

[54] **TOBACCO SMOKE FILTER**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 77,773, Oct. 5, 1970, abandoned.

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[51] Int. Cl. **A24d 5/50**

[58] Field of Search 131/261 R, 261 B,
131/10 R, 10.5, 203, 216, 202, 213

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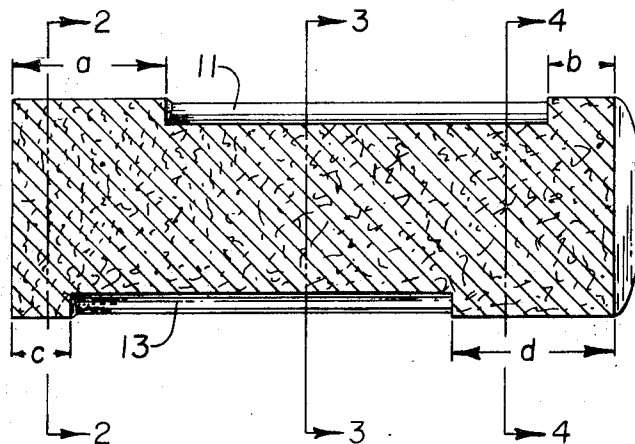
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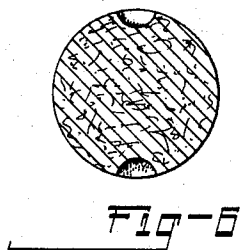
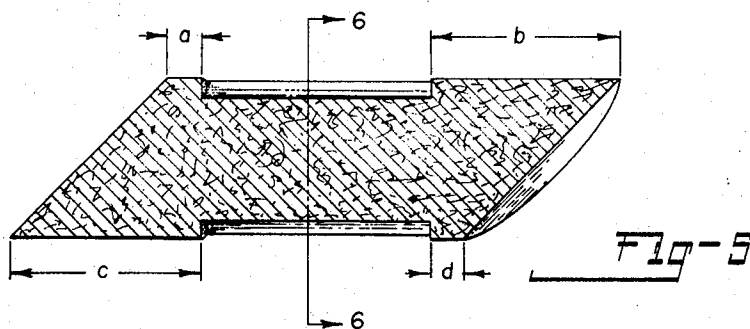
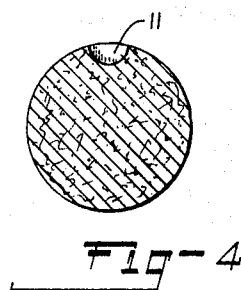
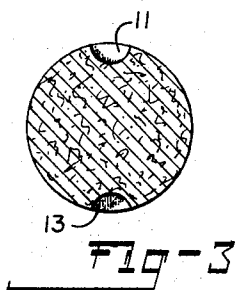
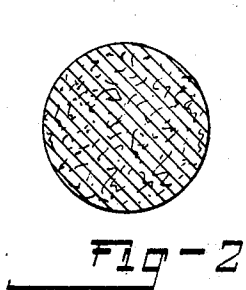
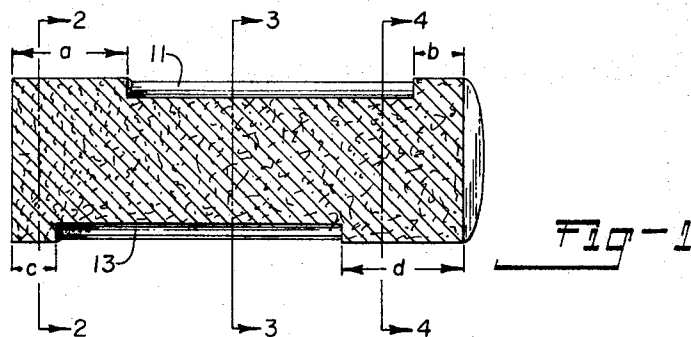
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[57] **ABSTRACT**

Tobacco smoke filters, each having a body formed from a permeable crimped textile tow and having a generally cylindrical form in order to be attached to the downstream end of a wrapped tobacco column in the formation of a filter cigarette. Each filter may have an overwrap or the wrapper of the tobacco column may be extended thereover to unite the same thereto. The filter body is provided with parallel lineal notched portions in the periphery thereof, the portions being located on opposite sides of the body. The notched portions may be located intermediate the ends of the body. Each may extend through one end portion of the same opposite the end through which the other may extend, may have a constant depth, or the depths thereof may be varied so that a constant slope is obtained. Plural parallel serated notched portions may be located at each of said opposite sides of the body and the notched portions may assume an angular array such that the angular displacement therebetween may be less than 180° at the downstream end thereof. Smoke passing through the filter will be affected by differences in pressure therein such that the flow pattern will be transverse as well as axial with respect thereto.

