

Jan. 22, 1952

F. W. LANIGAN

2,583,220

PROCESS OF LEVELING AND DRYING COATINGS WITH STEAM

Filed Dec. 24, 1948

2 SHEETS—SHEET 1

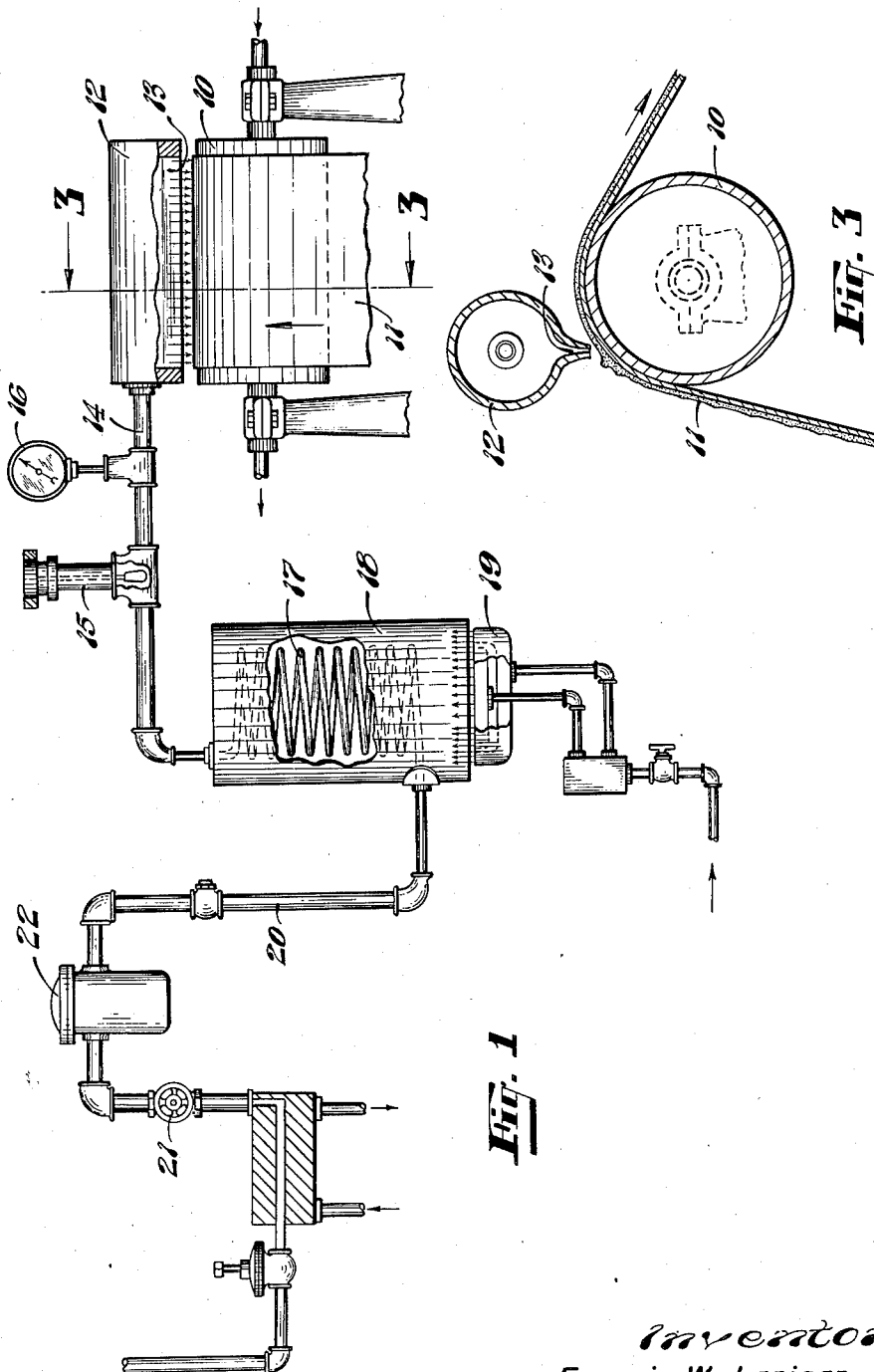


Fig. 1

Fig. 3

Inventor
Francis W. Lanigan

