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GRAVIMETRIC COATING CONTROL SYSTEM
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This application is a continuation in part of application Ser. No. 183,963 filed Mar. 30, 1962, by Joseph Sullivan Crowe for Gravimetric Coating Control System, now abandoned.

The present invention relates to a method and apparatus for measuring the amount of coating applied to a substrate material. More particularly, the invention relates to a gravimetric system for monitoring the weight of coating consumption and thereby controlling the thickness of the coating as it is being applied to the substrate material and while the coating is still in the wet or liquid state.

The industrial uses of coatings of all types are virtually endless. In the packaging industry alone, the use of coatings on various plastic, fibre and metal materials for either decorative, protective or adhesive purposes is a growing field. Such coating materials as natural and synthetic resins, paints, varnishes, waxes, sealants, adhesives, and certain metals, such as solder, are customarily applied as a film to a substrate material. Common methods of applying these film coatings to the selected substrate material are spraying, immersing, or by passing the substrate material, either as a continuous web or in sheet form, over an apparatus which carries the coating in a wet or liquid state.

While the term "coating" has been used above as describing a material to be applied to a substrate in a wet or liquid state by spraying, immersion, etc., it is to be understood that, for the purpose of the instant application, the term "coating" is intended to encompass the formation or extrusion of supported and unsupported plastic films of materials such as polyethylene, which films may be applied or laminated to a substrate in a liquid, semi-liquid or substantially solid state, or may remain as free films.

Whether the coating is applied as a protective film over the entire surface of an article or sheet or merely as narrow strips of solder or adhesive to the marginal edges of a substrate web, it is generally of prime importance that the uniformity of coating deposit be carefully controlled. This is so because, in addition to the necessity of depositing an adequate thickness to ensure good performance, it is equally important to avoid excessive coating thickness in order to keep waste of the normally expensive coating to a minimum.

In the past, time consuming and rather tedious methods have been employed in measuring and controlling coating weight and thickness. A commonly used test requires waiting until the coating has dried to a semi-wet or solid state, after which a test sample would be subjected to destructive testing to determine the coating weight. Such spot check systems are obviously slow and, accordingly, have motivated the development of more efficient devices whereby periodic inspection could be accomplished as the coating is continuously applied and without marring or destroying the coating by direct contact. There are disclosed in the prior art and are commercially available several such devices, all of which work on one or the other principles of optics, radiation, electrical charge, thermoelectrics, etc.

Many of the available devices have distinct limitations in that they are applicable only to particular types of coatings or carrier materials. That is, the operational principles inherent in many of these prior art systems are dependent on the nature of either the surface being coated or the coating itself, or both. Optic systems, for example, are applicable with acceptable accuracy only in situations where the light conductivity of the coating and reflective characteristic of the coated surface are determinable parameters. More versatile systems are available, of course, but in the main, they represent rather sophisticated devices which are costly to install and require a certain degree of excellence in operation and maintenance.

Many of these devices, although capable of highly accurate and reliable performance in the laboratory, have proven generally unsatisfactory in the practical environment of a production line where the variables of temperature, vibration, spurious light, human judgment, etc., are less easily controlled.

There is still a great need for the industry for a system of coating weight control which is not only insensitive to adverse shop conditions but which is also simple in construction, installation, operation, and maintenance. Such a system as is conceived would be generally mechanical in nature, and would have particular application to existing coating lines where current equipment discourages installation and maintenance of the complex electrical systems commonly associated with the more sophisticated devices, as well as to small coating operations where production economics rules out costly control equipment.

It is therefore an object of the present invention to provide an apparatus for rapidly and efficiently measuring the amount of coating being applied to a substrate material, which apparatus is simple in construction, operation and maintenance.

Another object of the invention is to provide an apparatus of the character described which does not interfere with the speed of operation and is non-destructive of either the coating or substrate material.

Another object of the invention is to provide an apparatus which periodically measures the amount of coating being applied to a selected quantity of substrate material to permit timely determination and control of the coating weight and thickness.

Still another object of this invention is to provide a method of rapidly and efficiently measuring the amount of coating being applied to a substrate material, which method entails simple mechanical principles and which neither interferes with the continuous coating operation nor is destructive of the coating or substrate material.

