While the metal coating film in many cases will present a satisfactory highly polished surface, the lustre of any coating formed in accordance with this invention which is not of maximum brilliance may be improved by passing the same through mirror finish rolls such as tungsten carbide rolls.

In the drawings,

Figure 1 is a diagrammatic sectional elevation showing the initial portion of a line or system for continuously coating metal in accordance with this invention;

Figure 2 is a diagrammatic view of one of the vacuum chamber units;

Figure 3 is a view similar to Figure 2 in which a single chamber is employed as distinguished from a plurality of interconnected chambers as shown in Figure 2;

Figure 4 is a view similar to Figure 2 in which the material to be coated is traveled through the coating chamber or chambers in a vertical plane as distinguished from a horizontal plane as shown in Figures 2 and 3;

Figure 5 is a diagrammatic view showing a plurality of connected units of the character shown in Figures 2, 3 and 4;

Figure 6 is a perspective view of a modified form of coating apparatus;

Figure 7 is a plan view of the apparatus of Figure 6;

Figure 8 is a sectional plan view of a modified form of coating apparatus;

Figure 9 is a detail view of the sealing means at the ends of the chamber shown in Figure 8;

Figure 10 is a perspective elevation of one end of the chamber shown in Figure 8, showing the overlapping seal which substantially precludes the entrance of air into the chamber when the pressure within the chamber is reduced;

Figure 11 is a diagrammatic view of one means for automatically feeding the vaporizable metal to the vaporizing means;

Figure 12 is a detail view of one of the crucibles which may be heated by electrical resistance or high frequency induction, and to which the coating metal is automatically fed in accordance with Figure 11;

Figure 13 is a side view showing the manner in which preformed articles, e. g., closures, container bottoms and containers are supported while being carried through the coating system;

Figure 14 is a top view of the conveyor and articles thereon to be coated as shown in Figure 11;

Figure 15 is a sectional view showing the base metal such as steel directly coated with an adherent film of coating metal such as aluminum, deposited from aluminum vapor; and

Figure 16 is a sectional view showing a base material such as steel coated with an adherent film of material such as lacquer, varnish or enamel over which is deposited directly a coating of metal such as aluminum deposited from aluminum vapor.

In carrying out the present invention, and as heretofore explained, we make a coated or laminated sheet or strip material in which the coating metal such as aluminum is preferably directly applied to the backing material such as steel. The properties and characteristics of the laminated product have been heretofore set forth. Not only is the invention useful in connection with the manufacture of sheet or strip materials for fabricating purposes, namely, for the manu-

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facture of closures, containers and other articles, but it can be used with equal success for coating prefabricated articles. That is to say, the closures may be stamped from the base metal or the containers may be drawn or otherwise formed from the base metal and then subjected to the coating operation.

The metal base is devoid of any surface accumulations or occluded gases since we find that it is a critical consideration for the production of smooth, brilliant continuous coatings of required adherence that the surface to be coated shall be clean and free of any contaminating influences.

In some cases, the sheet or strip or preformed article to be coated is preliminarily coated with a film or sealing material such as a varnish, lacquer or enamel. Such a surface will be smooth and glossy as distinguished from relatively roughened surfaces of the metal base which are sometimes encountered, but this coating must likewise be free of surface accumulations and contaminating influences.

The invention therefore comprises a laminated product in which the vaporized metal coating is deposited directly upon the base and is coextensive therewith or directly upon an intermediate film which has previously been coated upon the base and is coextensive therewith.

While the invention will be described in connection with the coating of vaporized aluminum upon a steel strip or sheet, it is to be understood that other vaporizable metals may be used exemplified by magnesium, silver, tin, zinc, chromium, nickel, etc. Moreover, alloys of which those composed of aluminum and silver, silver and zinc, aluminum and manganese, nickel and chromium are examples, may be employed. In referring to a "pure metallic coating," and "vaporized metal," we intend to include by these and similar expressions, elements as well as alloys.

The invention is particularly concerned with producing a novel laminated product comprising steel or black iron coated with aluminum which we have found to possess unusual properties and to open a wide field of usefulness.

We preferably employ a continuous process in which the strip or sheet is continuously traveled through the coating chamber and also through preliminary treating apparatus such as the cleaning means, the means for removing occluded gases, the annealing means, and subsequent treating means such as heating and/or cooling means and the brightening apparatus.

In general, where vaporized aluminum is being coated upon steel, the pressure in the coating chamber should be less than 100 microns and in the neighborhood of 1 micron. Lower pressures may, of course, be used, but are not essential to the successful operation of this invention to produce coated material suitable for many applications.

