

Sept. 10, 1957

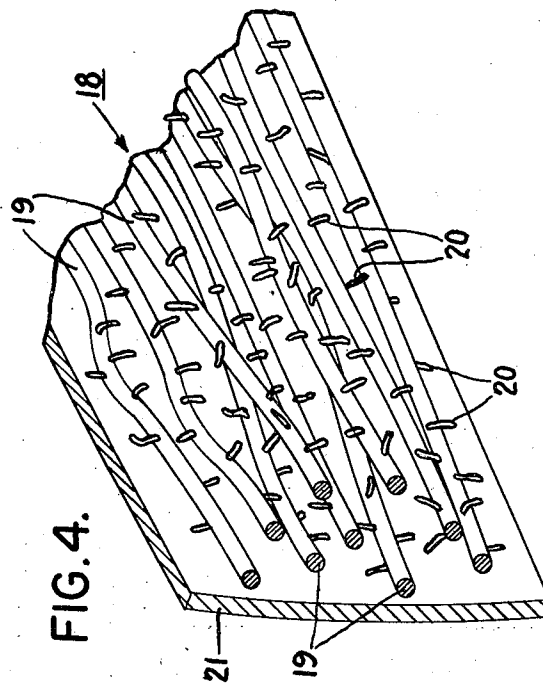
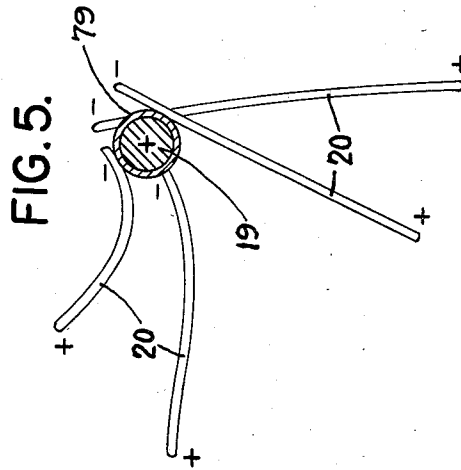
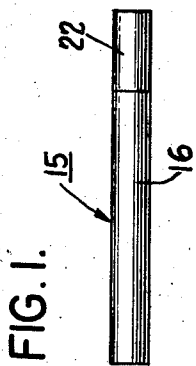
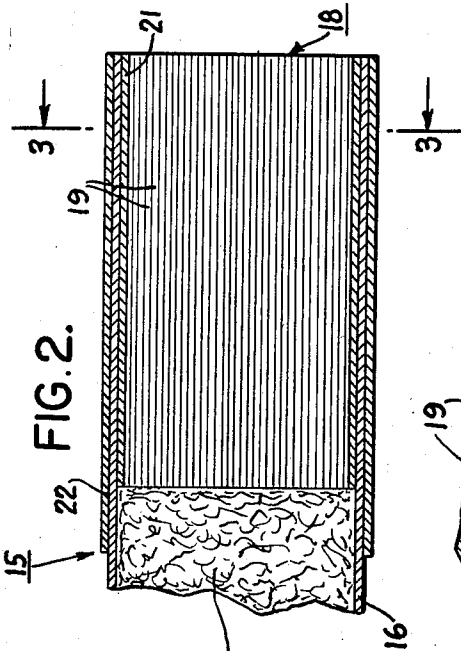
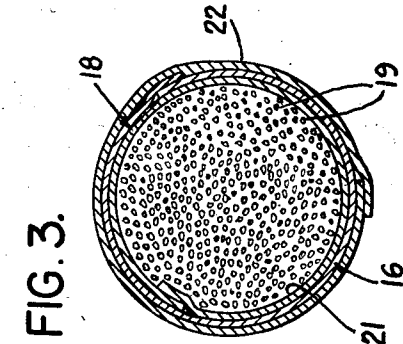
E. J. HACKNEY ET AL