Numerous other objects and advantages of the invention will be apparent as it is better understood from the following description, which, taken in connection with the accompanying drawings, discloses a preferred embodiment thereof.

These objects are accomplished with a gravimetric system which accurately and directly measures the weight of coating as it is consumed by the coating machine. There is provided, in association with the conventional coating equipment, a scale having a wide range of accurate sensitivity and a measuring receptacle containing a representative portion of the coating being applied supported on the scale. As the coating is consumed by the machine, the change in weight of the measuring recep-
table for a selected time interval, responsive to the weight of coating actually consumed for the interval, is recorded and related to the quantity of substrate material coated during the same interval to establish the consumption rate in terms of pounds of coating consumed per unit, per unit area, or per unit length, as the case may be. The consumption rate is then compared to a standard rate and a correction is effected based on the deviation from the standard for the selected time interval.

Regarding the drawings:

FIGURE 1 is a schematic, side elevation view illustrating one form of coating apparatus and method of the present invention, with portions of the apparatus shown in section;

FIGURE 2 is a perspective view of the metering rollers of the apparatus of FIG. 1, with parts broken away;

FIGURE 3 is a fragmentary view illustrating an alternate embodiment of the gravimetric system used in the present invention;

FIGURE 4 is a schematic wiring diagram representing one form of control system which may be incorporated in the present invention to achieve automatic coating weight correction and regulation;

FIGURE 5 illustrates still another embodiment of the gravimetric system used in the present invention as it is applied to a different form of coating apparatus.

In operation, the change in weight of reservoir 20 responsive to the rate of coating consumed in machine 10 is indicated directly on the face of scale 26. It is therefore possible to read machine consumption rate directly from the scale at any time, after the circulation flow has stabilized and as long as a supply remains in the reservoir 20, simply by recording the position of the scale indicator at the beginning of a selected period of time. In reading weight units, when related to the number of sheets 12 coated during the reading interval, can then be reduced to coating thickness and compared to a standard to determine if a correction is required.

Although the invention contemplates automatic correction of the machine control as hereinbefore described, it is equally well suited for manual operation, particularly in those operations where constant and continuous correction is not essential and production economics does not warrant an elaborate installation. If the latter is preferred, scale 26 may be provided with a maximum reading indicator 29 in addition to the usual needle indicator 30 (see FIG. 1). The maximum reading indicator comprises a graduated sector 29a and an arm 29b for mounting it to the main shaft of the scale. A "set" needle or lug 29c is formed on one end of the sector for engagement with the maximum reading indicator 30. When, it is desired to test the coating consumption, assuming the machine 10 has been operating for a period of time sufficient to establish equilibrium of flow through conduits 21 and 24 to and from the reservoir 20, the operator brings the "set" needle 29c against scale needle indicator 30 and tightens the needle adjusting screw 29d. The maximum reading indicator 30 is located in a fixed position on the face of the scale. As the coating is consumed from the reservoir, the needle indicator 30 recedes from the "set" needle so that, at the end of a predetermined time interval the operator reads the weight of coating consumption for the interval directly from sector 29a. This reading is then related to the number of sheets 12 which have passed through the machine for the same time interval, which may be determined either by counting the sheets directly or by knowing in advance the rate of feed. These two factors are then reduced to give coating weight per unit sheet which, when compared with the desired coating weight, indicates the deviation for the interval and amount of correction which is required to be made in the metering rollers.

It will be apparent that the manual technique just described is not an instantaneous determination of coating weight per unit, but rather represents average determination of coating weight taken from predetermined sheets. For many coating operations, such an average coating determination taken periodically throughout the course of a day is more than adequate to effectively control the coating quality and avoid excessive waste. For example, a completely manual system was experimentally tested recently in a container making operation using existing conventional coating apparatus, in which this case
was a machine incorporating an applicator and metering rollers similar to the arrangement illustrated in FIG. 1. The machine was applying a white alkyl resin decorative coating to sheets of C.M. paper made by C.M. (can making quality) black plate. A test time interval equivalent to the feed of 100 sheets was established, and the weight of coating consumed was determined for this time interval. Throughout some thirty readings made at various times, coating consumption per 100 sheets consistently registered 2.75 lbs., which reduces to an average reading of 0.0275 lb. per sheet. This was found to coincide with a calculated standard consumption rate for the particular job being run and, accordingly, proved the accuracy of the system of average consumption rate determination for those operations where periodic inspection is desirable or commonly used.

