

Sept. 11, 1945.

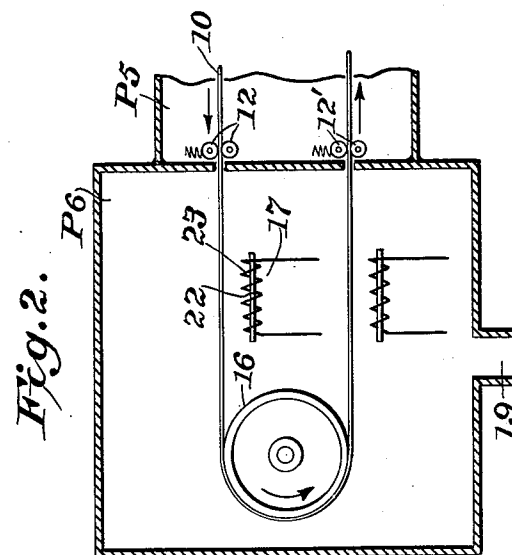
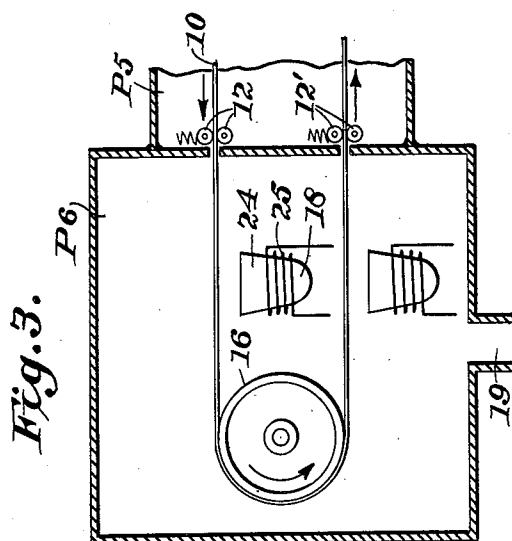
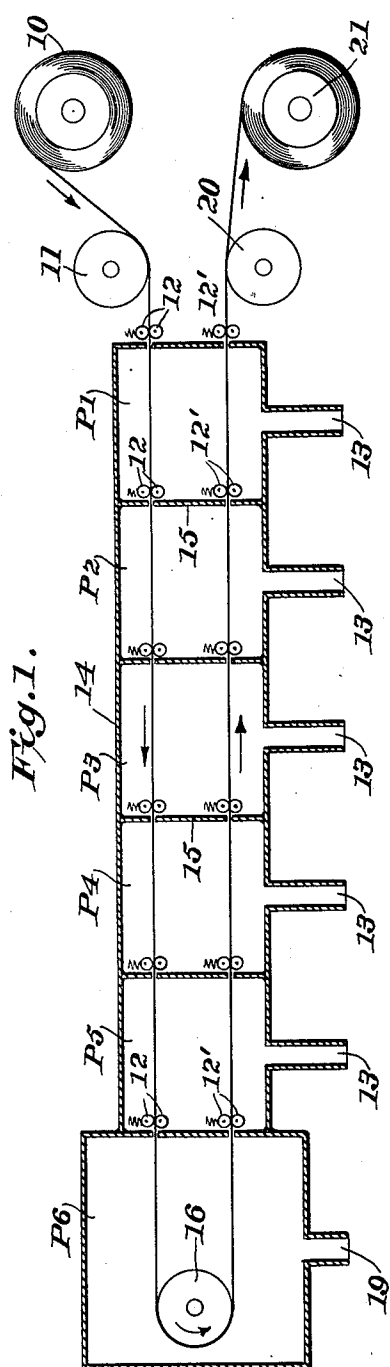
C. C. STOLL

2,384,500

APPARATUS AND METHOD OF COATING

Filed July 8, 1942

3 Sheets-Sheet 1



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Fig. 4.

