CENTRIFUGAL SPRAY COATING METHODS AND APPARATUS

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ABSTRACT OF THE DISCLOSURE

Centrifugal spray coating methods and apparatus for applying a uniform coating to the internal surfaces of centrifugal shells which utilizes an axially translatable centrifugal spray head having a rotatably driven centrifugal distributor with a centrally disposed charge cavity and a plurality of outwardly flared distributor teeth, a multiplicity of coaxial, axially spaced annular discs, concentric with the distributor and rotatably driven simultaneously therewith, wherein the radial gap between the inner marginal edges of the discs and the outer radial extremities of the distributor is sufficiently great to insure uniform application of spray material about the entire innermost marginal edges of all of the discs. Separable axially spaced skirts secured to the spray head and defining an axially enclosed annulus substantially free of air turbulence surrounding the discs. A means is provided for momentarily overcharging the spray head with spray material drawn from a source upon initiation of relative axial translation to bring the spray head to full discharge capacity substantially instantaneously.

The present invention relates generally to spray coating methods and apparatus and, more particularly, to an improved centrifugal spray coating system of the type commonly employed in coating the internal surface of a hollow workpiece such, merely by way of example, as a cylindrical shell which may ultimately comprise the sidewall of a container or the like. In its principal aspects, the invention is concerned with improved centrifugal spray coating methods and apparatus characterized by their ability to rapidly coat a workpiece surface with a material such as paint, lacquer, rust inhibiter, or other material in a liquid or semi-liquid state, yet wherein the coating applied to such surface is characterized by its uniformity.

In the field of centrifugal spray coating equipment, it has long been recognized that if a liquid or semi-liquid spray material, for example, paint or the like, is applied to a rotating disc at or near the center thereof, such material will flow radially toward the outer periphery of the disc because of the effect of centrifugal force and, assuming that the centrifugal force is sufficiently great, the particles of spray material will be projected from the periphery of the disc at a definite velocity. It has further been recognized that a practical spray system requires that the size of the centrifugally projected particles not exceed a known level. At the same time, however, such a system must be capable of discharging, within an allotted period of time, a quantity of material sufficient to coat the entire surface of the workpieces to be coated and, of course, such coating should be uniform thickness throughout.

Experiments have demonstrated that the size of centrifugally projected particles is a function of numerous conditions, including, but not limited to (1) the viscosity \( \mu \) of the material being sprayed, (2) the tangential velocity at the outer periphery of the spray disc, (3) the thickness of the layer of the material being sprayed, (4) the size of the spray disc, and (5) the shape of the outer periphery of the disc. Obviously, however, once a particular spray material has been selected, the viscosity \( \mu \) of that material is fixed and will not vary. Similarly, for a given spray head, the tangential velocity at the outer periphery of the disc will depend upon the diameter of the disc and the rotational speed \( \omega \) thereof. Again, once the disc has been selected and the maximum operating speed determined, the factor of tangential velocity will not vary, assuming, of course, that the spray head is being operated at its optimum operational speed. As to the thickness of the layer of the material at the periphery of the disc, it has been found that this is a function of the amount of material fed to the disc. Since it is essential that maximum particle size be controlled, it then becomes apparent that the maximum thickness of the spray material at all points about the periphery of the disc must be controlled. Preferably, such thickness should be uniform or substantially uniform about the peripheral edge of the disc in order to permit maximum application of the spray material to the workpiece without exceeding the maximum layer thickness at any point. Finally, it has been found that particle size can be controlled by forming the disc with a relatively sharp outer peripheral edge, thereby minimizing the tendency of particles to adhere to the disc.

Because of the foregoing limitations, imposed by virtue of the requirement that particle size of the spray material not exceed a maximum value, a spray device employing only a single spray disc has a limited capacity in terms of volume of material sprayed per unit of time and, consequently, in terms of area of coverage. It has, however, heretofore been proposed that the capacity of a disc-type centrifugal spray head can be increased by the simple expedient of providing a plurality of axially spaced, coaxial, parallel discs and simultaneously applying the spray material to each of such discs at or adjacent the central portions thereof. Consequently, as the discs are sequentially rotated, the spray material flows radially from each disc and is projected therefrom by the centrifugal forces developed. A typical example of such a conventional prior art construction is that shown in U.S. Patent No. 2,545,488 to E. O. Norris. Unfortunately, however, conventional centrifugal spray devices of the multi-disc type have not, prior to the advent of the present invention, provided a completely satisfactory solution to the problem of rapidly applying a uniform coating to a workpiece. One principal reason for this has involved the difficulty and indeed, inability to apply equal quantities of the spray material uniformly to each of the discs. Even in those instances where equal quantities of material have been fed to each disc, it has been found that the material is not uniformly applied to one or more of the discs and, consequently, the centrifugally projected particles of spray material emanating from the discs are not uniform in size. As a result, the coating applied to the workpiece is not uniform and often assumes a spackled or dimpled appearance similar, for example, to that found on an orange skin.

Consistent with the problems heretofore experienced regarding lack of uniformity of the spray material applied to the discs, it has also been found that as more and more discs are applied to the spray head, additional discs appear to contribute less and less to the overall capacity of the spray head—that is, the spraying efficiency of such additional discs has not been as great as the primary or first disc or discs.

It is a general aim of the present invention to provide an improved centrifugal spray coating system which over-
comes all of the foregoing disadvantages and which is characterized by its ability to rapidly apply a uniform coating of spray material to the surface of the workpiece to be coated. While not so limited in its application, the invention will find especially advantageous use in applying a uniform coating to the internal surface of cylindrical shells such as the cylindrical sidewall of a 55-gallon shipping drum of the type commonly made from sheet steel or other suitable material.

A related object of the invention is the provision of an improved multi-disk type of centrifugal spray device which, because of its novel construction, has a considerably greater capacity in terms of both area coverage and quantity of material sprayed than does a comparable multi-disk type spray device which does not embody the features of the invention. In this connection, it is an object of the invention to provide an improved centrifugal spray device of the multi-disk type wherein each spray disc, irrespective of the number of discs employed, has applied thereto a circumferentially continuous, substantially uniform coating of spray material, thereby resulting in the centrifugal projection of a peripheral uniform band or annulus of spray material. As a result of attaining this objective, each spray disc is used at or near maximum efficiency, thereby insuring that each disc contributes significantly to the overall capacity of the spray device.