The form of the invention illustrated in FIG. 1 and as hereinbefore described lends itself equally well to automatic determination and correction of coating consumption rate. FIG. 4 illustrates a control system and associated circuits which may be used to effect continuous automatic coating weight regulation and correction. By way of explanation and not limitation, the control system comprises a timer unit generally designated 40 which, when energized by a manual switch 42 through a branch circuit generally designated 41 from a low voltage power source to initiate the control sequence, will detect the sheets 12 passing through machine 10 as they strike and close a trip switch 43. Each time the switch 43 is closed, the impulse actuates a solenoid-operated pawl 44 which in turn drives a ratchet wheel 45 in the timer. This ratchet wheel has teeth corresponding in number to a predetermined number of sheets which will pass through the machine in a given time interval. That is, for a pre-selected control interval, which is a few seconds or minutes or fractions thereof, a ratchet wheel 45 is selected which will be caused to make one complete revolution during the control interval, responsive to a known number of sheets being fed during the same interval. The ratchet wheel is keyed to a shaft 46 which in turn rotates a signal wheel 47 through one revolution during the control interval. Signal wheel 47 is of an insulator material but carries on its periphery a conductor segment 48 which is brought into contact with two contact terminals 49, 49 to complete another branch circuit generally designated 50.

Branch circuit 50 comprises a variable rheostat 51 and a comparator unit 52 in series connection. The comparator 52 is a conventional electronic unit, the detail construction of which forms no part of the instant invention and is therefore not shown. Rheostat 51 is operatively associated with the scale 26 in a well known manner so that movement of needle indicator 30 effects a change in the setting of rheostat 51 and thereby a change in resistance in branch circuit 50. Although a variable rheostat is illustrated, it will be understood that other variable impedance means, such as condensers or balanced tubes, could be used to monitor the change in scale dial position and thus send out control impulses to effect the same result. As terminals 49, 49 are closed for an instant, corresponding with the beginning of the control interval, current flowing through circuit 50 and rheostat 51 will register in comparator unit 52 an instantaneous effective resistance value R1 corresponding to the position of needle indicator 30 on scale 26 at that particular instant. Ratchet wheel 45 continues through another revolution to again close terminals 49, 49, thereby terminating one complete control interval, and thereby registering a second resistance value R2 in the comparator corresponding to the changed position of needle indicator 30 due to coating consumption during the control interval. Thus, the comparator has registered coating consumption for a pre-selected interval in terms of change in circuit resistance.

A third branch circuit generally designated 54 is used to effect correction, if necessary, in succeeding intervals of operation. The comparator 52 is provided with a selector dial 53 by which standard or desired coating consumption rates per unit time can be selected. For any selected setting, the actual consumption of solenoids registered from rheostat 51 is automatically compared to the standard in the comparator 52 and a correction is made based on the indicated deviation, if any. The correction is accomplished through the circuit generally designated 54 by energizing either of a pair of delay relays 55, 56, which in turn energize either of a pair of solenoids 57, 58 for a pre-determined duration. These solenoids actuate normally retracted paws 59, 60 which drive ratchet wheels 61, 62 keyed to a shaft 63 to which micrometer 25 is fixed. Depending on the direction of deviation from the standard setting, micrometer 25 is either advanced or retarded by the appropriate ratchet to effect the necessary correction. That is, an indicated overweight in coating consumption is corrected when comparator 52 energizes the appropriate portion of circuit 54 through relay 55 and solenoid 57 to advance ratchet wheel 61 and thereby narrow the nip of metering rollers 16, 17. Conversely, an indicated underweight in coating consumption energizes the other portion of circuit 54 through relay 56 and solenoid 58 which actuates ratchet wheel 62 which retracts micrometer 25 and thereby opens the nip of the metering rollers. So long as manual switch 42 remains closed, each successive revolution of signal wheel 47 will send a signal to the comparator 52 and set in motion the comparison and corrective sequence, the effect thereby being to achieve continuous and instant control of coating consumption rate.

