March 14, 1961 J. C. WESTERVELT ET AL 2,974,632

APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGE

Filed April 23, 1958

2 Sheets-Sheet 1

Fig. 1

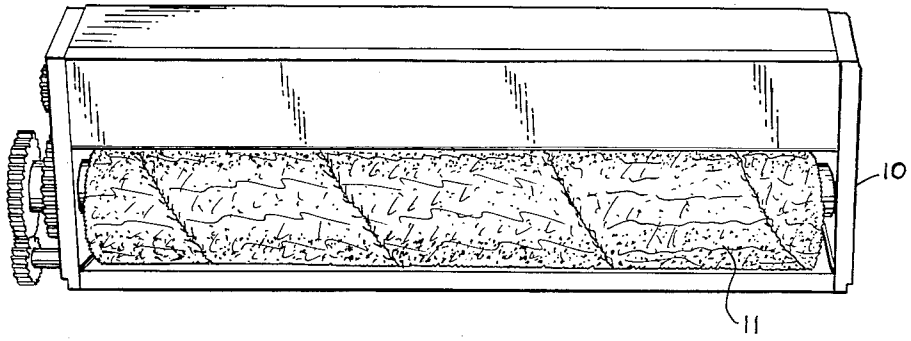


Fig. 2

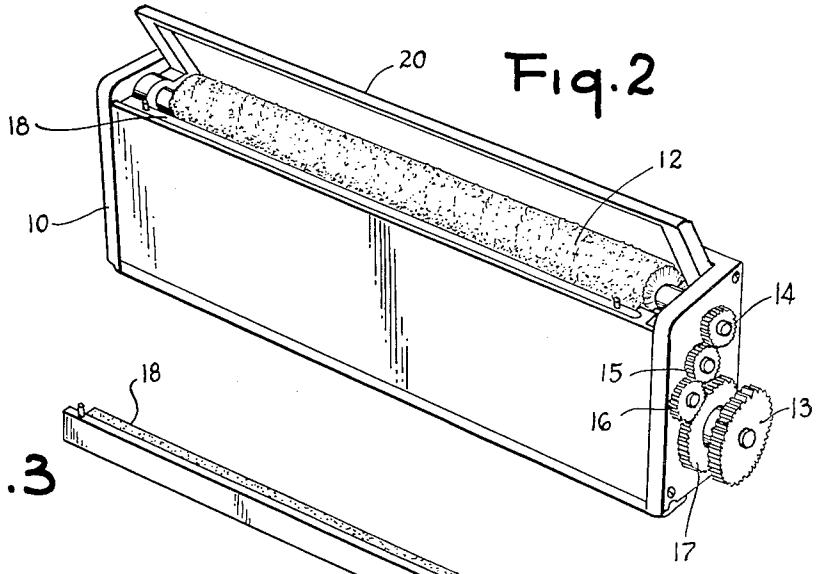


Fig. 3

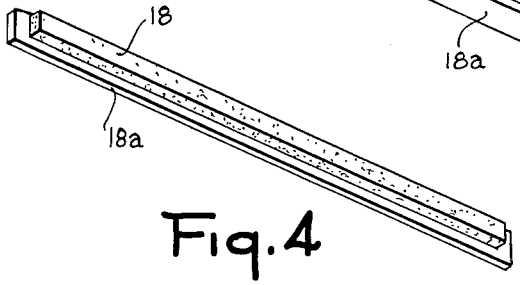


Fig. 4

INVENTORS
JOHN C. WESTERVELT
JAMES N. HILDERBRAND
BY
Ooms, McDougall, Williams & Hersh
ATTORNEYS