The deposited or condensed films for example of aluminum produced in accordance with this invention are relatively thin, generally having a thickness in the neighborhood of about two millionths of an inch to about one ten thousandth of an inch for permanently adhered coatings applied to a backing or base. Aluminum coatings cannot be applied to steel as thin as by this invention according to existing commercial practice.

Foils for cap spotting which do not have a backing other than the usual adhesive coat and for other purposes require a greater thickness,

for example in the neighborhood of about five ten-thousandths of an inch.

The aluminum is vaporized in any suitable apparatus such as electrical induction means, resistance means, or by energization of a filament, preferably one of tungsten, upon which globules of molten metal are formed and which supplies the heat required to melt and vaporize the metal from its surface. As explained above, we maintain a constant supply of aluminum to the vaporizing means so as to produce a substantially constant atmosphere of vaporized metal. The temperatures reached are those which are best for vaporizing the particular coating metal such as aluminum at the particular pressure in the coating chamber. Since the vaporization point of the coating metal, for instance aluminum is fixed, at a definite pressure, the rate of evaporation is controlled by the amount of energy supplied per second. While in the case of aluminum, the temperature should be one which will cause the aluminum to boil at the prevailing pressure, in the case of some metals which develop a substantial vapor pressure at temperatures near, but below their melting point, for instance silver, it is possible to produce a metal atmosphere by maintaining the metal at a temperature just below its melting point. Incandescent masses of silver can be used as sources of a constant and abundant supply of silver vapor.

The temperature of the base metal or other material to be coated, for example steel, should be substantially below that of the metallic gas in order to assure proper deposition or condensation. We have found that a temperature in the neighborhood of ordinary room temperature is conducive to satisfactory results and assures suitable adherence of the coating metal to the steel or other base. This adherence is further developed in some cases by preheating the metal to a higher temperature, in a protective atmosphere or preferably under reduced pressures. Likewise, after the coating operation, adherence is enhanced in some instances by elevating the temperature of the laminated metal above room temperature either within or without the vacuum.

In the case of an aluminum coated steel, it is preferable that the laminated metal be cooled sufficiently, before it is introduced in the atmosphere, to preclude objectionable oxidation of the steel or avoid excessive oxidation of the aluminum coating. This is particularly important where the coated metal, after the coating operation, is heated to promote adherence or the formation of a desired alloy either of the aluminum or steel or of other coating metals as where the metal coating is built up of different metals.

With respect to the use of metal alloys for the coating atmosphere, in some cases we employ separate sources for the elements which are to make up the alloy, so situated that their vapors intermingle, and control the heating so that each vaporizes at the desired rate to properly proportion the vapor mixture and hence deposit as an alloy of any desired composition upon the base. The sources are, of course, situated in the same coating chamber.

In other cases, the preformed alloy is employed as the source and the use of separate heating units for the alloying elements is unnecessary. Also, in some cases the base material is coated with a film of one metal followed by a coating with the film of another metal, and in such operations, a suitably high temperature is employed to assure that the respective films may alloy to the desired ex-

tent and that the film in contact with the base, if desired, may also alloy therewith. While the heating step incident to promoting this diffusion or alloying of the respective layers may be carried out at any point or points in the operation after deposition, it is preferable to conduct the alloying as a single step after the last coating has been deposited. As will be appreciated, with certain metals the temperatures incident to the depositing of the film or of subsequent films of different metals may be sufficient to promote alloying in which event a separate or positive heating step will not be required. This is true for example in the case where tin or zinc is deposited on steel or brass, since these elements have a relatively low melting point and diffuse readily at temperatures somewhat lower than their respective melting points.

Containers may be provided with an interior lining of the vaporizable metal, as well as an exterior surface film of the vaporizable metal, as for example, vaporized aluminum applied to black iron. The containers may be preformed, or the coatings may be applied to the blanks from which the containers are to be fabricated.

The aluminum lining prepared by vaporizing the metal in a vacuum may be applied directly to black iron because a combination of aluminum and iron will not produce iron rust. The inside surface of the container to receive the coating should be as smooth as it is practicable to have it. An even surface is necessary for efficiency and complete coverage. Furthermore, aluminum deposited on smooth metal is bright and highly reflective. The inside of the container may be polished with a suitable abrasive material after formation and the surface to be coated must be free of dust, grease and any foreign matter before the coating is applied.

