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SPECIFICATION

1. TITLE OF THE INVENTION

Method of Estimation of an Aeration Resistance in a Filter Plug

2. BACKGROUND OF THE INVENTION

This invention relates to a method of estimation of an aeration resistance in a cigarette filter plug.

Filters attached to cigarettes are prepared by a plurality of bundles of fibers having an approximately Y letter form (Y sectional area string) in a cross-sectional area made of crimped acetate filament windingly wrapped with papers.

In cigarette manufacturing, filters having six or four times the length of conventional filters, called "plugs", are prepared, cut to the conventional size, and attached to cigarettes. The method of estimation of the aeration resistance of this invention can be used both in plug production and in cigarette production.

Aeration resistance is an important nature of the filter and filter plug for cigarette production.

The aeration resistance means a pressure difference which occurs at both ends of the filter when air having a certain temperature humidity under normal pressure passes through the filter in an amount of flow of 17.5 milliliters per second and is expressed by water height (mm). Accordingly, the aeration resistance is a value having a pressure unit (or dimension).

The aeration resistance value gives a rough idea of how smooth the filter is to draw. The filterability of tar and nicotine in smoke depends greatly upon the aeration resistance, and it is much easier to measure the aeration resistance than to measure filterability. Accordingly, it is widely and often used as one of the important items of filter rod properties in the cigarette manufacturing industry.

The aeration resistance changes according to such factors as filter size, properties of fiber and the filling state of fibers.

In order to manufacture filter rods and plugs having the

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desired aeration resistance, it is necessary to know these factors previously. Accordingly, the method of estimating the aeration resistance is important and necessary for filter manufacturers.

This invention provides a method of estimating aeration resistance of the filter plug, by using an aeration resistance formula.

3. BRIEF DESCRIPTION OF THE INVENTION

The method of estimation of the aeration resistance of the filter plug in this invention is characterized by the sum of a friction resistance and a fluid resistance of the plug.

Further, it is characterized in that the aeration resistance of the filter plug of the tobacco filled with tow is estimated by the following formula:

$$PD = 4(16/Re_1) \times 9 \times (Di/Ls)^{0.17} \times (\rho x u^2/2gc) \times (L/DH) + (10.535/Re_2^{0.7672}) \times (\rho x u^2/2gc) \times (4\pi Sp/c^2)$$

PD: aeration resistance

Re_1: Reynolds number (Re) of the friction resistance formula

Re_2: Reynolds number of the fluid resistance formula

Di: distance between centers of the fibers

Ls: wetted perimeter of the filter section

ρ: fluid density

u: flow rate

L: filter length

DH: equivalent diameter of the friction resistance formula

Sp: projective area of crimped filaments to the vertical plane with respect to the flow

C: filter circumference

gc: weight conversion coefficient

According to this invention, the aeration resistance of the filter plug filled with tow can be estimated by using an aeration-resistant formula in the field of chemical engineering.

Thus, the most suitable determination of the materials,

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forms and sizes can be performed effectively, and filter plugs having smooth aeration resistance to draw can thereby be manufactured.

4. BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a model view of a sectional form of a filament denier at the tow-filling portion in an embodiment of this invention.

Fig. 2 is a model view which shows a contact state of each filament denier in Fig. 1.

Fig. 3 is an explanatory view of a diameter of the filament denier in Fig. 1(A).

Fig. 4 is an explanatory view of a wide size of a mass of the fiber in the contact state of each filament denier in Fig. 1(A).

Fig. 5 is an explanatory view of a height size of the fiber mass in the contact state of each filament denier in Fig. 1(A).

Fig. 6 is an explanatory view which shows an arrangement configuration of the fiber mass.

Fig. 7 is a comparison view of a measured value and an estimated value of the aeration resistance of the filter.

Fig. 8 is a view which shows the relation between the aeration resistance of the filter and the filter length.

Fig. 9 is a view which shows the relation between the aeration resistance and the circumference of the filter.

Fig. 10 is a view which shows the relation between the aeration resistance and the filament denier of the filter.

Fig. 11 is a view which shows the relation between the aeration resistance and a ferearea of the filter.

Fig. 12 is a view which shows the relation between the aeration resistance and the amount of the tow filling.

5. DETAILED DESCRIPTION OF THE INVENTION

An embodiment of this invention will be described with reference to Fig. 1 to Fig. 12 as follows.

Detected is a model for obtaining an aeration resistant formula for a method of estimation of the aeration resistance of the filter plug of the tobacco filled with tow.

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Fig. 1 is a model view which shows a sectional form of the filament denier in the tow-filling portion.

In Fig. 1, the filament 1 comprises a letter Y sectional form. In order to express this relation by some values, this relation is approximated by a shape which consists of three semicircles having a diameter A, three rectangles (AxB) and a regular triangle. In Fig. 1, FS shows a sectional area of the filament 1, HI shows the longitudinal width of the filament 1 and H2 shows a transverse, respectively. In addition, as a sectional area shape coefficient, a ferearea (FA) is used and is calculated by formula 1.

Formula 1

$$FA = \frac{FS}{H^1 \cdot H^2}$$

Fig. 2 is a model view which shows a contact state of each filament 1 in Fig. 1.

In the above tow-filling portion, since some filaments exist in a contact state, an example of a representative contact state is shown by Fig. 2(A) to Fig. 2(D).

As a model for obtaining an aeration resistant formula of the above filter, although the above contact state is also considered, in the following calculation a contact state pattern shown in Fig. 2(A) is used.

As a term which constitutes the aeration resistant formula of the above filter, an equivalent diameter DH in the friction resistance formula can be obtained by the formula 2.

Formula 2

$$D_H = \frac{4V}{S}$$

Wherein V: space volume of the filter
S: area contacting with fluid

The above space volume V is obtained based upon the filter length L, a circumferential length of the filter C, the amount of the tow filling W and a tow specific weight.

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In addition, an area S which contacts with the above fluid is defined as a value which deducts an area S_3 which contacts each filament from the sum of an inner area S_1 of the rolled paper and the total fiber surface areas S_2.

The above area S_2 can be obtained by basing upon the surrounding length of the filament sectional area shown in Fig. 1, and the above area S_3 is also obtained by basing upon the contact state of the filament (Fig.2(A)) respectively.

The portions where the filament contacts each other correspond to the fiber mass formed by poor blooming.

In the sectional form of the filament, when the length of a contact area in the section is B, one fiber mass is formed by contacting N bundles of filament and the circumferential length KL of this fiber mass is obtained by the formula 3.

Formula 3

$$KL = FL \cdot N-2\ (N-1) \cdot B$$

Wherein: FL: length of the filament (determined by A and B in Fig. 1)

When K pieces of the fiber masses of the above unblooming (fibers) exist in the tow sectional area, the total circumferential length SL in its sectional can be obtained by formula 4.

Formula 4

$$SL = (TD/FD - N \cdot K) \cdot FL + K \cdot KL$$

Wherein: TD: total denier
FD: filament denier of the filament

Furthermore, since the length of the filament denier 1 in the filter (tow-filling portion) is obtained by $(9 \times 10^5 \times W/TD)$, the area S to which the above fluid contacts can be calculated by the formula 5.

Formula 5

$$S = C \cdot L + 9 \cdot 10^5 \cdot (W/TD)\ \{(TD/FD - N \cdot K)\ (3\pi \cdot A/2 + 6B) + K\ (3\pi \cdot N \cdot A/2 + (4N+2)\ B)\}$$

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Then, A and B in Fig. 1 can be expressed with filament denier FD and ferearea FA by solving the relations between sectional area FS and filament denier FD, ferearea FA and sectional area FS due to the formula 1 and between sectional area FS and A, B shown in Fig. 1.

Fig. 3 is an explanatory view of the diameter of the filament 1 in Fig. 1.

In Fig. 3, the calculation of the longitudinal width H_1 and the transverse breadth H_2 in Formula 1 are shown.

In addition, the above diameter F can be obtained by formula 6.