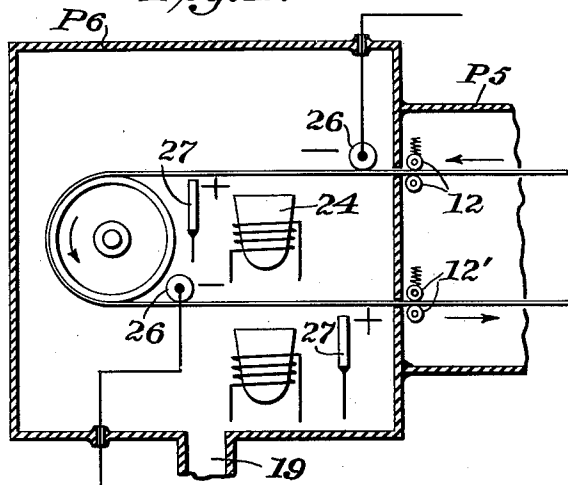


Fig. 5.

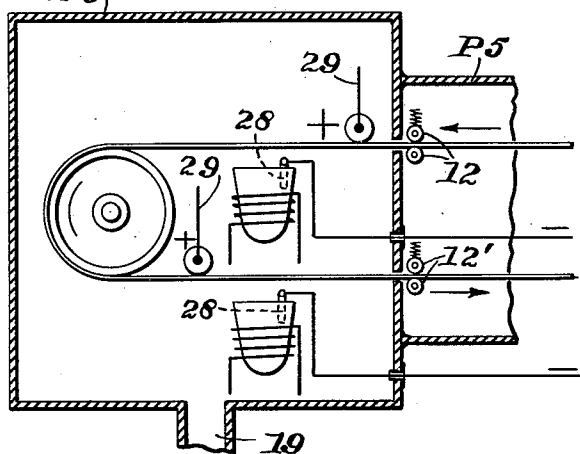


Fig. 7.

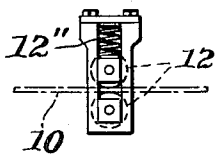
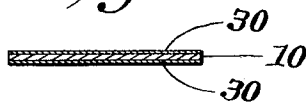


Fig. 6.



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3 Sheets-Sheet 3

Fig. 8.

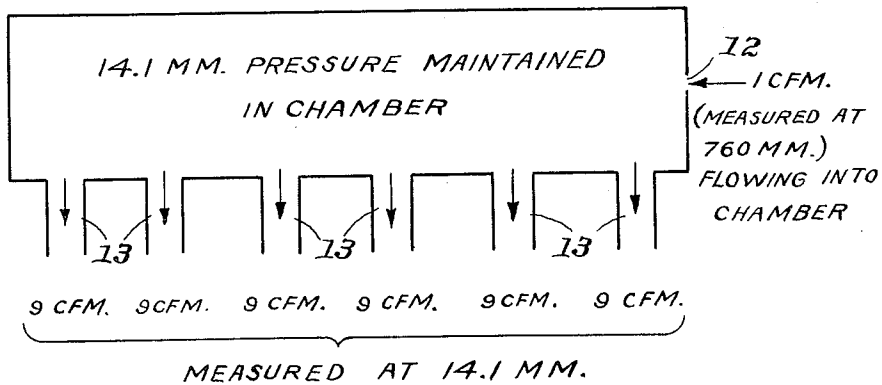
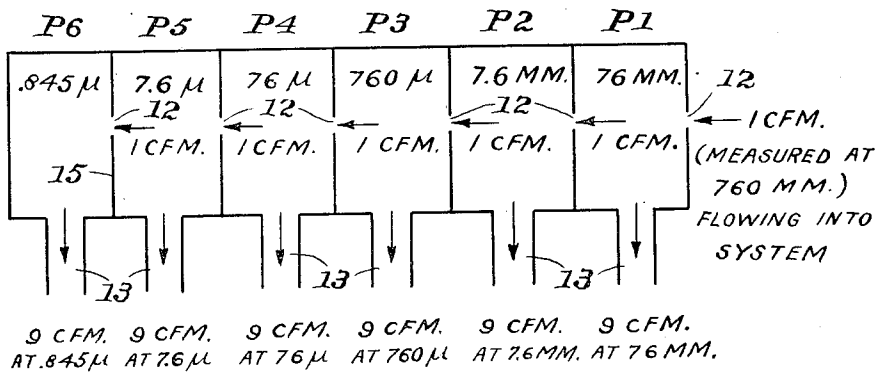


Fig. 9.