An ancillary object of the invention is the provision of an improved spray device which is compact in size, yet which, despite its compact size, is characterized by its ability to centrifugally project a comparatively larger quantity of spray material in a uniform pattern than has heretofore been possible with comparably sized conventional spray devices. It is a more specific object of the invention to provide an improved distributor and disc arrangement wherein a multi-disk centrifugal spray device wherein the material to be sprayed is transferred from the distributor to each of the discs in substantially uniform, circumferentially uninterrupted patterns, thereby insuring that a maximum quantity of spray material is delivered uniformly to and projected uniformly from each disc, while at the same time precluding the occurrence of localized areas of excess layer thickness of the spray material at spaced peripheral points on the discs and thereby precluding projection of particles of material which exceed a maximum size.

More particularly stated, it is an object of the invention to provide an improved multi-disk type centrifugal spray device wherein the spray material is uniformly distributed to all of the discs by a distributor, yet wherein the rotating distributor and rotating discs are fixed relative to one another, thereby eliminating the necessity for positioning bearings or the like within regions of the spray head contacted by the material being sprayed. As a consequence of obtaining this objective, centrifugal spray devices embodying the features of the invention are characterized by their ease of manufacture, reliability in operation, and by the fact that only minimum maintenance is required.

In accordance with another of the important aspects of the present invention, it is an object to provide an improved centrifugal spray device which is characterized by its versatility and which can be readily modified to permit effective use thereof in internally coating cylindrical workpieces which may vary widely in diameter from workpiece to workpiece.

Yet another important aspect of the present invention is to provide improved methods and apparatus for internally coating cylindrical workpieces which, upon initial application of a spray coating operational cycle, permit of substantially instantaneous and uniform application of the spray material at the full capacity of the spray device, whereby further decreasing the time required to coat a given workpiece while at the same time substantially eliminating waste of spray material adjacent the extremity of the workpiece, which waste would otherwise occur during initial charging of the spray head.

Other objects and advantages of the invention will become apparent as the following description proceeds, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a fragmentary side elevation, in vertical half section of an exemplary centrifugal spray coating device embodying the features of the present invention;

FIG. 2 is an end view of the exemplary material distributor used in conjunction with the spray coating device shown in FIG. 1;

FIG. 3 is a side elevation of the material distributor shown in FIG. 2;

FIG. 4 is a fragmentary end view of a portion of the material distributor and one of the annular spray discs, here diagrammatically illustrating the distribution pattern of spray material as the latter is distributed to the spray disc in accordance with the present invention;

FIG. 5 is a fragmentary diagrammatic representation similar to FIG. 4, but here depicting, in somewhat exaggerated form, a typical instance of non-uniform distribution of spray material upon a given spray disc which may occur in multi-disk centrifugal spray heads which do not employ the features of the present invention;

FIG. 6 is a diagrammatic view of an annular spray pattern, here shown in planar form, and representative of the distribution of spray material on all of the discs of a multi-disk spray head wherein provision is not made for applying substantially uniform coatings of spray material to each disc;

FIG. 7 is a fragmentary, and partially diagrammatic, elevational view of an exemplary centrifugal spray system for applying internal coatings to a cylindrical shell; and,

FIG. 8 is a fragmentary plan view, here depicting an exemplary cylindrical shell in phantom, together with a portion of the apparatus shown in FIG. 7 for moving the shell relative to a spray head embodying the features of the present invention so as to cause the latter to relatively traverse the inner shell surface during a spray coating cycle.

While the invention is susceptible of various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that it is not intended to limit the invention to the particular form disclosed, but, on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as expressed in the appended claims.

Referring now to the drawings, there is illustrated in FIG. 1 an exemplary centrifugal spray coating device, generally indicated at 10, which is particularly suitable for coating a surface of a workpiece in accordance with the present invention. While the particular type of workpiece to be coated is not critical to the present invention, it will be appreciated as the ensuing description proceeds, that the exemplary spray coating device 10 shown in FIG. 1 will find particularly advantageous, but by no means exclusive, use in coating the internal surface of a cylindrical shell such as the sidewall 11 (FIG. 7) of a conventional 55-gallon shipping container which can be made of sheet metal or any other suitable natural or synthetic sheet material.

In carrying out the present invention, and as best shown in FIG. 1, the exemplary centrifugal spray device 10 includes a rotatable spray head, generally indicated at 12, which is rigidly secured to one end of a drive shaft 14 by any suitable means such, for example, as a threaded connection 15. In the illustrative construction, the drive shaft 14, which is coupled to any suitable power source (not shown) for effecting rotation thereof, is rotatably supported coaxially within a cylindrical sleeve 16 by means of spaced bearings, there being one such bearing 18 shown in FIG. 1. As the ensuing description proceeds, it will be
come apparent to those skilled in the art that during a spray coating operation the spray device 10 can be either held stationary in an axially fixed position while the workpiece is not moved in an axial direction or alternatively, the workpiece can be held stationary while the spray head 12 is moved in an axial direction. In the first instance, the support sleeve 16 is preferably rigidly secured to a fixed structural member (not shown) while, in the second instance, suitable power means (not shown) must be provided for effecting controlled axial movement of the sleeve 16 and, consequently, of the rotating spray head 12 during a spray coating operation.

In order to permit distribution of the liquid or semi-liquid spray material on the surface of the workpiece to be coated, the exemplary spray head 12 includes an assembly of identical axially spaced, annular spray discs D1–D8, which are rigidly clamped between a pair of disc-like plates 19, 20, having an external diameter equal to the diameter of the discs D1–D8. In the illustrative form of the invention, the plate 19 includes a hub portion 21 which is rigidly mounted on the sleeve 14 for rotation therewith. A pair of axially directed tubular sleeves 22 are formed at diametrically opposed points on the plate 19 adjacent the outer peripheral edge thereof, the sleeves 22 here passing through apertures formed in the discs D1–D8 and thus serving to support the latter in parallel relation to one another in a substantially concentric manner with the shaft 14. The arrangement is such that washer-like spacers 25 positioned on the sleeve 22 between the adjacent discs serve to axially space the latter from one another and from the plates 19, 20. In the exemplary construction, the plates and discs are rigidly held together as a unitary assembly by means of headed fasteners 26 which are here threadingly coupled to opposite ends of the tubular sleeves 22. Thus, when the fasteners 26 are tightened, the plates 19, 20 and discs D1–D8 are drawn axially towards one another to form a rigid assembly of axially spaced spray discs which are rotatably driven by the shaft 14.