March 14, 1961 J. C. WESTERVELT ET AL 2,974,632

APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGE

Filed April 23, 1958

2 Sheets-Sheet 2

Fig. 5

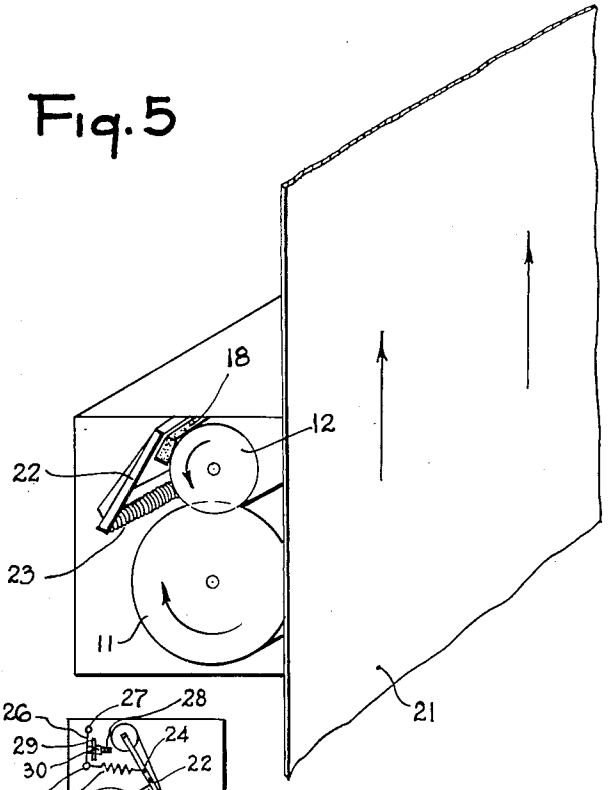
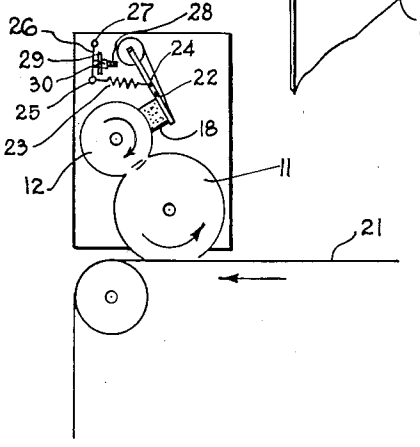


Fig. 6



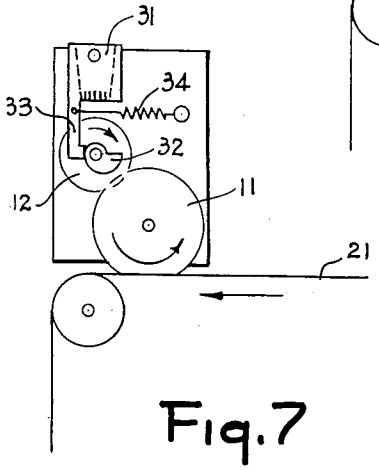


Fig. 7

INVENTORS
JOHN C. WESTERVELT
JAMES N. HILDERBRAND
BY
Ooms, McDougall, Williams & Hersh
ATTORNEYS

United States Patent Office 2,974,632 Patented Mar. 14, 1961

2,974,632

APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGE

John C. Westervelt and James N. Hilderbrand, Tulsa, Okla., assignors to Century Geophysical Corporation, Tulsa, Okla., a corporation of Delaware

Filed Apr. 23, 1958, Ser. No. 730,460

7 Claims. (Cl. 118—637)

This invention relates to the art of electro-photography; in particular, it concerns an improved apparatus for developing a visual image from an electro-static latent image formed by electrophotography on a sheet of paper or other material.

Developing a visual image from an electrostatic latent image is normally accomplished by depositing on the image-carrying sheet a quantity of finely divided dark-colored thermoplastic powder, commonly called "toner." The toner adheres to the electrically charged surface of the image-carrying sheet in proportion to the electric charge deposited thereon, with the result that the toner produces a visual representation on the sheet corresponding to the electrostatic latent image. This visual image is then "fixed" by heating the sheet and thus fusing the toner powder.

In the prior art various means have been employed to apply the toner powder to the charged sheet for developing electrostatic latent image. One widely used means has been the so-called magnetic brush, normally consisting of a stack of magnetized discs mounted for rotation on a spindle. In magnetic brushes of this character, the toner powder is mixed with iron powder and allowed to sift onto the surface of the brush from a suitable container mounted thereabove. The toner particles adhere to the iron particles and are thus held by the magnetic field on the surface of the magnetized "brush." The image-carrying sheet is advanced past the brush while it is being rotated, and the particles of toner powder are thereby brushed against the sheet. The iron powder is for the most part held on the discs by the magnetic forces, but the toner particles, not being magnetic, are attracted by the electric charges on the sheet and hence are deposited thereon in a density distribution corresponding to the electrostatic latent image.

Other devices for sprinkling toner powder on the surface of an image-carrying sheet are known to the art, but need not be described in detail herein. All of the prior-art developers have had serious shortcomings.