Formula 6

$$F = \sqrt{H_1 \cdot H_2} = \sqrt{\frac{FD}{9 \cdot 10^5 \cdot 1.32 \cdot FA}}$$

Thus, the corresponding diameter DH of the friction resistance formula in formula 1 can be obtained.

Fig. 4 is an explanatory view of the width size of the fiber mass in the contact state of each filament in Fig. 1(A).

In Fig. 4, the breadth size FW_1 of the fiber mass in the contact state of the filament of N bundles is obtained from Fig. 4 by using formula 7.

Formula 7

$$FW_1 = 1.\ 5A + \sqrt{3B} + (N-1)\ (5A/4 + \sqrt{3B}/2$$

Similarly, Fig. 5 is an explanatory view of a height size of the fiber mass in a contact state of each filament in Fig. 1(A).

In Fig. 5, the height size FW_2 of the above fiber mass is obtained from Fig. 5 by using the formula 8.

Formula 8

$$FW_2 = 2\ \{\ (2+\sqrt{3}\ )\ A/4+B)\ \}\ +X$$

Wherein $X = -\sqrt{3A}/4+3/2$

Fig. 6 is an explanatory view which shows an existent state

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of the fiber mass.

In Fig. 6, since the existent state of the above fiber mass in the tow-filling portion shows an indefinite shape, the breadth of the fiber mass is shown with its mean value, whereby its breadth is shown as a mean value FW (formula 9) when the fiber mass consists of the above breadth size FW_1 and of the height size FW_2 rotate to 90°.

Formula 9

$$W_1 = FW_1 \cdot \cos\theta$$
$$W_2 = FW_2 \cdot \cos\ (\pi/2-\theta)$$

$$FW = \frac{\int (W_1 + W_2)\ d\theta}{\int \theta d\theta}$$

The mean value Fd of the diameter when K pieces of the above fiber mass exist in the filter (tow-filling portion), is obtained by formula 10 from the relation of a diameter F shown in formula 6.

Formula 10

$$Fd = \{(TD/FD-N\cdot K)\cdot F+K\cdot FW/(TD/FD-(N-1)\ K\}$$

The above aeration resistant formula of the filter is obtained as the sum of the friction loss arising from the gas flow in the tube corresponding to the filter and the fluid resistance when the gas flows through the material having fiber form and size of the fiber in the tow-filling portion which is a constitution element in the above filter inner portion.

Fanning formula is adopted as a friction loss formula of the inner flow of the tube. It is shown by the formula 11.

Formula 11

$$\Delta P_v = 4\cdot f\cdot(\rho\cdot u_2/2\cdot gc)\cdot(L/D)$$

ΔP_v: aeration resistance due to friction loss
ρ: fluid density
L: filter length
f: tube friction coefficient
u: flow rate
D: inner diameter of the tube

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In this case, the sectional area of the tube in formula 11 is a circle and in cases other than the circle sectional area, or in this example a corresponding diameter DH obtained by formula 2 is used in place of the above D.

On the other hand, a tube friction coefficient f is a function of Reynolds number which is expressed as Re_1, said Re_1 being expressed by the formula 12.

Formula 12

$$Re_1 = \frac{DH \cdot \rho \cdot u}{\mu}$$

ρ: fluid (air) density
u: flow rate
μ: viscosity of fluid (air)

The above flow rate can be obtained easily by using the specific gravity of acetate when the air flows at the flow rate of Q through the filter having length L, circumference C, and the tow-filling portion W. In addition, the relation between the tube friction coefficient f and Reynolds number Re_1 is determined as shown in formula 13 by comparison with measured values.

Formula 13

$$f=16/Re_1 \cdot 9 \cdot (Di/Ls)^{0.17}$$

Di: distance between fiber centers
Ls: wetted parameter length of the filter section

The aeration resistance due to the fluid resistance is shown by formula 14.

Formula 14

$$\Delta P_f = C_D \ (\rho \cdot u^2/2 \cdot gc) \cdot (4\pi \cdot S_p/C_2)$$

ΔP_f: aeration resistance through fluid resistance
C: circumference of the filter
S_p: windingly crimped projective area to a vertical surface with respect to the flow

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C_D: resistant coefficient

A resistant coefficient C_D is obtained by formula 15 from the relation of the resistance which a cylindrical body placed at a right angle with respect to the flow receives from the flow of the fluid.

Formula 15

$$C_D = \frac{10.535}{Re_2^{0.7672}}$$

Furthermore, the above windingly crimped projective area Sp is obtained by the formula 16 from a height Y of the fiber windingly crimped and a diameter Fd.

Formula 16

$$Sp = Fd \cdot Y$$

Thus, the formula for the estimated aeration resistance of the filter is obtained by the formula 17 consisting of the sum of formula 11 which shows the friction resistance used for formula 12 and 13 and of the formula 14 which shows the fluid resistance used for formulas 15 and 16.

Formula 17

$$PD = 4 \cdot (16/Re_1) \cdot 9 \cdot (Di/Ls)^{0.17} \cdot (\rho u^2/2gc) \cdot (L/D_H) + (10.535/Re_2^{0.7672}) \cdot (\rho \cdot u^2/2gc) \cdot (4\pi \cdot S_p/C^2)$$

PD: aeration resistance
Re_1: Reynolds number of the friction resistant formula
Re_2: Reynolds number of the fluid resistant formula
Di: distance between centers of the fibers
Ls: wetted perimeter length of the filter section
ρ: fluid density
u: flow rate
L: filter length
D_H: correspondent diameter of the friction resistant formula
S_p: windingly crimped projective area to the vertical surface with respect to the flow
C: circumference of the filter
gc: weight conversion coefficient

The formula for estimated aeration resistance shown in the

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above formula 17 was confirmed to be effective in the comparison of a measured value by a test unit of the filter aeration resistance, and also reviewed regarding various kinds of effects of the parameters.

Fig. 7 is a comparison view of a measured value of the aeration resistance of the filter with its estimated value. As the above estimated value, a value calculated as including 15% of unblooming fiber is used, said estimated value showing a good coincidence with the measured value.

Further, the effect the blooming fiber exerts on the aeration resistance is great and great parts of dispersions in the measured values are caused by the degree of blooming.

Since the degrees of the unblooming (fibers) of the tow can be quantified by the measured value of the aeration resistance, the availability of the aeration resistant estimation formula of the filter in this example can be increased.

Fig. 8 is a graph which shows the relation between the aeration resistance PD and the length of the filter, and it was confirmed that the aeration resistance PD is in the proportion to the length L of the filter, by the estimated value and the measured value.

Fig. 9 is a graph which shows a relation between the aeration resistance PD and the circumference of the filter C, said graph being shown by the estimated value and its measured value of the aeration resistance PD when the circumference C is changed.

Fig. 10 is a graph which shows the relation between the aeration resistance PD and the filament denier FD of the single fiber, said filament denier FD being related to the formulas 4, 10 and the like.

In addition, Fig. 10 shows the estimated value and the measured value of the operation resistance PD when the filament denier FD is changed.

Further, although the test of the aeration resistance PD when the tow denier TD is changed is performed, the explanation of the description is omitted.

Fig. 11 is a graph which shows the relation between the aeration resistance PD and the ferearea FA of the tow fiber

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sectional shape, said ferearea being related to the formula 11.

The above relation is confirmed by the estimated value and the measured value.

Fig. 12 is a view which shows the relation between the aeration resistance PD and the tow filling weight W, said relation being confirmed by the estimated value and the measured value.

In the method of estimation of the aeration resistance of filter plugs according to this invention, the aeration resistance of the filter plug of cigarettes consisting of fiber having complicated shapes can be estimated correctly by the right dimension corresponding to the complicated element parameter by using the aeration resistance formula consisting of the sum of the friction resistance and the fluid resistance.

Accordingly, the most suitable values of the filter material, form and size can be effectively determined with high reliability by using an estimated aeration resistance of filters, thereby being able to prepare a filter provided with an aeration resistant characteristic suitable to smokers with ease.

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What is claimed is:

1. A method of estimation of an aeration resistance of a cigarette filter or a plug filled with tow wherein said aeration resistance is estimated as the sum of a friction resistance and a fluid resistance.