9 Claims, 24 Drawing Figures





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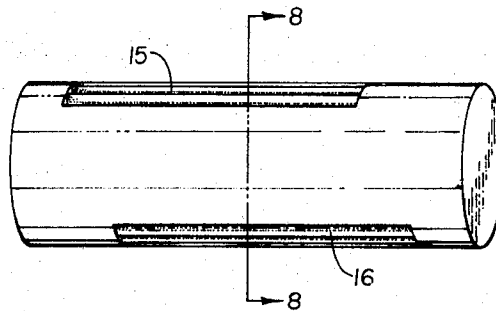


Fig-7

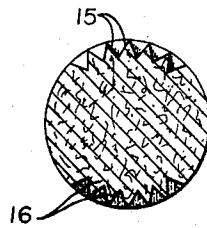


Fig-8

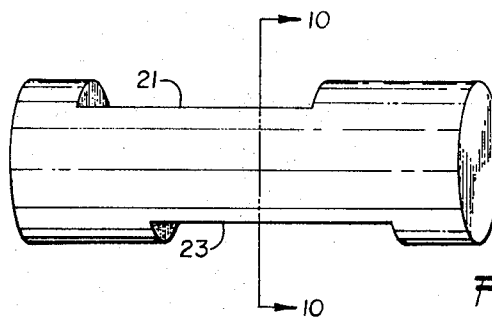


Fig-9

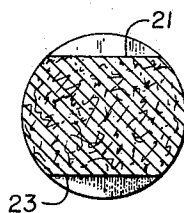


Fig-10

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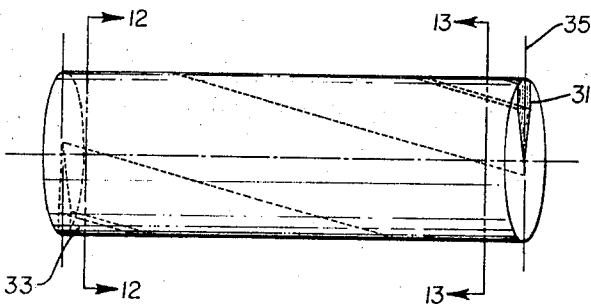


