United States Patent

Guilbault et al.

[15] **3,660,136**

[45] **May 2, 1972**

[54] METHOD OF COATING SLOTTED ARTICLES

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[73] Assignee: **General Electric Company**

[22] Filed: **Nov. 23, 1970**

[21] Appl. No.: **92,286**

Related U.S. Application Data

[63] Continuation of Ser. No. 765,807, Oct. 8, 1967, abandoned.

[52] **U.S. Cl.** **117/17**, 117/16, 117/18, 117/21, 117/DIG. 6

[51] **Int. Cl.** **B44d 1/095**

[58] **Field of Search** ..... 117/16, 17, 21, DIG. 6, 18

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[57] **ABSTRACT**

A method of applying a powdered coating composition to solid slotted articles comprising the steps of: preheating the article to the sintering temperature of the composition, coating the article in a conventional fluidized bed of the coating composition, cooling the article to ambient temperature, and coating the article in an electrostatic fluidized bed of the coating composition. The method may advantageously be utilized to apply an integral insulation to the deep, narrow winding slots of a dynamoelectric machine armature or stator.

3 Claims, 4 Drawing Figures

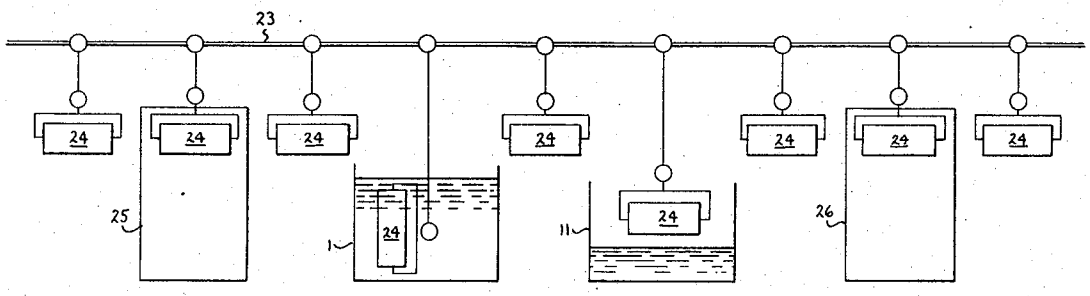


FIG. 1

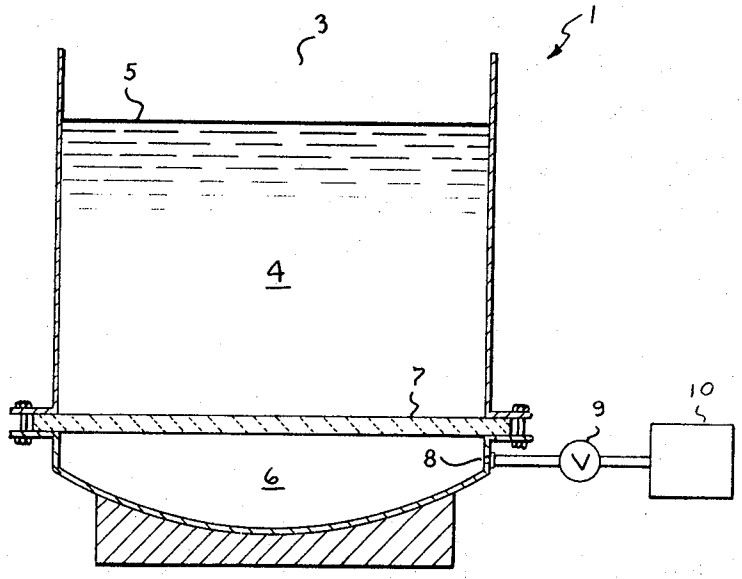
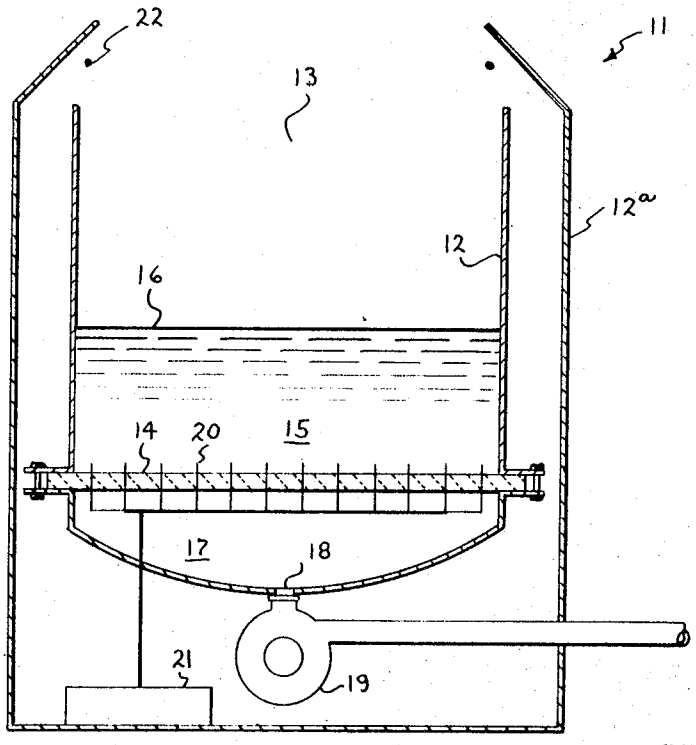