2. A method of estimation of an aeration resistance of a filter plug wherein said aeration resistance of a tobacco filter or a plug filled with tow is estimated as the following formula:

$$PD = 4(16/Re_1) \times 9 \times (Di/Ls)^{0.17} \times (\rho.u^2/2gc) \times (L/DH)$$

$$+ \frac{10.535}{Re_2\ 0.7672} \times \frac{\rho.u^2}{2.gc} \times \frac{4\pi.Sp}{C^2}$$

PD: aeration resistance

Re_1: Reynolds number of friction resistance formula

Re_2: Reynolds number of fluid resistance formula

Di: distance between centers of the fibers

Ls: wetted perimeter of the filter section

p: fluid density

u: flow rate

L: filter length

DH: equivalent diameter of the friction resistant formula

Sp: projective area of the filaments to a vertical plane with respect to the flow

C: filter circumference

gc: weight conversion coefficient



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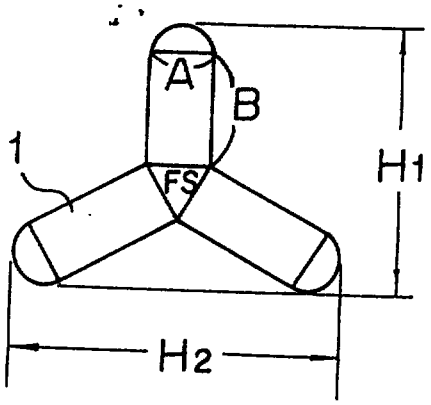
ABSTRACT

The aeration resistance of a cigarette filter plug filled with tow is estimated as a sum of a friction resistance and a fluid resistance by a formula 17.

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FIG. 1



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FIG. 2 (A)

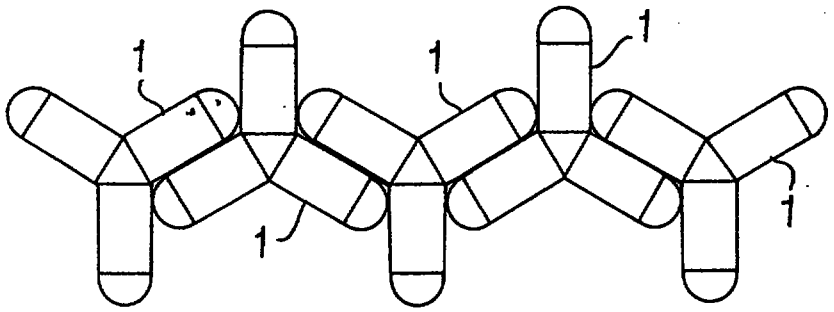


FIG. 2 (B)

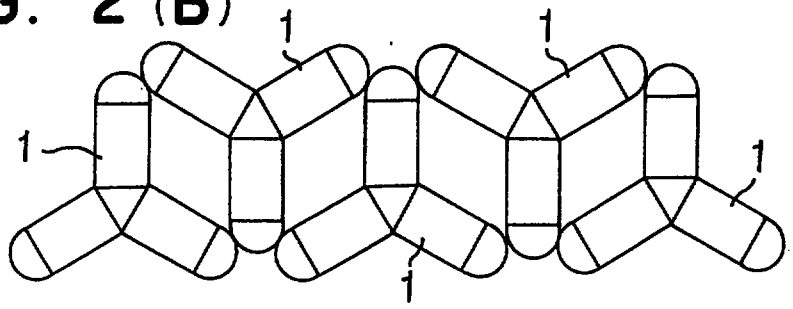


FIG. 2 (C)

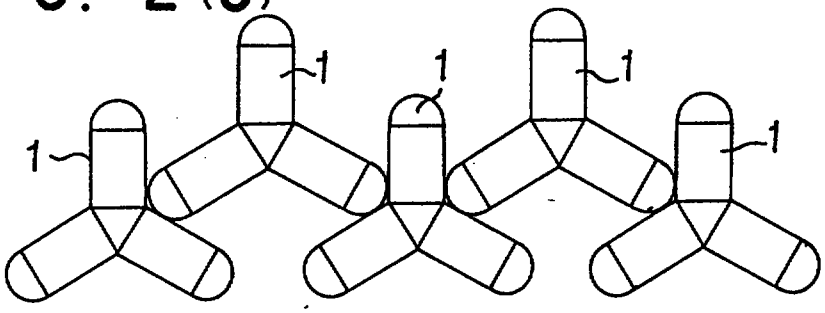
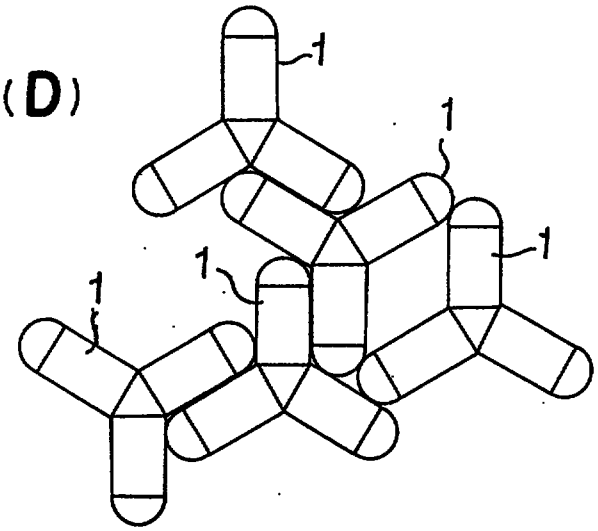


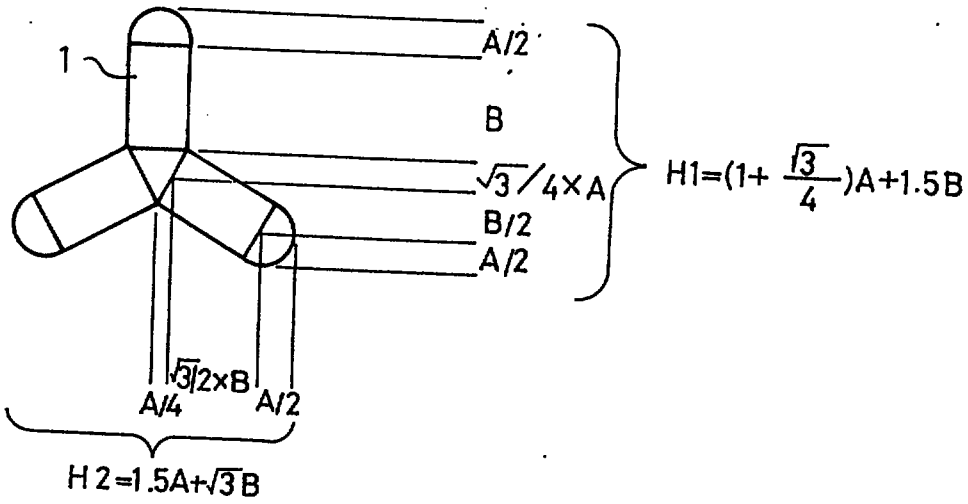
FIG. 2 (D)