For the purpose of supplying liquid or semi-liquid spray material to the discs, the exemplary spray head 12 includes a centrally disposed distributor 28 which is concentrically supported within the annular spray discs D1–D8 and rigidly mounted on the shaft 14 for simultaneous rotation with the shaft and discs. As best shown by reference to FIGS. 1, 2 and 3, the distributor 28 includes a hub portion 29 having an annular charge cavity 30 formed therein, and a plurality of generally axially extending, outwardly flared, distributor teeth 31 disposed outwardly of the cavity 30 but within the confines of the annular spray discs D1–D8. The arrangement is such that the spray material, which is normally maintained in a supply reservoir 32 (FIG. 7), is delivered under pressure by means of one or more pumps 34 (FIG. 7) through one or more injection nozzles 35, the latter here being supported on a collar 36 mounted on the support sleeve 16, directly into the charge cavity 30 in the distributor 28.

As a consequence of the foregoing construction, during a spray coating operation particles of the spray material delivered to the cavity 30 are moved outwardly (i.e., to the right as viewed in FIG. 1) along the teeth 31 due to the effect of centrifugal force with the particles of material being centrifugally projected outwardly from the teeth in substantially radial planes towards the inner peripheral edges of the discs D1–D8. It has been found that once particles of spray material are applied to the inner peripheral edges of the discs D1–D8, such particles proceed flow outwardly towards the outer peripheral edges of the discs along substantially radial lines under the influence of centrifugal force. As a consequence, in those instances where the particles are applied to peripherally spaced localized points on the inner peripheral edges of the discs, the particles will not be uniformly distributed about the discs, but rather will be concentrated in localized areas which are radially related to the points on the inner peripheral edges of the discs where the material is applied. Consequently, gaps are present on the discs between such points where little, if any, spray material is present. Therefore, those portions of the discs which do not receive particles of spray material do not contribute in any significant way, if at all, to the capacity of the spray device 10. Stated another way, and keeping in mind that the thickness of the layer of spray material on any given disc must be controlled so as not to exceed a maximum thickness, whereby preventing projection of excessively large droplets of material which would tend to spackle the surface of the workpiece, it will be appreciated that where the entire surface of a given disc is uniformly and continuously coated with the spray material, such a disc is capable of projecting a maximum quantity of spray material in a given period of time. However, when only circumferentially spaced areas of the disc are coated, the quantity of spray material delivered to such disc must be less or else the thickness of the coated areas will exceed the maximum thickness permissible, thereby leading to spalking of the coated workpiece.

In accordance with one of the important aspects of the present invention, provision is made for insuring that substantially equal quantities of spray material are delivered to each of the spray discs D1–D8 while at the same time the spray material delivered to each disc is applied substantially continuously and uniformly about the inner peripheral edge of that disc, thereby precluding the presence of voids or gaps in the particles of spray material applied to each disc. In order to accomplish this, and as best illustrated by reference to FIG. 4, advantage is taken of the fact that as particles of spray material leave a given point P on each tooth, such particles form bands of spray material which move substantially radially outward through the gap between the teeth 31 and the inner peripheral edges of the discs, such bands being represented in FIG. 4 by the reference numeral 38. It has further been found that the bands 38 of spray material, which bands lie in planes parallel to the planes of the discs, tend to increase in width as they get further from the point P of discharge from the teeth and closer to the inner peripheral edge of the adjacent disc. Keeping the foregoing in mind, it will be observed upon inspection of FIG. 4 that as particles of spray material leave point P on all of the teeth 31, which points are radially inward of a given disc D, such particles form a plurality of bands 38 which gradually increase in width as they move outwardly from the adjacent disc D to the inner peripheral edge of the adjacent disc D. Thereafter, the particles proceed outwardly on the disc along substantially radial lines under the effect of centrifugal force, with the particles ultimately being projected outwardly from the outer peripheral edge of the disc D into engagement with the adjacent surface of the workpiece to be coated (not shown).

As further indicated in FIG. 4, it will be noted that the particles of spray material are here shown as being projected from points P on the teeth 31 of the distributor, which points P are considerably closer to the inner peripheral edge of the adjacent disc D than were the points P shown in FIG. 4. As a consequence, the bands 38 of spray material reach the inner peripheral edge of the disc D before adjacent bands merge or blend into one another. Therefore, the particles of spray material are applied to the disc D at peripherally spaced localized areas, hereinafter referred to as the reference numerals 39. However, since substantially equal amounts of spray material are projected from the points P in FIG. 4 and the points P’ in FIG. 5, it will be appreciated that the thickness of the layers of spray ma-
terial represented by the reference numerals 39 in FIG. 5 will be appreciably greater than the thickness of the layer of material applied to the disc D in FIG. 4.

Accordingly, centrifugal spray heads made in accordance with the present invention are arranged so that the radial gap between the distributor teeth 31 and all of the discs D1–D8 is sufficiently great to insure that the spray material is applied continuously about the inner peripheral edges of all of the discs, thereby preventing the presence of localized areas on any given spray disc which are not coated with the spray material. It will, of course, be appreciated by those skilled in the art that the actual radial dimensions of the gaps between distributor teeth 31 and spray discs D1–D8 may vary widely dependent upon various factors such as the dimensions of the spray discs and the distributor head, the rotational speed \( \omega \) of the spray head, and the viscosity \( \eta \) of the particular spray material.