FIG. 2



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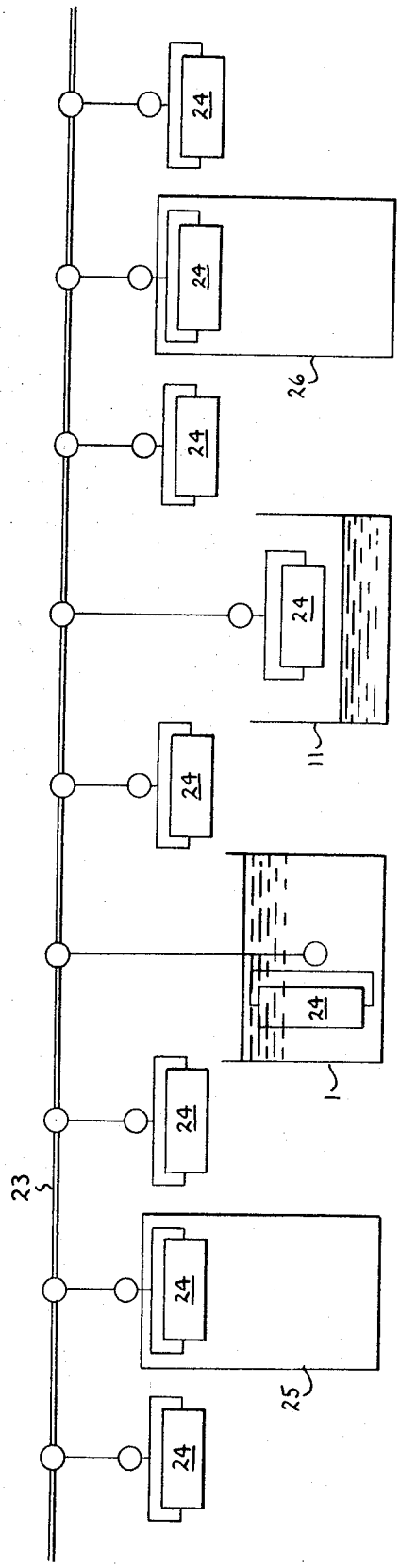

FIG. 3

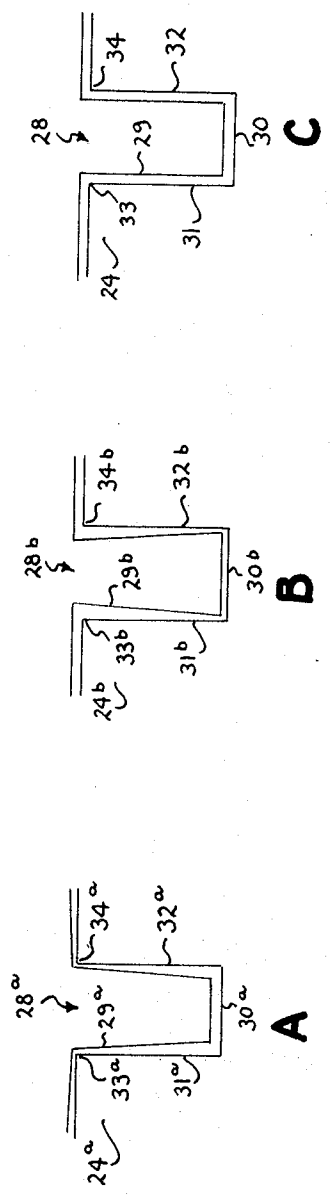

FIG. 4

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METHOD OF COATING SLOTTED ARTICLES

This is a continuation of application Ser. No. 765,807, filed Oct. 8, 1967, and now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to a method of applying a coating onto a surface of an article, and more particularly, to a method of applying a coating of powder to a slotted article.