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FIG. 3



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FIG. 4

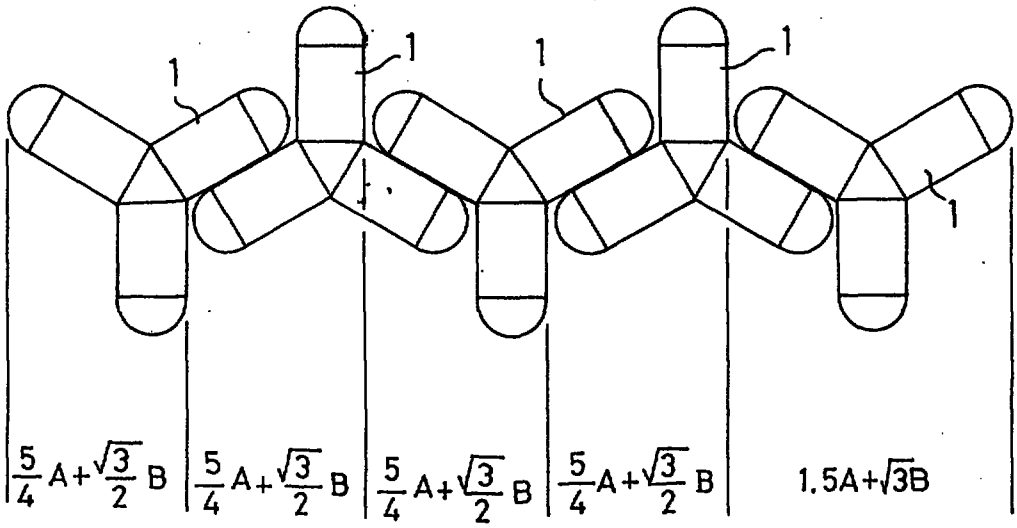


FIG. 5

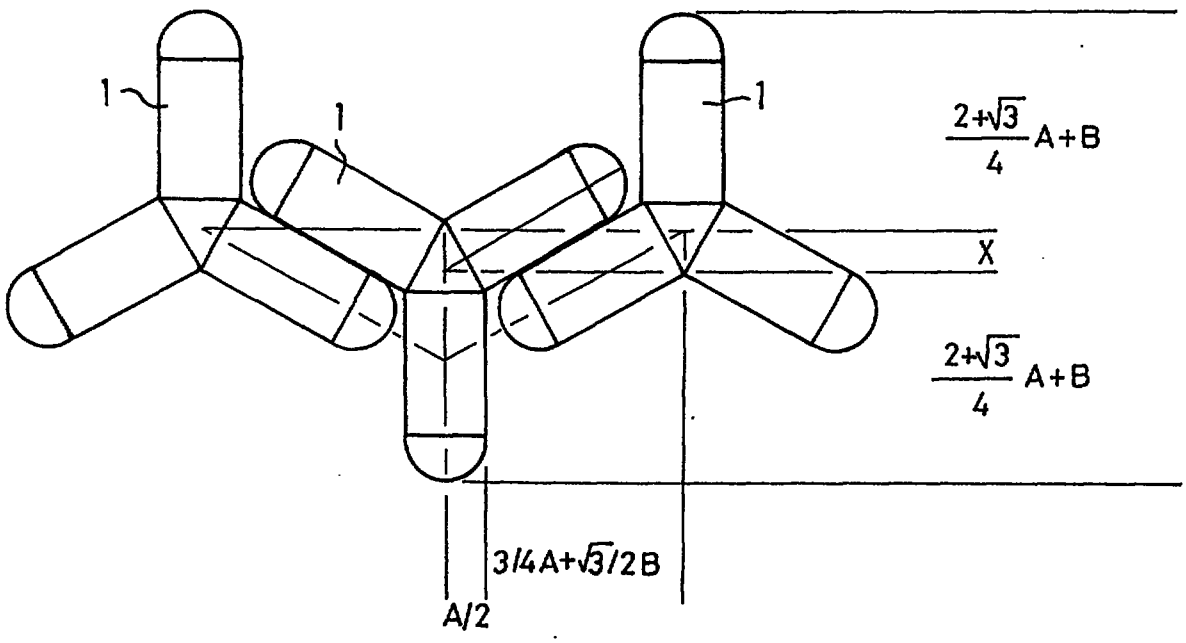
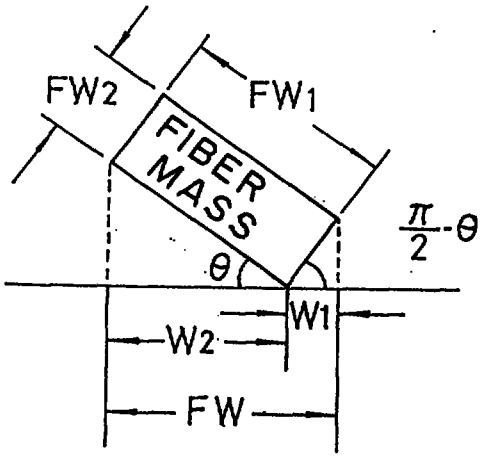


FIG. 6



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FIG. 7

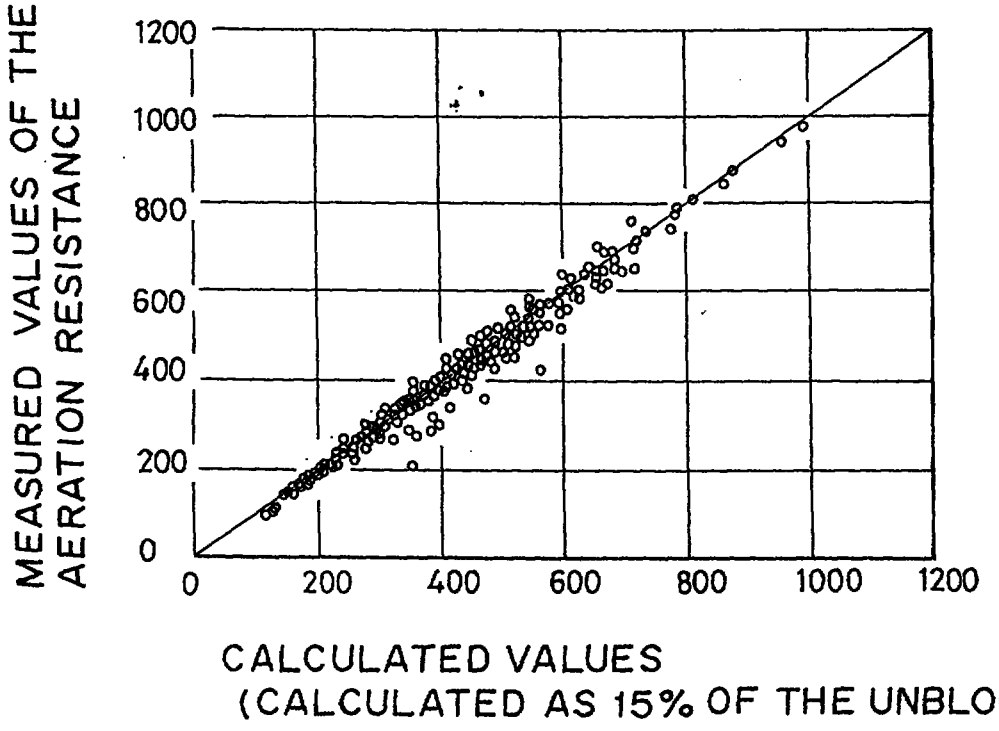
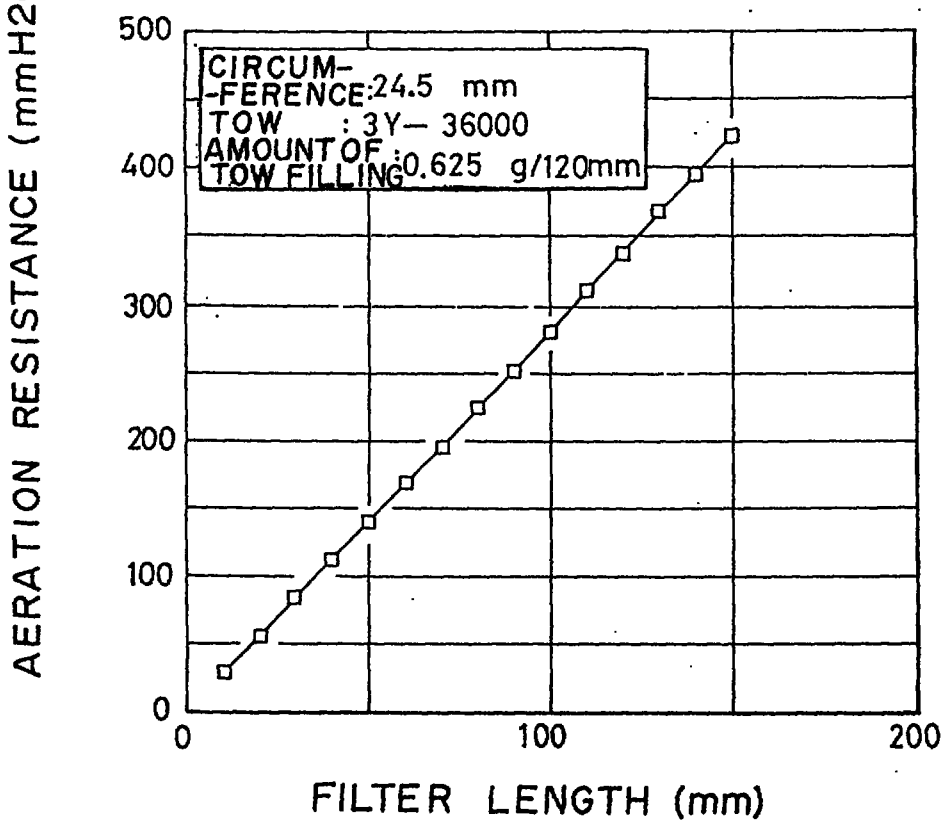