2,805,671

AEROSOL FILTERS

Filed Oct. 7, 1953

3 Sheets-Sheet I



INVENTORS
EDWARD J. HACKNEY
CHARLES D. FAUCETTE
FREDERICK R. DARKIS

BY

Kenyon Kenyon
ATTORNEYS

Sept. 10, 1957

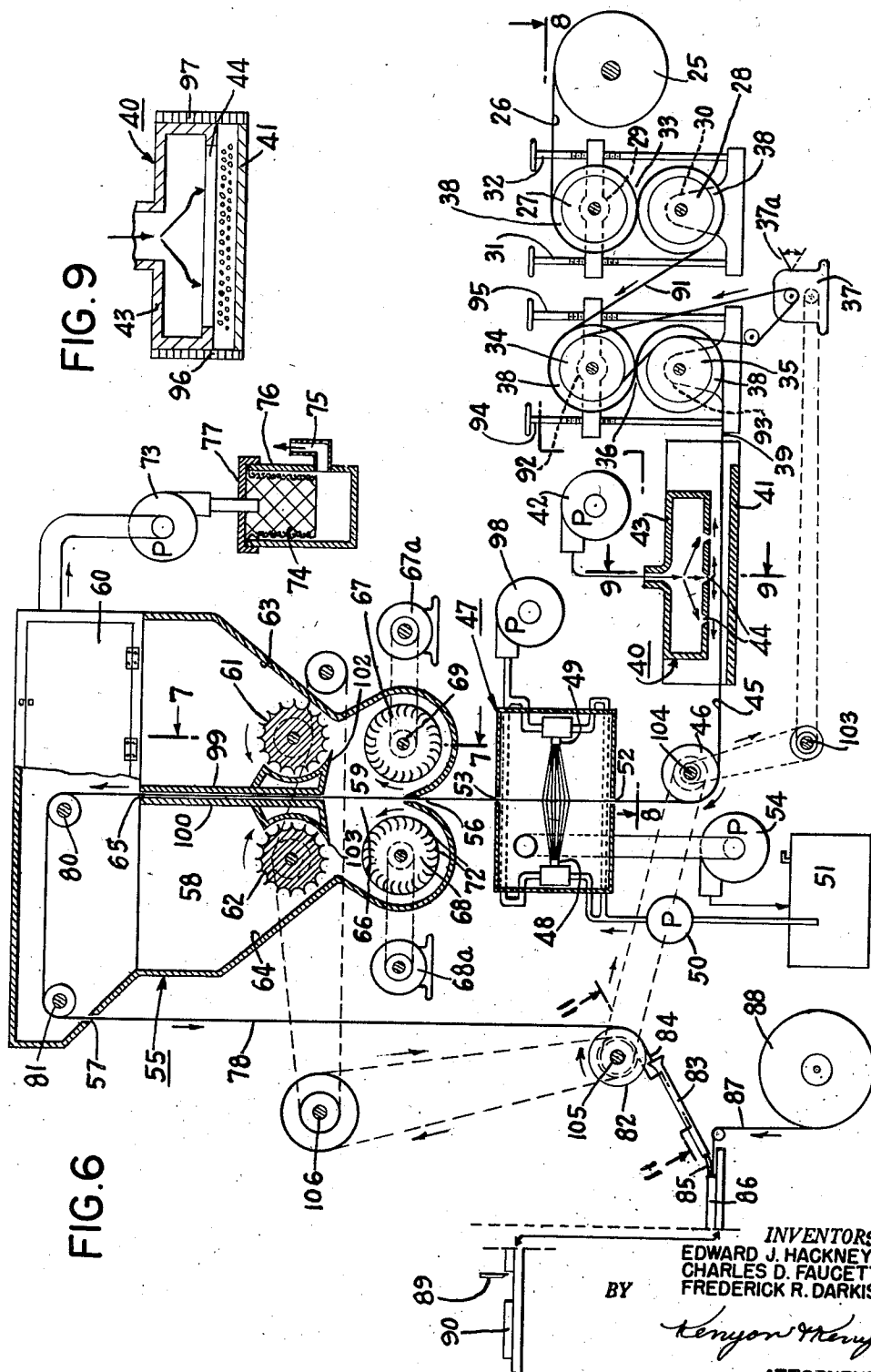
E. J. HACKNEY ET AL

2,805,671

AEROSOL FILTERS

Filed Oct. 7, 1953

3 Sheets-Sheet 2



Sept. 10, 1957

E. J. HACKNEY ET AL
AEROSOL FILTERS

2,805,671

Filed Oct. 7, 1953

3 Sheets-Sheet 3

FIG. 8.

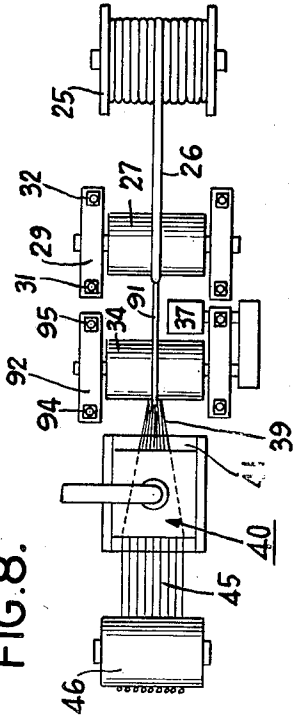


FIG. 10.

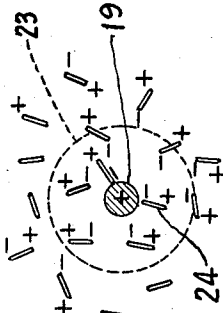


FIG. 11.

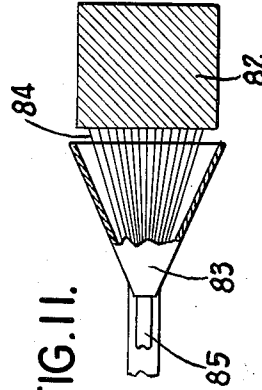
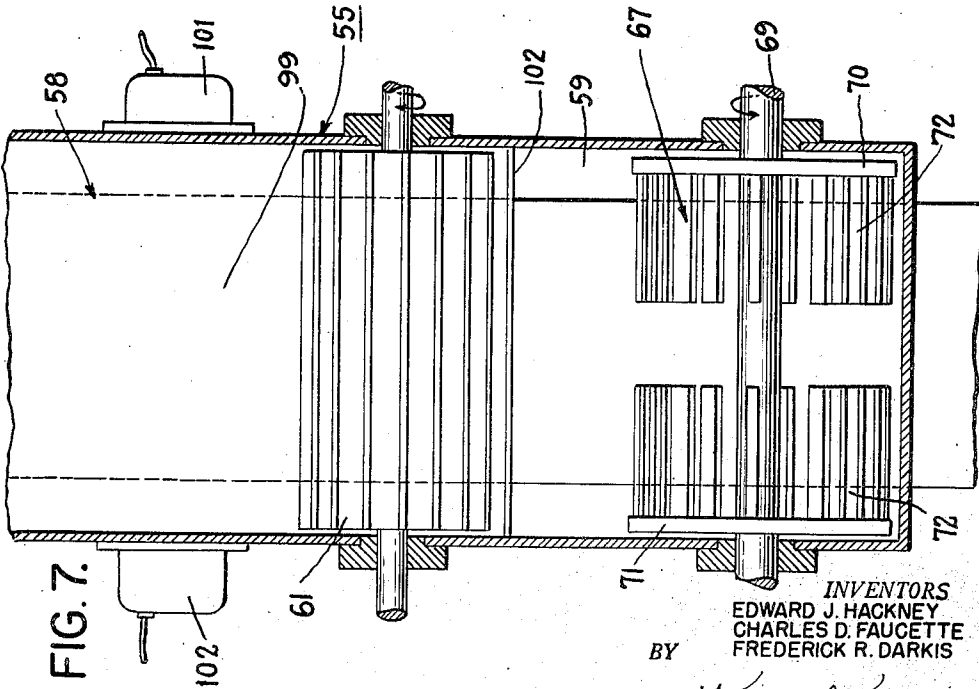


FIG. 7.



BY

INVENTORS
EDWARD J. HACKNEY
CHARLES D. FAUCETTE
FREDERICK R. DARKIS

Kenyon & Kenyon

ATTORNEYS

1

2,805,671

AEROSOL FILTERS

Edward J. Hackney, Charles D. Faucette, and Frederick R. Darkis, Durham, N. C., assignors to Liggett & Myers Tobacco Co., New York, N. Y., a corporation of New Jersey

Application October 7, 1953, Serial No. 384,684

14 Claims. (Cl. 131—208)

This invention relates to aerosol filters, and to a process and machine for making them. While the filter is believed to be useful for the filtration of any kind of aerosol or particulate suspension or dispersion in a gaseous medium, such as smoke, fog and the like, the following description sets forth by way of example a filter according to this invention which is especially adapted to be used in and to form part of a cigarette where the aerosol dispersion to be filtered is smoke produced by the burning of tobacco in the cigarette, being drawn into the mouth of the smoker.