The so-called fluid bed process is often used to apply coating powders to the surfaces of slotted articles. In the conventional fluidized bed process, a quantity of finely divided powder is placed in an upper chamber of a container having a lower chamber connected to a gas inlet opening. The gas is bubbled through a gas-pervious partition, which divides the chambers, and upwardly through the finely divided powder to cause the powder to appear and act as a fluid. When preheated articles are dipped into the fluidized powder, the powder adheres to the article to form a coating.

This conventional fluidized bed process has been used for applying coatings to slotted solid articles, for example, for applying insulation coatings to the core members of armatures and stators of dynamoelectric machines. These core members, often formed from a number of relatively thin, stacked laminations punched from suitable sheet magnetic material; are generally provided with a plurality of narrow winding slots to be used for mounting the windings of dynamoelectric machines. In coating the core members by this process, one of these members is heated to a temperature above the melting point of the coating powder, normally a resinous material such as an epoxy resin, and is then dipped into the fluidized powder for a brief period of time. The heated core member melts the fluidized resin to form an integral coating on the walls of the winding slots and on the ends of the core.

Attempts to employ only the conventional fluidized bed process to coat slotted solid articles, such as the armatures and stators discussed above which have relatively deep, narrow slots, have not been completely successful because the thickness of the applied coating has not been uniform. The prior art has offered one solution, causing the fluidized powder to move upwardly so as to contact the surface to be coated rather than have the article immersed down into the fluidized powder. A problem still remains, with processes of the latter type which use conventional coating powders, however, in that the coating thickness increases more powders, on the flat surfaces of the slots than on the sharp edges and corners. As the slots are required to be made deeper and narrower, a relatively heavy coating must be applied to adequately insulate the exterior edges and corners of the slots through the use of the fluidized bed. The resulting heavy build-up of coating in the slots can make installing windings in a dynamoelectric machine very difficult, and when the slots are extremely narrow, the coating may actually bridge across the slot width.

SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to provide a method of forming a uniform coating on slotted solid articles.

It is a more particular object of this invention to provide a fluidized bed method of forming a uniform coating on slotted solid articles wherein the build-up of coating material is minimized on the interior flat surfaces of the slots and maximized on the exterior edges and corners thereof.

It is a further object of this invention to provide such a method for applying a uniform coating of integral insulation on the core members such as armatures and stators of dynamoelectric machines.

Briefly stated, and in accordance with one aspect of this invention, deep narrow slots of a solid article can be coated through the use of a coating method which includes the application of powdered material in two separate types of steps. First of all, the article is preheated and then coated by a conventional coating process which results in a non-uniform coating of the slots which is thinnest on the exterior edges and corners of the slots, with the greatest thickness in the slot depths. The article is then cooled to ambient temperature and is coated by an electrostatic coating process. It has been found that due to the nature of the electrostatic process, the powder particles have a greater affinity for portions of the article having a high electrical flux density such as sharp corners and edges of the slots. Thus, the relative thickness of the coating applied to portions of the slots by the electrostatic coating process is just the opposite of that applied by the conventional coating process. The combination of these processes results in a substantially uniform coating over the entire surface of the slots. The resulting coating is then cured by conventional heat treatment. As an alternative which depends on the nature of the powdered material used for coating, the sequence of the coating steps can be reversed so that the slotted article is first coated by the electrostatic fluidized bed and then by the conventional fluidized bed.

This invention is recited in the appended claims.

A more thorough understanding of the objects and advantages of the invention may be obtained by referring to the following description taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a schematic representation of the conventional fluidized bed apparatus employed in the method of this invention;

FIG. 2 is a schematic representation of the electrostatic fluidized bed apparatus employed in the method of this invention;

FIG. 3 illustrates the sequence of steps conducted in the method of this invention; and

FIG. 4 shows the distribution of coating on the slots of an article after it has undergone various steps in the method of this invention.