Fig-11

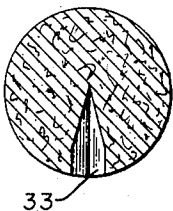


Fig-12

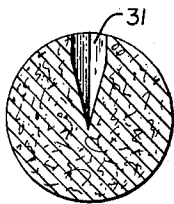


Fig-13

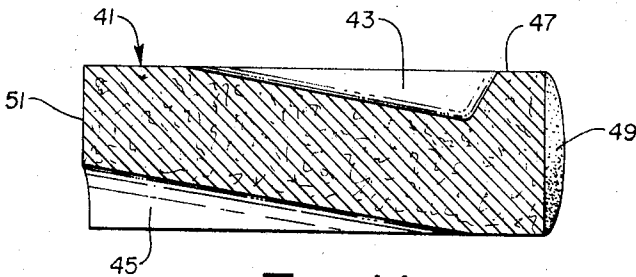


Fig-14

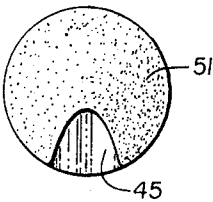


Fig-15

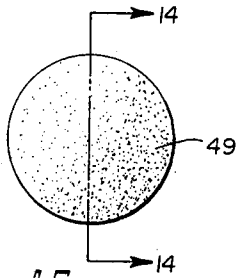


Fig-16

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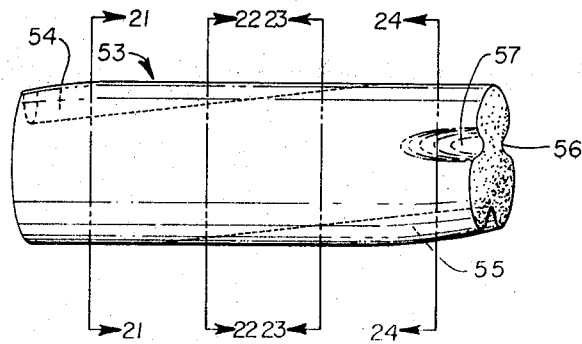


Fig-17

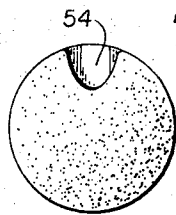


Fig-18

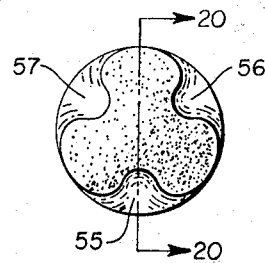


Fig-19

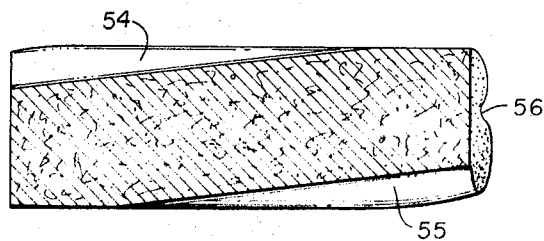


Fig-20

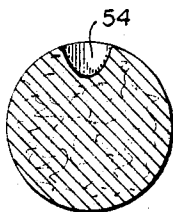


Fig-21

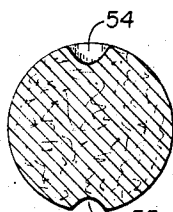


Fig-22

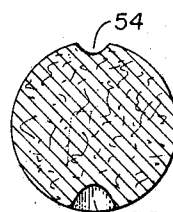


Fig-23

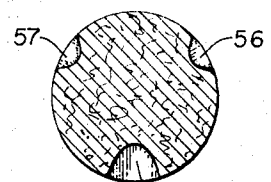


Fig-24

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TOBACCO SMOKE FILTER

This application is a continuation-in-part of copending application, Ser. No. 77,773, filed Oct. 5, 1970 and now abandoned.

This invention relates to an improved filtering device particularly adapted for use as a tobacco smoke filter.

A most important purpose of a tobacco smoke filter is to reduce the delivery of "tar," which is properly called the total particulate matter (TPM) in tobacco smoke. Another purpose of a tobacco smoke filter is to alter the composition of the smoke in a desired way such as the removal of certain compounds found in the vapor phase of tobacco smoke.

To accomplish these ends, many kinds of cigarette filters have been devised. Paper, cotton, and cellulose acetate fibers have been used, and more complicated configurations involving separate sections of cellulose acetate fiber with activated charcoal, or sections of paper and cellulose acetate fiber have been used. In most of these cigarette filters, the filter element is substantially the same diameter as the tobacco part of the cigarette, and varies from about 15 to about 25 mm in length. The composition and structure of these filters is substantially uniform everywhere in the transverse cross-section. The tobacco smoke traverses the filter from one end to the other in a manner we shall describe as "axial flow."

The pressure drop through this filter is determined by the material of construction, the packing density, the length, and the diameter. The diameter, being nearly the same for all cigarette filters, is not an important variable for use in affecting filtration. The habits and taste of cigarette smokers have demanded that the pressure drop through a cigarette not exceed about three inches of water, at a standard flow rate of 35 ml per two seconds of flow. With a given material and a given construction of a cigarette filter, the ability of the filter to remove TPM can be altered by changing the packing density, fineness of fiber, etc. However, the higher the TPM removal, the higher the pressure drop.

It is known that a filter of sufficiently large face area can remove substantially all of the TPM with acceptable pressure drop. An example of such a filter is the Cambridge filter; this filter in the axial-flow design is impractical because the required face area is intolerably large. That is, the required area is much greater than that of the transverse cross section of a cigarette.