by Theodore C. Browne
Attorney

Jan. 22, 1952

F. W. LANIGAN

2,583,220

PROCESS OF LEVELING AND DRYING COATINGS WITH STEAM

Filed Dec. 24, 1948

2 SHEETS—SHEET 2

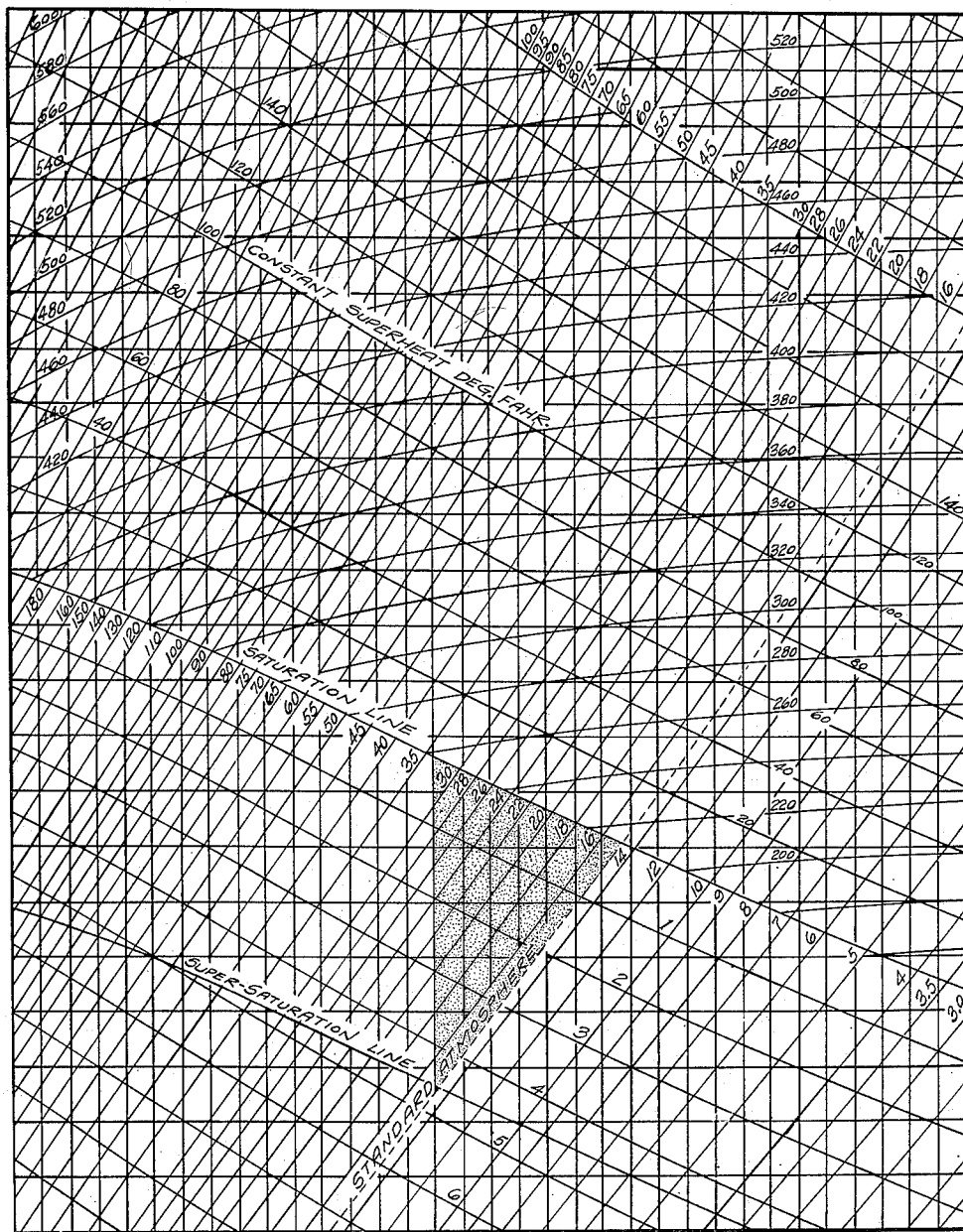


Fig. 2

INVENTOR.