A conventional fluidized bed apparatus 1 employed in the method of this invention is shown schematically in FIG. 1 and is fully described in U.S. Pat. No. 2,844,489 to Gemmer. It comprises a container 2 which may be constructed of a convenient structural material, such as, for example, steel or aluminum and has an open top as indicated at 3. The container 2 is divided into an upper chamber 4 in which powdered coating material 5 is confined and a pressure chamber 6, the two chambers being separated by a gas-pervious partition 7. This partition, which should be pervious to the gas used but impervious to the particles of coating material, may preferably take the form of a porous ceramic plate, although other similar structures may be advantageously used.

The container is provided with a gas inlet opening 8 which is adapted for connection through a shut-off valve 9 to a suitable source 10 of gas under pressure in order to pressurize the chamber. The source of gas may include many alternatives such as a "bottle" of precompressed gas, a conventional air compressor and accumulation tank if air is to be used or an air pump or blower attached to the inlet connection.

Any gas which is reasonably inert at the temperature and with the materials employed may be used as the gaseous medium for fluidizing the coating material. Air is usually satisfactory and is preferred for reasons of economy. In applications where it is necessary to avoid oxidation it is preferable to use nitrogen or some other non-oxidizing gas. The pressure of the gas may vary greatly, depending on the particular shape and dimensions of the container, as well as on the formulation and average particle size of the coating material used. The pressure should, however, be high enough to fluidize the largest particle of the coating composition, but it should not exceed the point where the upper level of the fluidized bed of coating material rises above the sides of the container or where an appreciable dust cloud of the finer particles of coating material is formed above the container.

In using this apparatus for the formation of coatings in accordance with the method of this invention, a quantity of the finely divided coating composition is placed in the upper chamber 4 of the container 2 and a gas under pressure is admitted through the valve 9 into the pressure chamber 6. The

type of coating material preferred will be discussed further on in the specification. The gas from the lower chamber **6** passes through the gas-pervious partition **7** and flows upwardly through many finely divided streams or in what might be characterized as a parallel upward flow from the entire upper surface of the partition **7** through the finely divided coating material. This upwardly moving gas fluidizes the bed of the coating composition so that it is ready for use in the coating operation.

The article or articles to be coated are first heated to a temperature above the sintering point of the particles contained in the powdered composition, but below the temperature at which any component of the composition is subject to rapid decomposition. The sintering point may be defined as the temperature at which the coating material is sufficiently sticky or tacky to adhere to the surface of the article and flows together to form a continuous film or coating. The article is then dipped into the fluidized coating material while still at an elevated temperature above the sintering temperature so that the particles contained in the coating composition which come into immediate contact with the surface of the article and adhere are melted thereon. The period of time during which the article is left in the fluidized bed of this coating composition and the preheat temperature of this article to be cooled can be used to control the thickness of the coating applied.

The foregoing type of conventional fluidized bed apparatus has been found to operate satisfactorily in the method contemplated by this invention. The structure of the fluidized bed forms no part of the invention, however, and it is contemplated that modifications of the foregoing apparatus could be used in an equally satisfactory manner. One such modification shown in the prior art would feature means for causing the fluidized composition to move upwardly so as to contact the surface to be coated so that the article would not be immersed in the fluidized material.

An electrostatic fluidized bed apparatus **11** employed in the method of this invention is shown schematically in FIG. **2**. It comprises a container **12** positioned within an outer casing **12***a* and preferably constructed of electrically insulating material and has an open top as indicated at **13**. A porous plate **14** divides the container into an upper chamber **15**, in which the powdered coating material **16** is confined, and a lower pressure chamber **17**. The chamber **17** is provided with an inlet **18** for the introduction of compressed air or another suitable gas. In this particular example, a blower **19** is connected to the inlet. A plurality of electrodes, such as **20**, are imbedded in the porous plate **14** and are connected to the high potential terminal of an electrical power supply **21**. The power supply may comprise, for example, a 90 k. v. Van de Graf generator, the output of which can be varied from 30 to 90 k. v. increments. A ground wire **22** surrounds the top of the container **12** to limit the loss of powder therefrom.