Large bundles of crimped textile fibers, known in the trade as tows, have been used extensively for the manufacture of cigarette filters. The vast majority of cigarette filters currently made in the United States are manufactured from such tows. Among the properties of textile tows that make them desirable for this use are: (1) they can be processed into filters continuously at very high manufacturing speeds; (2) filters made from the tows are fairly effective for trapping nicotine and tar, and (3) by proper selection of fibers and fiber modifications it is possible to selectively remove certain components from smoke.

Tobacco smoke filters of this invention are characterized by a filtration coefficient of about 0.25 or higher as calculated by the following equation:*

$$k = [-Ln(1-R)]/\Delta p$$

where R represents the fraction of tar or nicotine captured by the filters; Δp is the pressure differential across the filter and k is a constant related to the filter me-

dium. The value of k (designated filtration coefficient) for conventional filters made from textile tows is between 0.13 and 0.22 depending on the size and type of fibers (assuming Δp is expressed in inches of water at an air flow rate of 17.5 ml./sec.). *John E. Kiefer and George P. Touey in "Tobacco and Tobacco Smoke" Chapter X, E. L. Wynder and D. Hoffmann, Academic Press, New York (1967).

The mechanism of filtration that results in the efficiency of filters of this invention is not completely understood; however, there are certain aspects of this mechanism which are known to us. The efficiency of a conventional fibrous filter is related to the surface area of the fibers and the linear velocity of the smoke. The pressure drop is related to the same parameters, but by a different relationship. The present invention utilizes these parameters in a manner that results in higher efficiency and lower pressure drop than does the construction used in conventional filters.

When the surface area of a conventional filter is increased substantially by adding more fibers, the pressure drop of the filter is increased beyond the practical limit. We have found a means of increasing the surface area without an undesirable high pressure drop. This objective is accomplished by a physical configuration of fibers which results in a unique flow pattern within the filter. For example, a typical fibrous filter with a surface area of 275 cm² has a pressure drop of about 2.8 in. and a filtration efficiency of about 46 percent. If the surface area of this filter is increased to about 500 cm² by adding more fibers, the efficiency of the filter is increased to about 66 percent, but the pressure drop is increased to about 7.5 in. When the same high-pressure-drop filter is modified according to our invention, the pressure drop is reduced to no more than 3.0 in. and quite unexpectedly, the filtration efficiency ranges up to about 60 percent.

The filter elements of this invention are provided with notch means or longitudinal indentations or voids within the filters formed by the application of heat and/or pressure or by a cutting operation. For example, the filter element may comprise a porous filter body having an outer wall and end walls, said filter body defining at least first and second indentations, said indentations notch means extending from the surface of said outer wall into said body, said indentations being arranged so that upon drawing smoke into the filter a pressure differential is created between the first indentation and second indentation to cause a portion of the smoke to flow at a reduced linear velocity generally transversely through the filter from the area of one indentation toward the other indentation. Thus, smoke flowing through the filters will begin to flow axially through a face portion having a diameter about equal to the diameter of the cigarette. After entering the filter a portion of the smoke begins to flow generally diagonally as well as axially and thus is exposed to a relatively large face area of filter material. Due to the large face area the linear velocity of the smoke is decreased to thus enhance the filtration efficiency. The lower velocity also contributes to lower pressure drop.

A further understanding of the invention will be had from a consideration of the following description of the drawings:

IN THE DRAWINGS

FIG. 1 is a diagrammatic section showing one embodiment of a filter element of this invention.

FIGS. 2, 3, and 4 are cross-section views of the filter element of FIG. 1, the sections being taken along lines 2—2, 3—3 and 4—4, respectively, of FIG. 1.

FIG. 5 is a diagrammatic section of another embodiment of a filter element of this invention.

FIG. 6 is a cross-section view of the filter element of FIG. 5, taken along line 6—6 of FIG. 5.

FIG. 7 is a perspective view of still another embodiment of the filter element of this invention.

FIG. 8 is a cross-section view of the filter element of FIG. 7, taken along line 8—8 of FIG. 7.

FIG. 9 is a diagrammatic perspective view of a further embodiment of the filter element of this invention.