FIG. 8



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FIG. 9

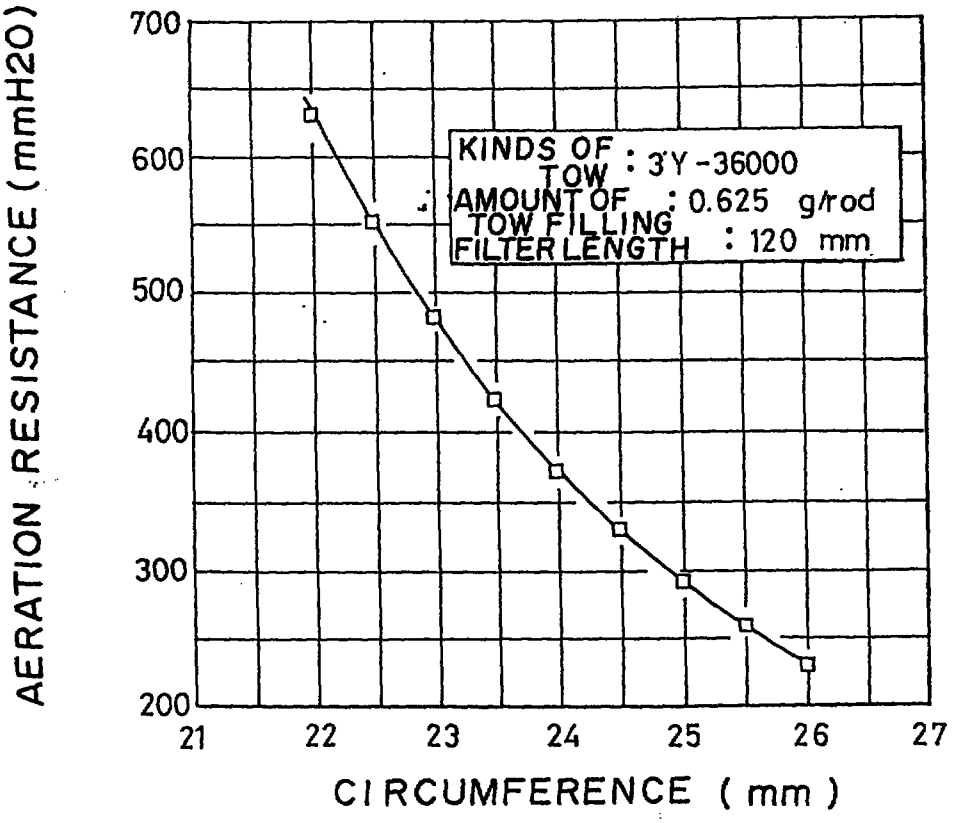
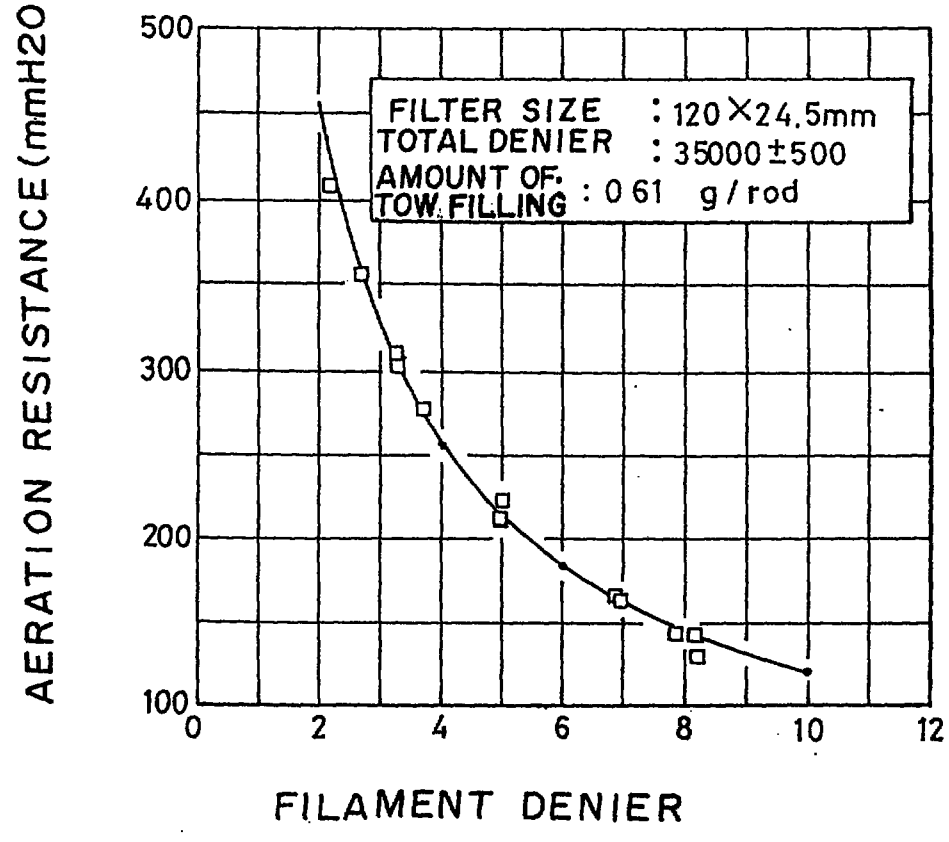