One of the most serious disadvantages of prior-art developers has been that the toner powder is not completely captive and, after the apparatus has been used for a while, the powder spreads throughout the developer housing, contaminating the sensitized sheets being developed and making the apparatus messy to handle and work with.

Another serious disadvantage of prior-art developers is that they all use the force of gravity in one manner or another to guide the toner powder from its storage magazine onto the image-carrying sheet, thus preventing the apparatus from being used in any attitude other than that for which it was designed.

The present invention provides a developer for electrophotographic images which can be used in any position and which is characterized by virtually complete freedom from vagrant powder particles. To provide such a developer is a major object of the present invention.

Another serious disadvantage of prior-art developers is that the toner powder, stored in a magazine in powder form, is subject to "caking up" in the presence of heat and humidity, becoming thereby incapable of flowing freely. This disadvantage is not present in the invention herein described, and therein resides another of its important objects.

A further object of this invention is to provide a developer for electrostatic photography which performs as well or better than the best magnetic-brush developers without requiring any magnetized components, thus contributing both simplicity and economy to the apparatus.

A still further object of the present invention is to provide a developer for electrostatic photography in which the quantity of toner powder fed to the surface of the image-carrying sheet can be accurately metered. The achievement of this object represents an important improvement over the prior art, since all the earlier developers were far from satisfactory in that respect.

Other objects and advantages of the present invention will be apparent as this specification proceeds.

An important feature of our invention consists in the replacement of the usual toner magazine with an integrated self-supporting cake of toner powder, from which small quantities of finely divided toner are removed by abrasion as needed.

We have found that it is possible to prepare toner powder in the form of a self-supporting integrated cake, sufficiently rigid to withstand ordinary handling and at the same time capable of yielding up adequate amounts of loose toner powder, having the original particle size, when the surface of the cake is suitably abraded with a stiff brush or other suitable means. Suitable cakes of toner can be prepared by mixing with the original finely divided powder small amounts of such well-known bonding agents as kaolin, resin binders, starch, sugar, or water, and then subjecting the material to pressure. Indeed, toner powder can be adequately caked for use in our invention by applying pressure alone, even without the use of any bonding agents, if the pressure used be sufficiently high.

We have found it desirable to provide additional mechanical strength for the toner cakes by mounting them on a rigid backing plate of metal, plastic, or other suitable substance.

For use in our developer, we prepare toner cakes in this manner and adapt them to be inserted when needed as replacement charges of toner. We have found that the toner powder, when supplied to the developer in this form, remains at all times captive and is very much easier to work with and to distribute properly without contamination of the apparatus. The shape and size of the toner cakes may suit the designer's convenience, depending upon the supply or volume of toner desired as a single charge and depending also on the dimensions of the image-carrying sheets to be developed.

To remove loose toner powder from a cake as above described and to transfer it to the surface of the sheets to be developed, we employ the cooperative action of two brushes. These brushes are rotatably mounted in such manner that they rub against one another during rotation, one of the brushes being in continuous abrading relationship to the surface of the toner cake and the other brush being in continuous wiping relationship to the surface of the image-carrying sheet.

The brush used for rubbing against and abrading the toner cake is preferably a rather stiff brush, which may be made from goat hair or other suitable bristles. By rotating continuously against the surface of the toner cakes, this stiff brush continuously abrades away small quantities of the toner powder and feeds it to the second brush coated with soft fur, which wipes the toner powder

onto the surface of the sheet to be developed. Suitable means may be used for controlling the pressure between the stiff brush and the toner cake, thereby metering or adjusting to the desired value the rate at which the toner is removed from the cake and fed to the second brush.

We have found that many types of fur may be used for the second brush, those of very soft texture being most suitable. Baby mouton fur is a particularly satisfactory type. On comparing sheared and unsheared furs, we have found that the sheared furs are better, since shearing removes the coarse outer hair and exposes the underlying down found on many animals.

In addition to using many types of animal furs successfully, we have found that soft natural fibers of vegetable origin and soft synthetic fibers can likewise be successfully employed as the surface material in the second brush.

As heretofore mentioned, the two brushes are in continuous rotation during the development operation, and the sheet to be developed is progressively advanced as the soft fur brush rubs against it. Best results are obtained when the direction of rotation of the soft fur brush is such that its motion at the line of contact with the sheet is opposite to the direction in which the sheet is being advanced.