One method of lining the cans is to melt and vaporize the aluminum by means of an electrically heated filament in a high vacuum. Tungsten wire is the most suitable material for the filament. Wire varying in diameter from 0.015 to 0.045 inch may be used, but 0.035 inch is a preferred diameter although 0.025 inch has been satisfactorily used. We have used 12 to 20 amperes, 6 to 10 volts. Rapid production is accomplished in the apparatus herein disclosed. The pressure used was quite low, being at least as low as 20 microns, and in many cases, as low as 1 micron. For some purposes, two or more coatings of aluminum may be built up to form a lining of desired thickness. In some cases, the aluminum coating is partially oxidized to render the lining more chemically or physically resistant, i. e., the lining is rendered harder. In those cases where the contents of the container will attack the aluminum lining, the lining may be suitably protected by a film of wax, chlorinated rubber or polyvinyl acetal resin. As will be appreciated, the galvanic protection afforded by the aluminum lining is substantial, and moreover increases the corrosion resistance. Small percentages of silver, i. e., 5% silver by weight in aluminum give a hard and adherent film.

Referring to Figure 1, the numeral 10 indicates a coil of suitable backing or base material which may be steel or black iron, paper, or some synthetic resinous material such as chlorinated rubber, "Vinylite" resin, polyvinyl acetal resin, cellulose acetate or other organic strip material and such strip is preferably directly coated, but in some cases may be provided with an intermediate film. The invention as stated is particularly

concerned and will be described in connection with strip steel or black iron. The steel band is led from the roll 10 through a suitable cleaning instrumentality 11 in the form of a bath, for example, a pickling bath to remove surface accumulations and scale, and the strip is conducted thence, through a suitable drier 12 to evaporate any liquid or moisture which may have been retained upon the surfaces. Thereafter, the steel band is continued through a bright annealing furnace 13 in which annealing is required, and as heretofore stated, this heating step will serve to reduce the amount of occluded gases in the metal. From the annealing apparatus 13, the strip is preferably coiled as at 10'.

Referring to Figure 2, a coil 10' of uncoated strip material is placed in the housing 14 at the feed end of the vacuum coating unit indicated as a whole at U, carried through the unit and coated, and then recoiled in the housing 14' at the delivery end of the unit. Both the housings at the feed and delivery ends of the unit are under vacuum and are closed by a suitable hinged door, gasketed to insure a tight seal when the chamber is under reduced pressure, but which will allow the doors to be opened when the vacuum is broken so as to permit a coated coil to be removed and an uncoated coil to be supplied. The coil 10' may be mounted on a suitable feeding shaft wholly supported within the unit and the recoil mechanism at the delivery end for drawing the strip through the unit may include a shaft operated by a suitable motor within the unit or from outside of the unit, the shaft in the latter case being suitably packed to afford a thorough seal.

The housing 14 opens into a closed conduit of reduced cross-section through which the strip is led as shown to the heating chamber 15 having suitable electrical heating means 16 therein and which chamber is, of course, under vacuum. In this heating chamber, the heating is carried out upon the continuously traveling strip to remove any occluded gases in the metal strip and also to vaporize any traces of volatile matter or surface accumulations. By this treatment and through the provision of a glow discharge means having electrodes 17, a perfectly clean metal surface is presented to the coating chamber and the heating chamber 15 is provided with means such as an exhaust pump 18 for positively exhausting any gases driven off in that chamber so that there is no possibility of polluting the metal atmosphere in the coating chamber. From the heating or out-gassing chamber 15, the metal is continuously traveled to the coating chamber 19. Between the chamber 15 and the chamber 19, cooling means are provided in the restricted passage 20 if required. In some cases, the restricted passage itself having external walls exposed to the atmosphere, will act to dissipate the heat sufficiently so that no positive cooling means is required. This connection 20 between the chambers may be elongated so that the metal to be coated enters the coating chamber at any desired temperature, for example, in the case of steel to be coated with aluminum, in the neighborhood of about room temperature. As explained above, if the metal enters the chamber at a more elevated temperature, this is not necessarily objectionable, and in some cases promotes adhesion and continuity of the deposited film.

In the construction shown in Figure 2, the coating chamber is shown as comprising a series of chambers 19a, 19b and 19c, and any desired

number of chambers may be employed. The chambers are connected by restricted passages 21 which may be provided with positive cooling means in the form of chilling rolls 22 or may be lined with suitable cooling coils. As heretofore explained, these restricted passage-ways whose exterior surfaces are exposed to the atmosphere may be elongated if desired in order to effect cooling of the strip as it passes from one chamber to the other where this is found preferable to the provision of positive cooling means. It is believed that the provision of intermediate cooling means between the respective coating chambers of the series is conducive to good results, but a single coating chamber 19 such as shown in Figure 3 may be employed satisfactorily in lieu of the series of chambers shown in Figure 2.

