Feb. 7, 1967 J. B. THOMPSON 3,303,041

METHOD AND APPARATUS FOR COATING THE INTERIOR OF HOLLOW BODIES

Filed March 26, 1964 3 Sheets-Sheet 1

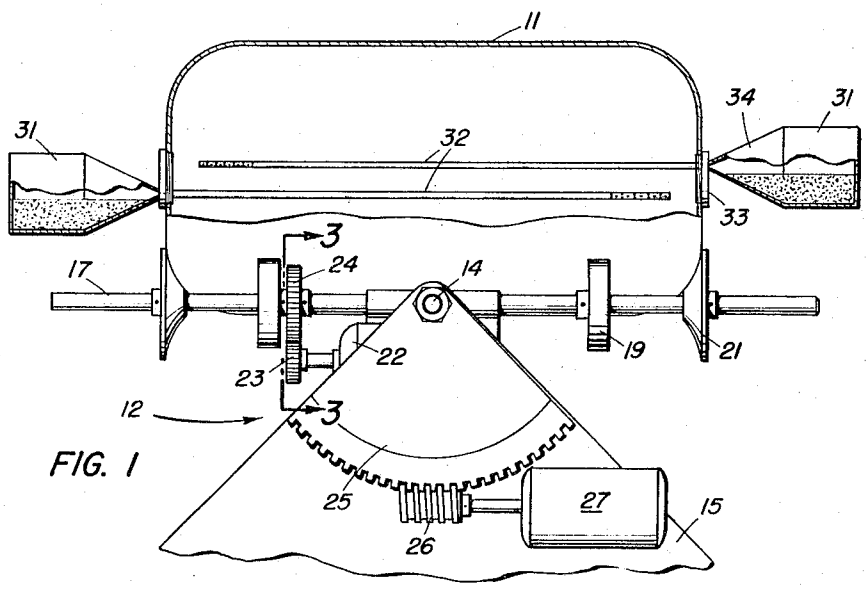


FIG. 1

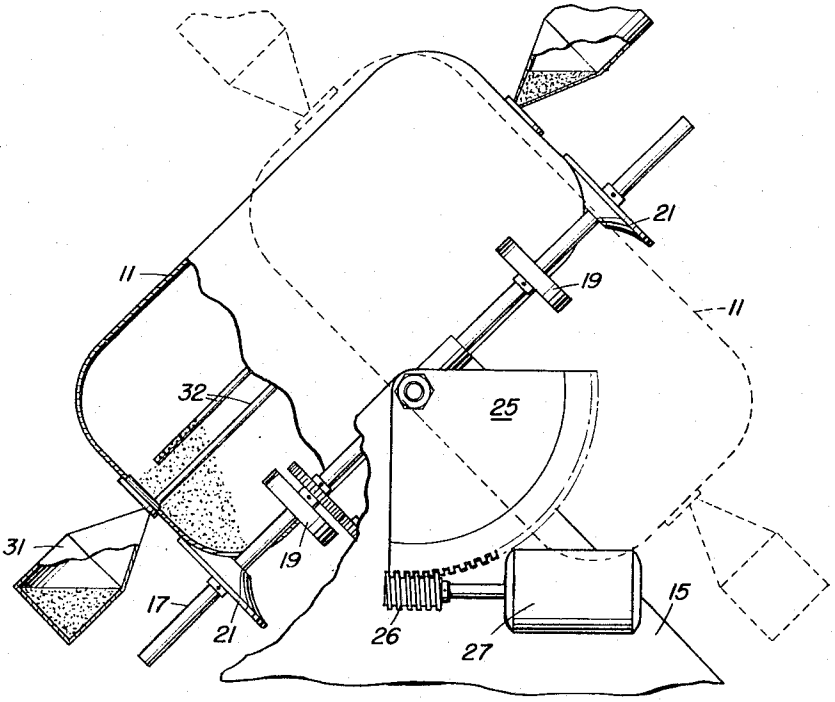


FIG. 2

INVENTOR
Jerome B. Thompson

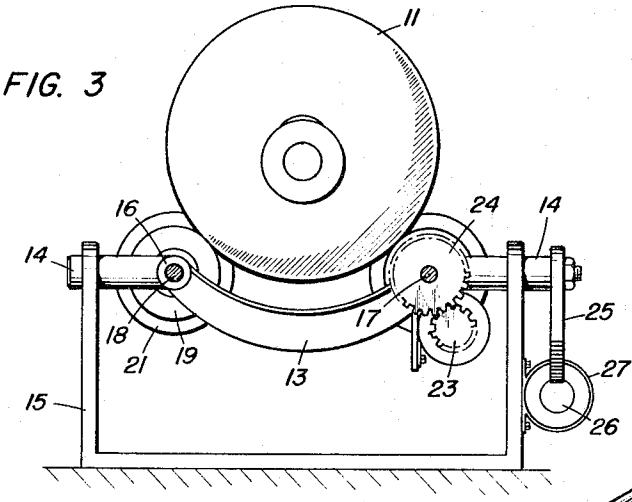
BY Claude Funkhouser
ATTORNEY

Feb. 7, 1967 J. B. THOMPSON 3,303,041

METHOD AND APPARATUS FOR COATING THE INTERIOR OF HOLLOW BODIES

Filed March 26, 1964 3 Sheets-Sheet 2

FIG. 3



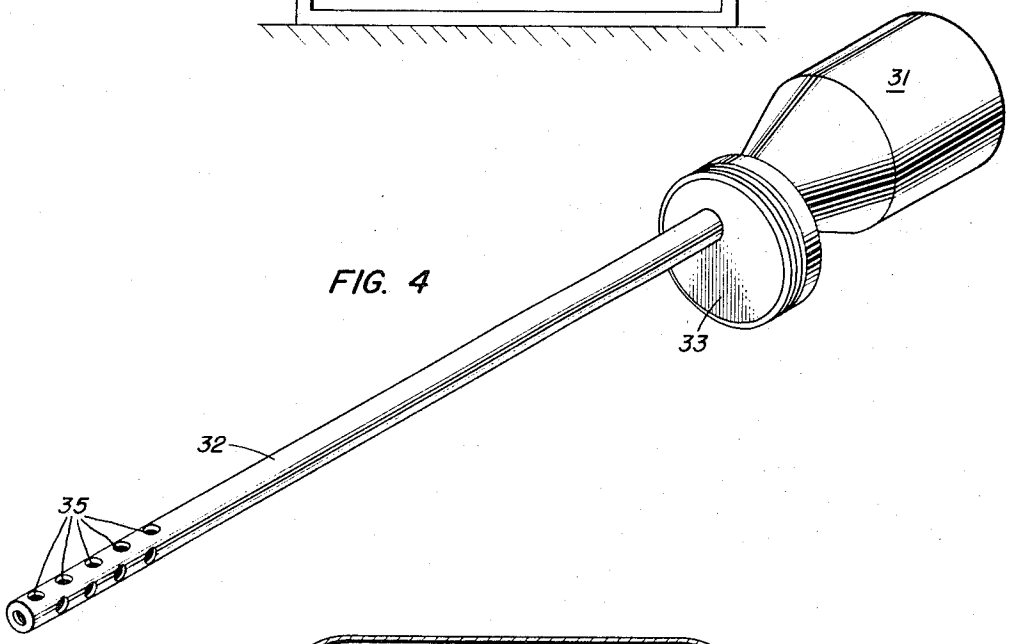


FIG. 4

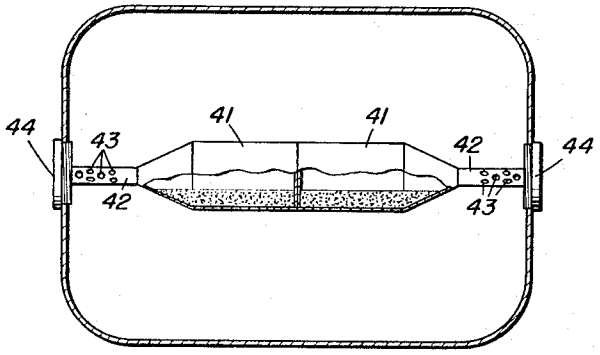


FIG. 5

METHOD AND APPARATUS FOR COATING THE INTERIOR OF HOLLOW BODIES

Filed March 26, 1964 3 Sheets-Sheet 3

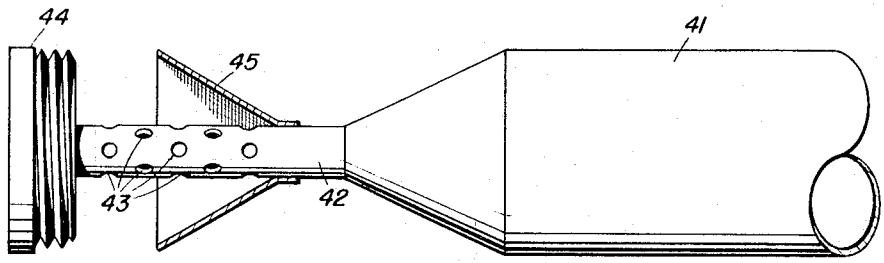


FIG. 6