Among the objects of the invention are to provide an aerosol filter which provides a large number of small fibers lying at right angles to the direction of gas movement through the filter, which permits such fibers to be preselected in accordance with the characteristics of the aerosol to be filtered, which permits the pressure drop through the filter to be predetermined, and which is especially effective in absorbing nicotine from tobacco smoke.

Other objects of the invention are to provide a process of making an aerosol filter in which spun textile filamentary material, which is to constitute the matrix of the filter, may be efficiently and conveniently provided with a fuzz-like attachment consisting of short rod-like particles or fibers of microscopic size, in which a tow of filaments of spun textile material is opened up and spread apart by electrostatic repulsion in order to prepare such filaments for further treatment, in which filaments of such material are passed through an agitated cloud of rod-like particles of microscopic size, while the filaments themselves are charged, in order to cause the rod-like particles to orient themselves as they enter the field of the charged filaments and to become attached thereto in a generally oriented relationship thus forming the fuzz.

Other objects of the invention are to provide machinery or apparatus for making an aerosol filter in which powered rollers having a surface of hard high-dielectric material are adapted to draw a tow of spun textile filaments through a pair of braked rollers having similar surfaces, whereby electrostatic charge is generated in the filaments of the tow and the tow is thereby opened up and spread apart by the mutual repulsion of the filaments, thus preparing it for further treatment; and in which electrostatically charged filaments of spun textile material are passed through an applicator chamber in which feeder rollers and beater fans maintain in proximity to the moving filaments an agitated cloud or suspension of rod-like particles of microscopic size which adhere to the surface of the filaments in oriented manner to form a fuzz-like attachment thereto.

In the drawings annexed to and forming part hereof—
Fig. 1 shows a filter-tipped cigarette;

2

Fig. 2 is a longitudinal section through the filter and adjacent portions of a filter-tipped cigarette;

Fig. 3 is a section in the plane 3—3 of Fig. 2;

Fig. 4 is a perspective of a portion of a cigarette filter 18 according to this invention, somewhat diagrammatic in form.

Fig. 5 is a section through one of the filaments 19, showing attached thereto a few of the oriented rod-like fibers 20, as seen under a microscope;

Fig. 6 is a diagrammatic longitudinal section through a machine according to this invention for making aerosol filters, with some parts in section and other parts in elevation;

Fig. 7 is a vertical section in the plane 7—7 of Fig. 6, showing a portion of the fiber-applicator box 55;

Fig. 8 is a horizontal diagrammatic section, looking downwardly, in the plane 8—8 of Fig. 6, showing the apparatus which stretches and charges the filament, and spreads the tow, thus readying it for further treatment;

Fig. 9 is a vertical section in the plane 9—9 of Fig. 6, showing the air blast which completes the spreading of the filaments in the tow;

Fig. 10 is a diagrammatic drawing to illustrate what is believed to be the mechanism by which the rod-like fibers 20 become oriented as they enter the field of the charged filament 19 in the fiber-applicator box 55; and

Fig. 11 is a section in the plane 11—11 of Fig. 6, showing the means by which the spread tow, after treatment, is gathered into a compact bundle.

The following, which describes the making of a preferred form of filter for filter-tipped cigarettes, is set forth for purposes of illustration and not to limit the invention, as hereinafter claimed.

THE FILTER STRUCTURE

A filter according to this invention comprises two main elements, which may and usually will for convenience be made of different materials, though they can be of the same material if desired. The first is the supporting matrix composed of long filaments, in most cases as long as the gas path through the filter and disposed generally in a direction parallel to the direction of gas movement. These filaments are not necessarily or usually straight (as wire would be). They are commonly somewhat warped or slightly kinked at regular intervals, resulting naturally or from the spinning operation by which they were made. The second is finely divided material, preferably in the form of short rod-like fibers (which in a cigarette filter will be not more than about 1000 microns in length), adherent to the peripheral surfaces of the matrix filaments and oriented in such manner that the major axis of the rod-like fibers extends generally at right angles to the direction of gas flow through the filter. Normally a very large number of such rod-like fibers are attached to the surfaces of the filaments, forming a sort of fuzz thereon. The filter as a whole consists of a compact package or bundle of matrix filaments extending generally parallel to each other and to the direction of gas movement through the filter, the surfaces of these filaments bearing the fuzz above-mentioned, and the entire bundle being enclosed within a wrapper impervious to gas at the prevailing pressure, which surrounds the sides of the bundle and leaves the ends open for the entrance and exit of gas. By suitably selecting the diameter and kinkiness of the matrix filaments, the character and density of the fuzz deposited along their

peripheral surfaces, and the degree of compactness of the bundle when made up into a finished filter structure, this invention enables a filter to be made in which pressure drop is reproducible and controllable; and which may be manufactured to have predetermined characteristics for the removal of aerosol particles of differing size distributions and densities according to the nature of the smoke, fog or the like to be filtered.

In general, the matrix filaments may be of any kind of spun textile material. Examples are the synthetics such as rayons, proteins, nylons, vinyls, fiber glass and their analogues. Carded or combed naturally-occurring fibers may also be used in some forms of filters. In general the material of the matrix filament should be one which is not deleteriously affected by contact with the gaseous medium to be filtered, and which does not deleteriously affect, as by desorption or otherwise, the gaseous medium which issues from the filter. A special requirement in the case of cigarette filters is that the filament be non-toxic and non-injurious if taken into the mouth.

Filamentary diameter and kinkiness are important chiefly for the bearing they have upon pressure drop. Pressure drop depends, for any given type of material used in accordance with this invention, upon the degree of lateral compression to which the bundle of matrix filaments is subjected when it has been assembled into a filter body, the frequency and degree of kinking and diameter of the matrix filaments, the density, diameter and length of the applied fuzz, the type of gaseous medium to be filtered, the length of the filter and the ratio of cross-sectional area of matrix filaments to the total cross-sectional area of the filter. These factors may be varied at will in using the invention and it is one of the advantages of the invention that when a filter of desired pressure drop and extractive power has been made according to the invention other filters can be made reproducing the desired performance by keeping the named factors the same.

For example, cellulose acetate of high acetone solubility, spun into continuous filaments about 35 to 55 microns in diameter and having, prior to stretching, about 9 crimps per inch, forms a satisfactory matrix filament for use in a cigarette filter. If the filter plug in such a cigarette is to be a half inch long, and to have a fuzz as hereinafter described, satisfactory pressure drop for comfortable smoking is achieved when about 5000 such filaments are compacted into a filter about $\frac{5}{16}$ " in diameter, which is average cigarette size. Under these circumstances the total cross-sectional area of the matrix filaments occupies about 14% of the total cross-sectional area of the filter.