In using this apparatus for the formation of coatings in accordance with the method of this invention, a quantity of the finely divided coating composition is placed in the upper chamber **15** of the container **12** and a gas under pressure, in this example air, is introduced into the lower chamber **17**. The type of coating material preferred will be discussed further on the specification. As in the conventional apparatus shown in FIG. **1**, the upward flow of air through the porous plate **21** and into the upper chamber **15** fluidizes the bed of coating composition. The article to be coated which is at room temperature and at a low or ground electrical potential is positioned above the bed of fluidized powder. When an electrical potential is applied to the powder through the electrodes **20**, the potential difference between the article to be coated and the electrostatically charged powder particles causes the former to electrostatically attract the latter. The particles are drawn out of the bed and onto the article to form a layer of powder thereon which is maintained by the electrostatic attraction therebetween. The thickness of the coating is determined by the amount of time the article is in the required proximity to the bed. The article would then be subjected to a subsequent heat treatment to fuse the layer of powder thereon into a permanent coating.

As with the conventional fluidized bed apparatus, the structure of the electrostatic apparatus forms no part of this invention. The particular illustration presented is based on an electrostatic fluidized bed apparatus built by the Sames Corp. It is to be understood that modifications of this apparatus can be utilized with the method of this invention without departing from the scope thereof.

In general, the conventional fluidized bed process has been known to work well with a wide variety of materials, as disclosed in the aforementioned Gemmer patent, U.S. Pat. No. 2,844,489, including thermoplastic and thermosetting resins. The former type of resin is typified by the polyethylenes, polyacrylates, polyamides, etc., and the latter is typified by the epoxies, polyesters, phenolics, melamine-formaldehydes, etc. Typical of epoxy or ethoxyline resins having extremely desirable properties for electrical insulation are those described in U.S. Pat. Nos. 2,324,483, 2,444,333, 2,494,295, 2,500,600, and 2,511,913, and similarly useful polyester resins are described in U.S. Pat. Nos. 2,936,296 and 2,889,304. Suitable coating materials are generally described as layer forming coating compositions containing particles which sinter when heated. The process can be used to coat any article which can be heated without damage to a temperature above the melting point of the coating composition and is especially suited for coating articles having an irregular or complex shape and made from one or more of a variety of metals, woods, glass, and different ceramic materials.

All of the coating compositions used in the conventional process can also be used in the electrostatic fluidized bed process. In addition, as is well known to those skilled in the art, many inorganic powders such as talc, various vitreous materials, metallic oxides and phosphers can be applied by this process.

A coating powder composition found to work especially well with the method of this invention is that which has been marketed by the General Electric Company under the trade name Alkanex, the composition comprising a condensation product of dimethyl terephthalate and a polyhydric alcohol together with suitable plasticizers and fillers. An application of this method to the coating of dynamoelectric machine armatures was conducted with Alkanex number 1003 powder, characterized by low flow, in the conventional fluidized bed and with Alkanex number 1008 powder, characterized by high flow, in the electrostatic fluidized bed.

FIG. **3** represents the various steps included in the method of this invention. A conveyor-hoist **23** or other suitable means can be utilized to move the article through the various fluidized beds and other apparatus which are utilized in the steps of the method. The article **24** to be coated is first preheated in suitable means **25**, such as a kiln, for a time necessary to raise the temperature thereof to at least the sintering temperature of the coating composition used in the conventional fluidized bed. When the article to be coated with Alkanex powder is a core member such as an armature of a dynamoelectric machine, it was found that preheating at 200° C for 2 hours was sufficient.

The article is then conveyed to the conventional fluidized bed **1** which has its coating composition fluidized by the currents of pressurized gas, and the article is either dipped into the bed or placed in close proximity to the bed. The thickness of the coating applied to the article can be controlled as a function of the length of time the bed is allowed to operate on the article. In the application of this method to the coating of an armature of a dynamoelectric machine, it was found advantageous to dip the armature vertically into the fluidized Alkanex number 1003 powder for 1.0 second, then reverse the ends of the armature and dip it vertically into the fluidized powder once again for 1.0 second.