FIG. 10



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FIG. 11

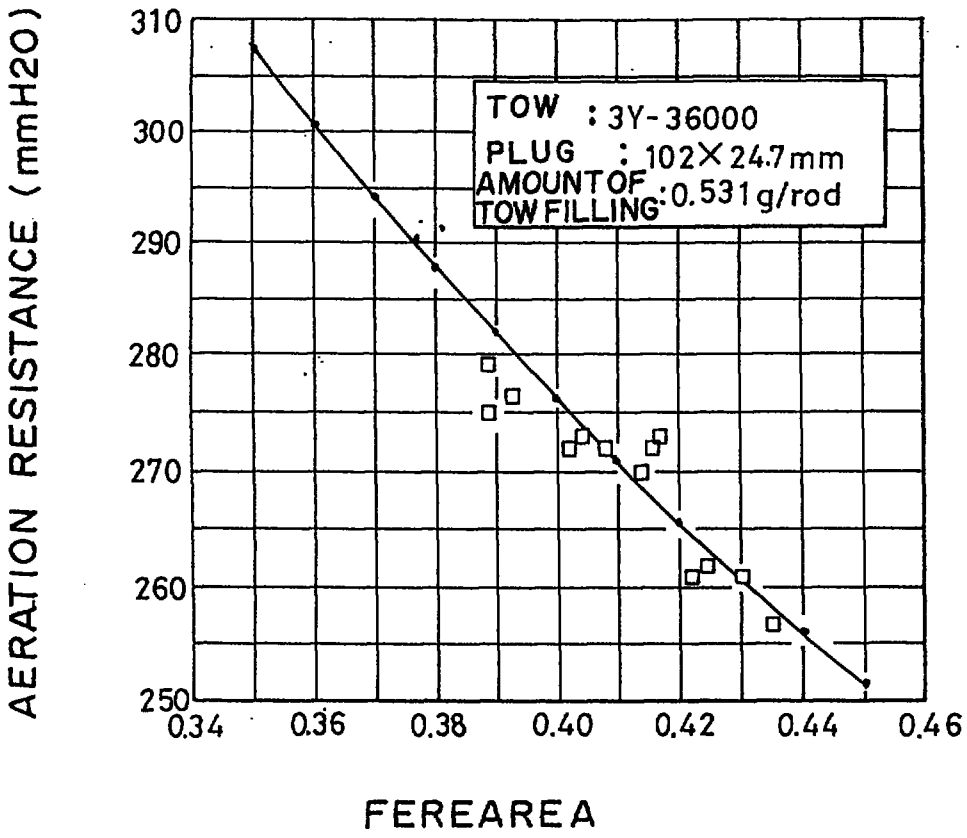
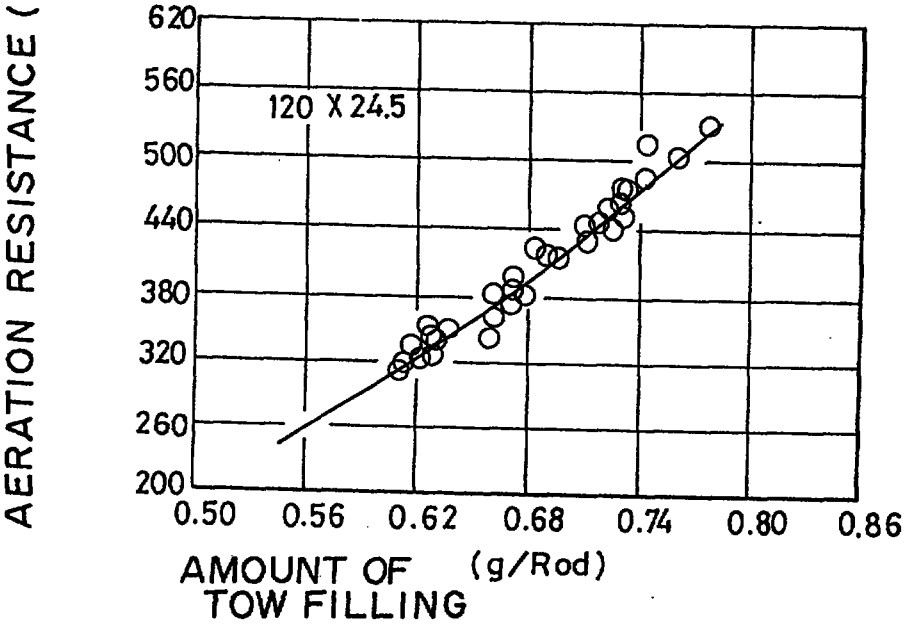


FIG. 12



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SPECIFICATION

1. TITLE OF THE INVENTION

Method of Estimation of an Aeration Resistance in a Filter Plug

2. BACKGROUND OF THE INVENTION

This invention relates to a method of estimation of an aeration resistance in a cigarette filter plug.

Filters attached to cigarettes are prepared by a plurality of bundles of fibers having an approximately Y letter form (Y sectional area string) in a cross-sectional area made of crimped acetate filament windingly wrapped with papers.

In cigarette manufacturing, filters having six or four times the length of conventional filters, called "plugs", are prepared, cut to the conventional size, and attached to cigarettes. The method of estimation of the aeration resistance of this invention can be used both in plug production and in cigarette production.

Aeration resistance is an important nature of the filter and filter plug for cigarette production.

The aeration resistance means a pressure difference which occurs at both ends of the filter when air having a certain temperature humidity under normal pressure passes through the filter in an amount of flow of 17.5 milliliters per second and is expressed by water height (mm). Accordingly, the aeration resistance is a value having a pressure unit (or dimension).

The aeration resistance value gives a rough idea of how smooth the filter is to draw. The filterability of tar and nicotine in smoke depends greatly upon the aeration resistance, and it is much easier to measure the aeration resistance than to measure filterability. Accordingly, it is widely and often used as one of the important items of filter rod properties in the cigarette manufacturing industry.

The aeration resistance changes according to such factors as filter size, properties of fiber and the filling state of fibers.

In order to manufacture filter rods and plugs having the

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desired aeration resistance[2], it is necessary to know these factors previously. Accordingly, the method of estimating the aeration resistance is important and necessary for filter manufacturers.

This invention provides a method of estimating aeration resistance of the filter plug, by using an aeration resistance formula.

3. BRIEF DESCRIPTION OF THE INVENTION

The method of estimation of the aeration resistance of the filter plug in this invention is characterized by the sum of a friction resistance and a fluid resistance of the plug.

Further, it is characterized in that the aeration resistance of the filter plug of the tobacco filled with tow is estimated by the following formula:

$$PD = 4(16/Re_1) \times 9 \times (Di/Ls)^{0.17} \times (\rho x u^2/2gc) \times (L/DH) + (10.535/Re_2^{0.7672}) \times (\rho x u^2/2gc) \times (4\pi Sp/c^2)$$

PD: aeration resistance

Re_1: Reynolds number (Re) of the friction resistance formula

Re_2: Reynolds number of the fluid resistance formula

Di: distance between centers of the fibers

Ls: wetted perimeter of the filter section

ρ: fluid density

u: flow rate

L: filter length

DH: equivalent diameter of the friction resistance formula

Sp: projective area of crimped filaments to the vertical plane with respect to the flow

C: filter circumference

gc: weight conversion coefficient

According to this invention, the aeration resistance of the filter plug filled with tow can be estimated by using an aeration-resistant formula in the field of chemical engineering.

Thus, the most suitable determination of the materials,

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forms and sizes can be performed effectively, and filter plugs having smooth aeration resistance to draw can thereby be manufactured.

4. BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a model view of a sectional form of a filament denier at the tow-filling portion in an embodiment of this invention.

Fig. 2 is a model view which shows a contact state of each filament denier in Fig. 1.

Fig. 3 is an explanatory view of a diameter of the filament denier in Fig. 1(A).

Fig. 4 is an explanatory view of a wide size of a mass of the fiber in the contact state of each filament denier in Fig. 1(A).

Fig. 5 is an explanatory view of a height size of the fiber mass in the contact state of each filament denier in Fig. 1(A).

Fig. 6 is an explanatory view which shows an arrangement configuration of the fiber mass.

Fig. 7 is a comparison view of a measured value and an estimated value of the aeration resistance of the filter.

Fig. 8 is a view which shows the relation between the aeration resistance of the filter and the filter length.

Fig. 9 is a view which shows the relation between the aeration resistance and the circumference of the filter.

Fig. 10 is a view which shows the relation between the aeration resistance and the filament denier of the filter.

Fig. 11 is a view which shows the relation between the aeration resistance and a ferearea of the filter.

Fig. 12 is a view which shows the relation between the aeration resistance and the amount of the tow filling.

5. DETAILED DESCRIPTION OF THE INVENTION

An embodiment of this invention will be described with reference to Fig. 1 to Fig. 12 as follows.

Detected is a model for obtaining an aeration resistant formula for a method of estimation of the aeration resistance of the filter plug of the tobacco filled with tow.

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Fig. 1 is a model view which shows a sectional form of the filament denier in the tow-filling portion.

In Fig. 1, the filament 1 comprises a letter Y sectional form. In order to express this relation by some values, this relation is approximated by a shape which consists of three semicircles having a diameter A, three rectangles (AxB) and a regular triangle. In Fig. 1, FS shows a sectional area of the filament 1, HI shows the longitudinal width of the filament 1 and H2 shows a transverse, respectively. In addition, as a sectional area shape coefficient, a ferearea (FA) is used and is calculated by formula 1.

Formula 1

$$FA = \frac{FS}{H^1 \cdot H^2}$$

Fig. 2 is a model view which shows a contact state of each filament 1 in Fig. 1.

In the above tow-filling portion, since some filaments exist in a contact state, an example of a representative contact state is shown by Fig. 2(A) to Fig. 2(D).