However, we have found that in a typical spray head embodying the features of the present invention and intended for use in coating the interior surface of a conventional 55-gallon shipping container with a viscous material such as paint or the like, and where the spray head is operating at a speed of approximately 7,000 r.p.m., the minimum radial gap between the distributor teeth 31 and any given (e.g., D8 in FIG. 1) should be on the order of approximately one inch. Similarly, we have found that under the foregoing conditions, the maximum radial gap between the distributor teeth 31 and any given disc (for example, the disc D1 in FIG. 1) should be on the order of one and one-half inches. Thus, under these conditions, we have found that the particles of spray material are applied continuously about all of the discs, since the radial gap provided is sufficient to permit merging or blending of the bands of spray material emanating from adjacent teeth at or just prior to the time the bands reach the inner peripheral edge of the discs. That is to say, under these conditions, FIG. 4 is representative of the pattern of spray material applied to the disc D8. As for the remaining discs D1–D7 (which discs are all spaced radially further from the teeth 31 than is disc D8), the adjacent bands 38 of spray material will tend to overlap slightly on the spray discs. We have found, however, that such overlap does not appreciably affect the uniformity of the coating applied to the workpiece, whereas gaps present on one or more of the discs do tend to affect the uniformity of the coating applied to the workpiece.

In order to facilitate an understanding of the present invention, reference is made to FIG. 6 wherein there is depicted a typical spray pattern which can occur where the radial gaps between the distributor teeth 31 and one or more of the discs D1–D8 are less than the desired minimum gaps. Thus, assuming the same set of exemplary conditions as described above, it will be appreciated upon reference to FIGS. 1 and 6 conjointly that where the radial gap between the distributor teeth 31 and the disc D5 is comparable to that represented diagrammatically in FIG. 4, the spray material will be applied continuously about the disc D5. Consequently, the disc D5 will be completely coated and will be operating at close to 100% efficiency. Similarly, the discs D1–D4 inclusive will also be continuously and substantially uniformly coated. Therefore, the discs D1 through D4 will also be operating at, or approximately at, 100% efficiency. However, under these conditions, the radial gaps between the distributor teeth 31 and all of the discs D6 through D8 will be less than the desired minimum gaps, thereby producing patterns of spray materials applied to the discs which are similar to those represented in FIG. 5. Consequently, since under these exemplary conditions the discs D6 through D8 are spaced from the distributor teeth 31 by radial gaps which are less than the minimal permissible gap, particles of the spray material are applied to localized, circumferentially spaced areas 39 (FIG. 5) of such discs and substantially no particles of spray material are supplied to the intervening disc portions 40. Moreover, as the radial gap gets progressively smaller (for example, when contrasting the radial gaps between the distributor teeth 31 and the discs D6 through D8), the intervention of the discs which are void of particles of spray material become circumferentially larger and, conversely, the areas of the disc covered by spray material become smaller.

Experimentation has conclusively demonstrated that the foregoing undesirable spray patterns actually occur on the spray disc which are not covered sufficiently far from the distributor teeth 31 to permit merging or blending of the bands emanating from common points on adjacent teeth. Thus, FIG. 6 is here representative of the pattern of spray material actually applied to an annular screen secured to the outer periphery of a spray head 12 of the type shown in FIG. 1, but wherein the radial gaps between the distributor teeth and the discs D6 through D8 were less than a desired minimum distance for a given sized spray head running at a given rotational speed and wherein the spray material possessed known characteristics of viscosity and adhesiveness. Under such conditions, it was observed that the spray material was applied substantially uniformly and continuously about the inner periphery of the discs D1 through D5, thereby resulting in the application of a uniform continuous coating to the screen surrounding the discs D1–D5 as shown in FIG. 6. Consequently, it was observed that the only areas of disc D5 which was not covered by spray material was applied to localized circumferentially spaced areas 39 (FIG. 5) representing only approximately 60–65% of the total disc area. Substantially no spray material was applied to the intervening disc portions 40 (FIG. 5). Here represent of approximately 35–40% of the disc area. Consequently, no spray material was applied to the screen in the regions surrounding the voids on the disc. Similarly, it will be observed that spray material was applied to less than 50% of the total area of disc D7 which is, of course, even closer to the distributor teeth than is disc D6. Finally, less than one-third of the total area of disc D8 was covered with spray material in this particular experiment. Obviously, the placement of additional discs (here represented by the reference numeral D9) on the exemplary spray head operating under these conditions would serve no useful purpose since only a small fraction of the total area of such discs would be useful in applying spray material to the workpiece.

Those skilled in the art will appreciate that the quantity of spray material delivered to each disc in a multi-disc spray head 12 of the type illustrated over a given period of time will be substantially identical irrespective of the radial gap between the distributor and the discs. Therefore, since such spray material is concentrated over progressively smaller areas of discs D6 to D8, the thickness of the layers 39 (FIG. 5) of spray material on discs D6 through D8 will be progressively greater. This, of course, means that if the spray material is being delivered to discs D1 through D5 at a rate sufficient to insure that such discs are operating at maximum spraying capacity (that is, that the thickness of the layer of spray material on such discs is maximized commensurate with the permissible particle size to be projected against the workpiece), then the particles projected from discs D6 through D8 will be progressively greater in size with the particles projected from each disc exceeding the maximum particle size permitted. The foregoing results directly from the fact that the localized layer thicknesses on discs D6 through D8 is greater than the maximum layer thickness permitted. As a consequence, the excesses of these particles are projected against the工作piece surface by discs D6 through D8 will tend to create a speckled appearance on the coated surface similar to that found on an orange skin. In an effort to compensate for this, it is possible for the operator to significantly decrease the quantity of spray material applied to each of the discs so that the thickness of spray material on discs D6 through D8 does not exceed a maximum level,
thereby insuring that the particles projected from such discs are at or below a maximum size. However, under these conditions, the thickness of spray material appearing on discs D1 through D5 will be considerably less than the permitted maximum, thereby creating a condition where in discs D1 through D5 are being utilized at less than their rated capacity. Since less spray material would then be delivered to discs D1-D5, particles of spray material projected therefrom would be smaller than the maximum permissible size and, consequently, smaller than the particles projected from discs D6-D8, thereby still tending to produce a speckled appearance on the coated workpiece. Moreover, where the rate of delivery of spray material is decreased, it is necessary to either slow down the spray coating operation in order to apply a coating of a desired thickness on the workpiece or, alternatively, the coating applied to the workpiece must be considerably thinner than would otherwise be applied.