The single chamber shown in Figure 3 is connected with the housings 14 and 14' and associated construction as described above in connection with Figure 2. In Figures 2 and 3, we have shown the metal as passing through the coating chamber or chambers in a horizontal plane while in Figure 4, we have shown the metal as being coated while travelling in a vertical plane, and for this purpose, after the metal leaves the coiled roll 10', it is turned 90° through any suitable turning guides (not shown) disposed at 23. This turning operation takes place at any convenient time or place in the line after the strip 10 leaves the roll and is conducted under vacuum. Instead of the turning mechanism, the feed and recoil shafts and the roll may be vertically disposed.

The unit including the coating chambers 19 and housings 14 and 14' are exhausted or maintained at a suitably reduced pressure by a vacuum pump or combination of pumps of any suitable construction connected to the exhaust manifold pipe 24 having leads to the individual chambers as shown in Figure 2 or to the single chamber as shown in Figure 3. Within the coating chambers are disposed suitable vaporizing means which may be in the form of filaments as shown at 25 or electrical resistance or induction heated crucibles as shown at 26 or aluminum cathode for sputtering.

By reason of the vaporizing devices, a constant supply of the gaseous coating metal is maintained in the chamber 19, and as will be later explained, automatic means are provided to insure that the supply of metal to be vaporized is continuously replenished as needed. After the metal strip has travelled through the coating chamber, it is continuously led while maintained under vacuum through a cooling zone or vapor trap formed by the cooling coils 27 which surround the closed conduit leading from chamber 19c and which serve to trap any vapors which are discharged from the chamber 19c. This cooling means 27 likewise serves to lower the temperature of the travelling strip material. A similar trap 29 may be disposed at the other housing end, but this condition is generally taken care of in the chamber 15 where any objectionable vapors are continuously removed.

The coated material is drawn through the apparatus and after coating is rewound on a suitable reel in the housing 14'. Where it is desired to heat the coated strip before it is rewound, a heating means 15' similar to the heating chamber 15 is interposed before the cooling means 27. As will be noted, the heating and cooling in each case takes place under a vacuum.

Referring to Figure 2, it will be observed that separate exhaust connections 28 having adjustable valves are provided for each chamber of the series. This permits selective variation of the reduced pressures maintained in each chamber so that the coating operation is rendered flexible.

Referring to Figure 5, we have illustrated several units U as shown and described in connection with Figures 2, 3 and 4, connected by leads 28' to a manifold 29 leading to a suitable exhausting means. Any number of units may be so associated in communicating relation, suitable valves *v* being provided to establish communications between the several units and any one unit and the exhausting means, whereby the units may be brought into communication with each other or independently exhausted. In the preferred operation of the method, an uncoated coil 10' is introduced into one unit *a* which is exhausted and the strip coated as above described. Another uncoated coil is positioned in the unit *b* and when the coating is finished in unit *a*, the exhausting means is shut off from communication with unit *a* and communication is established between the units *a* and *b* through the valves in their respective leads and the manifold. This breaks the vacuum in unit *a* and simultaneously reduces the pressure in unit *b*. Communication between units *a* and *b* is now closed, and the coated coil is removed from the housing 14' of unit *a* and an uncoated coil placed in the housing 14 of this unit. Of particular importance, the reduction of pressure created in unit *b* enables the unit to be exhausted to the required vacuum in a shorter time and requires less work on the part of the exhausting apparatus. Unit *b* is therefore immediately available for coating purposes and coating is carried out therein as described. This method is continuous in that while the operations just described are taking place in connection with units *a* and *b*, a coating operation under vacuum may be taking place upon another coil in unit *c*. This method is therefore rapid, economical, and thoroughly reliable for coating continuous strips or for coating sheets of predetermined length as well as fabricated articles. Two units will provide a very substantial coating capacity, but as stated, any number of units may be employed.

One of the advantages of the method shown in Figures 2 to 5 is the ability to bring the coating chamber 19 to the best or most desired condition for coating by vaporization with a minimum of pumping effort, and therefore at a more rapid rate. That is, a greater vacuum is required in the chambers 19a, 19b and 19c than is required in the remainder of the apparatus, namely, the housings and the chambers 15 and 15', and there are cases, for example, where a greater vacuum is desirable in one or two of the chambers 19a, 19b and 19c. Our method enables advantage to be taken of the law relating to the diffusion of gases at reduced pressure, in that we are able, with a minimum of pumping effort, to rapidly bring the chambers 19a, 19b and 19c to the required reduced pressure, and at the same time produce a reduced pressure in the other chambers which is sufficient for their respective particular purposes. In other words, in our apparatus we are able to operate with a pressure gradient existing in the system with a minimum pressure or the highest vacuum existing in the vaporization chamber 19.