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UNITED STATES PATENT OFFICE

2,384,500

APPARATUS AND METHOD OF COATING

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Application July 8, 1942, Serial No. 450,164

4 Claims. (Cl. 117—119)

This invention relates to the treatment in vacuum of metallic and non-metallic materials, such as individual articles or strips of indefinite length, e. g., closure caps and containers, strip steel or black iron, wire, textiles, plastics, including synthetic plastics, fabricated fibrous materials, such as fiber board and paper, and comminuted substances, such as cork and mica. While useful for any type of vacuum treatment, the invention is particularly useful in coating material with aluminum, silver, tin, zinc, copper, and other metals and alloys in vapor form. In such a metal vapor coating operation, the metal vapor atmosphere is created under reduced pressure in a vacuum chamber, and the coating is formed by condensing the metal upon the material in the chamber.

It has been proposed for coating with the vaporized metal that the material to be coated and the coating apparatus be positioned in a sealed vacuum chamber; or in a sealed vacuum chamber having associated therewith mechanical air barriers, such as adjacent chambers separated from the vacuum chamber by mechanical air locks, so that when the coating operation is completed, the material may be removed or replaced without destroying the vacuum in the chamber. This procedure is objectionable, for the reason that mechanical operation of the air locks is necessary for ingress and egress of the material, and the travel of material into and out of the coating chamber cannot be continuous. It has also been proposed to utilize liquid seals at the inlet and outlet openings of the coating chamber, but such seals have for various reasons been found to be unsatisfactory.

All of the prior methods have the objections that they are complicated and not sufficiently rapid for commercial purposes, are limited as regards the materials which may be coated, and present the difficulty that different batches of materials are not uniformly coated. Because of the necessity for forming the metallic vapor and condensing the same upon the material under a substantial and critical degree of vacuum, it has not been heretofore considered feasible to continuously coat material, except by recourse to the expedients mentioned above and which have been regarded as essential to preserve the vacuum conditions.

A primary object of the present invention is to provide a method and apparatus for treating material, such as individual articles or strips, in a vacuum chamber with the material traveling into and out of the chamber continuously or intermit-

tently without the necessity for operating mechanical devices for opening and closing the inlet and outlet openings and without the use of any physical barrier, such as a liquid seal at such openings. The invention comprehends the association with the vacuum treating chamber of a series of separately evacuated chambers through which the material passes successively as it enters and leaves the treating chamber, each of the adjacent chambers being in communication with one another through an opening or openings and having maintained therein a degree of vacuum with the vacuum increasing progressively from the first chamber to the treating chamber.

It is apparent that as material passes from the atmosphere into the vacuum system and out again through suitable openings there will be a considerable leakage of air into the system. The purpose of passing the material through a series of separately evacuated chambers is to prevent this air leakage from destroying the vacuum in the treating chamber. 90% (more or less) of the air leaking into the system can be ejected by the pump on the first vacuum stage. A similar percentage of the remainder may be removed by the pump on the second stage. Thus, after several such separate evacuations, the air remaining of that which leaks into the system is so little as to be negligible, and can easily be removed by the pump on the treating chamber.

The aforesaid improvements allow continuous coating or treating of individual articles or strip of indefinite length to be carried out at high speed without interruption, and assure that coatings having the required coverage and thickness will be uniformly obtained.