Francis W. Lanigan

BY

Theodore C. Browne

Attorney

UNITED STATES PATENT OFFICE

2,583,220

PROCESS OF LEVELING AND DRYING
COATINGS WITH STEAM

Francis W. Lanigan, Lincoln, Mass., assignor to
Dewey and Almy Chemical Company, North
Cambridge, Mass., a corporation of Massachu-
setts

Application December 24, 1948, Serial No. 67,225

4 Claims. (Cl. 117—64)

1

This invention comprises a novel process for leveling coating materials on fabricated webs or sheets, such as paper or woven or felted fabrics. It also includes within its scope a novel process for simultaneously leveling and drying water suspensions of such amorphous or plastic coating materials on webs.

The term leveling is used herein in a broad sense to include smoothing with or without the removal of excess coating material and applying the same continuously or in stripes.

One object of the invention is to improve the smoothness and uniformity of coatings spreadable by heat and pressure. Another object is to increase the range of coating materials that may be handled and to include those of higher viscosity than it has been heretofore practical to use. A still further object, when using water suspensions of the coating materials, is to dry the coated web simultaneously with the leveling operation, thereby obviating the very substantial expense heretofore necessary for drying the coated web by festooning it in a hot room.

It has been the practice for many years to employ an air knife for leveling fluid coatings applied to webs or sheets. In these prior instances, the leveling effect of the air has depended upon the velocity of the blast and that is a direct function of its pressure drop before impingement on the coated web. In practice it has been necessary to limit the pressure drop of the blast in order to avoid large energy losses and undesirable working conditions caused by turbulence set up in the air of the room into which the blast expands and the difficulty of handling the great volume of air required at high pressure drops. Therefore, in coating a web with materials of high viscosity it has been found impossible heretofore on any practical basis to achieve a pressure drop sufficiently great to allow the air to act as an effective leveling agent.

Other considerations likewise militate against the use of expanded air in leveling high viscosity coating materials. Air expansions in such practice take place well up in the range of superheat, since, under usual conditions, air itself is a high superheated fluid. Furthermore, air is a fluid which adheres closely to the so-called perfect gas laws and is also a fluid of relatively low specific heat. Without theorizing upon these facts, it can be stated that they all tend to result in an objectionably high temperature loss per unit weight of expanded air. This expansion of air produces a pronounced refrigerating effect which is well known and often utilized in producing

2

liquid air but which is very detrimental in conditioning plastic coating materials for spreading.

High temperature loss of the fluid blast is in fundamental opposition to the requirements of the operation of coating webs with high viscosity materials. Expansion of air, in normal practice, will result in a blast temperature well below the temperature of the coating material. Heat, therefore, will be removed from the coating material unless the air is heated after compression to such a temperature level that its use is entirely uneconomical for such purposes.

Attempts have also been made to utilize steam, or mixtures of air and steam, for leveling or applying amorphous materials to webs. In the case of coatings adversely effected by moisture, the use of saturated steam results in an inferior coating both in quality and appearance. Coatings so treated often have an emulsified and blotched appearance. The reason for this lies in the fact that the expansion of saturated steam always results in condensation of free moisture in the steam blast. This moisture, under influence of the energy derived from the steam expansion, mixes intimately with the coating material and generally results in the formation of an emulsion. This effect is evident to an increasing extent as the original pressure of the steam is raised.

Even in the case of coating material not adversely effected by moisture (e. g. water suspensions), the use of saturated steam merely deposits in the coating more moisture by condensation, and while in this case it may act as a leveling agent, it is of no value in reducing the water content. Hence the coated web must be dried by other means.

Many experiments have been conducted in an attempt to solve this problem by using saturated steam on water repellent coatings but no success was achieved regardless of the pressure behind the steam blast.

It has been found that a high temperature level, such as is offered by expanding steam, is not alone sufficient in either case. In the first case inferior quality of the resulting coating prohibits the use of steam, and in the second case nothing worthwhile is gained by the use of a fluid that can be provided only at increased expense.