This method and the advantageous results thereof may be achieved in several ways. For instance, the passages from the housings 14 and 14'

and from the respective chambers 15 and 15' and 19a, 19b and 19c are, for example, in the case of strip metal of a thinness or narrow cross section such as will just allow the metal to freely travel in order that diffusion between the housings and the respective chambers may be reduced to a minimum. Where chilling means, heating means, or supporting or conveying means are interposed in such restricted passages, they so occupy the passage as to likewise reduce the possibility of any substantial diffusion. Again, as shown in Figure 2, the manifold 24 is exhausted by a single line E to the exhausting means and therefore the admittance speed or evacuation speed will be greatest in the chambers 19a, 19b and 19c which are closest to the exhaust pipe leading to the exhaust means, whereas the housings 14 and 14' and the chambers 15 and 15' will exhibit a pressure gradient with respect to the chambers 19, that is, will be less exhausted. Under such conditions, operation of the exhausting apparatus will rapidly bring all of the coating chambers 19 or any one or two of them to the desired reduced pressure, and the other chambers and housings to a satisfactory reduced pressure, and by reason of the restricted passages, between the housings and the various chambers, the amount of diffusion will be negligible in the coating operations.

While we have illustrated in Figure 2 a single exhaust line E connected to the manifold, there may be several such lines connecting to a single exhaust means or to independent means. In such cases, the restricted passages between the housings and respective chambers will likewise act to preclude any substantial diffusion and the valves in the lines leading from the housings 14-14' or the housings and chambers 15 and 15' to the manifold (where the latter are connected to the manifold), for example, may be closed when a suitable vacuum has been established therein so that all of the further exhausting may be accomplished with respect to the coating chambers 19 or any one or two of them where a higher degree of vacuum is required.

Furthermore, we provide in some cases a separate exhausting means for each of the housings and chambers. With this method and construction the restricted passages between the housings and chambers again act to prevent any substantial diffusion, and the exhausting means may be discontinued when a reduced pressure has been established in any housing or any chamber in the required degree.

In the methods just described above, less pumping effort is necessary, and the coating chambers are brought to the desired reduced pressure in a minimum of time.

In referring to exhausting means we mean, preferably, some multi-stage type using a suitable fore-pump for the preliminary exhaustion and higher vacuum pumps for subsequent stage or stages.

By reason of the restricted passages, the possibility of any substantial diffusion occurring is so reduced to a minimum that the method will operate satisfactorily, notwithstanding there may be slight leaks, for example, in the housings 14 or 14'.

In this connection, and as herein explained, where articles of greater dimension than steel strip are being coated, the passages likewise will be of a cross-sectional dimension to just clear such articles, and suitable baffles, e. g. flexible,

may be disposed therein, if necessary, in order to reduce the possibility of diffusion.

In Figures 6 and 7, we have shown a modified form of coating apparatus comprising a single vacuum chamber 30 which may resemble an enlarged bell jar. The chamber 30 is provided with connections 31 leading to a suitable exhaust means for maintaining a reduced pressure or vacuum within the chamber as in the case of the coating chamber 19 previously described.

Within this chamber there is provided supporting means 32 for a coil of material 33 to be coated which in the present instance is strip metal. A rewind or reeling mechanism is supported at 34 and is rotated by means of the intermeshing gears 35 from a hydraulic or air motor 36 having fluid pipes 36'. A similar motor may be employed for operating the recoil reel disposed in the housing 14' of Figure 2. The strip from the coil 33 is led in the form of a loop about the metal vaporizing device 37 or it may be led directly and in a straight line from the coil 33 into coating relation with one or more of the metal vaporizing devices 37, being drawn continuously from the roll 33 by the rewind mechanism 34. As the coated metal is formed, it is rewound at 34 into a coil of coated or laminated metal and a suitable interleaving strip 38 may be simultaneously wound between the convolutions to protect the coated surface if desired. This interleaving material may be wax paper or materials generally used for similar purposes.

It will be noted that in this operation the metal constituting the coil 33 has been previously cleaned and degassed and/or annealed. It may be in the form of steel of foil thickness or steel such as would be used for fabricating closures or containers or other products or paper or organic films.

In some cases, as where it is desired to transfer the aluminum coating to another backing, the interleaving material 38 may be provided with an adhesive surface which will, upon being interleaved, transfer or remove the nonadherent aluminum coating from the surface of the metal or other strip material, which is inherently or deliberately made non-retentive, and upon which the aluminum has been initially deposited.