FIG. 10 is a cross-section view of the filter element of FIG. 9 taken along line 10—10 of FIG. 9.

FIG. 11 is a diagrammatic perspective view of a still further embodiment of the filter element of this invention.

FIGS. 12 and 13 are cross-section views of the filter element shown in FIG. 11 taken along lines 12—12 and 13—13, respectively, of FIG. 11.

FIG. 14 is a cross-section view taken along line 14—14 of FIG. 16 of another embodiment of this invention showing the relative positions and configuration of the indentations formed in the body of the filter element.

FIGS. 15 and 16 are end views of the filter element shown in FIG. 14.

FIG. 17 is a diagrammatic perspective view of still another embodiment of this invention showing the relative positions of a pair of short indentations arranged at either side of a longer indentation located at the same end of the filter.

FIGS. 18 and 19 are end views of the two ends of the filter element illustrated in FIG. 17.

FIG. 20 is a cross-section view of the filter element of FIG. 17 and taken along line 24'—24' of FIG. 19.

FIGS. 21—24 are cross-section views of the filter element of FIG. 17 and are taken along lines 21—21, 22—22, 23—23, and 24—24, respectively therein.

This invention will be described by referring to cigarette filters made from a textile tow. The textile tow may be made from thermoplastic fibers such as polyolefin, polyester, cellulose ester, and biphasic fiber. The filter may be formed from a crimped textile tow by methods known in the art. It is to be understood that the filter could be made from any known filter material which can be shaped.

Referring now to the drawings, the filter elements illustrated in the several sketches are made from a textile tow that has been formed into a cylindrical rod or filter body and passed through a device that cuts, presses, or stamps the body to produce notch means or indentations or voids. The pressing or stamping may be adapted to a continuous process, or it may be a batch process. It is to be understood that each filter element or body in use may be provided with an overwrap to enclose the notch means and form smoke chambers or channels or the wrapper for the column of tobacco in a cigarette may be extended to provide the same. For ease of description we will not refer to the overwrap further in this description of the invention.

When smoke is drawn through a filter such as is shown in FIG. 1, a portion of the smoke traverses that portion of the filter element designated as *a* into notch means 11, and then through section *b*, likewise there is parallel flow through portion *c*, into indentation 13 and through portion *d*. To cause smoke to flow through the filters of this invention in the manner desired it is necessary that the filters be constructed so that a pressure differential between the indentations on opposite sides of the filter is created by drawing smoke through the filter. For example, if Δp of portion *a*/ Δp of portion *c* = Δp of portion *b*/ Δp of portion *d*, there is not a differential pressure between indentation 11 and indentation 13 and the filter operates according to conventional principles, that is, the smoke flows axially through the filter. However, if Δp of portion *a*/ Δp of portion *c* does not equal Δp of portion *b*/ Δp of portion *d* a pressure differential is developed between indentations 11 and 13, and the smoke then flows generally axially through the filter into one end thereof and along the path of least resistance into the first indentation in the path and then diagonally through the mid-section of the filter into the indentation having the lower pressure and finally axially out of the filter. We believe the efficiency of the mid-section of the filter between the indentations for trapping smoke particles is high since the smoke particles travel generally perpendicular to the fibers and are moving at a reduced linear velocity because of the increased face area of the filter medium.

With the filter illustrated by FIG. 1, the desired pressure differentials across the fibrous section between notch means 13 and notch means 11 are accomplished by offsetting the notch means so that distance *a* is greater than distance *c* and distance *b* is less than distance *d*. This condition results in a pressure differential between notch means 13 and notch means 11 and a substantial flow from notch means 13 to notch means 11 (assuming the general direction of flow is from left to right). The fraction of the total smoke that flows from notch means 13 to notch means 11 depends on (1) the lengths of *a*, *b*, *c* and *d*; (2) the lengths of notch means 13 and notch means 11; (3) the distance between notch means 13 and notch means 11, and (4) the porosity of the fibrous portion of the filter.

Other methods of achieving the inequality Δp of *a*/ Δp of *c* $\neq$ Δp of *b*/ Δp of *d* and subsequent pressure differential between notch means 13 and notch means 11 are possible. For example, the filter tips can be cut at an angle other than 90° to the longitudinal axis as illustrated by FIG. 5. Thus, the notch means or voids may be directly opposed rather than offset as shown in FIG. 1.