For the purpose of illustration, the comparator unit 52 may incorporate a circuit that is substantially the same as or similar to the bridge circuit 23 disclosed in the U.S. patent to Godley II 2,545,576; or the comparator circuits disclosed in the U.S. patents to Tyson 2,473,457 and Ayres, 2,676,253. Each of these circuits functions to compare an input to be tested with a standard or predetermined input, and to provide an output if the input deviates from the standard, which output effects a correction in the input to bring it into conformity with the standard.

Up to this point there has been described a form of the invention wherein reservoir 20 is portable and sufficiently small to be suspended directly from scale 26. There are coating operations, however, requiring larger coating supply reservoirs of a permanent or fixed nature. For example, where the coating must be heated to a molten state before application, such as in certain soldering, wax flushing and hot-melt adhesive coating operations, the reservoir is usually in the form of a large vat or tank rigidly fixed to the floor or a frame member. As will be appreciated, it would be virtually impossible to suspend such reservoirs on a scale device in the manner as hereinbefore described and expect to achieve reliable accuracy.

There is illustrated in FIG. 5 a modification of the present invention which is particularly adapted for coating operations where the fixed supply reservoir obtains. By way of explanation and not limitation, there is shown a reservoir 70 permanently mounted to a frame 71 above a heating unit 72, such as a bank of flame jets. Reservoir 70 may supply any type of coating applicator, but in the form as illustrated, pick up roller 73 withdraws the molten coating from the top of the reservoir 70 and delivers it to a metering or applicator roller 74, as the case may be, for ultimate deposit on a substrate material. In this form of the invention, scale 26 is suspended on a slide 75 which operates in a swiveling frame. A worm 76 operated by a hand wheel 77 regulates the height of slide 75 for reasons to be hereinafter expressed.

Suspended from scale 26 is a measuring receptacle 78 which is in communication with stationary reservoir 70 through a flexible conduit 79. By reason of the flexible communication, a level of coating is maintained in meas-
uring receptacle 78 in exact conformity with the level in reservoir 70, and yet receptacle 78 is free to move vertically independently of the reservoir. Thus, the said assembly resembles a clairvoyant manometer to the exclusion of a fixed or inflexible communication passage between the two liquid chambers. As the level of coating in reservoir 70 recedes during the course of operation, receptacle 78 may be lowered periodically by worm 76 to ensure that at least a minimum level is maintained in the measuring receptacle at all times.

In this embodiment, scale 26 is provided with a lock mechanism 80 comprising a dent 81 and a double acting solenoid 82. A solenoid actuated valve 83 is provided in the port connecting conduit 79 with reservoir 70 to control the flow of coating therebetween. A timing mechanism for energizing lock mechanism 80 and valve 83 at appropriate intervals is associated with timer 40 and comprises a reduction gear 84, a valve cam 85, and lock cam 86 all keyed to a shaft 87. Gear 84 meshes with a gear 85 on shaft 46 in the timer (see FIG. 4) so that cams 85 and 86 are rotated at half the speed of signal wheel 47. Cam 85 is provided with a raised dwell 89 for closing switch 90 which energizes valve 83. Cam 86 is provided with both a raised dwell 91 and recessed dwell 92 for controlling a switch 93 for energizing the respective coils of solenoid 82.

The sequence of operation is as follows: When contact 48 first closes terminals 49, 49, to initiate a control interval and register a resistance R 1 in comparator 52, the raised dwell 91 on cam 86 simultaneously closes switch 93 to lock the workings of scale 26. This prevents movement of the scale dial and vertical movement of measuring receptacle 78 during the control interval, during which time valve 83 remains open to permit escape of coating from the receptacle 78 as the level of the coating in reservoir 70 recedes. Then at the termination of the control interval, when contact 48 again closes terminals 49, 49, the dwell 89 on cam 85 closes switch 90 to instantly close valve 83. Simultaneously, recessed dwell 92 on cam 86 closes switch 93 to unlock the scale 26. Valve 83 and terminals 49, 49 remain closed just long enough for the scale indicator 30 to move to a new position in response to the weight of coating removed from receptacle 78, thereby registering a resistance R 2 in the comparator 52. The subsequent comparing and corrective sequence is the same as that hereinbefore described, the ratchets 61, 62 being geared to an appropriate micrometer adjustment, such as 25, for controlling roller 74.