The rod-like fibers which, according to the preferred form of this invention, are adherent to the peripheral surfaces of the matrix filaments and are oriented so as to extend in a direction generally at right angles to the direction of gas flow through the filter, may consist of any elongated fiber-like material whose particles are of substantially greater length in one axis than in an axis at right angles thereto and preferably are rod-like in form. For convenience in exposition, and by way of illustration but not to limit the invention, these particles will be described herein as if they were short sections of solid rod, circular in cross-section, and of length substantially greater than their diameter. They are herein called "fibers."

For high efficiency in filtering an aerosol-containing gas, it is necessary to provide in the filter a very large number of such fibers disposed at right angles to the axis of gas flow. The rate at which such fibers capture aerosol particles suspended in the moving gas stream depends, among other things, on the diameter of the fiber and the diameter of the particles. In general, relatively large fibers have a low capture-rate for the very small particles. In cigarette smoke as it reaches a cigarette

filter the particles range in size from about 0.1 to 15 microns in diameter. In order to provide a satisfactory rate of capture for particles near the smaller end of this range, it is necessary that the diameter of the fibers be less than about 25 microns. While this is a relative matter, and fibers of larger diameters may be used when less efficient filtration of smaller particles can be tolerated, we have found that fibers of diameter from about 5 to 25 microns are satisfactory for cigarette smoke, although with fibers of this size capture-rate appears to fall off in respect to particles smaller in diameter than about 0.3 micron. In the preferred form of this invention the diameter of the fibers should not exceed about 40 microns or the diameter of the matrix filaments whichever is less.

The length of the fibers, on the other hand, may be materially greater than their diameter. Where it is desired to compact the matrix filaments very closely together, so that the gas spaces between them are restricted, the desirable length of the rod-like fibers may be very short, on the order, say, of 15 to 50 microns. Where, however, more space is available between the matrix filaments, whether because of their crimping or because they are to be spaced farther apart to avoid excessive pressure drop, fibers may be employed having a greater length. For example, in making cigarette filters a convenient and desirable fiber-length is about 300 microns. In general, the upper limit of length for these fibers is that at which they no longer exhibit the function of orientation when they enter the electrostatic field of the filament, as hereinafter disclosed. The rod-like fibers may consist of any natural or synthetic substance which is not deleteriously affected by the gaseous medium to be filtered, and does not deleteriously affect, by desorption or otherwise, the gaseous medium issuing from the filter. Other specific requirements may exist in particular cases. For example, in the case of a filter to be used in a cigarette, this substance should be one which is non-toxic and non-injurious if taken into the mouth.

In the filter of a filter-tipped cigarette there is used, according to one form of this invention, particles of alpha cellulose, the preferred form and size being rod-like fibers having an average diameter of about 15 microns and a length of about 300 microns, with examples of measured diameter from 8 to 24 microns, and of measured length from 70 to 620 microns.

The means to enclose the sides of the bundle of filaments, and thus to complete the filter, may be any material which is substantially impervious to gas at the pressures which prevail when the filter is in use. A steel container is one example. In the case of a cigarette filter, the enclosing means is preferably a paper tube with overlapped margins adhesively secured together. In any case the ends of the matrix filaments are left free or else in communication with suitable gas passage-ways.

A filter-tipped cigarette embodying this invention is shown in Figs. 1 to 4. The cigarette 15 comprises a paper wrapper 16 containing tobacco 17 and a filter plug indicated generally at 18. The filter plug includes a bundle of cellulose acetate filaments 19, each filament having a multiplicity of rod-like fibers 20 adherent to its peripheral surface, the entire bundle of filaments being enclosed within a paper wrapper 21. Filaments 19 and paper wrapper 21 are of equal length, preferably about a half inch. Cigarette wrapper 16 fits snugly about plug wrapper 21. The two may be secured together by adhesive if desired. Preferably a mouth-piece wrapper 22 of waterproof paper may be wrapped around that end of the cigarette which contains plug 18.

The above-described filter may if desired, be manufactured by first causing a tow of raw matrix filaments, as drawn from supply, to become electrostatically charged; then passing the tow through an agitated suspension in air of the fibers which are to be adhered to the surface of the filaments; and finally assembling the filaments

into a bundle which is then suitably enclosed as by a paper tube. The result of agitating the suspension of fibers in air, usually done by mechanical means such as a fan, is to cause the fibers to acquire electrostatic charges by air friction, and these charges it is believed play a part in the subsequent orientation of the fibers when they enter the electrostatic field surrounding each charged filament. The electrostatic field 23 (see Fig. 10) surrounding each filament 19 as it travels through the cloud of fibers, causes each individual fiber within that field, for example, fiber 24, to be rotated about its center and drawn towards filament 19, to which it strongly adheres (see Fig. 5). Thereafter the filaments, having thus acquired a sort of fuzz, are assembled together in a bundle and provided with an enclosure which maintains them in assembled and generally parallel relation. Such a bundle is illustrated by filter plug 18 shown in Figs. 2 and 3. The foregoing process is now covered by our Patent No. 2,774,680, granted December 18, 1956.

In order to explain more fully how this process may be carried out, there is disclosed herein one form of apparatus, now covered by our Patent No. 2,778,403, granted January 22, 1957, suitable for carrying out the process. The apparatus disclosed is primarily intended for the manufacture of filter plugs to be incorporated into cigarettes, but with obvious modifications can be used for the manufacture of filters embodying the invention that are made for other uses.

APPARATUS FOR MAKING THE FILTER

Referring to Figs. 6, 7, 8, 9, and 11, from a supply reel 25 a tow 26 is drawn consisting of the number of spun textile filaments desired in the completed filter. Rollers 27 and 28 are mounted upon respective bearings 29 and 30, the bearing 29 being movable towards and from the bearing 30. Suitable means, for example screw-threaded clamps 31 and 32, enable the cylindrical faces of rollers 27 and 28 to be moved towards each other and held under compression at their line of contact or bite 33.