The embodiment of the filter element shown in FIGS. 7 and 8 utilizes notch means defined by a series of ridges 15, 16 formed in opposite sides of the filter body, the notch means being offset from the mid-point of the filter body. The smoke flow through a filter of this type is axial as it enters the filter, substantially transverse as it moves from the region notch of one means to the region of the other notch means through the filter and then generally axially out of the other end of the filter.

In FIGS. 9 and 10 we have shown another embodiment of our filter in which the notch means 21, 23 are formed by cutting away a pair of opposed segments of the filter body to present a rather large area for smoke to penetrate when flowing from one notch means to the other.

In FIGS. 11, 12 and 13 we have shown a further embodiment of a filter element of this invention. The filter body is provided with a pair of oppositely disposed notch means 31, 33. The notch means or void spaces at the ends of the filter rod are generally shaped as slots. Each of the notch means or slots extends beyond the center of the filter body but each terminates short of the mid-point of a line extending from the axial center line of the filter body to the periphery of the filter body. The notch means are set at an angle to the axial center line of the filter body and decrease in size as they extend down the filter body until they run out of the body after passing the mid-point thereof. This arrangement of the notch means will cause smoke to flow diagonally through the filter to achieve high removal of TPM at a relatively low pressure drop in the manner described earlier herein.

In FIGS. 14, 15 and 16 we have illustrated still another embodiment of the filter element of this invention. The filter body 41 is provided with a first notch means or slot 43 and a second notch means or slot 45, the notch means being generally oppositely disposed in the filter body and are set at an angle to the axial center line of the filter body. The first notch means 43 begins at a point along the outer wall of the filter body and is spaced inwardly from one end thereof and gradually extends deeper into the filter body to a point near the other end of the filter body and there it terminates short of the end wall of the filter element. The second notch means 45 begins on the opposite side of the filter body near the opposite end thereof. This notch means extends along the body and gradually extends deeper into the filter body to the end thereof and it exits through that end wall 51 of the filter element. The surfaces of the filter element defining the lower surface of each of the notch means are generally parallel to each other and are spaced apart for a distance generally equal to less than the distance from the end of the filter to the point where the nearest notch means begin in the sidewall of the filter. An advantage of this particular construction is that some of the smoke passing through the filter is subjected to additional axial filtration as the smoke passes through the filter as the end 49 having the unbroken surface as shown in FIG. 16. Also the end of the filter having the unbroken surface has a pleasing appearance.

FIGS. 17-24 show another embodiment of a filter element of our invention. The filter body 53 defines a pair of similar notch means 54, 55 oppositely disposed in the filter body. The notch means respectively terminate through the ends of the filter body. This arrangement of the two notch means causes the smoke to flow diagonally through the filter as described earlier herein. Additionally, there is provided at one end of the filter body a pair of secondary notch means or indentations 56, 57 which start about one-fifth the length of the filter body from one end thereof and extend through that end. These two secondary notch means are arranged one on either side of and about 120° around the periphery of the filter body from the longer notch means which exits through that end of the filter body. The two secondary notch means serve to alter to some degree the smoke flow by causing some smoke flowing toward the opposed notch means to be diverted and flow toward the shorter notch means.

FIGS. 18 and 19, respectively, show the two ends of the filter body 53. FIGS. 20-24 are sections of the filter

body 53 shown in FIG. 17 and showing the relative positions of the major and minor notch means in the filter body.

The invention will be further illustrated by the following examples of preferred embodiments although it will be understood that these examples are included merely for purposes of illustration and are not intended to limit the scope of the invention.

EXAMPLE I

The paper-wrap was removed from conventional cigarette filter rods made from 1.6 denier per filament, 48,000 total-denier cellulose acetate tow containing 8 percent triacetin. Indentations notch means, 2-mm deep and 10mm long, were made on each side of the rods. The rods were paper wrapped and cut into 25mm filters. The cuts were made at a 45° angle to the longitudinal axis of the filter (FIG. 5). The filters were attached to 60mm cigarette columns and evaluated for filter efficiency by the procedure described in *Tobacco Science* 4, pp. 51-61 (1960). They had a very low pressure drop (1.1 inch of water) and trapped 31 percent of the TMP. The filtration coefficient was 0.31. Conventional cellulose acetate filters remove about 20 percent of the TMP at this pressure drop.

