Dec. 17, 1957 S. A. JOHNSON 2,816,523

APPARATUS FOR VACUUM COATING ELECTRICAL RESISTORS

Filed April 9, 1954 2 Sheets-Sheet 1

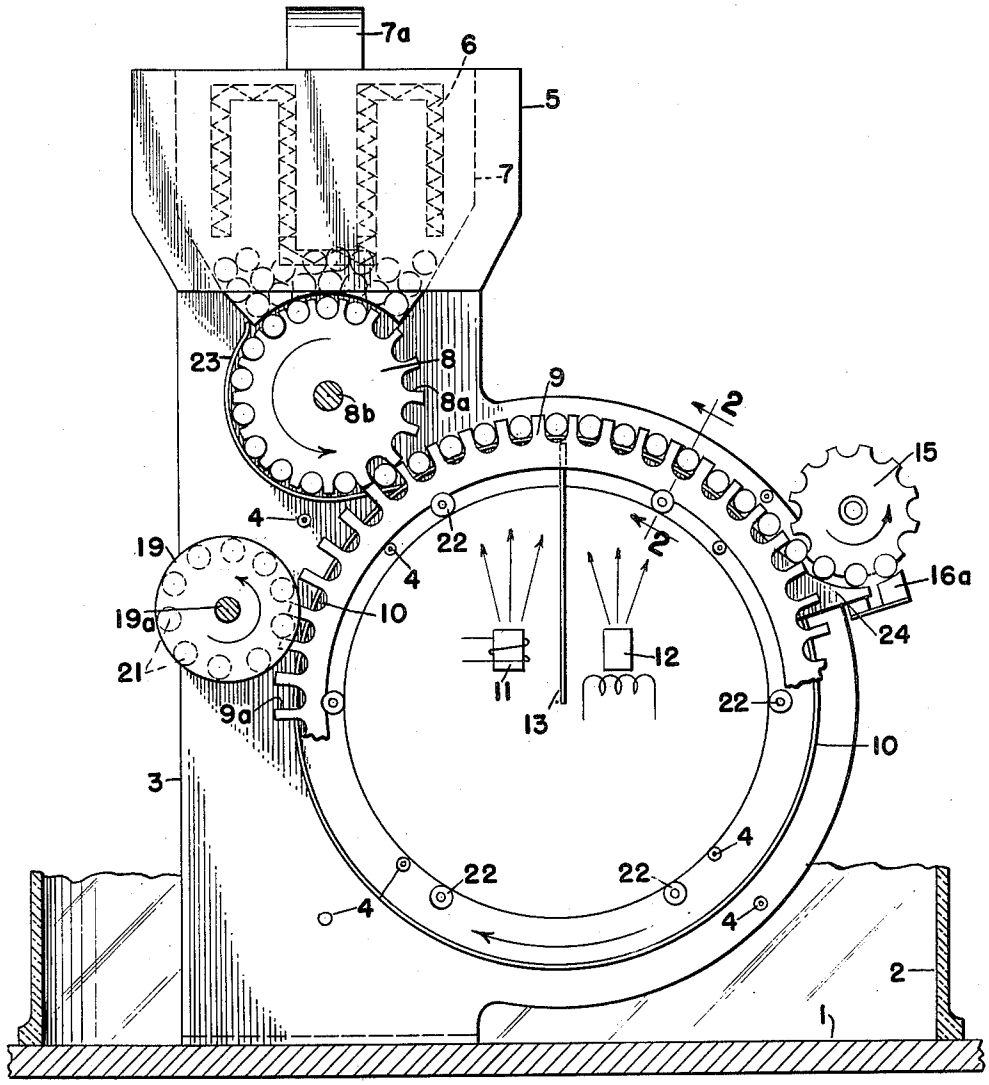


FIG.1

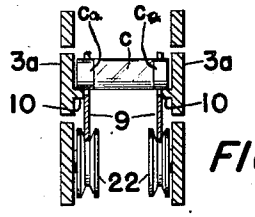


FIG.2

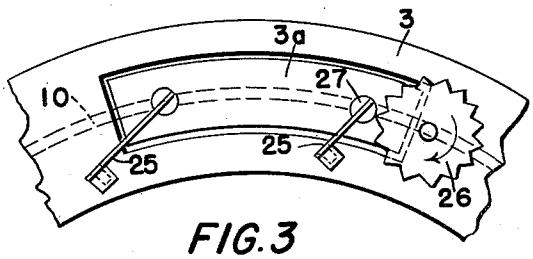


FIG.3

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APPARATUS FOR VACUUM COATING ELECTRICAL RESISTORS

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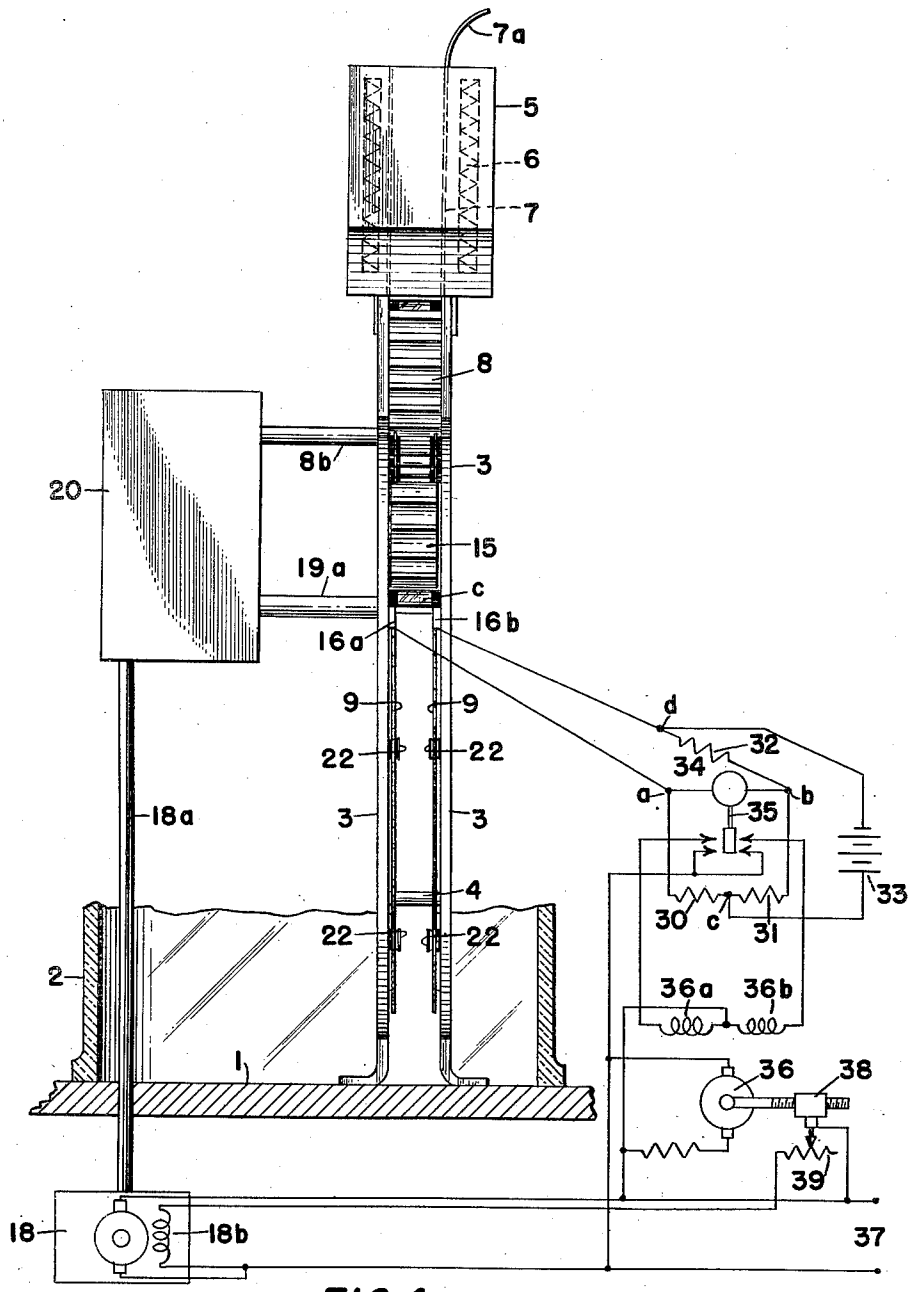


FIG. 4

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APPARATUS FOR VACUUM COATING ELECTRICAL RESISTORS

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Application April 9, 1954, Serial No. 422,169

6 Claims. (Cl. 118—8)

This invention relates to apparatus for producing electrical resistors of the type comprising metallic films deposited upon tubular or cylindrical dielectric carriers. While my invention is especially useful for the production of electrical resistors, it is not limited to such use and may have other uses in the coating art.