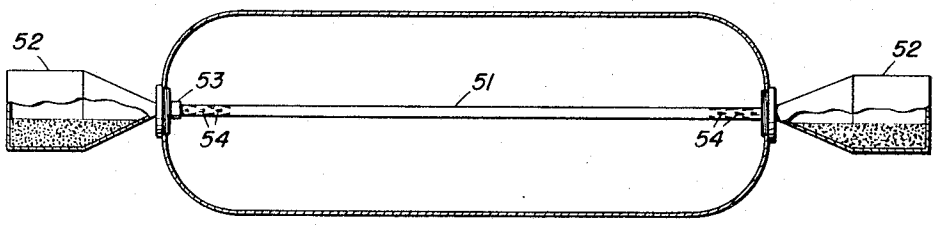


FIG. 7

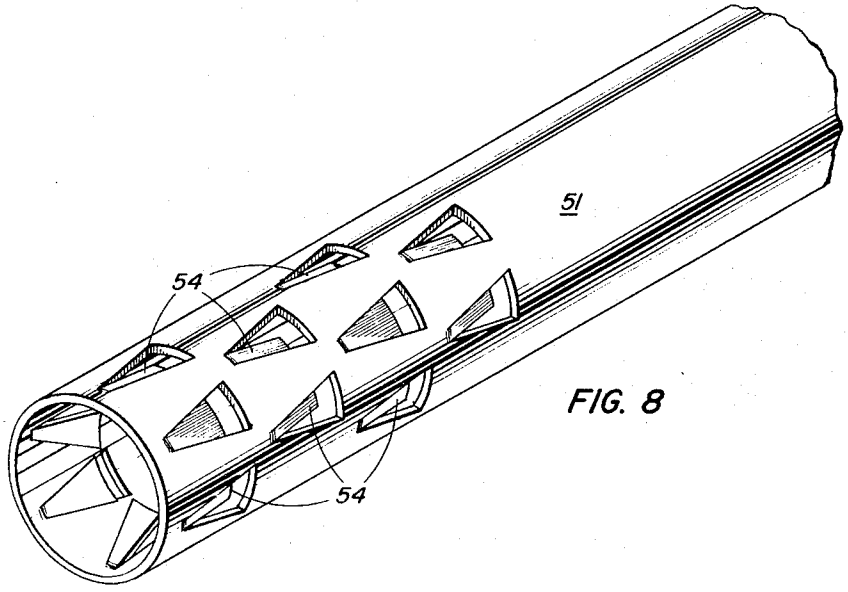


FIG. 8

United States Patent Office 3,303,041 Patented Feb. 7, 1967

3,303,041

METHOD AND APPARATUS FOR COATING THE INTERIOR OF HOLLOW BODIES

Jerome B. Thompson, Cumberland, Md., assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

Filed Mar. 26, 1964, Ser. No. 356,004
6 Claims. (Cl. 117—18)

This invention relates to an improved method and apparatus for coating the interior surfaces of substantially closed ended bodies. More specifically, this invention is concerned with the method and apparatus for embedding powder granules on the adhesive-coated interior surface of rocket motor casings.

Rocket casings are typically composed of steel, Fiberglas, resin laminates and like materials selected for their high strength to weight ratios. The rocket casing is commonly lined with a rubber or resin composition which serves as an insulator, flame inhibitor, and shrinkage boot. These liners cannot be effectively bonded directly to the casing and it is therefore necessary to treat the interior surface of the casing in order to render it more conductive to an effective bond. The treatment commonly used is the embedment technique.

Briefly, the conventional embedment process consists of cleaning the casing interior and applying thereto a coating of adhesive. The powder granules are then embedded in the adhesive by one of two methods: by filling the chamber, or by tumbling and tilting.