It will be understood, of course, that the measured weight of coating withdrawn from receptacle 78 is not a direct measure of the coating consumed from reservoir 70 during the control interval, but instead represents a determinable proportion thereof. That is the change in weight of receptacle 78 for the control interval is to the weight of coating actually consumed as the volume change in the receptacle 78 is to the volume of coating consumed; and, since the change in height in both the receptacle and reservoir is identical, the proportionality is equivalent to the ratio of cross sectional areas of the two enclosures. Since this is a determinable ratio, the selected standard setting read into comparator 52 on selector dial 53 is scaled proportionally to compensate for the indirect measurement.

There has been described a basically simple and yet accurate system for measuring and controlling the weight of a liquid or wet coating as it is being applied directly to a substrate material. Although for exemplary purposes the invention has been described primarily in connection with a type of coating machine wherein individual sheets are coated sequentially, it will be understood that it is equally suited for web coating, immersion coating, spray coating, compound lining, the application of plastic films to a substrate, or any other type of coating operation where coating consumption per unit time is capable of gravimetric determination.

It is thought that the invention and many of its attendant advantages will be understood from the foregoing description, and it will be apparent that various changes may be made in arrangement and detail of parts of the apparatus mentioned herein and in the steps and their order of accomplishment of the method described herein, without departing from the spirit and scope of the invention or sacrificing all of its material advantages, the form hereinbefore described being merely a preferred embodiment thereof.

I claim:

1. Apparatus for applying coating material to a plurality of metal sheets comprising an applicator roller, a back-up roller, a conveyor for feeding said metal sheets between said rollers, a pair of metering rollers disposed horizontally with respect to one another and one of which engages against said applicator roller, a reservoir to hold a quantity of said coating material, a conduit extending between said reservoir and said metering rollers, a pump to force coating material from said reservoir through said conduit to the nip of said metering rollers, a pump positioned below said metering rollers, a return conduit for directing material falling off of said metering rollers and into said sump to said reservoir, a scale supporting said reservoir and indicating the weight of said reservoir and coating material therein, whereby the weight of coating material consumed during an interval in which a number of sheets are coated can be determined to ascertain the amount of coating applied to each of said sheets.

2. The apparatus defined in claim 1 wherein said scale includes a variable impedance so that at any given time the instantaneous effective impedance corresponds to the weight of said reservoir and coating material therein and said apparatus further comprises a comparator in circuit with said variable impedance, means to close said circuit for an instant each time a predetermined number of said metal sheets have been coated to register the change of effective impedance at said time in said comparator, electrical means in circuit with said comparator to adjust the distance between said metering rolls to thereby regulate the rate of consumption of said coating material, whereby said comparator compares each change in impedance and therefore the corresponding rate of consumption with a predetermined standard and energizes said electrical means to adjust the distance between said metering rolls to equalize said rate of consumption and said predetermined standard.

3. The apparatus defined in claim 2 wherein said variable impedance is a rheostat.

4. The apparatus defined in claim 2 wherein said circuit closing means comprises two open terminals in said circuit adapted to be bridged to close said circuit, a branch circuit which circuit includes a power source, a solenoid operated pawl, and a switch positioned so as to close each time one of said metal sheets passes by it and completely the branch circuit and operate said pawl, a ratchet wheel engaged with said pawl, a signal wheel connected with said ratchet wheel to rotate therewith, a conductor segment mounted on said signal wheel, whereby each time one of said metal sheets engages and closes said switch said pawl rotates said ratchet wheel one notch and when said predetermined number of sheets have passed by said switch said conductor segment bridges said terminals to close said circuit.

5. The apparatus defined in claim 2 wherein said electrical means to adjust the distance between said metering rolls comprises a first ratchet wheel, a first solenoid operated pawl operable to increase said distance, a second ratchet wheel, a second solenoid operated pawl operable to rotate said second ratchet wheel to decrease said distance, a first relay in circuit with and adapted to energize said first solenoid operated pawl and a second relay in circuit with and adapted to energize said second solenoid operated pawl, said first relay energizing said first solenoid operated pawl to increase said distance, said second relay energizing said second solenoid operated pawl to reduce said distance.
is to be increased said first relay is energized by the comparator and when the distance between the metering rolls is to be decreased said second relay is energized by the comparator.

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