As a model for obtaining an aeration resistant formula of the above filter, although the above contact state is also considered, in the following calculation a contact state pattern shown in Fig. 2(A) is used.

As a term which constitutes the aeration resistant formula of the above filter, an equivalent diameter DH in the friction resistance formula can be obtained by the formula 2.

Formula 2

$$D_H = \frac{4V}{S}$$

Wherein V: space volume of the filter
S: area contacting with fluid

The above space volume V is obtained based upon the filter length L, a circumferential length of the filter C, the amount of the tow filling W and a tow specific weight.

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In addition, an area S which contacts with the above fluid is defined as a value which deducts an area S_3 which contacts each filament from the sum of an inner area S_1 of the rolled paper and the total fiber surface areas S_2.

The above area S_2 can be obtained by basing upon the surrounding length of the filament sectional area shown in Fig. 1, and the above area S_3 is also obtained by basing upon the contact state of the filament (Fig.2(A)) respectively.

The portions where the filament contacts each other correspond to the fiber mass formed by poor blooming.

In the sectional form of the filament, when the length of a contact area in the section is B, one fiber mass is formed by contacting N bundles of filament and the circumferential length KL of this fiber mass is obtained by the formula 3.

Formula 3

$$KL = FL \cdot N-2\ (N-1) \cdot B$$

Wherein: FL: length of the filament (determined by A and B in Fig. 1)

When K pieces of the fiber masses of the above unblooming (fibers) exist in the tow sectional area, the total circumferential length SL in its sectional can be obtained by formula 4.

Formula 4

$$SL = (TD/FD - N \cdot K) \cdot FL + K \cdot KL$$

Wherein: TD: total denier
FD: filament denier of the filament

Furthermore, since the length of the filament denier 1 in the filter (tow-filling portion) is obtained by $(9 \times 10^5 \times W/TD)$, the area S to which the above fluid contacts can be calculated by the formula 5.

Formula 5

$$S = C \cdot L+9 \cdot 10^5 \cdot (W/TD)\ \{(TD/FD - N \cdot K)\ (3\pi \cdot A/2+6B) + K\ (3\pi \cdot N \cdot A/2+ (4N+2)\ B)\}$$

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Then, A and B in Fig. 1 can be expressed with filament denier FD and ferearea FA by solving the relations between sectional area FS and filament denier FD, ferearea FA and sectional area FS due to the formula 1 and between sectional area FS and A, B shown in Fig. 1.

Fig. 3 is an explanatory view of the diameter of the filament 1 in Fig. 1.

In Fig. 3, the calculation of the longitudinal width H_1 and the transverse breadth H_2 in Formula 1 are shown.

In addition, the above diameter F can be obtained by formula 6.

Formula 6

$$F = \sqrt{H_1 \cdot H_2} = \sqrt{\frac{FD}{9 \cdot 10^5 \cdot 1.32 \cdot FA}}$$

Thus, the corresponding diameter DH of the friction resistance formula in formula 1 can be obtained.

Fig. 4 is an explanatory view of the width size of the fiber mass in the contact state of each filament in Fig. 1(A).

In Fig. 4, the breadth size FW_1 of the fiber mass in the contact state of the filament of N bundles is obtained from Fig. 4 by using formula 7.

Formula 7

$$FW_1 = 1.\ 5A + \sqrt{3B} + (N-1)\ (5A/4 + \sqrt{3B}/2$$

Similarly, Fig. 5 is an explanatory view of a height size of the fiber mass in a contact state of each filament in Fig. 1(A).

In Fig. 5, the height size FW_2 of the above fiber mass is obtained from Fig. 5 by using the formula 8.

Formula 8

$$FW_2 = 2\ \{\ (2+\sqrt{3})\ A/4+B)\ \} + X$$

Wherein $X = -\sqrt{3}A/4+3/2$

Fig. 6 is an explanatory view which shows an existent state

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of the fiber mass.

In Fig. 6, since the existent state of the above fiber mass in the tow-filling portion shows an indefinite shape, the breadth of the fiber mass is shown with its mean value, whereby its breadth is shown as a mean value FW (formula 9) when the fiber mass consists of the above breadth size FW_1 and of the height size FW_2 rotate to 90°.

Formula 9

$$W_1 = FW_1 \cdot \cos\theta$$
$$W_2 = FW_2 \cdot \cos(\pi/2-\theta)$$

$$FW = \frac{\int (W_1 + W_2)\, d\theta}{\int \theta d\theta}$$

The mean value Fd of the diameter when K pieces of the above fiber mass exist in the filter (tow-filling portion), is obtained by formula 10 from the relation of a diameter F shown in formula 6.

Formula 10

$$Fd = \{(TD/FD-N\cdot K)\cdot F+K\cdot FW/(TD/FD-(N-1)\,K\}$$

The above aeration resistant formula of the filter is obtained as the sum of the friction loss arising from the gas flow in the tube corresponding to the filter and the fluid resistance when the gas flows through the material having fiber form and size of the fiber in the tow-filling portion which is a constitution element in the above filter inner portion.

Fanning formula is adopted as a friction loss formula of the inner flow of the tube. It is shown by the formula 11.

Formula 11

$$\Delta P_v = 4\cdot f\cdot(\rho\cdot u_2/2\cdot gc)\cdot(L/D)$$

ΔP_v: aeration resistance due to friction loss
ρ: fluid density
L: filter length
f: tube friction coefficient
u: flow rate
D: inner diameter of the tube

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In this case, the sectional area of the tube in formula 11 is a circle and in cases other than the circle sectional area, or in this example a corresponding diameter DH obtained by formula 2 is used in place of the above D.

On the other hand, a tube friction coefficient f is a function of Reynolds number which is expressed as Re_1, said Re_1 being expressed by the formula 12.

Formula 12

$$Re_1 = \frac{DH \cdot \rho \cdot u}{\mu}$$

ρ: fluid (air) density
u: flow rate
μ: viscosity of fluid (air)

The above flow rate can be obtained easily by using the specific gravity of acetate when the air flows at the flow rate of Q through the filter having length L, circumference C, and the tow-filling portion W. In addition, the relation between the tube friction coefficient f and Reynolds number Re_1 is determined as shown in formula 13 by comparison with measured values.

Formula 13

$$f=16/Re_1 \cdot 9 \cdot (Di/Ls)^{0.17}$$

Di: distance between fiber centers
Ls: wetted parameter length of the filter section

The aeration resistance due to the fluid resistance is shown by formula 14.

Formula 14

$$\Delta P_f = C_D \ (\rho \cdot u^2/2 \cdot gc) \cdot (4\pi \cdot S_p/C_2)$$

ΔP_f: aeration resistance through fluid resistance
C: circumference of the filter
S_p: windingly crimped projective area to a vertical surface with respect to the flow

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C_D: resistant coefficient

A resistant coefficient C_D is obtained by formula 15 from the relation of the resistance which a cylindrical body placed at a right angle with respect to the flow receives from the flow of the fluid.

Formula 15

$$C_D = \frac{10.535}{Re_2^{0.7672}}$$

Furthermore, the above windingly crimped projective area Sp is obtained by the formula 16 from a height Y of the fiber windingly crimped and a diameter Fd.

Formula 16

$$Sp = Fd \cdot Y$$

Thus, the formula for the estimated aeration resistance of the filter is obtained by the formula 17 consisting of the sum of formula 11 which shows the friction resistance used for formula 12 and 13 and of the formula 14 which shows the fluid resistance used for formulas 15 and 16.

Formula 17

$$PD = 4 \cdot (16/Re_1) \cdot 9 \cdot (Di/Ls)^{0.17} \cdot (\rho u^2/2gc) \cdot (L/D_H) + (10.535/Re_2^{0.7672}) \cdot (\rho \cdot u^2/2gc) \cdot (4\pi \cdot S_p/C^2)$$

PD: aeration resistance
Re_1: Reynolds number of the friction resistant formula
Re_2: Reynolds number of the fluid resistant formula
Di: distance between centers of the fibers
Ls: wetted perimeter length of the filter section
ρ: fluid density
u: flow rate
L: filter length
D_H: correspondent diameter of the friction resistant formula
S_p: windingly crimped projective area to the vertical surface with respect to the flow
C: circumference of the filter
gc: weight conversion coefficient

The formula for estimated aeration resistance shown in the

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above formula 17 was confirmed to be effective in the comparison of a measured value by a test unit of the filter aeration resistance, and also reviewed regarding various kinds of effects of the parameters.