By the filling method, the adhesive coated chamber is placed in an upright position and simply filled with powder. After the adhesive has cured, the loose powder is removed. This prior art method may not be advantageously employed to embed the interior surface of large chambers, because the abrasive action of the large quantities of powder on the wet adhesive surface destroys the coating. A further disadvantage of the filling method is that it is extremely wasteful of powder, which powder may be partially or totally coated with adhesive wiped from the chamber surface, rendering it unacceptable for further embedding use. In a large casing, the amount of powder required by the filling method may be as great as one hundred times the amount actually embedded in the chamber.

A variation of the filling method has been utilized to embed the interior surface of large rocket cases. One dome of the chamber is coated with the adhesive and placed in an upright position, and this dome is filled. After the adhesive is cured the powder is removed and the other dome is coated and embedded in a like manner. Finally, the cylindrical section is coated and the chamber is placed on a tumbling table in a horizontal position. Powder is added and the chamber rotated to embed the cylindrical section. This technique results in less powder wastage, but requires more time than the filling method because of the delay for curing of each section. There is also the possibility of bald spots and overlaps at the junctures of the separately embedded zones.

By the tumbling and tilting procedure, the case is placed on a tumbling table which is equipped with rollers to drive the case about its longitudinal axis. The table is placed on a pivot so that the casing can be simultaneously tipped while it is rotated. Powder is then placed in the chamber in sufficient quantity to fill it to its axis. Rotation of the casing in its tilted position suffices to embed the end domes while the cylindrical portion of the casing

is coated when the casing is rotated in the horizontal position. This procedure reduces the amount of powder required for the initial charge, and provides for a more uniform distribution over the casing surface. However, an excess of powder amounting to about ten times the quantity actually embedded is still required. A further disadvantage arises from the extremely critical conditions required to achieve completely satisfactory results. If the adhesive is too soft, the abrasive action of several hundred pounds of dry granules shifting over the adhesive will wipe it off the surface, resulting in bald areas, multilayers, and a balled mass of adhesive-contaminated powder granules. If the adhesive is too hard, poor and shallow embedment is obtained.

If properly embedded, a rocket casing will have a uniform layer of adhesive about 15–30 mils thick. The powder granules will be embedded deeply in the adhesive in a monolayer giving the appearance of uniform coarse sandpaper.

It is, therefore, an object of this invention to provide a new and improved method and apparatus for coating the interior surface of hollow bodies, whereby the coating material is applied uniformly to the surface to be coated, yet with a substantial reduction in the amount of excess coating material required to accomplish an adequate and uniform coating layer.

It is a further object of this invention to provide a new and improved method and apparatus for coating the entire interior surface of a substantially closed ended drum-shaped body, whereby the coating material is applied gradually and continuously to the interior surface, and whereby the drum is simultaneously rotated about its longitudinal axis and tilted through varying angles during the coating operation.

The above objects are accomplished according to this invention by placing the drum to be coated on a table which rotates the drum about its longitudinal axis. The table is mounted on a pivot, so that the inclination of the longitudinal axis of the drum may be varied in a vertical plane. The coating material is stored in hoppers, which may be located either outside of the drum or inside of the drum. Ducts containing ports extend from the hopper for the purpose of dispensing the coating material over the drum interior surface which has been previously coated with an adhesive. When one end of the continuously rotating drum is raised by the tilting apparatus, the coating material flows from the appropriate hopper and coats the lower end of the drum. Similarly, the other end of the drum is coated with the direction of the drum tilt is reversed. Excess coating material which has not adhered to the ends of the drum during the tilting stages of the operation will coat the cylindrical portion of the drum while the drum is rotated in a horizontal position.

The operation and arrangement of the invention, together with further objects and advantages may be best understood and appreciated by reference to the following description and the accompanying drawings, wherein:

FIG. 1 is a diagrammatic illustration of the drum and tilt table structure shown in a horizontal position.

FIG. 2 is a diagrammatic illustration showing the structure of FIG. 1 in one of its tilted positions.

FIG. 3 is an end elevation view of the structure illustrated in FIGS. 1 and 2.

FIG. 4 is a view showing the duct and port details of the embodiment of FIGS. 1–3.