Two powered rollers 34 and 35 are mounted upon respective bearings 92 and 93, the bearing 92 being movable towards and from bearing 93 under control of screw-threaded clamps 94 and 95 so that the rollers may be held under predetermined compression at their line of contact or bite 36. Rollers 34 and 35 are driven from a variable speed gear box 37 controlled by lever 37a. The arrangement is such that tow 26, drawn from supply 25, passes between the bite 33 of rollers 27, 28, then around and in contact with a portion of the peripheral surfaces of each of rollers 28 and 34, and then passes between the bite 36 of powered rollers 34, 35. Each of rollers 27, 28, 34 and 35 is covered on its peripheral surface with a tread 38 of hard high-dielectric material, for example, hard rubber. When the clamps 31, 32 are tightened to press rollers 27 and 28 into engagement with each other, the effect in coaction with their bearings is that these rollers become braked, and the portion of the tow at 91 passing from the braked rollers 27, 28 to the powered rollers 34, 35 is highly stretched. In order that the stretching action may give rise to high friction between the tow and the surfaces of braked roller 28 and powered roller 34, the tow is arranged in its passage through the rollers so that it first passes around and in contact with a portion of the rubberized periphery of one of the braked rollers after leaving the bite between them, and then passes around and in contact with a portion of the rubberized periphery of one of the powered rollers before entering the bite between them. Thus the stretching action of the tow at 91 between bite 33 and bite 36 is accompanied by slippage of the tow under heavy tension against the hard rubber surfaces of rollers 28 and 34. By reason of this slippage under heavy tension, each of the several filaments in the

tow acquires a substantial electrostatic charge from one or the other or both of said rubberized surfaces.

Since the several filaments in the tow have, by reason of the above stretching and sliding action received like charges, they become mutually repulsive and as the tow leaves the bite 36 it exhibits a marked tendency to spread laterally (see Fig. 8, at place marked 39).

In order to assist the separating or spreading tendency of the tow, it may then if desired be run over a table 41 beneath an air blast device 40 fed with air from a pump 42 and having side guide walls 96 and 97. The tow leaving the air blast device at 45 is at its maximum separation. For example, a tow comprising about 5000 filaments of 16 denier and intended to form the filter plug for a cigarette, will at 45 be in the form of a flattened ribbon from 4½ to 6 inches in width and of a thickness preferably not greatly exceeding the thickness of one or two filaments. At this point, and until the tow is finally condensed in funnel 83, the individual filaments are generally at such distance from each other as to show visual separation at least of the major groups, but most filaments remain within the electrostatic field of their neighboring filaments whereby the tow is kept in its spread condition.

Powered roller 46 receives the flattened tow coming from the air blast device, and directs it in an upward direction into an adhesive applicator box 47 through which the tow passes while in flattened condition. The application of adhesive is not necessary to the realization of the advantages of this invention, but is desirable in the manufacture of filters which are intended for use in cigarettes. The reason is that the adhesive, when hardened, promotes cross-linking between matrix filaments and thus gives to the filter body the added degree of strength which seems to be necessary to enable the finished filter plug to withstand the action of cutting knives without distortion.

Adhesive may conveniently be applied in applicator box 47 through spray nozzles 48, 49 fed by pump 50 from a source 51 and atomized by air supplied by pump 98. Since the openings 52 and 53 through which the flattened tow enters and leaves applicator box 47 would permit escape of adhesive spray, means is provided to maintain a negative pressure within box 47. This may conveniently take the form of a pump 54 adapted to draw adhesive spray or mist from the interior of box 47 and to return it to source 51, through a separator (not shown) if desired.

From adhesive applicator box 47 the flattened ribbon of tow passes to the fiber applicator box 55 having openings 56 and 57 through which the tow enters and leaves the box. Applicator box 55 consists of a hopper portion 58 and an agitation chamber 59. A door 60 permits finely-divided fiber material to be introduced into hopper 58.

Positioned in the lower part of hopper 58 are a pair of powered fluted feed rollers 61, 62, positioned respectively adjacent the inwardly sloping side walls 63, 64 of hopper 58. Between rollers 61 and 62 are mounted a pair of walls 99, 100 forming a channel 65 through which the tow is adapted to pass. Each of walls 99 and 100 is provided at its lower end with a curved shoe 102, 103, concentric respectively with the cylindrical surface of revolution described by the outer edges of the flutes of the rollers 61 and 62 and closely adjacent thereto. Thus each fluted roller and its shoe forms a feeder of predetermined size for delivering fiber particles from hopper 58 to agitation chamber 59.

In the agitation chamber 59 of box 55 are suitably journaled and positioned a pair, and preferably two pairs, of agitator fans 67, 68 powered to rotate at high speed, for example 1800 R. P. M., by motors 67a and 68a respectively. Such fans may be made as follows: Upon a shaft 69 are secured two flat circular plates 70 and

71 (see Fig. 7). Upon the flat surface of each plate are secured a series of curved blades 72 projecting at right angles to the plane of the plate and adapted to rotate with it. The fans are powered to rotate in such direction that the blades, in their nearest approach to the path of the tow, move in an upward direction (see Fig. 6). Thus fiber particles are propelled in a direction parallel to the direction of movement of the tow, and towards the same, and the suspension of these particles in the air is maintained in the form of a dense and agitated cloud through which the charged filaments pass and in which they attract large numbers of fiber particles.

To aid rollers 61, 62 in feeding finely-divided material to agitation chamber 59, it is desirable to secure a pair of powered vibrators 101, 102 (see Fig. 7) to the outer walls of hopper 58. To prevent the escape of fiber particles through openings 56 and 57, a pump 73 is arranged to draw air from box 55 and to discharge it into a separator 76 containing a cloth bag 74, an air escape vent 75 and a removable cover 77. Finely-divided material recovered in bag 74 may be returned to the system through door 60.

After passing over rollers 80 and 81 and leaving box 55 through opening 57 the tow at 78 is in the form of a flattened ribbon consisting of a plurality of filaments each having on its surface a layer 79 of adhesive material and also having adherent thereto a large number of particles of finely-divided fibers (see Fig. 5). This tow after passing around the powered roller 82 enters condensing funnel 83. At point 84 (see Fig. 11) the tow is about to be gathered into a bundle of desired external configuration. At point 85, where it emerges from funnel 83, the tow has been gathered into a bundle possessing the desired cross-sectional configuration which, in the case of filters made to be incorporated in cigarettes, is substantially circular in outline and about $\frac{5}{16}$ " in diameter. It is then ready to be enclosed in a suitable wrapper.