It will be seen from the foregoing that spray heads embodying the features of the present invention—that is, spray heads constructed so that the radial gap between the distributor teeth and all discs is sufficiently great to permit merging or blending of the bands of spray material emanating from these points on the distributor teeth lying in a common radial plane at or before the time that such bands are applied to the adjacent spray disc—will permit the application of spray material substantially uniformly and continuously to all discs, thereby insuring that substantially the entire surface area of each disc is coated with spray material. Under such conditions, it is possible to inject spray material into the spray head at the full rated capacity of the spray head while still insuring that the size of the particles of spray material projected from the discs are substantially uniform from disc to disc and do not exceed a predetermined level. Consequently, the coating applied to the workpiece is characterized by its uniformity and smoothness throughout its entire surface area. Because of the foregoing, it is also possible to coat a given surface area to a prescribed thickness in considerably less time than has heretofore been possible.

It will, of course, be understood from the foregoing that a critical feature of the present invention resides in the proper selection of radial gaps between the distributor teeth and the spray discs D1-D8, which gaps may vary dependent upon the nature of the material being applied and the size of the spray head. Such gaps must be sufficiently great to insure that the spray material is applied continuously about the inner peripheral edge of that disc which is closest to the distributor 18. The maximum permissible radial gap is considerably less critical to the present invention, it being understood that such gap must be sufficiently small to permit manufacture of a spray head which will fit within the workpiece to be coated. Moreover, it is desirable that the radial gap be kept as small as practical in order to assure that the particles of spray material do not slow down to a point where they lose proper directivity and are deposited on the disc.

In accordance with another of the important aspects of the present invention, provision is made for applying a uniform annular band of spray material to the interior surfaces of cylindrical shells which may have any one of a wide range of different diameters, yet wherein this can be accomplished with the same basic spray head and associated equipment. In this connection, we have found that where a centrifugal spray head is used to apply a uniform annular band of spray material to the interior surface of a shell (e.g., the shell 11 depicted in FIG. 7), it is essential that the particles of spray material be projected from the outer periphery of the spray discs D1-D8 with a motion in the plane of the discs and such particles must then flow toward the shell 11 without deviating significantly from such plane. In order to achieve this result, it is necessary to dimension the spray discs so that the outer peripheral edges of the latter are in close spaced proximity to the surface being coated. Absence of such close dimensional proximity between the outer peripheral edges of the spray discs and the surface being coated results in air turbulence in the vicinity of the spray head 12, and such turbulence tends to urge the particles of spray material out of their intended planes of motion, with consequent non-uniform coating of the product. For this reason, it has been found necessary to dimension a spray head with each significantly different sized shell diameter.

In keeping with this aspect of the present invention, provision is made for shielding the spray head 12 from the effect of air turbulence, thereby permitting use of a single spray head with a wide range of different diameters shells even though there may be a significant radial gap between the outer peripheral edges of the spray discs D1-D8 and the interior surface being coated. To accomplish this, and as best illustrated by reference to FIG. 1, the exemplary spray head 12 is provided with a pair of removable annular skirts 41, 42 which are respectively secured to the outer surfaces of the plates 19, 20 by means of the threaded fasteners 56. As hereinbefore mentioned, the skirts 41, 42 are considerably greater in diameter than are the plates 19, 20 and the discs D1-D8. As a consequence of this construction, it is merely necessary to employ relatively inexpensive skirts which are slightly smaller in diameter than is the internal diameter of the surface being coated, and such skirts will effectively eliminate the tendency of air turbulence to affect the path of movement of particles of spray material flowing from the spray head toward the surface being coated. Therefore, when the spray device 10 is being utilized to coat the inner surface of a shell having either a smaller of a larger diameter than that of the skirts 41, 42 it is merely necessary to remove the skirts 41, 42 and replace such skirts with either smaller or larger skirts respectively, thereby permitting effective use of a single spray head with different sized shells and further enhancing the uniformity of the coating applied thereto.

Referring next to FIGS. 7 and 8 conjointly, there has been diagramatically illustrated a typical system for coating the internal surfaces of cylindrical shells on a mass production basis and in accordance with the features of the present invention. Thus, as here illustrated, cylindrical shells 11 are fed to a spray coating station, generally indicated at 44, in serial order, by means of a conveyor belt 45 or the like. The particular means for driving the conveyor belt are not critical to the present invention, and may take any of a wide variety of conventional forms well known to those skilled in the art. It should suffice to say that the drive systems for the conveyor belt is such that control means are provided for automatically positioning the belt to transfer shells from work station to work station, and for intermittently stopping the belt as successive shells reach each work station so as to permit performance of an operational cycle. In the present instance, in order to insure that the shells 11 are properly aligned with each different work station, for example, the spray coating station 44, the belt is provided with a plurality of positioning lugs 46 which serve to accurately position the shells at predetermined points on the conveyor belt 45.

In carrying out this form of the invention, the spray device 10 embodying the features of the present invention is positioned above the belt 45 and in alignment with the spray coating station 44, the arrangement being such that when the belt 45 stops, the cylindrical shell 11 is spatially positioned beneath the spray device 10. At this point, it is merely necessary to cause relative axial movement between the shell 11 and the spray device 10 so that the spray head 12 axially traverses the shell. In order to facilitate an understanding of the present invention, there has here been disclosed and will hereinafter be described an exemplary system wherein the spray device 10 is stationary and is mounted on a fixed structural member (not shown),
while the cylindrical shell 11 is moved vertically upward about the spray head 12, it being understood that the shell could be held stationary while the spray head is passed axially therethrough.