FIG. 5 is a diagrammatic illustration of a modified

embodiment of the coating material dispensing device of the invention.

FIG. 6 is a view showing the duct and port details of the embodiment of FIG. 5.

FIG. 7 is a diagrammatic illustration of a further modified embodiment of the coating material dispensing apparatus.

FIG. 8 is a view showing the duct and port details of the embodiment of FIG. 7.

The preparation of the casing surface for embedments in accordance with this invention can be essentially the same as employed for any other type of embedment process. The interior of the case is buffed or grit blasted and degreased by sponging, washing, or otherwise cleaning by accepted preparative methods. The case interior is then sprayed, brushed, or rolled to obtain a uniform coating of adhesive about 15–30 mls. thick. The adhesive preferred for this use are thixotropic, high viscosity, room temperature curing epoxy resins. However, other suitable adhesives can be employed without the necessity of modifying the embedment process of the instant invention.

This adhesive coating is then permitted to obtain a predetermined tackiness and then the powder granules, having the shape of right cylinders 35–70 mils in length and diameter, are embedded in accordance with the method and apparatus herein described.

Referring to FIGS. 1–3, the casing **11** to be coated is placed on a tumbling table indicated generally at **12**. The table **12** comprises a cradle **13** the ends of which comprise pivot shafts **14** rotatably mounted in a supporting frame **15**. A hollow sleeve **16** is fixed to each end of carriage **13**. Rotatably mounted in sleeves **16** is a pair of roller shafts **17** and **18**, each of which in turn carry a pair of rollers **19** and a further pair of rollers **21**. Rollers **21** have a substantially conical surface, and may be adjusted axially along roller shafts **17** and **18** so as to accommodate casings of various lengths. Rollers **21** serve to provide support for the casing so that it will not slide axially when in the tilted position.

Rotation of the casing during the embedment process may be accomplished, by way of example, by a drive system comprising an electric motor **22**, a pinion gear **23** driven by the motor, and a driven gear **24** fixed to roller shaft **17** and in mesh with gear **23**. The rotation of roller shaft **17** imparts rotation to the casing by means of a frictional drive through rollers **19** and **21**.

The table **12** may, by way of example, be tilted by means of a motor driven worm and sector unit. Sector **25** is fixed to pivot shaft **14** and may be actuated by a worm **26** driven by a reversible motor **27**, preferably of a variable speed type, which may be mounted on frame **15**.

The coating material dispensing means illustrated in FIGS. 1–3 will now be described. Two separate identical units are employed. Each is comprised of a hopper **31**, a ported duct **32**, and a port cover **33**. The hopper **31** has a loading hatch (not illustrated) and has a conical portion **34** to which the duct **32** is attached. The angle of this cone is not critical, but must be less than that of the maximum table tilt to permit all of the powder to flow out of the hopper. The duct **32** directs the coating material to the opposite end of the chamber to be coated, and is pressed through and integrated with the port cover **33** which thus supports the duct and hopper assembly in the casing. This design, with large units, may require extra supports disposed to engage the case surfaces. The end of the duct **32** is normally directed at the opposite port cover so that little coating maaterial impinges directly upon wet adhesive.

The ports in the ducts can be varied widely in design without altering the concept or adversely effecting the function of the embedment process. It has been found that the holes should be about three times as wide as the embedment granules to prevent clogging due to bridging action of the particles. The volume of powder distributed, its speed and direction are best controlled by varying the number of holes, their position and direction, and the presence or absence of baffles. Drilled holes **35**, as illustrated in FIG. 4, have been found to suffice for the embodiment of FIGS. 1–3.

The embodiment of FIGS. 1–3 has been found to be generally applicable to a wide variety of casing shapes, but is ideal for large motors with very small axial ports. The hopper and duct assembly is preferably installed unloaded and the embedment powder introduced through the hatches provided.

It is to be understood that the tumbling table illustrated diagrammatically in FIGS. 1–3 may be also utilized in the embodiments of FIGS. 5 and 7.