The present invention is based on a discovery made while endeavoring to operate with a steam blast at high temperature. Having made no progress by varying the pressure it was decided to superheat the high pressure steam. Accordingly, steam at about 135 lbs. per sq. in. gauge (150 lbs.

abs.) was superheated 100° F. to a temperature of about 460° F. The expansion of this steam, although it leveled the coating mechanically with relative ease, showed no improvement in coating quality as judged by its emulsified appearance and hence the procedure was a failure. However, while maintaining this superheat at 460° F. the steam pressure was reduced to 65 lbs. per sq. in. gauge and thereupon the coating immediately showed marked improvement in appearance and soon the web was coming off the roll with an exceptionally clear and smooth coating.

A great number of runs were then made and as an end result it became apparent that as long as the expanded steam reached atmospheric pressure with no more than 4.5% theoretical free moisture, the coatings exhibited excellent qualities. The conditions (temperature and pressure) of the steam before expansion were found to be governed solely by the consideration just set forth and it was found that extremely high viscosity materials could be applied to and leveled on the web with ease and with excellent resultant quality.

Likewise it was found that water suspensions could be dried almost instantly in such a blast and the resultant coated web rolled up with no tackiness within a few feet of the line of impact of the blast itself. This was also found to be true of water suspensions of such high viscosity as to prohibit their application by any other similar method.

In other words, a successful process had been found which is characterized by utilizing the high temperature level of expanded steam while eliminating the condensation normally taking place during such an expansion. That is, the use of steam and dry heat at a high temperature level will produce the desired coating effect with marked operational advantages. For instance, the higher the temperature level to which the expanded fluid is raised, the higher can be the viscosity of the coating material to be applied. If the temperature level of the expanded fluid is above that of the coating material, many advantages accrue. First, the transfer of heat will be to the coating material thus increasing the fluidity (lowering the viscosity) and giving a greatly improved facility of application. In the second place, the drying effect of this heat transfer can be utilized as above set forth. Furthermore the uniformity and smoothness of the coating is enhanced to a striking degree.

The explanation for the phenomenon of dry steam expanding below its saturation pressure lies in the fact that steam can exist in a dry but supersaturated state even at atmospheric pressure for a short but appreciable length of time as long as the total potential free moisture content of the steam is low. In this case the limiting total potential free moisture must be very close to 4.5% since any appreciable increase above this figure causes water to condense in the water repellent coating.

Considering this theory further, it should be noted that it is possible to achieve an original steam condition such that expansion to atmospheric pressure will result in dry steam at temperatures above 212° F. This fact makes it possible to level coatings of viscosities considerably above those heretofore employed since the increased temperature will maintain them fluid during application.

It will be obvious that the use of a steam blast

such as described herein must be characterized by a minimum velocity and a minimum quantity (which together determine a certain minimum kinetic energy) in order to achieve the desired leveling effect. In other words, a predetermined number of pounds of steam must be delivered from the orifice each minute to operate successfully on a predetermined quantity of coating for a web of given width.

By the process of my invention the effect of dry, high-temperature heat is superimposed upon this minimum kinetic energy effect and will be shown to extend widely the scope and usefulness of this technique of utilizing the energy of superheated fluid.

These and other advantages of my novel process will be best understood and appreciated from the following description of the preferred manner of putting it into practice as illustrated in the accompanying drawings, in which:

Fig. 1 is a diagrammatic view of one suitable apparatus for carrying out the process of my invention,

Fig. 2 is a chart showing the properties of steam under varying conditions of temperature and pressure, and

Fig. 3 is a view in cross-section on the line 3—3 of Fig. 1.

The illustrated apparatus comprises essentially a driven steam heated drum or breast roll 10 by which the web 11 to be treated is fed and presented to the steam blast. A linear velocity of 100 to 250 feet per minute is a satisfactory rate of web travel. Supersaturated steam is directed in a continuous blast against the web 11 while supported upon the roll 10 from an elongated plenum chamber 12 having a projecting nozzle 13 provided with a longitudinal slit orifice. In practice the orifice may be 0.006" in width and the nozzle externally streamlined in contour. Steam is supplied to the plenum chamber 12 through a pipe 14 in which is placed a thermometer 15 and a pressure gauge 16. The pipe 14 is a continuation of the coil 17 constituting part of a superheater 18 heated by a burner 19. Steam at boiler pressure is brought to the superheater through a pipe 20 provided with a valve 21 and a steam separator 22, all of commercial construction.