The unwinding, coating and rewinding, including interleaving and the transferring of the aluminum coat to the adhesive surface of the interleaved strip are all conducted under a vacuum and constitute another example of a continuous operation. When the coating has been completed, the jar or chamber 30 is opened and the coated roll is removed from the rewind mechanism 34 and a roll of material to be coated is placed on the standard 32 for another operation.

In the construction shown in Figures 2, 3 and 4, provision is made for applying a film to each side of the strip material 10 but, if desired, the positioning of the vaporizing devices may be such that a coating is produced only upon one side of the strip. In the construction shown in Figures 6 and 7, the coating is applied to only one side of the strip but if desired, additional vaporizing devices may be positioned on the other side of the strip from the device 37 so as to provide a film upon both sides of the moving strip.

Referring to Figure 8, we have shown a further modification, in which successive areas of the strip material 10 are progressively and intermittently coated in the sectional chamber 60. In this method, the metal vaporizing means are similar to

those previously described and the metal is preferably directly travelled to and through the chamber 60 from the drying means 12 or the bright annealing apparatus 13 as the case may be. A suitable intermittent feeding means (not shown) is associated with the metal strip to intermittently feed a section thereof substantially equal to the effective coating length of the chamber 60 upon each actuation. The chamber is provided at its ends with a sealing construction best understood upon reference to Figures 9 and 10. Each end of the box is provided with metal blocks 61 extending for a distance greater than the width of the sheet or web to be coated and which may be welded or otherwise secured to the end walls of the sections of chamber 60 as at 62. The blocks 61 are recessed to provide dove-tail grooves 63, in each of which is anchored one section of a rubber sealing strip 64. Bearing upon the outer face of each of the strips 64 which extend throughout the length of the sheet or strip receiving passage or opening 60' defined between the end walls of the sections of the chamber and the blocks 61, are sealing clamp members 65 which at their upper and lower ends are adjustably connected together. In the operation of the invention, release of the sealing clamping members 65 permits the strip material to be fed into the chamber 60 for a suitable length to be coated. Thereafter, the clamping members 65 are clamped to force the resilient strips 64 together, thereby rendering the chamber air-tight, and a suitable vacuum is drawn therein. The metal vaporizing means are now operated and a coating deposited upon the area of the strip within the chamber. Thereafter, the vaporizable means are de-energized, the vacuum within the chamber 60 is broken, and the clamping members 65 are released to permit the sheet to be freely travelled. The intermittent feeding means are now actuated to bring another predetermined area within the chamber 60, whereupon the chamber is again sealed and a vacuum drawn, and a coating atmosphere provided. By means of this intermittent action, the entire length of the coil of steel may be provided with an aluminum or other metal coating on one or both sides.

Preferably, the vaporizable metal used in connection with the chamber 60 will be supported by filaments 25, but resistance or induction heated crucibles 26 may be employed if desired. The filaments are particularly useful because they can be so readily energized and deenergized for intermittent coating purposes. Where the crucible is employed with induction or resistance heating means, predetermined sized globules, lengths of wire, powder or pellets of the vaporizable metal are automatically fed thereto so as to provide a suitable vaporized metal atmosphere sufficient to properly coat the area of the strip within the chamber.

In the various apparatus illustrated, we have shown both filament and crucible vaporizing means within the chambers. It is to be understood, that in any one single chamber, all of the devices should be the same. Where a series of chambers are used, however, filaments may be used in one of the chambers and crucibles in another.

It is to be understood that while we have illustrated a continuous strip of material being coated, individual strips of any desired length may be suitably fed through the coating system while carried flat upon a conveyor or suspended therefrom. In this connection, also, one or both sides

of a flat material such as strips or sheets may be coated, depending upon the position of the metal vaporizing means. Likewise, where the metal is coated upon both sides and it is desired to use an intermediate organic film, this will be applied to both sides of the strip or sheet.

In some cases, instead of forming the metal into a coil 10', it is introduced directly from the drier 12 or the annealer 13 into the coating chamber continuously passing from these instrumentalities into the unit. Also, in such cases, we sometimes provide at the entrance and exit ends of the unit a liquid sealing leg preferably of substantially U-shape through which the continuous strip is traveled. The seal is established by means of a suitable liquid maintained in the leg such as water, mercury, molten lead and other satisfactory liquids, as set forth in pending application Serial No. 343,306.

Where liquid sealing legs are employed it may be necessary to provide special means for preventing contamination of the coating metal by contact with the sealing liquid or vapor therefrom: For example, mercury will alloy with freshly deposited aluminum. We overcome this objection in that the coated steel emerging from the vacuum coating apparatus is first led through a layer of oil of low vapor pressure floating on top of the mercury of the exit sealing leg, whereby the oil film thus applied to the aluminum coated sheet will prevent contact between the mercury and the aluminum coating.