The embodiment illustrated in FIG. 5 is designed for use in domed casings having a large diameter to length ratio and a center port at one or both ends sufficiently large to accommodate the internally placed hoppers. Hoppers **41** are placed back to back and may or may not be fitted with hatches. The hoppers can be loaded either before or after installation in position. In the latter case, loading is accomplished by providing removable plugs. The powder is introduced by funneling it into the hopper through the open-ended duct with the casing in a tilted position. After filling of one hopper, a plug is inserted into the associated duct far enough so as to prevent powder from passing from the hopper out of the ports in the duct. The tilt of the casing is then reversed and the process repeated for the other hopper. When both hoppers have been filled, the casing is placed in a horizontal attitude, and the plugs are withdrawn so that the ports are opened, but not so far as to permit powder to escape through the duct to the exterior of the casing. The unit is then ready for use.

In the embodiment of FIG. 5, the ducts **42** are usually quite short and may be simply drilled to provide the port holes **43**. Connection to the port covers **44** provides the support as in the embodiment of FIGS. 1–3. Baffles **45** may be provided for the ducts to direct the powder flow, as shown in FIG. 6.

The embodiment of FIG. 7 utilizes a single connecting duct **51** between the two externally located hoppers **52**. This arrangement is especially suitable for casings with low diameter to length ratios, where it is undesirable to have all the powder for the comparatively large cylindrical area impinge upon the domes of the casing. The single duct **51** is permanently or semi-permanently attached to one hopper and may be connected to the other hopper by a simple flexible slip connector **53**. To assemble this unit the duct **51** and the attached hopper are passed into the casing from one end until the opposite end of the duct extends through the opposite port sufficiently far to permit the other hopper to be connected to the duct by means of slip connector **53**. Then the assembly is positioned so that the port covers may be inserted into the ports to seal the chamber.

FIG. 8 illustrates the port details for use in the embodiment of FIG. 7. The powder ejection holes **54** are made by slitting the duct **51** on a short circumferential arc and then pushing in that edge. It is to be noted that these flanged ports are directed so that only powder flowing from the hopper at the opposite end of the duct may pass through the port, to insure that the powder is directed substantially at the casing port covers as it flows from the duct.

In operation, the hoppers are installed and loaded with powder. The amount of powder required for use in this process has been found to be only 20–50% in excess of the amount ultimately desired to be embedded. For instance, if 40 pounds of embedment is indicated, then 25–30 pounds would be placed in each hopper. To allow for installation time and provide for uniformity in processing, time is provided for pre-embedment cure of the adhesive. This time is based on tackiness measurements. In the process utilized by the instant invention,

the adhesive may be much more fluid and its exact condition much less critical than in the previously used embedment processes.

The rocket motor casing is then rotated at a rate of 3–20 r.p.m. and tipped, first toward one end and then the other until all the powder has been distributed. The time for each tipping cycle can be from 1–5 minutes per cycle. The number of cycles usually employed is from 5 to 10. It is desirable that the powder addition be slow so that there is little unembedded powder present in the casing at any time. Rotation is usually restricted to one direction, though reversal is beneficial if there are slivers or other projections on the interior of the casing. The maximum angle of tilt recommended is 45 degrees.

The powder is sprinkled from the duct ports onto the opposite casing port covers and domes of the casing, sticking where it hits open adhesive surface. Excess powder not adhering to the domes runs to the cylindrical portion of the casing interior and is embedded there as the tilt table assumes its horizontal attitude. When the powder supply in the hoppers is consumed, the rotation and tilt of the casing is stopped, and the excess loose powder in the casing is removed after the adhesive has had time to cure completely. The small amount of excess powder may be removed by a vacuum sweeper and discarded.

When a regularly dimensioned particulate material is scattered over an adhesive surface it will be randomly positioned. There will be intergranular spaces of all sizes, but too small to admit additional particles of the original size. To increase the coverage and hence the strength of the ultimate case bond, it has been found desirable to use two sizes of powder sequentially. This is known as bimodal embedment. Applying this process to the Polaris second stage casing, for example, approximately 60 pounds of 70 mil powder, of which about 40 pounds will be embedded, are used in the first step. The 40 pounds will be embedded fairly rapidly, and the hoppers are then emptied and reloaded with 10 pounds of 45 mil powder. About half of the 10 pounds finds position in the bond layer, and the strength of the case bond is increased about 10–15%. This process can be repeated, but the further gains will be much less significant.

The coating process of the instant invention thus provides several advantages over the processes previously in use. The conditions required for effective embedment are much less critical, and highly uniform coatings may thereby consistently obtained. Powder wastage resulting from the need to provide sufficient excess to assure adequate coverage is greatly reduced, with attendant economy of equipment, supplies and operation. Time requirements are greatly reduced for the pre-embedment cure and the actual embedment operation. Finally, safety hazards represented by excessively large amounts of powder granules are substantially reduced.