The chart shown in Fig. 2 is known as the Mollier chart of the thermodynamic properties of steam and is taken from Figure 10 of Keenan and Keyes, "Thermodynamic Properties of Steam," John Wiley & Sons, Inc., New York, 1936, copyright 1936 by Joseph H. Keenan and Frederick J. Keyes. In this chart enthalpy is laid off as the ordinate and entropy as the abscissa. Pressures are indicated by the slightly curved lines extending at substantially 60° to the horizontal. The "saturation line" at which dry steam theoretically becomes saturated steam is indicated as such. The lower limit of supersaturation of steam is represented by a line parallel to the saturation line at about 60 B. t. u./lb. below it, and that line is marked "super-saturation line" on the chart. The "standard atmosphere" line shows the final condition of steam expansion since that line represents conditions of the steam when expanded through the nozzle to atmospheric pressure. The vertical lines show isentropic energy changes, that is, changes in total energy at constant entropy and therefore represent the adiabatic reversible expansion of the steam through the nozzle from whatever degree of superheat is initially employed. The position

of this line is derived from data presented in Keenan, "Thermodynamics," John Wiley & Sons, Inc., New York, 1947.

The super-saturation line crosses the standard atmosphere constant pressure line at about 4.6% on the constant moisture line. From this, in turn, it may be seen that for 90° F. superheat, the highest steam pressure possible without condensation on expansion to the atmospheric line is 70 p. s. i. a. or 55 p. s. i. g. (gauge pressure). It will be noted that the lines marked 20, 40, 60, 80 etc. indicate constant superheat of the steam in degrees Fahrenheit, and that the lines below the saturation line marked 1, 2, 3 etc. indicate theoretical or potential percentage of moisture in the expanding steam.

It has been discovered that the most economical conditions favorable for leveling and drying plastic coatings are those in which the steam expanding isentropically passes through the triangle bounded (1) by the standard atmospheric line, (2) the saturation line, and (3) a vertical line from the point at which the standard atmosphere line intersects the super-saturation line. That area is set off by shading in the chart of Fig. 2. For example, if steam at an absolute pressure of 60 lbs. is given 120° of superheat, in expanding isentropically it will cut the saturation line at a pressure of about 23.5 lbs. In further expansion in supersaturated condition it will cut the standard atmosphere line in dry condition but with about 2.5% indicated theoretical content of moisture. In all cases the pre-expansion conditions imposed upon the steam are such as to insure the availability of the necessary kinetic energy to achieve the leveling of the coating. With the slot width previously given and at a rate of application of the coating material at 4.3 lbs. of coating per ream of paper, steam velocities of the order of 1000 to 3000 feet per second are satisfactory and develop a kinetic energy in the blast of 10,000 to 20,000 ft. lbs. per sec. The steam consumption under these conditions for a 12" slot which is 0.006" in width, thus having an area of 0.072 sq. inches, will run from about 290 lbs. of steam per hour at 80 lbs to about 100 lbs. of steam per hour at 30 lbs pressure (absolute).

It is to be understood that the production of dry steam to meet the objects previously set forth is feasible in other ways. For instance, the expansion may take place entirely in the superheated region with good results. In such a case, however, any superheat remaining in the expanded steam is completely wasted while the initial superheat is of course more costly to attain. Hence, such a method of operation has a serious economical drawback and lies outside the scope of the present invention.

The preferred process, therefore, is characterized by the maintenance of dry heat by exploiting the supersaturation property of steam while operating at relative low initial degrees of superheat and pressure. This is, of course, in the interest of economy and gives entirely satisfactory results.

In further illustration of the process of this invention, the following actual test runs are noted:

Test No. 1.—Super finish calender stock; thermoplastic coating, M. P. 154–158° F., 125 C. P. viscosity at 200° F.; speed of web 200 ft./min.; 12 lbs. gauge steam pressure (absolute 27 lbs.), orifice slit .006", 60° F. superheat. Results, smooth, high gloss coated sheet; weight, 8.15 lbs. per ream.

Test No. 2.—Super calender body stock; same

thermoplastic coating material; 18 lbs. gauge steam pressure (absolute 33 lbs.), 60° F. superheat. Results, smooth continuous film; weight, 4.3 lbs. per ream.