In order to permit relative axial movement between the cylindrical shell 11 and the spray head 12, the illustrative spray coating station 44 is provided with a pair of oppositely facing C-shaped brackets 48 (best illustrated in FIG. 8) which are respectively disposed on either side of the conveyor belt 45. Each of the C-shaped brackets 48 includes a pair of upright posts 49 having annular flanges 50 formed adjacent the upper ends thereof, such flanges normally being disposed at the level of or slightly below the level of the upper surface of the belt 45. The arrangement is such that when the belt 45 is stopped with a cylindrical shell accurately positioned in the spray coating station 44, a lower peripheral edge 51 of the shell is disposed immediately above the two pairs of flanges 50. As best shown in FIG. 7, the brackets 48 are coupled to the actuating plungers 53 of a suitable fluid-actuated piston and cylinder arrangement, here fragmentarily shown at 54. It will, of course, be understood by those skilled in the art that any suitable control means can be provided for actuating the piston and cylinder assembly 54 in timed relation to starting and stopping of the conveyor belt 45, and, in particular, it should not herein the details of such well known and conventional control systems. Rather, it should suffice to point out that when the piston and cylinder arrangement 54 is energized to project the plunger 52 vertically upward, the C-shaped brackets 48 are raised, thereby firmly seating the cylindrical shell 11 on the flanges 50 and raising the shell 11 off of the conveyor belt 45. As the shell 11 approaches the spray head 12, the latter is turned on so as to initiate a centrifugal spray coating operation. Continued vertical upward movement of the shell 11 causes the spray head 12 to traversally traverse the axial length of the shell, thereby applying a uniform coating to the internal surface of the latter. When the shell 11 has completely traversed the spray head 12, the latter is deactivated and the fluid connections to the piston and cylinder arrangement 54 are reversed, thereby returning the plunger 52, brackets 48, and shell 11 towards their lowest position as shown in FIG. 7. If desired, a second coating can be applied to the inner surface of the shell during downward vertical movement of the latter.

It will be appreciated by those skilled in the art that under normal operating procedures it is desirable to permit flow of the spray material through the spray head during those periods when the spray head 12 is positioned within the shell 11, thereby preventing loss of spray material and undesirable application of the material to the outer surface of the shell and other objects in the immediate vicinity of the spray station 44. Unfortunately, however, each time that the flow of spray material is stopped, the material accumulated on the distributor 28 (FIG. 1) and the spray discs D1-D8 is expelled from the spray device 10. Therefore, each time that a spray coating operation is initiated, a definite delay is encountered during which the distributor and spray discs are again charged to their full capacity. During the charging period, the density of the spray emanating from the spray head 12 is gradually built up to a maximum level. As a consequence of the foregoing, the coating applied to the inner surface of the cylindrical shell 11 during the initial charging period is less dense than that applied once the spray head 12 is charging to full capacity. Heretofore, it has been either necessary to accept such deviations in coating uniformity or, alternatively, it has been necessary to charge the spray head 12 prior to the time that the latter enters the shell 11, thereby resulting in a loss of spray material and possible undesirable coating of environmental objects.

We claim as our invention:

1. A centrifugal spray head for coating the internal surface of a hollow shell with spray material, said head comprising, in combination, a power driven shaft having a vertical axis for driving said head, a material distributor secured to said shaft, said distributor comprising a hub portion having a centrally disposed charge cavity and a plurality of distributor teeth with inner and outer substantially parallel surfaces disposed concentrically about said shaft, said inner and outer surfaces of the distributing teeth being outwardly flared from said hub portion, a plurality of axially spaced annular spray disc fixedly mounted on said shaft for rotation therewith about the shaft axis, said

2. A centrifugal spray head for coating the internal surface of a hollow shell with spray material, said head comprising, in combination, a power driven shaft having a vertical axis for driving said head, a material distributor secured to said shaft, said distributor comprising a hub portion having a centrally disposed charge cavity and a plurality of distributor teeth with inner and outer substantially parallel surfaces disposed concentrically about said shaft, said inner and outer surfaces of the distributing teeth being outwardly flared from said hub portion, a plurality of axially spaced annular spray disc fixedly mounted on said shaft for rotation therewith about the shaft axis, said
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13 discs being in coaxial, concentric, surrounding relation to said teeth with the inner marginal edges of said discs being radially spaced from said teeth, and means for continuously feeding spray material to said charge cavity during rotation of said spray head so that particles of spray material are forced outwardly along said teeth and centrifugally projected therefrom in substantially radial planes so as to be applied to the inner marginal edges of said spray discs, the inner marginal edges of said spray discs being spaced from said teeth by a radial gap to insure that particles of spray material projected from any given point on each tooth form a band of spray material within said gap, each of said bands lying in a radial plane normal to the axis of said shaft and increasing in circumferential width at increased radial distances from said teeth, the radial extent of said gap between said teeth and the closest one of said discs being sufficient to insure that the body of spray material projected from points on said teeth lying in a common radial plane blend with one another in proximity to the inner edge of said closest one of said discs so that particles of spray material having given characteristics of viscosity are substantially uniformly applied continuously about the inner marginal edges of said discs when the latter are driven at a given rotational speed.

2. A centrifugal spray head as set forth in claim 1 further characterized in that the outer marginal edges of said discs are chamfered to form knife edges.

3. A centrifugal spray head as set forth in claim 1 further characterized in that the inner and outer marginal edges of said discs are chamfered to form knife edges.

4. A centrifugal spray head as set forth in claim 1 further characterized in that said spray material feeding means includes a nozzle and support means therefor for directing spray material into said cavity, a pump, and conduit means for coupling said nozzle to said pump and said cavity.

5. The combination as set forth in claim 1 further characterized in that said cavity during rotation of said spray head so that particles of spray material are forced outwardly along said teeth and centrifugally projected therefrom in substantially radial planes so as to be applied to the inner marginal edges of said spray discs, the inner marginal edges of said spray discs being spaced from said teeth by a radial gap to insure that particles of spray material projected from any given point on each tooth form a band of spray material within said gap, each of said bands lying in a radial plane normal to the axis of said shaft and increasing in circumferential width at increased radial distances from said teeth, the radial extent of said gap between said teeth and the closest one of said discs being sufficient to insure that the body of spray material projected from points on said teeth lying in a common radial plane blend with one another in proximity to the inner edge of said closest one of said discs so that particles of spray material having given characteristics of viscosity are substantially uniformly applied continuously about the inner marginal edges of said discs when the latter are driven at a given rotational speed.

8. A centrifugal spray head for coating the internal sidewall surface of a 55-gallon drum with a viscous coating material such as paint or the like, said head comprising, in combination, a power driven shaft having a vertical axis for driving said head, a material distributor secured to said shaft for rotation therewith about said shaft axis, said distributor having a centrally disposed hub portion and a plurality of generally axially extending, substantially flat distributor teeth flaring outwardly from said hub portion disposed concentrically about said shaft, an annular charge cavity formed in said hub portion inwardly of said teeth, a multiplicity of axially spaced annular spray discs fixedly mounted on said shaft for rotation therewith about the shaft axis, said discs being in coaxial, concentric, surrounding relation to said teeth with the inner marginal edges of said discs being radially spaced from said teeth, and means for continuously feeding viscous coating material to said charge cavity during rotation of said spray head so that said material is forced outwardly along said teeth and centrifugally projected therefrom in substantially radial planes so as to be applied to the inner marginal edges of said discs when said discs are driven at a given rotational speed.