EXAMPLE II

Bonded filter tips (25-mm in length) made from 1.6 den./fil. 88,000 total denier cellulose acetate tow, with the paper wrapper removed, were cut with a razor blade to give generally, the shape shown in FIG. 1. The areas *b* and *c* were three millimeters long. The slices removed from the filter were approximately 17-mm in length and 1-mm in thickness. The cut filter was paper wrapped and attached to 60-mm cigarettes. The filters removed 62 percent tar at filter pressure drop of 2.9 inches. This represents a filtration coefficient of 0.34.

EXAMPLE III

Example I was repeated using filters from 1.6 denier per filament, 72,000 total denier cellulose acetate tow. These filters had a pressure drop of 2.3 inches of water and removed 52 percent TPM. The filtration coefficient was 0.32.

EXAMPLE IV

The paper wrapper was removed from a conventional 1.6 den./fil. 57,000 total denier cellulose acetate filter 25-mm in length. The filter was molded at 90°C. to a configuration substantially as shown in FIG. 1. The lengths of *a* and *d* were 8-mm and the lengths of segments *b* and *c* were 0. The filter was paper wrapped and attached to 60-mm tobacco columns. The filters removed 52 percent tar at a pressure drop of 2.6 inches. This represents a filtration coefficient of 0.28.

EXAMPLE V

A conventional filter containing a highly perforated paper wrapper and made from 1.2 den./fil. 65,000 total denier polyethylene fiber tow with 25 cpi. was placed in a mold. The mold was heated at 120°C. for 5 min. to fuse some of the fibers together at random points of contact (for filter rigidity) and to form the design illustrated in FIG. 1. The resulting 25-mm filter (FIG. 1) was paper wrapped and attached to a 60-mm tobacco column. Smoking tests revealed that the filter removed

60 % TPM at a pressure drop of 2.8 inches. The filtration coefficient was 0.33.

EXAMPLE VI

Conventional 25-mm filters, wrapped in highly perforated paper, and containing 1.0 den./fil., 60,000 total denier poly(ethylene terephthalate) polyester fibers with 20 cpi. were placed in a heated mold for 5 min. at 240°C. to harden the filters to give the design illustrated in FIG. 1. The filters were attached to 60-mm tobacco columns. They removed 60% TPM and had a pressure drop of 2.9 inches. This filter had a filtration coefficient of 0.31.

EXAMPLE VII

A bicomponent fiber consisting of 60 percent polypropylene and 40 percent poly(ethylene terephthalate) polyester was converted to a crimped tow of 65,000 total denier (1.8 den./fil.). The tow was placed in a mold heated for 5 minutes at 160°C. to give the filter designs shown in FIG. 1. The 25-mm filter was then paper wrapped and attached to a 60-mm tobacco column. The filter removed 56% TPM at a filter pressure drop of 2.3 inches. This represents a filtration coefficient of 0.35.

EXAMPLE VIII

A conventional filter 25-mm long containing the standard paper wrapper was placed in a heated mold (100°C.) for 2 seconds. The mold was provided with depressor blades with a "saw tooth" edge. The depressor blades not only cut the paper wrapper but also placed the grooves on both sides of the filter as shown in FIG. 11. The filter was made from 1.6 den./fil. 68,000 total denier cellulose acetate tow. The grooved filters were wrapped in a heavy paper and when tested were found to remove 59% TPM at a filter pressure drop of 2.7 inches. This represents a filtration coefficient of 0.33.