Test No. 3.—Super calender finish; thermoplastic coating material same as above; 28 lbs. steam pressure (absolute 43 lbs.), 80° F. superheat. Results, smooth high gloss coated sheet obtained; weight, 3.8 lbs. per ream.

Test No. 4.—Super calender finish body stock; thermoplastic coating material, M. P. 183–187° F., 10,000 C. P. viscosity at 250° F.; 68 lbs. steam pressure (absolute 79 lbs.), 140° F. superheat. Results, excellently coated sheet, very smooth coating; weight 3.5 lbs. per ream.

Test No. 5.—No. 37 body stock; coating material 15.18 lbs. clay, 6.7 lbs. water, 2.7 lbs. starch, total solids 68%; web feed approximately 100 ft./min.; 12 lbs. gauge steam pressure (absolute 27 lbs.), 60° F. superheat. Results, a continuous film and coated web in completely dried condition within 1 ft. of the line of supersaturated steam contact; weight, 29.5 lbs. per ream.

Test No. 6.—Super calender body stock; vinyl acetate emulsion 57% solids; 27 lbs. (absolute) steam pressure; speed of web 100 ft./min.; 60° F. superheat. Results, smooth continuous coating, moderate gloss, slight penetration into stock.

Test No. 7.—Stock No. 43461; D & A coating material X. T. P. 564 (M. P. 68–70° C., 125 C. P. at 200° F.); 31 lbs. steam pressure (absolute); speed of web 100 ft./min.; 80° F. superheat. Results, smooth continuous film, satisfactory doctoring.

Test No. 8.—Stock No. 43462; Paraffin wax coating; (M. P. 120° F.); 21 lbs. steam pressure (absolute) speed of web 250 ft./min.; 40° F. superheat. Results, very smooth coating, some penetration into stock.

It will be noted that in each of the above test runs steam superheated to the degree stated and expanded isentropically in the steam blast will reach standard atmospheric pressure in dry condition, as indicated by its vertical expansion line in passing through the shaded triangular area of the chart of Fig. 2. The process of my invention is characterized by steps carried out under these conditions.

On the other hand, if for example steam at 100 lbs. abs. superheated 80° were employed, it would expand through the nozzle in a process indicated by a vertical line in the chart of Fig. 2 that would cut the saturation line at approximately 50 lbs. pressure and would then cut the standard atmosphere line with about 7% free moisture—well below the supersaturation line. Under such conditions a mottled, unsatisfactory appearance would be imparted to the coating.

Having thus disclosed my invention and described in detail illustrative test runs, I claim as new and desire to secure by Letters Patent:

1. The process of leveling heat and pressure-spreadable coatings on fabricated webs, which is characterized by the steps of moving a coated web continuously at a rate of 100 to 250 ft./min. past a transverse slit orifice disposed adjacent to the web, and directing against the coating material on the web from the orifice a continuous blast of steam at 21–80 lbs./sq. in. and superheated before expansion by 40 to 230° F. so that when it is expanded against the web it becomes dry supersaturated steam with no more than 4.5% indicated free moisture content, the steam being delivered at a velocity of 1000–3000 ft./sec. and at a rate

7

of 100-290 lbs./hour/0.072 sq. inches of slit orifice area.

2. The process defined in claim 1 further characterized by the fact that when expanded to atmospheric pressure the steam remains dry and at a temperature above that of the coating material and thus transfers heat to the coating material without condensation.

3. The process defined in claim 1 characterized by the employment of steam at a pressure above atmospheric and superheated to such a degree that in expanding through the orifice to atmospheric pressure it encounters the coating material in supersaturated condition at a temperature above 212° F.

4. The process defined in claim 1 in which the spreadable coating contains water and clay and in which the dry supersaturated steam dries the coating as it is spread upon the web.

FRANCIS W. LANIGAN.

8

8

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,282,564	Gage -----	Oct. 22, 1918
1,980,923	Lebel -----	Nov. 13, 1934
1,985,203	Charbonneau -----	Dec. 18, 1934
2,065,032	Spooner -----	Dec. 22, 1936
2,229,921	Goff -----	Jan. 28, 1941
2,438,366	Illingworth -----	Mar. 23, 1948

FOREIGN PATENTS

Number	Country	Date
257,449	Great Britain -----	Sept. 2, 1948

20