When our invention is used as above described, the developing apparatus can be operated in any position. This characteristic makes our developer particularly valuable for use in air-borne equipment, guided missiles, and the like, wherein the attitude of the developing apparatus relative to the force of gravity changes during use.

The remarkable freedom from powder contamination which is characteristic of our developer appears to be due at least in part to the fact that the toner powder is sufficiently attracted to the surface of the fine fur brush that it has no tendency to pull away therefrom except in response to the electric forces present on the latent image. The result is developed images which are sharp, clean, and more free from background "shadow."

In the appended drawing, we have shown several embodiments of our invention. Fig. 1 is a perspective view of a typical developer according to our invention, the apparatus being shown in a position wherein the fine fur brush is plainly visible. Fig. 2 is a view of the Fig. 1 developer from a different angle, in which the abrading brush and the toner cake are visible. Figs. 3 and 4 are views of typical toner cakes provided with reinforcing backing plates. Fig. 5 is a diagrammatic view showing one means of mounting the developer of our invention for active cooperation with a sheet to be developed, the sheet in Fig. 5 being positioned to advance in a vertical direction. Fig. 6 is another diagrammatic view in which our developer is shown arranged for use in conjunction with a moving sheet advancing in a horizontal plane. Fig. 7 is a diagrammatic view generally similar to Fig. 6, wherein the sub-combination comprising our novel brush assembly is used in conjunction with a conventional loose-powder toner magazine.

Referring first to Fig. 1, we show therein a perspective view of an actual working embodiment of our invention which has been successfully employed in electrophotographic oscillographs. Fig. 2 is a view of the same structure from a different angle, showing the top of the apparatus with the hinged cover moved backward.

The frame or housing **10** provides journal bearings for two rotary brushes, the fur brush **11** and the stiff abrading brush **12**, both of which are cylindrical in shape and are of such length as substantially to fill the entire length of the housing **10**. It should be understood that in practical embodiments of the invention the width of the brushes **11** and **12** will be made slightly greater than the width of the image-carrying sheet to be developed.

As may be readily seen from Fig. 1, the fur brush **11** is made by covering the exterior of a cylindrical mandrel with a spiral coating of a very soft fur such as baby mouton. The abrading or combing brush **12**, made of relatively stiff bristles such as goat hair, is mounted above the fur brush **11** and so positioned that the bristles of brush **12** bear against the fur of brush **11**, so that, in rotating, they pass to some extent through the outer portions of the fur brush **11** and hence comb it, a procedure which assists substantially in achieving uniform distribution of toner powder throughout the brush **11**.

As may be best seen in Fig. 2, the brushes are provided with suitable driving gears which make it convenient to rotate them simultaneously in response to any desired source of rotary motive power connected to the driving gear **13**. Coupling gears **14**, **15**, **16**, and **17** interconnect the combing or abrading brush **12** and the fur brush **11**, causing brush **12** to turn in the opposite direction from that of brush **11** and at a substantially higher speed, to facilitate the combing action heretofore mentioned.

Near the upper part of Fig. 2, just inside the forward wall of casing **10**, the toner cake **18** may be seen. This toner cake, which is also shown in Figs. 3 and 4, is mounted on spring-loaded arms, not visible in Figs. 1 and 2 but diagrammatically shown in the other figures presently to be described. The arms supporting the toner cake **18** are pivotally journaled in the end plates of the housing **10** so as to afford to the toner cake a limited range of arcuate movement, permitting it to bear at all times against the surface of abrading brush **12** despite the wearing away of the toner cake as it is used.

As shown in Figs. 3 and 4, the toner cake is preferably cemented to or otherwise mounted on a stiff or rigid backing member **18***a*, made of metal, rigid plastic, or other suitable material, which also provides a convenient means of supporting the cake on its supporting arms.

The dimensions of the toner cake will of course be governed by the brush length and will in practical embodiments also be influenced by the total length of the image-carrying sheet normally to be developed. It is usually most convenient to use toner cakes of such size that they will provide approximately enough toner powder for the development of one entire roll of image-carrying paper or other sheet material. This arrangement permits replacing the toner cake as a matter of routine each time the exhausted roll of sensitized sheet material is replaced.

It is not essential, however, that the size of the toner cake be so proportioned as to require its replacement at the same time as the replacement of the sensitized sheet. Smaller sized toner cakes may be used, and replaced during the development operation. This is possible because the brush **12** and the fur brush **11** in operation carry in suspension on their respective surfaces substantially more toner powder than is necessary to continue normal development during the short period required for replacing the toner cake.