The invention will be described in connection with strip material of indefinite length, such as black iron or steel band suitable for the manufacture of container closures, containers, and other products. By "strip material" is meant metallic and non-metallic material of varying width, thickness and length, as well as wire.

A preferred form of the invention is shown for purposes of illustration, and it is to be understood that the apparatus and method may be modified within the scope of the appended claims.

Referring to the drawings:

Figure 1 is a diagrammatic view;

Figures 2 and 3 are detail diagrammatic views, showing means for forming the metallic vapor and coating the traveling strip;

Figures 4 and 5 are detail views showing means for positively directing the metallic vapor upon the strip to coat one side or consecutively and/or

simultaneously coat both sides of the same while it is traveling through the coating stage;

Figure 6 is a sectional view of strip material having a coating condensed from metallic vapor on both sides thereof;

Figure 7 is a detail view of the yieldably mounted rolls at the entrance and exit openings of each chamber; and

Figures 8 and 9 are diagrammatic views for illustrating the effectiveness of the invention.

The apparatus for carrying out the method includes a treating stage or chamber P_1 and one or a plurality of associated chambers or stages P_1, P_2, P_3, P_4, P_5 , all of the chambers being maintained under reduced pressure and the successive adjacent chambers communicating with each other through a restricted opening or openings through which the material continuously travels from the atmosphere to the treating stage and back to the atmosphere without interruption and without breaking the vacuum.

The treating chamber P_1 may be used for treating material for any desired purpose in connection with which a vacuum is useful, such as coating, degassing or drying.

For purposes of illustration, the invention is described hereinafter as being employed in the coating of metal, and the particular coating operation described is the application of a metallic vapor to the material introduced through the treating chamber. Moreover, the invention is described as applied to the coating of a continuous strip, although it will be understood that individual articles may be treated or coated.

There is indicated at 10 a reel of strip material, such as black iron or steel band, having a thickness suitable for the manufacture of closure caps, cans, and other products. The material is fed over an idler 11 through a restricted opening 12 into a vacuum chamber or stage P_1 which is in communication with the atmosphere through the openings 12. Each opening 12 is of a size to pass the strip material 10 without scratching the same, and may be variable in size to accommodate various thicknesses of strips without objectionable leakage. This variability may be obtained in any suitable manner as by rolls 12' mounted over the openings 12 in a manner to seal the same and yieldingly pressed toward one another as by springs 13' as shown in detail in Figure 7. These rolls may be idlers or, if desired, may be positively driven in any suitable manner (not shown). The openings 12 are restricted to allow a minimum flow of air between the communicating stages, whereby to maintain the desired vacuum differential in the various reduced pressure stages with minimum pump capacity. In the present illustration, the vacuum chamber or stage P_1 is continuously exhausted by means of an outlet 13 leading to a vacuum pump (not shown), whereby the desired degree of vacuum may be maintained in the chamber. A series of vacuum chambers, such as just described, provide five stages, P_1, P_2, P_3, P_4 , and P_5 , in advance of the treating stage P_6 . A greater or lesser number of stages may be found best for the operation.

The several vacuum chambers are defined by partitions 15, each partition having restricted openings 12 therein, whereby the metal strip material may pass from one stage to the next. Each vacuum chamber is also provided with an outlet 13 leading to a separate pump for controlling the pressure in the chamber. In this connec-

tion, the pressure is progressively reduced toward the left of Figure 1, i. e., toward the coating chamber or stage which has the greatest magnitude of reduced pressure and at all times a pressure suitable for the coating operation. The chamber P_6 will ordinarily be larger or of greater volume than the other vacuum chambers, and contains one or more idlers 16, over which the metal strip continuously passes, as well as metal evaporating means 17 and 18, as shown in Figures 2 to 5. A separate vacuum pump is likewise employed to maintain the desired low pressure in the chamber P_6 through the outlet 19.