One object of the invention is to devise apparatus for coating carriers in which the carriers are automatically loaded upon a moving carriage from a bulk supply and are conveyed by the carriage through a coating zone where the coating is applied to the carriers.

Another object of the invention is to devise an arrangement in which the film deposited upon the tubular carrier is of uniform thickness around the entire cylindrical surface of the carrier. Provision is made to rotate each carrier about its own axis as it passes through the coating zone.

A further object of the invention is to devise apparatus for applying coatings to a plurality of tubular carriers in such a manner that the coatings on all of the carriers will be uniform. This is accomplished by automatically controlling the speed of conveying the carriers through the coating zone in response to a device which senses or measures a characteristic of the coating on the carriers as they leave the coating zone.

Another object of the invention is to devise apparatus for applying a protective film over a thermally evaporated metallic film before exposing the metallic film to the atmosphere. Both coating operations are carried on at the same time but in different sections of the coating zone.

A preferred form of the invention is illustrated in the accompanying drawing, in which:

Figure 1 is a side elevational view of the apparatus with one of the side supporting members removed;

Figure 2 is a sectional view on an enlarged scale taken along the line 2—2 of Figure 1;

Figure 3 is an enlarged fragmentary view showing details of the construction in the same area as that of Figure 2; and

Figure 4 is an end elevational view of the apparatus including a schematic representation of the means for controlling the operation of the apparatus.

Referring to Figure 1 of the drawing, the apparatus is mounted on a base plate 1 and enclosed by a bell jar 2. The enclosure thus formed is evacuated by means of suitable apparatus not forming a part of this invention and not shown. Two side members 3 are held in spaced relation by spacers 4 and form the main supporting structure of the apparatus. Mounted on the uppermost portion of the supporting structure is a housing 5 containing heating coil 6 and enclosing a removable hopper 7 which contains a supply of carriers to be coated. In this instance the carriers are formed of short sections C of glass tubing which have been fire polished on each end and have had a conducting collar Ca formed on each end by any well known process, see Figure 2. Immediately below the housing 5 is the feed wheel 8 for transferring carriers from hopper 7 to a movable carriage. This wheel has radial slots 8a formed in its periphery for the purpose of receiving carriers from hopper 7. Transfer wheel 8 is located immediately below the hopper 7, the bottom of the hopper being open and the sides of the hopper conforming with the periphery of the wheel 8 so that carriers contained within the hopper may fall by gravity into the slots 8a. A curved guide 23 is provided to hold the carriers in the radial slots 8a of feed wheel 8 while they are being transferred to a movable carriage comprising carrier wheel 9. The hopper 7 may be removed through the open top of the housing 5 by the finger tab 7a. When the hopper is filled with carriers, the bottom is closed by a curved, sliding wall section which may be removed through an opening in one of the side members 3 after the hopper is in position above the wheel 8.

In order to provide an unobstructed coating zone and convenient access to the coating material sources, carrier wheel 9 is constructed of two annular rings supported in spaced relation by grooved rollers 22 which are mounted on side members 3. The peripheries of these rings have radial slots 9a formed therein for the purpose of receiving the tubular carriers, and the pitch or spacing between the centers of the radial slots in the carrier wheel 9 and in the feed wheel 8 are identical. In order to rotate the carrier wheel 9 and maintain the two rings in proper relationship or alignment, a driving wheel 19 is provided having mounted thereon a series of rollers 21 which are of approximately the same diameter as the tubular carriers. The pitch or spacing between the center lines of the rollers 21 is identical with the pitch of the radial slots in carrier wheel 9 and feed wheel 8. As the feed wheel 19 rotates in a counterclockwise direction, the rollers 21 successively engage corresponding radial slots 9a in the carrier wheel 9, thereby causing carrier wheel 9 to rotate in a clockwise direction. Suitable gearing is provided between driving wheel 19 and feed wheel 8 so as to maintain carrier wheel 9 and feed wheel 8 in synchronism at all times.