To permit convenient access to the interior of the housing **10**, and particularly to facilitate replacement of the toner cake **18**, the housing **10** is preferably provided with a hinged cover **20**, normally closed during operation but which may be tilted open, as shown in Fig. 2, when replacement of a toner cake is desired.

The structural interrelation of the brushes, the toner cake, and the spring-loaded arms which support the toner cake is brought out more clearly in the diagrammatic views Figs. 5 and 6. As shown therein, the image-carrying sensitized sheet **21**, after being charged and exposed to provide the desired electrostatic image, is passed in contact with the fur brush **11**, the direction of advancement of the sensitized sheet **21** being opposite in direction to the motion of the surface of brush **11** along the line of contact.

Mounted above fur brush **11** in both the Fig. 5 and Fig. 6 embodiments one may see the stiffer combing or abrading brush **12**, so mounted as to bear against the fur brush **11** and also to rub against the toner cake **18**. As

heretofore mentioned, the speed of rotation of the brush **12** is faster than that of the brush **11**, so that the relatively stiff bristles of brush **12** perform a combing action on the fur brush **11**.

The toner cake **18**, as heretofore mentioned, is carried on a pair of spring-loaded arms **22**, one of which may be seen in Fig. 5. The spring **23** which causes the arms **22** to bear forward and hence maintain the toner cake **18** in firm contact with the abrading brush **12** is a multiturn spring so designed that its force is practically constant throughout the small arc of movement permitted to the arms **22** during the wearing down of a toner cake **18**. This results in substantially uniform pressure between cake **18** and abrading brush **12** throughout the life of the toner cake **18**.

Preferably, to facilitate accurate metering of the toner, the force exerted by spring **23** should be made conveniently adjustable. Since the particular type of force adjustment provided for the spring **23** is not critical, this adjustability is merely illustrated diagrammatically in Fig. 6. In that view, the spring **23** is shown as a tension spring, stated at one end on a seat **24** carried on arm **22** and seated at its other end on a spring seat **25** mounted on the free end of an arm **26**, pivoted to swing on a fixed pivot **27**. An adjustment screw **28** is mounted on a suitable stationary boss **29** in such a position that its end bears against the arm **26** and hence controls its angular position. Preferably a lock nut **30** is carried on the adjustment screw **28** to permit its being securely fastened in any desired position.

It will of course be understood that any type of resilient means, including compression, tension, or torsion springs, may be employed as a means of maintaining the cake **18** in the proper position against the abrading brush **12**.

Since the cake-carrying arms **22** are preferably rigidly joined together so as to move forward and backward as a unit, only one spring **23** and adjusting means therefor need be used.

The principal difference between the embodiments shown in Figs. 5 and 6 consist in the relative positions of the developing apparatus and the sheet to be developed. In Fig. 5 the sheet is shown advancing in a vertical direction and bearing against the fur brush **11** along its side. In Fig. 6, on the other hand, the developer is mounted over the sheet which, in that embodiment, is advanced in a horizontal direction during the developing step. We have found that both the arrangements shown in Figs. 5 and 6 work equally well, and, in fact, we find that the operation of our developer is essentially independent of the direction of the force of gravity thereon. As previously mentioned, this versatility with respect to positional attitude is one of the great elements of superiority of our invention over the prior art.

We strongly recommend that our cake toner be used with brush developers of the type herein disclosed, since the full benefits of the invention can only be realized when the entire combination is employed. We have, however, found that the sub-combination consisting of the brushes **11** and **12** can be usefully employed in conjunction with a conventional source of powdered toner, as shown in Fig. 7. Therein, the toner is carried in powdered form in a magazine **31**, pivotally mounted in the housing above the stiff brush **12**. The shaft which turns brush **12** is provided at one end with a cam **32**, and the toner magazine is provided with a cam follower **33**, proportioned to bear against the cam **32**. A suitable spring **34** is provided to maintain the cam follower **33** bearing at all times against the cam **32**.

In the operation of the Fig. 7 embodiment, the toner magazine **31** is agitated once during each revolution of the brush **12**, by the cooperative action of the cam **32** and the follower **33**. With each agitation a certain amount of toner powder is released from the magazine **31** and allowed to drop onto brush **12**. Brush **12** transfers the toner powder onto the soft fur brush **11**, combing it as it does so, and the toner is then transferred by the soft fur brush **11** onto the surface of the sheet **21**.