9. The method of uniformly coating the internal surface of a hollow shell comprising the steps of vertically positioning a rotatable centrifugal distributor coaxially within the shell, vertically positioning a multiplicity of coaxial, axially spaced annular discs concentrically about the distributor, establishing a radial gap between the inner marginal edges of the discs and the outer radial extremities of the distributor sufficiently great to insure that particles of spray material projected centrifugally from the distributor are applied substantially uniformly about the entire innermost marginal edges of all of the discs, rotatably driving said distributor and discs simultaneously about a common vertical axis, feeding spray material to said distributor during rotation thereof, translating said distributor and said discs axially relative to said shell, positioning shielding means in the gap between said distributor and said discs, and driving said discs, as to minimize air turbulence therein and rotatably driving said shielding means simultaneously with said discs and distributor.

10. A centrifugal spray head for coating the internal surface of a hollow shell with coating material having a viscosity μ said head comprising, in combination, a
power driven shaft having a vertical axis for rotatably driving said head at a known speed \(\omega\), a material distributor secured to said shaft for rotation therewith about the shaft axis, said distributor having a centrally disposed hub portion including a charge cavity and a plurality of distributor teeth having substantially parallel inner and outer surfaces which flare outwardly from said hub portion, a multiplicity of axially spaced annular spray discs fixedly mounted on said shaft for rotation therewith about the shaft axis, said discs being in coaxial, concentric, surrounding relation to said teeth and radially spaced therefrom with the disc spaced radially outward from the outer surfaces of said teeth being spaced therefrom by a radial gap and the radial gap between said teeth outer surfaces and each successive adjacent disc being progressively greater toward the bases of said outwardly flared teeth, and means for continuously feeding coating material to said charge cavity, the radial gap between the free extremities of said teeth and the inner peripheral edge of the adjacent spray disc being dimensioned in accordance with the parameters \(\mu\) and \(\omega\) such that particles of coating material projected centrifugally from the outer surfaces of the teeth are applied substantially uniformly and continuously about the inner peripheral edge of said adjacent spray disc.

11. A centrifugal spray head for coating the internal surface of a cylindrical sidewall for a 55-gallon container with coating material having a viscosity \(\mu\), said head comprising, in combination, a power driven shaft having a vertical axis for rotatably driving said head at a rotation speed on the order of 7,000 r.p.m., a material distributor secured to said shaft for rotation therewith about the shaft axis, said distributor having a central hub portion and a plurality of substantially flat sided generally axially extending, distributor teeth which flare outwardly from said hub portion, an annular charge cavity formed on said hub portion inwardly of said teeth, a multiplicity of axially spaced annular spray discs fixedly mounted on said shaft for rotation therewith about the shaft axis, said discs being in coaxial, concentric, surrounding relation to said teeth and radially spaced therefrom with the disc spaced radially outward from the free extremities of said teeth being spaced therefrom by a radial gap on the order of one inch and the radial gap between said teeth and each successive adjacent disc being progressively greater toward the bases of said outwardly flared teeth and with the maximum radial gap therebetween being on the order of one and one-half inches, and means for continuously feeding coating material to said charge cavity, the radial gap between the free extremities of said teeth and the inner peripheral edge of the adjacent spray disc being sufficient to ensure that particles of coating material having a viscosity \(\mu\) are projected centrifugally from the free extremities of the teeth and are applied substantially uniformly and continuously about the inner peripheral edge of said adjacent spray disc when the latter is rotating at a speed on the order of 7,000 r.p.m.

12. A centrifugal spray head for coating the internal surface of a hollow shell with coating material having a viscosity \(\mu\), said head comprising, in combination, a power driven shaft having a vertical axis for rotatably driving said head at a known speed \(\omega\), a material distributor secured to said shaft for rotation therewith about the shaft axis, said distributor having a centrally disposed charge cavity and a plurality of substantially flat sided distributor teeth which flare outwardly from said hub portion, a multiplicity of axially spaced annular spray discs fixedly mounted on said shaft for rotation therewith about the shaft axis, said discs being in coaxial, concentric surrounding relation to said teeth and radially spaced therefrom with the disc spaced radially outward from the free extremities of said teeth being spaced therefrom by a radial gap and the radial gap between said teeth outer surfaces and each successive adjacent disc being progressively greater toward the bases of said outwardly flared teeth, first means for continuously feeding coating material to said charge cavity during rotation of said head, and second means for momentarily feeding an overcharge of coating material to said head upon initiation of a spray coating cycle so as to charge said head to full capacity substantially instantaneously, the radial gap between the free extremities of said teeth and the inner peripheral edge of the adjacent spray disc being dimensioned in accordance with the parameters \(\mu\) and \(\omega\) such that particles of coating material projected centrifugally from the free extremities of the teeth are applied substantially uniformly and continuously about the inner peripheral edge of said adjacent spray disc.

13. A centrifugal spray head for coating the internal surface of a hollow shell with coating material having a viscosity \(\mu\), said head comprising, in combination, a power driven shaft for rotatably driving said head at a known speed \(\omega\), a material distributor secured to said shaft for rotation therewith, said distributor having a centrally disposed charge cavity and a plurality of outwardly flared distributor teeth, a multiplicity of axially spaced annular spray discs fixedly mounted on said shaft for rotation therewith, said discs being in coaxial, concentric, surrounding relation to said teeth and radially spaced therefrom with the disc spaced radially outward from the free extremities of said teeth being spaced therefrom by a fixed radial gap and the radial gap between said teeth and each successive adjacent disc being progressively greater toward the bases of said outwardly flared teeth, means for continuously feeding coating material to said charge cavity, the radial gap between the free extremities of said teeth and the inner peripheral edge of the adjacent spray disc being dimensioned in accordance with the parameters \(\mu\) and \(\omega\) such that particles of coating material projected centrifugally from the free extremities of the teeth are applied substantially uniformly and continuously about the inner peripheral edge of said adjacent spray disc, means for shielding interposed in the zone between said shell and said head so as to minimize air turbulence therefrom and said shielding means being attached to said spray head and rotatable therewith.