In the event that objectionable amounts of mercury vapors from the sealing leg at the entrance to the evacuated system are not removed by the trap 29 or from the de-gassing chamber 15, or by means of refrigerating coils or condensing surfaces within the evacuated system adjacent to the end of the aforesaid sealing leg in advance of the coating chamber 19, then these traces of mercury vapor are removed by an agent having a strong affinity for mercury such as metallic sodium, potassium or other alkali metal disposed between the sealing leg and said coating chamber. Capsules containing the absorbing metal can be separately vaporized by induction heating so that a film will be deposited upon the walls of the system ahead of the aluminum coating chamber 19, and this operation will be performed after initial evacuation but before aluminizing commences.

As explained above, the use of liquid sealing legs affords a completely continuous operation, in that the strip material need not be coiled for inclusion in the housing 14, but may be led directly from the dryer 12 or annealer 13 into the coating apparatus.

Referring to Figure 11, there is illustrated an automatic means for continuously feeding aluminum wire or strip to be vaporized to a filament 25. For this purpose, a reel 40 of aluminum wire 41 approximately .025 inch in diameter, is provided, and the wire is passed through guide rolls 42 to an intermittent feeding mechanism indicated as a whole at 43. In this feeding mechanism, the solenoids 44 are intermittently energized to cause the jaws of the chucks 45 to engage and disengage the wire. Upon energization of the solenoids 44, the chucks engage the wire 41 and move it a predetermined distance so that a section of proper length is disposed within the convolutions of the filament 25 where it may be vaporized. This automatic means for supplying the vaporizable aluminum to the filament may be associated with a constantly energized filament

and thus assures a constant and continuous supply of vaporizable material. The automatic means also is used with a filament which is intermittently energized as in the coating chamber of Figure 8. The filaments 25 are of sufficiently rugged construction to support the wire 41 and are not impaired by the movement incident to disposing the sections of wire intermittently within the convolutions thereof. In some cases, it is desirable to actually sever the wire and for this purpose we provide a pair of cooperating knives 46 which engage the wire and sever the same at the end of its feeding movement. The severing of the wire by means of knives 46 is desirable in that the wire 41 having been disposed within the coils 47 of the filament will drop into supporting relation by the coils when the wire is severed. This construction is preferred, but in some cases, reliance can be had upon the filament itself melting off a sufficient and constant length of the wire. It is, of course, understood that the automatic mechanism illustrated in Figure 11 may be associated with any of the apparatus illustrated in the drawings and may be disposed entirely within the coating chamber, although it is satisfactory to introduce the wire exteriorly of the chamber, through a close-fitting packing or seal, so that it will not be necessary to break the vacuum in order to replenish the coils 40. It is further to be understood that the wire 41 is supported at all times in feeding relation to the filament 25 so that when portions are severed or melted, actuation of the feeding means 43 will deliver a predetermined section of the wire in centered relation so as to be supported on the filament convolutions.

In Figure 12, we have illustrated in detail a refractory crucible 26 in which the contents may be heated by electrical resistance or inductance heating. In association with this crucible 26, there is provided a feeding means as shown in Figure 11 and which is similar in all important respects with that shown and described.

In Figures 13 and 14, we have illustrated a foraminous belt 50 upon which are supported caps, can bottoms and also containers which are to be coated in accordance with this invention. The various articles are maintained in position on the belt 50 by permanent or temporary magnets 51, and the coating may be carried out in any of the apparatus described herein. At the conclusion of the final step of the coating operation, i. e., when the conveyor reaches housing 14', a suitable means is employed to remove the coated articles from the belt 50.

In Figures 13 and 14, we have illustrated crown caps at 52, screw caps at 53, lug caps at 54, can bottoms at 55 and containers at 56. These various articles as well as containers, may be coated interiorly or exteriorly, or both, in accordance with their positions on the belt. Thus the outside of an article may be coated during part of the movement of the belt whereupon the article, held in position by a temporary magnet is inverted by a suitable means (not shown) and the inside coated or lined during another period of the travel of the belt. It is to be noted that the belt 50 is provided with a multiplicity of openings to permit communication through the belt. It is preferably formed of stainless steel and the sections thereof may be hinged as shown at 57.