It should be understood that the foregoing disclosure relates to only a few preferred embodiments of the invention, and that numerous modifications or alterations may be made therein without departing from the spirit and the scope of the invention as set forth in the appended claims.

What is claimed and desired to be secured by Letters Patent of the United States is:

1. A device for coating the interior surface of a drum comprising:
- drive means for rotating the drum about its longitudinal axis;
- tilt means for varying the inclination, in a vertical plane, of the longitudinal axis of the rotating drum;
- support means for supporting the drum during the coating operation;
- coating material reservoir means mounted in predetermined relation to the drum substantially along the longitudinal axis of the drum;
- means including a plurality of ports for providing communication for coating material between said reservoir means and the interior of the drum;
- said drive means and said tilt means being operative to effect simultaneous rotation of the drum and alternate raising and lowering of the respective ends of the drum, thereby to facilitate uniform application of the coating material to the sides and ends of the drum interior.

2. A device for coating the interior surface of a drum comprising:
- drive means for rotating the drum about its longitudinal axis;
- tilt means for varying the inclination, in a vertical plane, of the longitudinal axis of the rotating drum;
- support means for supporting the drum during the coating operation;
- coating material reservoir means mounted externally of said drum at each end thereof in a predetermined relation thereto, and substantially along the longitudinal axis of the drum;
- duct means extending from each of said reservoir means through the respective substantially closed adjacent end portions of the drum and into the drum interior;
- said drive means and said tilt means being operative to effect simultaneous rotation of the drum and alternate raising and lowering of the respective ends of the drum, thereby to facilitate uniform application of the coating material to the side ends of the drum interior.

3. A device for coating the interior surface of a drum comprising:
- drive means for rotating the drum about its longitudinal axis;
- tilt means for varying the inclination, in a vertical plane, of the longitudinal axis of the rotating drum;
- support means for supporting the drum during the coating operation;
- coating material reservoir means mounted internally of the drum in a predetermined relation thereto, and substantially along the longitudinal axis of the drum;
- means including a plurality of ports for providing communication for coating material between said reservoir means and the interior of the drum;
- said drive means and said tilt means being operative to effect simultaneous rotation of the drum and alternate raising and lowering of the respective ends of the drum, thereby to facilitate uniform application of the coating material to the sides and ends of the drum interior.

4. The method of coating the interior surface of a drum comprising:
- applying a layer of adhesive to the interior surface of the drum;
- rotating the drum about its longitudinal axis;
- simultaneously rocking the rotating drum;
- gradually introducing a quantity of granular coating material into the interior of the drum during the rotation and rocking of the drum so that the coating material will adhere to the adhesive.

5. The method of coating the interior surface of a drum comprising:
- applying a layer of adhesive to the interior surface of the drum;
- rotating the drum about its longitudinal axis;
- simultaneously varying the angle which the longitudinal axis of the drum makes with respect to a horizontal reference plane; and
- coating the interior surface of the drum by causing a granular coating material to impinge upon alternate ends of the drum as the respective ends of the drum are alternately rocked to a depressed attitude, thereby causing the coating material to adhere to the adhesive layer.

6. The method of coating the interior surface of a drum comprising:

applying a layer of adhesive to the interior surface of the drum;

rotating the drum about its longitudinal axis;

simultaneously varying the inclination, in a vertical plane, of the longitudinal axis of the rotating drum, whereby one end of the drum is alternately raised above and lowered below the other end of the drum;

and coating the interior surface of the drum by gradually introducing a granular coating material into the rotating and rocking drum in such a manner that the material is applied alternately to the respective ends of the drum as the respective ends of the drums are rocked into the relatively lower position thereof.

References Cited by the Examiner

UNITED STATES PATENTS

1,850,576	3/1932	Zimmerman	118—418
2,146,819	2/1939	Hall	117—18

WILLIAM D. MARTIN, *Primary Examiner.*

REUBEN EPSTEIN, L. DEWAYNE RUTLEDGE, *Examiners.*

M. R. DINNIN, H. E. BEHREND, P. F. ATTAGUILE, *Assistant Examiners.*