In the case of filters made to be incorporated in cigarettes, the wrapper is a paper tube. Preferably the bundle formed in funnel 83 is advanced into a forming tube 86 (see Fig. 6) where it is continuously wrapped in a strip of paper 87 drawn from a source 88. The machine for wrapping the bundle of filaments 85 in a tube of paper 87, and cutting the same off into tubes of desired length by means of knife 89, is essentially the same as the known machinery for the manufacture of cigarettes. Such machines are well known and will not be described in detail here.

In manufacturing filter-tipped cigarettes as shown in Figs. 1-4, it is preferable to form an intermediate product 90 consisting of a continuous bundle of cellulose acetate filaments, with adherent finely-divided fibers, which is about 3 inches long and is contained in a paper tube of the same length. Such intermediate product is afterwards severed into appropriate half-inch lengths for insertion in individual cigarettes. This may be done automatically in known machines which need not be here described.

If the nature of the adhesive requires the subsequent application of heat in order to set or bake it, intermediate product 90, handled in the same manner as cigarettes, may be introduced into low-temperature baking ovens for the required length of time.

PROCESS OF MAKING THE FILTER

The process of manufacture according to this invention may now be more fully described, having reference to the aforementioned apparatus, by way of example only. For illustration the process to be set forth pertains to the manufacture of cigarette filters.

Applying the electrostatic charge.—Preferably the electrostatic charge is applied to a tow of spun textile filaments such as cellulose acetate by friction with a hard,

high-dielectric solid. If desired, however, the charge may be applied in other known ways, as for example by friction with gas molecules such as a hot-air blast, by corona discharge, or by administration of a direct electrical charge. In the preferred form of the process the tow is drawn from a source of supply through the bite of a pair of braked rollers having hard rubber surfaces by means of a pair of powered rollers having similar surfaces. The tow may be threaded through the rollers in such manner that it passes around a portion of one of the braked rollers after leaving the bite between them, and around a portion of one of the powered rollers before entering the bite between them. Thus a pronounced stretch is introduced into the filaments of the tow, by reason of the resistance of the braked rollers, and the individual filaments of the tow are brought into hard slipping engagement with the surface of the rollers, thus acquiring a strong electrostatic charge. The existence of this charge is made evident by the tendency of the tow to spread as it leaves the powered rollers, the individual filaments at this point being similarly charged and mutually repulsive.

Further spreading the tow by air blast.—If desired or necessary, the individual filaments of the tow may be further separated and spread apart by suitable air blast applied thereto after the tow leaves the powered rollers above-mentioned. Such a device is indicated at 40.

When the tow has been flattened into a ribbon of substantial width and a thickness preferably not much more than that of one or two filaments, and each filament bears a strong electrostatic charge, it is then ready for application of finely-divided fibers. Such application may take place immediately, or may be preceded if desired by application to the tow filaments of a layer of adhesive material. At this time and during the subsequent stages of treatment, each or most of the individual charged filaments continues to be within the electrostatic field of at least its neighboring filaments, and thus under the influence of a force tending to keep the filaments separated one from another.

Applying the adhesive.—The application of adhesive to the filaments is by no means necessary to secure firm adherence of the fibers thereto. Electrostatic attraction is sufficient to assure a permanent attachment between the fibers and the peripheral surfaces of the supporting filaments, and such attraction will last indefinitely even after the filter has been incorporated in a cigarette. (See filter No. 3 in the table which follows near the end of this specification.) The use of an adhesive is, however, desirable in the manufacture of filters for use in cigarettes, in order to give the filter plug as a whole the necessary degree of rigidity and resistance to compression which will permit it to be cut without deformation by the knives of a cigarette-making machine. For this purpose it is preferred to coat the peripheral surfaces of the filaments before they pass to the fiber applicator box, with a layer of a substance which is a solvent for the particular filament used. Then, when the surface of the filament has been wetted with such solvent and a soft solid solution has formed, contacting filaments will tend to stick together and thus give the entire filter bundle greater internal strength. It is usually desirable to heat the filter plugs, after the manufacture of the intermediate product 90 is completed, in order to harden or dry the surface of the filament, particularly if the same is to be used immediately in cigarette manufacture.

It is also desirable, when making a cigarette filter, to use an adhesive which will not give any noticeable taste to the smoke issuing from the filter into the mouth of the smoker. In making cigarette filters in which the filaments are made of cellulose acetate, the preferred adhesive is triethyl citrate. After the intermediate products 90 have been made, they may be heated for about two hours at 175° F. in order to bring the setting of the

adhesive to a prompt completion. However, the hardening of the adhesive occurs spontaneously at a slow rate and ultimately the desired degree of firmness can be achieved without heating, if a sufficient length of time is available.

Applying the fibers.—Whether or not the filaments have been coated with adhesive, the next step of the process is to move the ribbon-like flattened band of charged filaments into a zone where they pass in intimate contact with an agitated suspension or cloud of finely-divided fibers which, as above stated, may be of any material of appropriate size and non-deleterious material, but preferably consist of small rod-like particles of alpha cellulose having a diameter from about 8 to 24 microns (average 15) and a length of from about 70 to 620 microns (average 300). Each fibrous particle of microscopically small size, such as the alpha cellulose just described, has the property when it has entered the field surrounding a charged filament, of rotating in space till its end oppositely charged from that of the filament is nearest to the filament, and as thus oriented it is drawn towards the surface of the filament until it makes contact therewith. This end of the fiber is then strongly held in contact with the filamentary surface while the opposite end of the fiber is repelled thereby. The result is that, in general, the fibers which become attached to the peripheral surfaces of the charged filaments stand out therefrom in a manner which might be characterized as resembling a fuzz, although under a microscope the fuzz does not appear particularly dense.

The quantity of fibers picked up by the filaments can be controlled by regulating the speed at which the filaments pass through the cloud and the density of the cloud. The greater the speed, or the less the density, or both, the less will be the pick-up of fuzz.

Assembling and wrapping the bundle.—After the tow of spread and charged filaments has been passed through an agitated cloud of fiber particles, as described, the tow is then passed to a funnel or the like where it is gathered into a compact bundle preferably of circular outline as seen in cross-section, and thence fed directly to a place where it is automatically and continuously wrapped in a paper tube.

Examples

Five cigarettes, each containing a filter plug, were made and tested for weight of material removed by the filter per puff of smoke. The plugs were made from cellulose acetate tow in which the individual filaments were 16 denier and the total denier of the tow was 117,000 before stretching. The individual filaments contained on the average 9 crimps per inch before stretching. During stretching the denier of the tow was reduced to about 92,000. This did not result in any measurable reduction in the average diameter of the individual filaments which, by measurement, was 43.3 microns. The stretching did however reduce the number of crimps to about 5 or 6 to the inch.