Referring now to Figures 2 and 3 of the drawing, it will be seen that side members 3 have formed on the inside faces thereof arcuate stationary tracks 10. These tracks are shown as forming a complete circle on each side member, but, if so desired, the lower portions of the track may be omitted. These tracks are provided to support the ends of the tubular carriers and are so positioned that the carriers do not touch the bottom of radial slots 9a in the carrier wheel 9. As the tubular carriers are transferred to the radial slots 9a of the carrier wheel 9, they rest upon the stationary tracks 10 and the rotation of the carrier wheel 9 causes them to roll along the tracks, thereby effecting rotation of each carrier about its own axis. In order to assure the continued uniform rotation of the tubular carriers, it has been found desirable to vibrate the sections of track 10 which extend over the coating zone in such a manner as will tend to cause the carriers to rotate independently of the rotation caused by the carrier wheel 9. This is accomplished by isolating a section 3a of each side member 3 and providing sufficient clearance around it to allow the desired vibration to take place. These isolated sections 3a are supported by means of springs 25 which have one end fixed to the side members 3 and the other end attached to posts 27 mounted on sections 3a. The angular position of these springs will determine the direction in which sections 3a are permitted to vibrate and the vibration is set up by the rotation of toothed wheel 26 which engages one of the posts 27. As shown in Figure 3, the mounting springs 25 are arranged with their axes at an angle to the adjacent track 10 so that the isolated track sections are vibrated with a

component of movement parallel with the track and another component transversely of the track. The arrangement is such that when the isolated track sections are being moved upwardly, they simultaneously move rearwardly in opposition to the direction of rotation of the carrier wheel **9**. While this is the preferred arrangement, some advantage may be obtained by vibrating the isolated track sections in a vertical direction only.

Returning now to Figure 1, it will be seen that the coating zone is divided into a first section and a second section by a baffle **13**. Mounted within the inner circumference of carrier wheel **9** so as to irradiate the first portion of the coating zone is a source **11** of a molecular radiation of a suitable metal to form the resistive coating, such as chromium or a nickel-chromium alloy. Similarly mounted on the opposite side of baffle **13** in such a position as to irradiate the second section of the coating zone is a source **12** of vaporized protective coating material such as silicon monoxide.

At the opposite end of the coating zone from feed wheel **8** is a delivery wheel **15** of similar construction to that of feed wheel **8**. An unloading ramp **24** is provided between rings **9** to transfer the carriers from carrier wheel **9** to delivery wheel **15**. As the carriers are transferred to delivery wheel **15**, it is caused to rotate and rotation of wheel **15** moves the carriers onto two contact blocks **16***a* and **16***b* which are insulated from each other and from other parts of the machine. In order to avoid the possibility of the first carrier to be transferred jamming the apparatus before synchronism is established between delivery wheel **15** and carrier wheel **9**, delivery wheel **15** is spring mounted by means not shown. Contact blocks **16***a* and **16***b* are positioned to engage the low resistance collars carried at the ends of the carriers, and these blocks are provided with connection leads which extend through the base **1** for purposes indicated below. These contact blocks are sufficiently long so that by the time one carrier is in a position to move off of the rear end of the block, another carrier is in position to move onto the block at the front end. As the carriers pass beyond the outer end of the contact blocks, they drop out of the slots in the wheel **15** and are conveyed by any suitable means, such as an inclined chute, to the bottom of the bell jar where they may be deposited either upon the base **1** or within a suitable tray or bucket enclosed within the jar.

The feed wheel **8** and the driving wheel **19** are driven by a suitable power source, such as the electric motor **18** mounted below the base **1** and having a drive shaft **18***a* extending through the base and driving a gear train **20** which in turn drives shafts **8***b* and **19***a* of wheels **8** and **19**. The operation of the coating apparatus described above is believed to be obvious from the description. The preferred conditions for producing a satisfactory resistor by the thermal evaporation process carried out by this apparatus are set forth in U. S. Patent No. 2,586,752.

Since the thickness of the film formed on the tubular carriers is affected by the speed of rotation of carrier wheel **9**, it is desirable to govern this speed of rotation in order to maintain a uniform thickness of film on all the carriers. For this purpose contact blocks **16***a* and **16***b* are connected to a suitable electric circuit for sensing or measuring the resistance of the metallic film deposited on the carriers by the source **11**, and a suitable control arrangement responds to a change in resistance from a desired value to vary the speed of the carrier wheel in a direction to restore the resistance to the desired value. One suitable sensing circuit and control arrangement is shown diagrammatically in Figure 4. The sensing circuit comprises a Wheatstone bridge having two arms **30** and **31** connected in series between diagonal points (*a*) and (*b*) and another pair of arms formed of resistor **32** and the resistor element resting on contact blocks **16***a* and **16***b* and also connected in series across points (*a*) and (*b*). A suitable source of current **33** is connected across the other pair of diagonal points (*c*) and (*d*) and a zero-center current-responsive device **34** is connected between diagonal points (*a*) and (*b*). The bridge is adjusted so that when the coated resistor has a desired resistance value, the bridge is balanced and the armature **35** of the current device **34** is in neutral position. If the resistance value varies from the desired value, the armature **35** will move in one direction or the other, depending upon whether the resistance value is greater or less than the desired value. Armature **35** is arranged to control the direction of rotation of a pilot motor having an armature **36** and a divided field winding **36***a* and **36***b*. The motor armature is energized from a suitable supply circuit **37**, and connections are controlled by armature **35** to energize one or the other field winding sections **36***a* or **36***b*, to drive the motor armature **36** in one direction or the other when the armature **35** moves from its neutral position. The motor **36** operates with suitable means represented by the threaded shaft and collar **38** to vary the resistance **39** which is connected in the energizing circuit of the field winding **18***b* of motor **18**, the armature of motor **18** being constantly energized from supply circuit **37**.