14. A centrifugal spray head for use in coating the internal surface of hollow shells having a given one of diverse internal diameters, said head comprising, in combination, a power driven shaft for driving said head, a material distributor secured to said shaft for rotation therewith, said distributor having a centrally disposed charge cavity and a plurality of distributor teeth disposed outwardly of said cavity, a multiplicity of axially spaced annular spray discs fixedly mounted on said shaft for rotation therewith, said discs being in coaxial, radial spaced, concentric, surrounding relation to said teeth, means for continuously feeding spray material into said charge cavity, and separable axially spaced skirts removably secured to said spray head, said skirts having a greater external diameter than said discs and defining an axially enclosed annulus substantially free of air turbulence surrounding said discs.

15. A centrifugal spray head for use in coating the internal surface of hollow shells having a given one of diverse internal diameters, said head comprising, in combination, a power driven shaft for driving said head, a material distributor secured to said shaft for rotation therewith, said distributor having a centrally disposed charge cavity and a plurality of distributor teeth disposed outwardly of said cavity, a multiplicity of axially spaced annular spray discs fixedly mounted on said shaft for rotation therewith, said discs being in coaxial, radial spaced, concentric, surrounding relation to said teeth, means for continuously feeding spray material into said charge cavity, and separable axially spaced skirts removably secured to said spray head, said skirts having a greater external diameter than said discs and defining an axially enclosed annulus substantially free of air turbulence surrounding said discs.

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free to pass relatively through said shell while said skirts define with said discs and shell an enclosed annulus surrounding said discs substantially free of air turbulence.

16. A centrifugal spray head for use in coating the internal surface of hollow shells having a given one of diverse internal diameters, said head comprising, in combination, a power driven shaft for driving said head, a material distributor secured to said shaft for rotation therewith, said distributor having a centrally disposed charge cavity and a plurality of distributor teeth disposed outwardly of said cavity, a multiplicity of axially spaced annular spray discs fixedly mounted on said shaft for rotation therewith, said discs being in coaxial, radially spaced, concentric, surrounding relation to said teeth, means for continuously feeding spray material into said charge cavity, a first annular skirt removably secured to the first of said multiplicity of discs, a second annular skirt removably secured to the last of said multiplicity of discs, said first and second skirts being axially spaced apart and each having a greater external diameter than said discs and defining an axially enclosed annulus substantially free of air turbulence surrounding said discs.

17. A distributor for use with a centrifugal spray head of the type employing a multiplicity of coaxial annular spray discs, said distributor comprising a hub portion adapted to be rigidly secured to said spray head, a charge cavity formed in said hub portion, and a plurality of generally axially extending, substantially flat sided distributor teeth integral with said hub portion and flaring outwardly from the latter and disposed outwardly of said charge cavity.

18. A distributor for use with a centrifugal spray head of the type employing a multiplicity of coaxial annular spray discs, said distributor comprising a hub portion adapted to be rigidly secured to said spray head, an annular charge cavity formed in said hub portion and coaxial therewith, and a plurality of generally axially extending, distributor teeth having inner and outer substantially parallel surfaces integral with said hub portion, and flaring outwardly therefrom and disposed outwardly of said annular charge cavity.

19. A distributor for use with a centrifugal spray head of the type employing a multiplicity of coaxial annular spray discs, said distributor comprising a hub portion, an annular charge cavity formed in said hub portion and coaxial therewith, a plurality of generally axially extending, distributor teeth having outwardly flared substantially parallel inner and outer surfaces integral with said hub portion, and means for securing said hub portion to said head in coaxial relation thereto.

20. The method of internally coating a cylindrical surface comprising the steps of positioning a centrifugal spray head adjacent one end of the surface and coaxial therewith, rotationally driving the spray head, translating the spray head axially relative to the surface, charging the spray head with a constant flow of spray material during relative translation of the head through the cylindrical surface, and momentarily overcharging the spray head with spray material upon entry of the head into the interior of the cylindrical surface so as to bring the spray head to full discharge capacity substantially instantaneously and thereby applying a coating of substantially uniform thickness throughout the entire axial length of the cylindrical surface.

21. The method of internally coating a cylindrical surface comprising the steps of positioning a centrifugal spray head adjacent one end of the surface and coaxial therewith, rotationally driving the spray head, translating the spray head axially relative to the surface, charging the spray head with a constant flow of spray material during relative translation of the head through the cylindrical surface, momentarily overcharging the spray head with spray material upon entry of the head into the interior of the cylindrical surface so as to bring the spray head to full discharge capacity substantially instantaneously and thereby applying a coating of substantially uniform thickness throughout the entire axial length of the cylindrical surface, stopping the flow of spray material to said head upon alignment of said head with the other end of the surface, reversing the direction of relative axial translation between the head and the surface, charging the spray head with a constant flow of spray material during reverse relative translation of the head through the cylindrical surface, and momentarily overcharging the spray head with spray material upon entry of the head into the interior of the cylindrical surface from the other end so as to again bring the spray head to full discharge capacity substantially instantaneously and thereby applying a second coating of substantially uniform thickness throughout the entire axial length of the cylindrical surface.

22. In a centrifugal spray coating system including a centrifugal head comprising a multiplicity of axially spaced discs and a material distributor for supplying spray material to said discs, and pump and conduit means for charging said distributor; said system also including a work support and means for relatively reciprocating said head and said work support; the improvement comprising means for momentarily accelerating said pump at the beginning of each reciprocation.

23. In the method of coating a workpiece reciprocated relative to a centrifugal spray coating head, said head having distributor means being charged with coating material during each such reciprocation, the improvement comprising momentarily feeding an overcharge of said material to the distributor means at the beginning of each reciprocation so as to charge the distributor means to full capacity substantially instantaneously.

References Cited

UNITED STATES PATENTS

5 888,091 5/1908 Kestner .......... 239—222.11
2,545,490 3/1951 Norris .......... 239—222 X
3,017,116 1/1962 Norris .......... 117—93.42 X
3,130,066 4/1964 Brady .......... 117—93.43
3,171,600 3/1965 Eckey .......... 239—222 X
3,197,143 7/1965 Norris .......... 239—223

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