The fibers attached to the filaments (except in filter No. 1 where no fibers were used) consisted of alpha cellulose in the form of rod-like particles which, by measurement, were found to be from 8 to 24 microns in diameter (average 15 microns) and from 70 to 620 microns in length (average 300 microns).

The adhesive material was triethyl citrate. In each case about 5,000 cellulose filaments, comprising an aggregate cross-sectional area calculated to be 0.01135 sq. in., was formed into a bundle one half inch long and wrapped in a paper tube to form a plug having a total cross-sectional area of 0.0822 sq. in. Thus the aggregate cross-sectional area of the filaments, by calculation, was 13.8% of the total cross-sectional area of the plug. This however does not take into account cross-linking between filaments caused by the adhesive nor the area occupied by the alpha cellulose fibers.

FILTRATION EFFECTIVENESS OF FIVE CIGARETTE FILTERS MADE AS ABOVE-DESCRIBED AND DIFFERING FROM EACH OTHER AS SHOWN IN THIS TABLE.

Filter No.	As a percent of Total Weight in the Filter			Milligrams of Smoke Removed per Puff ¹
	Cellulose Acetate Filaments	Adhesive	Alpha Cellulose Particles	
1	100	0	0	0.7
2	82	8	10	1.4
3	84	0	16	1.9
4	78	5	17	1.9
5	75	5	20	2.7

¹ "Puff" means the passage of 31 cc. of air into a lighted cigarette for a period of 2 seconds, repeated once every minute.

The foregoing shows that a bundle of cellulose acetate filaments free of adherent alpha cellulose fibers possesses some ability to capture aerosol particles from a gas passing through the filter, but that such ability is limited. It is believed that, if the cellulose acetate filaments were perfectly straight like rods of glass or metal, capture of aerosol particles would be limited to larger particles which have an appreciable Stokes' law rate-of-fall, and would not include particles less than 0.3 micron in radius. At the same time the above figures indicate that the presence of alpha cellulose particles, attached to the peripheral surfaces of the cellulose acetate filaments in the manner herein disclosed, substantially increases the total weight of material removed from the gas stream. The effectiveness of the filter in removing such material increases with increase in the quantity of alpha cellulose particles present, until the number thereof causes too great a pressure drop for comfortable smoking.

While the above invention has been described primarily with reference to filters and their manufacture for incorporation in and as part of a cigarette, which said filters are of relatively small diameter and short gas path, it is intended that this invention shall include filters and their manufacture for other applications such as for use in gas masks, air purification systems, ventilation, industrial smoke and dust control, dehydration of vapors, and the like. This invention is not limited to the specific means or steps or apparatus herein shown and described but extends to and includes all equivalents thereof which, in the combinations recited in the subjoined claims, operate in the same or similar manner to achieve the results therein set forth.

While the spun textile filaments are here described for illustration as being disposed generally parallel to the direction of gas-flow through the filter, and no twisting is produced in condensing funnel 83 as here shown, a filter may be made in accordance with this invention in which the filaments, after the fuzz has been applied and the tow gathered into round form, are then twisted together so that they occupy helical paths in the filter. Such twisting will, of course, cause the path of gas-flow to be correspondingly twisted, but the filaments will nevertheless continue to be generally parallel to the direction of gas-flow. Such twisting may be employed to assist in keeping the bundle compact, or as a further control in assuring a desired degree of pressure drop.

While the rod-like fibers are herein described for illustration as being at right angles, or generally at right angles, to the direction of gas flow through the filter or to the axis of the filter plug, in practice such fibers may be disposed in a somewhat heterogeneous angular relationship thereto. It is believed that the most efficient use of the fibers is made when a majority of them are substantially at right angles, as stated, but this is not essential to the invention since the only effect of having a majority of the fibers at an angle other than a right angle is to make a less efficient use of the available material. The effective length of a fiber for filtering pur-

poses is, of course, a projection of the fiber in a plane at right angles to the direction of gas flow.

In the apparatus herein shown the several moving parts may all be powered from a common source, which may be the motor which drives the forming and cutting mechanism 86, 89. Power from this motor may be communicated (by means not shown) to a shaft 103. From shaft 103 power may be delivered to variable speed gear box 37 for driving rollers 34 and 35. From shaft 103 power may also be delivered to shaft 104, on which roller 46 is mounted, thence to shaft 105, on which roller 82 is mounted, and thence to shaft 106 from which fluted rollers 61 and 62 may be driven in opposite directions at suitable low speed. For convenience, fans 67 and 68, which require high speed rotation, are here shown as being separately powered.

Preferably condensing funnel 83 should be of flattened configuration, as shown in Figs. 6 and 11. This shape appears to produce a more satisfactory distribution of alpha cellulose fuzz throughout the cross-sectional area of the filter.

What is claimed is:

1. An aerosol tobacco smoke filter comprising a compact bundle of textile filaments disposed generally parallel to the direction of gas-flow through the filter, a multiplicity of rod-like fibers of diameter not exceeding about 40 microns or the diameter of the filaments whichever is less, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the direction of gas-flow through the filter, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and generally paralleling said filaments and said rod-like fibers extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage spaces, and means to enclose the sides of the bundle.

2. An aerosol filter comprising a compact bundle of textile filaments disposed generally parallel to the direction of gas-flow through the filter, a multiplicity of particles of alpha cellulose not exceeding along their minor axes the diameter of the filaments, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the direction of gas-flow through the filter, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and generally paralleling said filaments and said particles extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage means, and means to enclose the sides of the bundle.

3. An aerosol tobacco smoke filter comprising a compact bundle of cellulose acetate filaments disposed generally parallel to the direction of gas-flow through the filter, a multiplicity of rod-like fibers of diameter not exceeding about 40 microns or the diameter of the filaments whichever is less, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the direction of gas-flow through the filter, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and generally paralleling said filaments and said rod-like fibers extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage spaces, and means to enclose the sides of the bundle.

4. An aerosol filter comprising a compact bundle of cellulose acetate filaments disposed generally parallel to the direction of gas-flow through the filter, a multiplicity of particles of alpha cellulose not exceeding along their minor axes the diameter of the filaments, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end ex-

tending generally at right angles to the direction of gas-flow through the filter, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and generally paralleling said filaments and said particles extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage means, and means to enclose the sides of the bundle.