The embodiment of Fig. 7 is less satisfactory in several important respects than the preferred embodiments shown in Figs. 1–6. For one thing, it is not capable of such accurate metering of the toner as we can obtain by the use of our novel brush arrangement in combination with a cake toner supply. For another thing, the Fig. 7 arrangement is not versatile with respect to positional attitude. It can only be successfully operated when the toner magazine is substantially directly above the brush **12**. Finally, because the Fig. 7 embodiment releases powdered toner in much less closely controlled amounts than with the preferred form of the invention, the Fig. 7 arrangement is not characterized by nearly the same freedom from vagrant toner powder as is characteristic of the preferred forms. It can, however, be used successfully in place of magnetic-brush developers in applications wherein it is not convenient to use cake toner.

While we have in this specification described in considerable detail certain typical embodiments of our invention, it should be understood that the illustrated forms of the invention are merely exemplary. Persons skilled in the art can make many changes therein and modifications of the structures shown without departing from the spirit of our invention. We therefore desire that the scope of the invention be determined primarily with reference to the appended claims.

We claim:

1. Apparatus for developing a visual image from a latent electrophotographic image on an elongated sensitized sheet by distributing toner powder thereover in a density pattern corresponding to the charge distribution in said image, comprising a toner source consisting of a cake of finely divided dark-hued thermoplastic powder pressed into a body having structural integrity but capable of releasing said powder from its surface in small quantities upon being abraded, a first cylindrical brush having abrasive properties, a second cylindrical brush having a surface formed of very soft fibers such as animal down, means for advancing the sheet to be developed progressively through a pre-selected development zone, means supporting said toner cake and said brushes in said zone, and means for rotating said brushes while said sheet is being advanced, said cake and said brushes being positioned with said first brush bearing against and abrading said toner cake as said first brush rotates and also bearing against said second brush, and with said second brush also bearing against said sheet as said second brush rotates, wiping the image-carrying surface of said sheet progressively as said sheet advances through said zone, whereby toner powder is continuously removed from said cake by said first brush, transferred to said second brush, and by said second brush transferred to the surface of said sheet.

2. The combination defined in claim 1 wherein the outer surface of said first brush comprises uniformly distributed stiff bristles operative simultaneously to abrade the surface of said cake and to comb the fine fibers of said second brush, whereby toner powder removed from said cake by said first brush is distributed in substantially uniform density throughout the fine fibers of said second brush.

3. The combination defined in claim 1 wherein resilient means are provided for urging said toner cake into contact with said first brush, said resilient means being manually adjustable for controlling the quantity of force exerted on said toner cake by said first brush for metering the rate at which toner powder is removed by abrasion from said cake.

4. The combination defined in claim 1 wherein the outer surfaces of said first brush comprises uniformly distributed bristles of stiffness comparable to that of goat's hair, said bristles being operative during rotation of said

first brush simultaneously to remove toner powder by abrasion from said cake and to comb the fine fibers of said second brush, thereby distributing toner powder substantially uniformly throughout said fine fibers of said second brush.

5. The combination defined in claim 1 wherein the outer surface of said first brush comprises uniformly distributed stiff bristles operative simultaneously to abrade said cake and to comb said second brush and wherein resilient means are provided for urging said toner cake against said first brush, said resilient means being adjustable to control the quantity of force exerted on said toner cake by said first brush and thereby metering the rate at which said first brush removes toner powder from said cake and transfers it to the fine fibers of said second brush.

6. The combination defined in claim 1 wherein the abrasive surface of said first brush consists of substantially uniformly distributed goat's-hair bristles and wherein the outer surface of said second brush is formed of baby mouton fur.

7. The apparatus defined in claim 1 having also means for adjustably controlling the force with which said first brush bears against said cake, whereby the rate at which powder is removed from said first cake by said brush may be regulated.

References Cited in the file of this patent

UNITED STATES PATENTS

280,885	Vaughan	July 10, 1883
2,372,225	Rieke	Mar. 27, 1945
2,468,266	Lyons et al.	Apr. 26, 1949
2,624,652	Carlson	Jan. 6, 1953
2,732,775	Young et al.	Jan. 31, 1956
2,807,704	Allen et al.	Sept. 24, 1956
2,811,465	Greig	Oct. 29, 1957