In the case where articles of greater dimension than relatively thin strip material are being coated in accordance with the apparatus and methods herein described, the apparatus will be suitably

enlarged to permit the passage of such articles through the respective instrumentalities of the unit. In this connection, where preformed articles are carried by the conveyor 50, they may be fed thereto at the feed end 14 of the unit from a suitable magazine maintained under air-tight or vacuum conditions, and discharged at the delivery end 14' of the unit into a suitable hopper or other collecting means, likewise maintained under vacuum or air-tight conditions. The magazine and hopper may be disposed within the unit or may be disposed outside of the unit and connected thereto through suitable air-tight connections. This will be particularly the case where caps, can bottoms and containers are being coated.

It will be observed that the construction shown in Figure 11 enables the feeding automatically of a predetermined quantity of metal to be vaporized to the vaporizing instrumentalities. This metal may be in the form of a wire, as disclosed in Figure 11, or individual lengths of wire or pellets or powder. In the case of the pellets, powder, and small lengths of wire, these may be fed automatically from a suitable magazine disposed within or without the chamber, to the vaporizing devices. Where the magazine is without the chamber, suitable air locks are provided so that introduction of the individualized metal does not occasion loss of vacuum. Such individualized charges may be substituted for the continuously fed wire in any of the apparatus herein described.

Referring to Figure 15, we have shown at 66 a base of any suitable material, such as steel or black iron, paper or film of organic material, directly coated with a coextensive film of aluminum 67 deposited from aluminum vapor.

In Figure 16, we have shown a similar base 66 provided with a coextensive intermediate film 68, such as lacquer, varnish or enamel upon which is deposited a coextensive coating 67 of aluminum deposited from aluminum vapor.

As explained above, the base 66 may be formed of paper or other flexible material, such as synthetic resins and cellulose derivatives, as well as chlorinated rubber or metal foils, i. e., of steel. In this manner, suitable materials are provided which are useful for providing center spots and overall facings for caps and closures. As understood, the backing or base in the case of spotting materials is provided with a suitable adhesive coating for securing the spot or overall facing to the cushion liner of the closure.

Foils of this character, of course, may be used for their insulative qualities and decorating characteristics.

Also, in the case of two-part caps, particularly those of the screw cap type, the inner member may be produced in accordance with this invention by coating the steel with a coextensive film of aluminum either inside or outside, or both. Likewise, the outer threaded member may be similarly coated.

Wherever desirable, the aluminum coating prepared in accordance with this invention, whether for spotting materials or as for linings for closures and containers, may be provided with a coating of suitable lacquer or varnish. Such organic coatings are useful where chemical action between the contents and the lining or foil might be set up.

While we have referred herein to steel band or strip, the invention is equally applicable to the coating of other material in continuous length, for example, wire, and wire screening.

We claim:

1. The method of coating in a plurality of closed coating chambers having means for coating under reduced pressure with vaporized metal, the chambers being in communication with one another and with a suitable exhausting means for maintaining the reduced pressure therein, which comprises placing material to be coated in one chamber, evacuating that chamber while the material is therein, vaporizing the coating metal in that chamber and coating therein while the vacuum is maintained, placing uncoated material to be coated in a second chamber, upon completion of coating in the first chamber, establishing communication between the chambers so as to break the vacuum in the chamber in which coating has been completed, and reduce the pressure in the chamber in which coating under reduced pressure is about to begin, connecting the last-mentioned chamber to the exhausting means while cutting off communication between said chamber and the first chamber, and carrying on the coating operation described with respect to the first chamber in the second chamber while removing coated material from the first chamber and placing uncoated material to be coated therein.

2. The method in accordance with claim 1 in which the material to be coated is steel strip, and the vaporized metal for coating the same is aluminum.

3. The method in accordance with claim 1 wherein a continuous length of strip material is coated in each unit while traveling therethrough.

4. A method in accordance with claim 1 in which the material to be coated has a temperature lower than the temperature of the coating metal, whereby the latter is condensed upon the material.

5. A method in accordance with claim 1 in which the material to be coated is strip metal and the vaporized metal for coating the same is aluminum, and wherein the strip metal is maintained at a temperature lower than the temperature of the vaporized metal whereby the latter condenses thereon.

6. An apparatus of the class described comprising a plurality of chambers, leads from each of said chambers to a manifold, and an exhaust connection connected to said manifold, valves in each of said leads for establishing communication between a chamber and the manifold and for establishing communication between at least two of said chambers, and a valve in the exhaust connection for establishing communication with the manifold, whereby one of said chambers may be exhausted to the exclusion of the others, and a second chamber about to be exhausted may be vented to said exhausted chamber to reduce the pressure in the second chamber and thus reduce the amount of exhausting required to exhaust said second chamber.

7. An apparatus in accordance with claim 6 having means in each unit for continuously traveling a strip to be coated therethrough.

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