In the chamber P_6 , the coating metal is evaporated and the pressure therein is maintained at the critical condition for assuring that a uniform continuous coating will be condensed from the metallic atmosphere upon the traveling strip 10. The coated strip continuously leaves the chamber P_6 and may pass through the same openings 12, which then are large enough to allow passage of the material simultaneously in both directions without touching or engaging the walls of the openings. Preferably, the strip is passed through openings 12' in the partitions 15 spaced from the openings 12 and successively through the several stages of pressure to the atmosphere, and over the idler 20 to the re-wind reel 21. This re-wind reel is positively driven and forms a means for drawing the strip from the reel 10 continuously and at a constant but variable rate of speed through the vacuum and coating stages. Other means for continuously traveling the material may be employed.

In Figure 2, the evaporating means consists of a filament 22 in which is disposed a rod 23 of the coating metal, the same being evaporated upon energization of the filament. Filaments are disposed between the runs of the band 10, as shown, and beneath the same, whereby both surfaces of the strip are uniformly and simultaneously coated while traveling through the chamber P_6 .

In Figure 3, which shows an alternative vaporizing means, the metal evaporating means includes a suitable crucible 24 containing the metal to be evaporated and a resistance heater 25 surrounding the same to evaporate the metal upon being energized. The disposition of the crucibles is identical with that of the filaments of Figure 2, whereby the traveling strip may be uniformly and simultaneously coated upon both sides with a film of any required thickness of the coating metal. The heater 25 may be an induction coil, if desired, so as to vaporize by induction.

In some cases it is desirable to positively direct the vaporized metal upon the moving strip in the chamber P_6 , and referring to Figure 4 there is utilized an electrode 26 for imparting a charge to the moving strip and an electrode 27 of opposite polarity disposed in proximity to the strip and the vaporizing means, in this instance a crucible 24, whereby the vaporized metal is positively directed upon the moving surface of the strip. Any other suitable means for positively directing the vaporized metal upon the strip may be utilized, as, for instance, the sputtering cathode of Figure 5, wherein an electrode 28 is introduced into the crucible so as to make electrical contact with the molten metal inside. This electrode will be at a negative potential with respect to the strip which is connected to the positive side of a high voltage direct current source through the electrode or connection 29. The va-

por directing means described may be interposed at any convenient point in the chamber P_6 and is shown diagrammatically for purposes of convenience and illustration.

Where one side of the strip is to be coated, only one of the vaporizing means will be active, so that a laminated sheet may be produced having a coating upon either or both sides. As shown in Figure 6, the strip 10 has a similar coating 30 on each side thereof.

In some cases, different metals may be interposed in the respective vaporizing means so that, for example, one side will have a coating of silver, and another a coating of aluminum.

From the foregoing, it will be understood that the successive vacuum chambers have progressively increasing vacuum in advance of the treating chamber P_6 . It is, thereby possible to maintain a suitable vacuum in the treating chamber with substantially less pump capacity for the chamber P_6 than would be necessary if the latter communicated directly with the atmosphere. That is, this result is accomplished in a manner which permits the use of a total pumping capacity substantially less than would be required to maintain any given degree of vacuum in the treating chamber if the latter directly communicated with the atmosphere through openings having a corresponding leakage area.

The advantage of the stage method of obtaining a high vacuum in a vacuum system in spite of substantial leakage openings is illustrated in the following concrete example. Referring to the vacuum chamber shown, in Figure 8, there is provided an opening 12 to atmosphere which allows 1 cubic foot per minute (measured at 760 mm.) of air to enter the chamber and the chamber is evacuated through outlets 13 by 6 pumps rated at 9 c. f. m. each or a total of 54 c. f. m. Since 1 c. f. m. at atmospheric pressure expands 54 times, therefore the pressure in the chamber is reduced to a figure $760/54 = 14.1$ mm.