The article is next removed from the fluidized bed and allowed to cool to ambient temperature. Then it is moved to the

electrostatic fluidized bed **11**, held horizontally over the electrostatic bed, and rotated slowly to insure a uniform coating. The article is held in this position for a time necessary to apply the desired coating thickness, while the powder itself is fluidized and electrically charged. The armature of the dynamoelectric machine may be coated with the Alkanex 1008 powder in this bed by being held at a height of about 2–4 inches from the fluidized powder for 4.0 seconds. The final step in the method is curing of the coated article by suitable means **26**, such as a kiln, at a temperature and for a time which depends on the powder used for coating. The Alkanex powder used in this example was cured for 2 hours at 200° C.

When Alkanex powder or similar powder is used as the coating composition, it has been determined that the order of the steps in the method of this invention should be as described. The conventional fluidized bed coating step is used prior to the electrostatic since if the reverse sequence was used, the Alkanex powder applied by the electrostatic process would start to cure when the coated article was heated prior to coating with the conventional fluidized bed. Poor bonding between the two coating layers would result. If other powders are used as the coating composition, the order of the steps may not be critical.

The use of two types of coating steps in accordance with the method of this invention provides a more uniform coating on most slotted articles. However, it is particularly useful for coating articles having slots less than about 1 inch wide. With narrower slots, it has been found that it is difficult to adequately coat the total depth of the slot with any single, known coating process. The slot depth to slot with ratio at which coating problems begin to occur varies with the width of the slot in question. Where the slots are less than 1 inch wide, it can generally be said that coating problems occur where the slot depth to slot width ratio is about 4 to 1.

In one instance, armatures of dynamoelectric machines having rectangular slots with a width of 0.145 inch and a depth of 0.625 inch could not be successfully coated by either the conventional fluidized bed process alone or by the electrostatic fluidized bed process alone. After the two processes were used on the armatures in accordance with this invention, the coating on the armatures passed a 1,200 volt to ground electrical insulation test. Armatures with slots as narrow as 0.125 inch and as deep as 0.9375 inch have been successfully coated with this method. A uniform coating was obtained on these slots which did not interfere with windings placed into the slots, and yet this coating passed a 2,500 volt to ground electrical insulation test.

FIG. **4** shows the relative coating thickness on the bottom, sides, and edges of a slot **28** after the article **24** has been through each of the coating steps of the method of this invention. In particular, FIG. **4***a* shows the thickness of a coating **29***a* after the article has been coated by the conventional fluidized bed alone. The coating thickness is greater on the bottom **30***a* of the slot **28***a* than on each of the sides **21***a*, **32***a* and smallest on the edges **33***a*, **34***a*. FIG. **4***b* shows a coating **29***b* applied to the slot after the article has been treated by the electrostatic fluidized bed alone. The coating thickness is greatest around the edges **33***b*, **34***b* of the slot and thinnest on the bottom **30***b* thereof. It can thus be seen that by virtue of the method of this invention, which includes the application of coating by both types of fluidized beds, a uniform coating on deep, narrow slots in a solid article may be obtained, as shown in FIG. **4***c*.

While the invention has been described with specificity, it is the intent of the appended claims to cover all variations which come within the true spirit and scope of the foregoing disclosure.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A method of applying a substantially uniform layer of fusible powdered coating composition containing particles therein which sinter when heated to an article having slots therein characterized by a slot width of less than 1 inch and a slot depth to width ratio of at least 4 to 1, said method comprising the steps of:

a. preheating the slotted article to at least the sintering temperature of the coating particles but below the deterioration temperature of the article;

b. coating the slotted article, after the slotted article has been preheated, in a conventional fluidized bed of the coating composition;

c. cooling the coated slotted article to the ambient temperature after the slotted article has been coated in the conventional fluidized bed;

d. coating the coated slotted article in an electrostatic fluidized bed of the powered coating composition; and

e. heating said coating to a temperature sufficient to fuse said coating.

2. A method of applying a substantially uniform layer of fusible powdered coating composition containing particles therein which sinter when heated to an article having slots therein characterized by a slot width of less than 1 inch and a slot depth to width ratio of at least 4 to 1, said method comprising the steps of:

a. coating the slotted article in an electrostatic fluidized bed of the powdered coating composition;

b. heating the coated slotted article to at least the sintering temperature of the coating particles but below the deterioration temperature of the article;

c. coating the coated slotted article in a conventional fluidized bed of the coating composition.

3. The method of claim **2**, further comprising the step of fusing the coating composition after the article has been coated in the electrostatic fluidized bed of the coating composition.

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