5. A tobacco smoke filter plug suitable for use in filter-tipped cigarettes comprising a compact bundle of textile filaments disposed generally parallel to the major axis of the plug, a multiplicity of rod-like fibers of diameter not exceeding about 40 microns or the diameter of the filaments whichever is less, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the axis of the plug, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and generally paralleling said filaments and said rod-like fibers extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage spaces, and a paper tube enclosing the bundle.

6. A filter plug suitable for use in filter-tipped cigarettes comprising a compact bundle of textile filaments disposed generally parallel to the major axis of the plug, a multiplicity of particles of alpha cellulose of sizes not exceeding about 1000 microns along their major axes and about the diameter of the filaments along their minor axes, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the axis of the plug, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and generally paralleling said filaments and said particles extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage means, and a paper tube enclosing the bundle.

7. A filter plug suitable for use in filter-tipped cigarettes comprising a compact bundle of cellulose acetate filaments disposed generally parallel to the major axis of the plug, a multiplicity of rod-like fibers of diameter not exceeding about 40 microns or the diameter of the filaments whichever is less, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the axis of the plug, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and generally paralleling said filaments and said rod-like fibers extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage spaces, and a paper tube enclosing the bundle.

8. A filter plug suitable for use in filter-tipped cigarettes comprising a compact bundle of cellulose acetate filaments disposed generally parallel to the major axis of the plug, a multiplicity of particles of alpha cellulose of sizes not exceeding about 1000 microns along their major axes and about the diameter of the filaments along their minor axes, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the axis of the plug, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and generally paralleling said filaments and said particles extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage means, and a paper tube enclosing the bundle.

9. A filter plug suitable for use in filter-tipped cigarettes comprising a compact bundle of cellulose acetate filaments having a diameter of about 35 to 55 microns disposed generally parallel to the major axis of the plug, a multiplicity of rod-like fibers of diameter not exceeding the diameter of the filaments and of length not exceeding

13

about 1000 microns, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the axis of the plug, and a paper tube enclosing the bundle, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and generally paralleling said filaments and said rod-like fibers extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage spaces, the rod-like fibers comprising from about 10% to 20% the weight of the plug.

10. A filter plug suitable for use in filter-tipped cigarettes comprising a compact bundle of cellulose acetate filaments having a diameter of about 35 to 55 microns disposed generally parallel to the major axis of the plug, a multiplicity of particles of alpha cellulose of sizes about 8 to 24 microns along their minor axes and 70 to 620 microns along their major axes, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the axis of the plug, said filaments being in proximate contiguous relation having gas-flow passages spaces therebetween in longitudinal relation with and generally paralleling said filaments and said particles extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage means, and a paper tube enclosing the bundle, the alpha cellulose comprising from about 10% to 20% the weight of the plug.

11. A filter plug suitable for use in filter-tipped cigarettes comprising a compact bundle of textile filaments having a diameter of about 43.3 microns and 5 to 6 crimps to the inch disposed generally parallel to the major axis of the plug, a multiplicity of particles of alpha cellulose of sizes about 8 to 24 microns along their minor axes and 70 to 620 microns along their major axes, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the axis of the plug, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and general paralleling said filaments and said particles extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage means, and a paper tube wrapped about the bundle of such diameter that the aggregate cross-sectional area of the filaments is about 13.8% of the cross-sectional area of the tube.

12. A filter plug suitable for use in filter-tipped cigarettes comprising a compact bundle of cellulose acetate filaments having a diameter of about 43.3 microns and 5 to 6 crimps to the inch disposed generally parallel to the major axis of the plug, a multiplicity of particles of alpha cellulose of sizes about 8 to 24 microns along their minor axes and 70 to 620 microns along their major axes, each thereof being secured adjacent one of its ends to a peripheral surface of one of said filaments with its other end extending generally at right angles to the axis

14

of the plug, said filaments being in proximate contiguous relation having gas-flow passage spaces therebetween in longitudinal relation with and generally paralleling said filaments and said particles extending across said passage spaces in multiple spaced relation along the longitudinal extent of said passage means, and a paper tube wrapped about the bundle of such diameter that the aggregate cross-sectional area of the filaments is about 13.8% of the cross-sectional area of the tube.

13. A filter plug suitable for use in a filter-tipped cigarette comprising a compact bundle of textile filaments disposed generally parallel to the direction of flow of smoke through the filter, a multiplicity of elongated particles of alpha cellulose not exceeding about 1,000 microns in greatest dimension secured to the peripheral surfaces of said filaments and extending generally at right angles to said direction of flow of smoke, the filaments forming gas-flow passage spaces between and parallel to themselves, and the said particles extending across said gas-flow passage spaces in multiple spaced relation along the longitudinal extent thereof, and a paper tube enclosing the bundle.

14. A filter plug suitable for use in a filter-tipped cigarette comprising a compact bundle of cellulose acetate filaments disposed generally parallel to the direction of flow of smoke through the filter, a multiplicity of elongated particles of alpha cellulose not exceeding about 1,000 microns in greatest dimension secured to the peripheral surfaces of said filaments and extending generally at right angles to said direction of flow of smoke, the filaments forming gas-flow passage spaces between and parallel to themselves and the said particles extending across said gas-flow passage spaces in multiple spaced relation along the longitudinal extent thereof, and a paper tube enclosing the bundle.

References Cited in the file of this patent

UNITED STATES PATENTS

413,036	Demuth	Oct. 15, 1889
729,680	Schwartz	June 2, 1903
945,917	Cottrell	Jan. 11, 1910
1,854,475	Littlefield	Apr. 19, 1932
1,876,251	Lehman	Sept. 6, 1932
1,952,502	Kinhead	Mar. 27, 1934
2,058,620	Petitmerment	Oct. 27, 1936
2,126,422	Tarrant	Aug. 9, 1938
2,221,443	Davidson	Nov. 12, 1940
2,358,227	Hiers	Sept. 12, 1944
2,372,437	Lathrop et al.	Mar. 27, 1945
2,447,374	Smyser	Aug. 17, 1948
2,573,964	Green et al.	Nov. 6, 1951
2,615,477	Crawley	Oct. 28, 1952
2,688,380	MacHenry	Sept. 7, 1954
2,707,308	Taylor et al.	May 3, 1955
2,740,184	Thomas	Apr. 3, 1956

FOREIGN PATENTS

413,694	Great Britain	July 20, 1934
665,278	Great Britain	Jan. 23, 1952