Referring to the chamber shown in Figure 9 which is similar to Figure 8 except for the addition of partitions 15 between the pumps each having an opening 12 similar to that which opens to the atmosphere, it will be observed that since 10 c. f. m. at 76 mm. is evacuated from stage P_1 (1 c. f. m. to stage P_2 , 9 c. f. m. to pump) it follows that the 1 c. f. m. from atmosphere expands 10 times and the pressure in that chamber is reduced to

$$\frac{760}{10} = 76 \text{ mm.}$$

Similarly, the pressures in stages P_2 , P_3 , P_4 and P_5 are reduced respectively to 7.6 mm., 760 microns, 76 microns and 7.6 microns. In stage P_6 the 1 c. f. m. entering expands to 9 c. f. m. Consequently, the pressure is reduced in this stage

$$\frac{7.6}{9} = .845 \text{ micron}$$

The ratio of the pressure obtained in stage P_6 of Figure 9 to that obtained in the chamber of Figure 8 is

$$\frac{.845 \text{ micron}}{14.1 \text{ mm.}} = \frac{.845 \text{ micron}}{14,100 \text{ microns}} = \frac{1}{16,700}$$

In other words, the simple addition of partitions 15 in the chamber of Figure 8 improves the vacuum 16,700 times.

The above calculations involve some only approximately true assumptions as to the behavior

of air and the actual behavior would produce an even higher vacuum in stage P_6 of Figure 9.

It is to be understood that pumps of various sizes, leakage openings of various sizes and various pressures in the different stages can all be used successfully within the scope of this idea. Likewise, the method can be used to remove any other gas as well as air leakage.

I claim:

1. The method of coating in vacuum comprising continuously traveling material from the atmosphere into and through a plurality of successive stages of reduced pressure in advance of a coating stage, the first stage being open to the atmosphere and the subsequent stages including the coating stage communicating consecutively, openly and directly with each other, maintaining the reduced pressure in each stage including the coating stage below the pressure of the immediately previous stage, maintaining the reduced pressure in said coating stage effective to assure removal of substantially all extraneous gases from the coating stage and the traveling material, and coating the material while it is traveling through said coating stage.

2. The method of coating in vacuum comprising continuously traveling material from the atmosphere into and through a plurality of successive stages of reduced pressure in advance of a coating stage, the first stage being open to the atmosphere and the subsequent stages including the coating stage communicating consecutively, openly and directly with each other, maintaining the reduced pressure in each stage including the coating stage below the pressure of the immediately previous stage, maintaining the reduced pressure in said coating stage effective to assure removal of substantially all extraneous gases from coating stage and the traveling material, and coating the material while it is traveling through said coating stage, and returning the coated material from the coating stage to the atmosphere through a stage of reduced pressure communicating with the coating stage and the atmosphere whereby the passage of the material from the atmosphere through the coating stage and back to the atmosphere is conducted without interruption and without breaking the vacuum.

3. The method of coating in vacuum comprising continuously traveling material from the atmosphere into and through a plurality of successive stages of reduced pressure in advance of a coating stage, the first stage being open to the atmosphere and the subsequent stages including the coating stage communicating consecutively, openly and directly with each other, maintaining the reduced pressure in each stage including the coating stage below the pressure of the immediately previous stage, maintaining the reduced pressure in said coating stage effective to assure removal of substantially all extraneous gases from the coating stage and the traveling material, and coating the material while it is traveling through said coating stage by vaporizing a metal in the coating stage and condensing the vapor upon the material.

4. An apparatus of the class described comprising a plurality of closed chambers arranged in consecutive relation, restricted openings affording direct communication between the chambers, openings in one of said chambers for affording direct communication to the atmosphere, exhaust means for the said chambers, one of said chambers, remote from said last mentioned chamber,

constituting a coating chamber, coating means in said coating chamber, the said openings being arranged in pairs, and means for introducing material to be coated through one of the openings in said chamber communicating with the atmosphere and for carrying the same through one of the openings in each of the respective succeeding

chambers to the coating chamber and for continuously carrying the coated material from the coating chamber back through the other openings in the respective chambers while all of the chambers are in exhausted condition.

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