EXAMPLE IX

Conventional cellulose acetate filter rods (100-mm in length) wrapped in a highly perforated paper were molded in the laboratory apparatus for 2 seconds at 125°C. to give the configuration shown in FIG. 14. The rods were wrapped in a heavy commercial filter paper wrap (Ecusta 3744) and cut into 25-mm filters. The filters were attached to 60-mm tobacco columns and evaluated for filter efficiency by the procedure described in *Tobacco Science* 4, pp. 51-61 (1960). The Total Particulate Matter (TPM) removal values for the diagonal flow filters prepared from various 1.6 den./fil. tows are shown below:

25-mm Filter

Tow	Triacetin %	Pressure Drop In.	Removal %	K Value
1.6 - 52,000	5.9	2.3	51	0.31
1.6 - 52,000	5.9	2.4	50	0.29
1.6 - 60,000	5.7	2.7	49	0.26
1.6 - 66,000	7.9	2.8	55	0.28
1.6 - 66,000	5.9	2.9	55	0.27

EXAMPLE X

A highly perforated paper wrapped, conventional cigarette filter rod made from 1.6 denier per filament 52,000 total denier crimped cellulose acetate tow containing 8 percent triacetin was molded into a filter con-

figuration shown in FIG. 17. The overall filter length was 25-mm. The indentations or notch means 54 and 55 were 20-mm long and 2-mm deep at the ends of the filter body. The voids 56 and 57 were 5-mm long and 2-mm deep. SEveral filters prepared in this manner were paper wrapped and attached to 60-mm tobacco columns. The cigarettes were automatically smoked and the efficiency of the filters was determined according to the procedure described in *Tobacco Science* 4, pp. 51-61 (1960). The filters had an average pressure drop of 1.7 in. of water (measured to an air flow rate 17.5-ml per sec.) and removed 54 percent of the TPM from the smoke. Conventional acetate tow filters with this pressure drop remove only 30 percent tar.

EXAMPLE XI

A diagonal flow paper filter (creped soft porous tissue paper), 25-mm long, was molded to the configuration shown in FIG. 1 and when tested removed 61% TPM (total particulate matter) of cigarette smoke at a pressure drop of 2.0 in. ($k=47$). A 20-mm filter used in the normal manner (axial flow) removed 60% TPM at a pressure drop of 2.6 in. ($k=36$). This work demonstrates that molding a paper filter rod into 25-mm diagonal flow filters reduces the filter pressure drop significantly (less than a 20-mm axial flow paper filter), and the TPM removal remains the same as a 20-mm axial flow paper filter.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention as described hereinabove.

We claim:

1. Tobacco smoke filter element adapted to be used with an outer wrap, said element comprising a porous filter body having an outer side wall and end walls characterized in that said filter body defines a single pair of first and second notch means, said notch means extending from a surface of said outer side wall into said body, said first notch means being located adjacent one end of said filter element and terminating short of the other end thereof and said second notch means being located adjacent the other end of said filter element and terminating short of said one end, said first and second notch means being disposed, respectively, on opposite sides of the longitudinal axis of said filter element so that upon drawing smoke into the filter element a pressure differential is created between the first notch means and second notch means to cause a portion of the smoke to flow generally diagonally through the filter element from the region of one notch means toward the other notch means.

2. Tobacco smoke filter element of claim 1, wherein each of said notch means is defined by a generally semi-cylindrical wall formed in the surface of said filter body.

3. Tobacco smoke filter element of claim 1, wherein each of said notch means is defined by a series of ridges aligned axially with the longitudinal axis of the filter body.

4. Tobacco smoke filter element of claim 1, wherein said notch means are angularly disposed in said filter body with respect to the longitudinal axis thereof.

5. Tobacco smoke filter element of claim 4, wherein the innermost surfaces of the first and second notch means are disposed substantially parallel to each other.

6. Tobacco smoke filter element of claim 5, wherein the notch means, respectively, extend more than half-way through the filter body at each end thereof and extend progressively a lesser distance into the filter body until each terminates at the surface of the body at points adjacent the center portion of the body.

7. Tobacco smoke filter of claim 1, wherein said end walls lie in generally parallel planes which are inclined with respect to the longitudinal axis of said filter body.

8. Tobacco smoke filter element of claim 1, wherein one of said notch means terminates short of an end wall

of said filter element.

9. Tobacco smoke filter element of claim 1, wherein secondary notch means are defined by said filter body, said secondary notch means being equal in length to less than one-half the length of the filter element and each extends from the same end wall of the filter element, said secondary notch means being arranged one on either side of one of said notch means and spaced around the periphery of the filter element from said notch means.

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