The control circuit shown in Figure 4 is arranged so that an increase in resistance of the coated resistors above the desired value will effect a slowing down of the speed of the motor **18**, and a decrease in the resistance value below that desired will effect an increase in the speed of the operation of the motor **18**. So long as the coated films are of the desired resistance value, the armature **35** will remain in neutral position and the motor **18** will operate at a constant speed. It will be obvious that other arrangements than the particular arrangement illustrated and described may be employed for regulating the speed of the carrier wheel **9**. Also, other devices may be used to sense the thickness of the coating.

I claim:

1. Film forming apparatus comprising a movably mounted carriage having means thereon to convey a plurality of carriers to be coated through a coating zone, means to rotate said carriers with respect to said carriage while traversing said coating zone, means for storing a supply of said carriers, means for loading said stored carriers on said carriage at one end of said coating zone, a vacuum chamber enclosing said carriage, said rotating means, said storage means and said loading means, and a source of molecular radiation arranged within said chamber to simultaneously irradiate said carriers as they pass through said coating zone.

2. Apparatus for depositing films upon cylindrical carriers comprising, in combination, a movably mounted carriage having means thereon to convey a plurality of carriers in succession through a coating zone, two tracks mounted adjacent to and parallel with said carriage through said coating zone, said carriers being supported at their ends upon said tracks and being free to roll on said tracks as they are conveyed through said coating zone, means to deposit a film on said carriers as they pass through said coating zone, and means to vibrate said tracks in a plane perpendicular to the axis of said carriers.

3. Film forming apparatus comprising a movably mounted carriage having means thereon to convey a plurality of carriers through a coating zone, means to rotate said carriers with respect to said carriage while traversing said coating zone, means for storing a supply of said carriers, means for heating said stored carriers, means for loading said stored carriers on said carriage in succession at one end of said coating zone, a vacuum chamber enclosing said carriage, said rotating means, said storage means, said heating means, and said loading means, a source of metallic molecular radiation arranged within said chamber to irradiate said carriers as they pass through the first section of said coating zone, and a source of non-metallic molecular radiation arranged within said

chamber to irradiate said carriers as they pass through the remaining section of said coating zone.

4. Apparatus according to claim 3 wherein said rotating means comprises two stationary tracks mounted adjacent to and parallel with said carriage to support the ends of said carriers in rolling relation with said tracks, and means to vibrate said stationary tracks in a plane perpendicular to the axis of said carriers.

5. Apparatus according to claim 4 and including means mounted within said chamber for sensing the conductivity of the metallic film formed on said carriers, and means responsive to variations in said conductivity to vary the speed of said carriage.

6. Apparatus for depositing films upon cylindrical carriers comprising, in combination, a carrier wheel comprising two annular carrier rings mounted in spaced coaxial relation and having radial slots formed in the periphery thereof to receive said carriers, two stationary, arcuate tracks mounted adjacent the outside faces of said carrier wheels in concentric, parallel relation thereto and providing supports for the ends of carriers located within said slots, a driving wheel having driving members thereon which engage the radial slots in said carrier rings causing said carrier wheel to roll said carriers along

said stationary tracks, a hopper mounted above said carrier wheel to store said carriers, a feed wheel having radial slots formed in the periphery thereof and mounted between said hopper and said carrier wheel, said feed wheel serving to transfer said carriers in succession from said hopper to the radial slots in said carrier rings, an unloading ramp disposed between said carrier rings at a discharge station spaced from said feed wheel, a delivery wheel at said discharge station having radial slots formed in the periphery thereof to receive said carriers unloaded by said ramp, sensing means embodied in said unloading ramp for sensing a condition of the unloaded carriers, and means controlled by said sensing means for controlling the speed of rotation of said carrier wheel.

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