Fig. 7 is a comparison view of a measured value of the aeration resistance of the filter with its estimated value. As the above estimated value, a value calculated as including 15% of unblooming fiber is used, said estimated value showing a good coincidence with the measured value.

Further, the effect the blooming fiber exerts on the aeration resistance is great and great parts of dispersions in the measured values are caused by the degree of blooming.

Since the degrees of the unblooming (fibers) of the tow can be quantified by the measured value of the aeration resistance, the availability of the aeration resistant estimation formula of the filter in this example can be increased.

Fig. 8 is a graph which shows the relation between the aeration resistance PD and the length of the filter, and it was confirmed that the aeration resistance PD is in the proportion to the length L of the filter, by the estimated value and the measured value.

Fig. 9 is a graph which shows a relation between the aeration resistance PD and the circumference of the filter C, said graph being shown by the estimated value and its measured value of the aeration resistance PD when the circumference C is changed.

Fig. 10 is a graph which shows the relation between the aeration resistance PD and the filament denier FD of the single fiber, said filament denier FD being related to the formulas 4, 10 and the like.

In addition, Fig. 10 shows the estimated value and the measured value of the operation resistance PD when the filament denier FD is changed.

Further, although the test of the aeration resistance PD when the tow denier TD is changed is performed, the explanation of the description is omitted.

Fig. 11 is a graph which shows the relation between the aeration resistance PD and the ferearea FA of the tow fiber

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sectional shape, said ferearea being related to the formula 11.

The above relation is confirmed by the estimated value and the measured value.

Fig. 12 is a view which shows the relation between the aeration resistance PD and the tow filling weight W, said relation being confirmed by the estimated value and the measured value.

In the method of estimation of the aeration resistance of filter plugs according to this invention, the aeration resistance of the filter plug of cigarettes consisting of fiber having complicated shapes can be estimated correctly by the right dimension corresponding to the complicated element parameter by using the aeration resistance formula consisting of the sum of the friction resistance and the fluid resistance.

Accordingly, the most suitable values of the filter material, form and size can be effectively determined with high reliability by using an estimated aeration resistance of filters, thereby being able to prepare a filter provided with an aeration resistant characteristic suitable to smokers with ease.

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What is claimed is:

1. A method of estimation of an aeration resistance of a cigarette filter or a plug filled with tow wherein said aeration resistance is estimated as the sum of a friction resistance and a fluid resistance.

2. A method of estimation of an aeration resistance of a filter plug wherein said aeration resistance of a tobacco filter or a plug filled with tow is estimated as the following formula:

$$PD = 4(16/Re_1) \times 9 \times (Di/Ls)^{0.17} \times (\rho.u^2/2gc) \times (L/DH)$$

$$+ \frac{10.535}{Re_2\ 0.7672} \times \frac{\rho.u^2}{2.gc} \times \frac{4\pi.Sp}{C^2}$$

PD: aeration resistance

Re_1: Reynolds number of friction resistance formula

Re_2: Reynolds number of fluid resistance formula

Di: distance between centers of the fibers

Ls: wetted perimeter of the filter section

p: fluid density

u: flow rate

L: filter length

DH: equivalent diameter of the friction resistant formula

Sp: projective area of the filaments to a vertical plane with respect to the flow

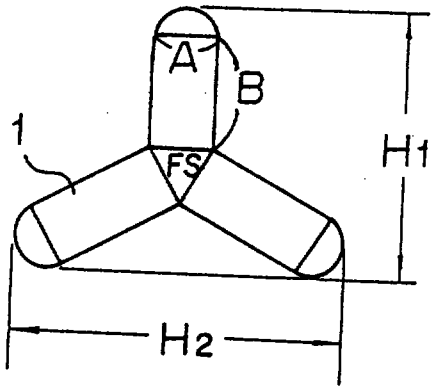
C: filter circumference

gc: weight conversion coefficient

* C L M S *

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FIG. 1



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FIG. 2 A

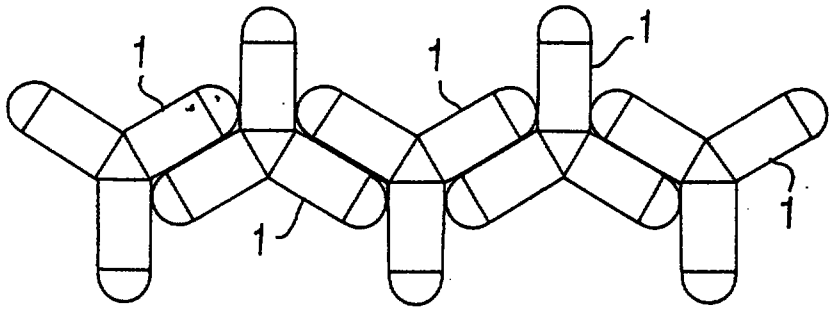


FIG. 2 B

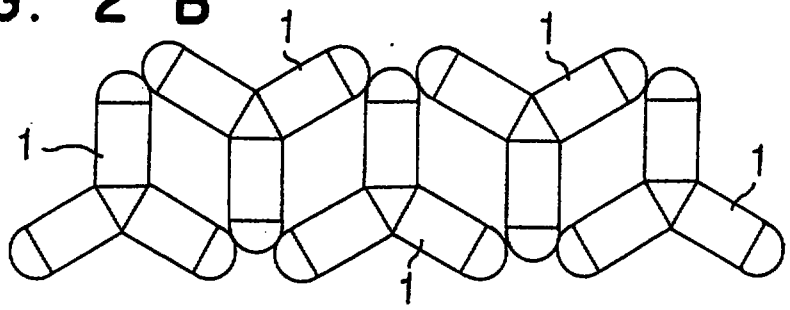


FIG. 2 C

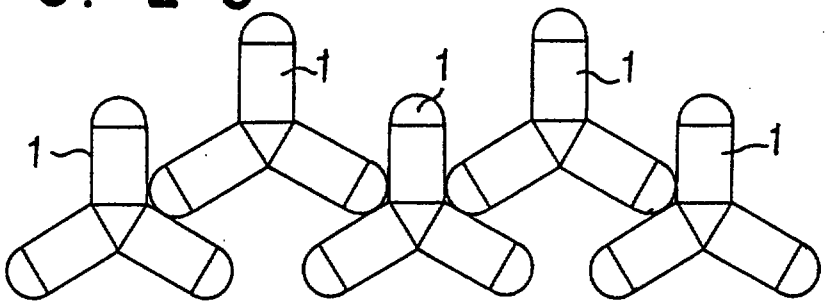
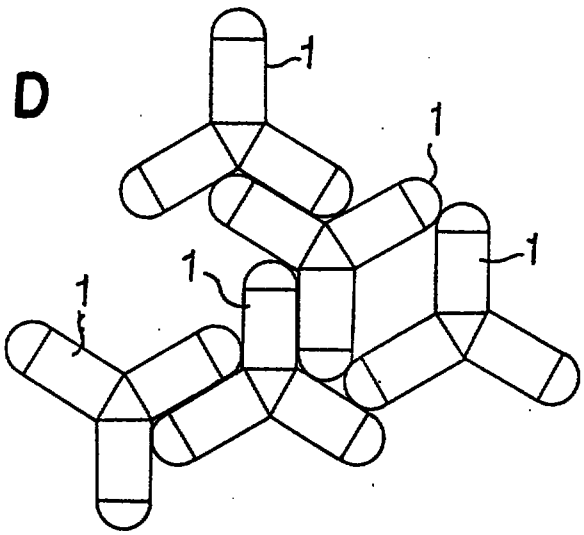
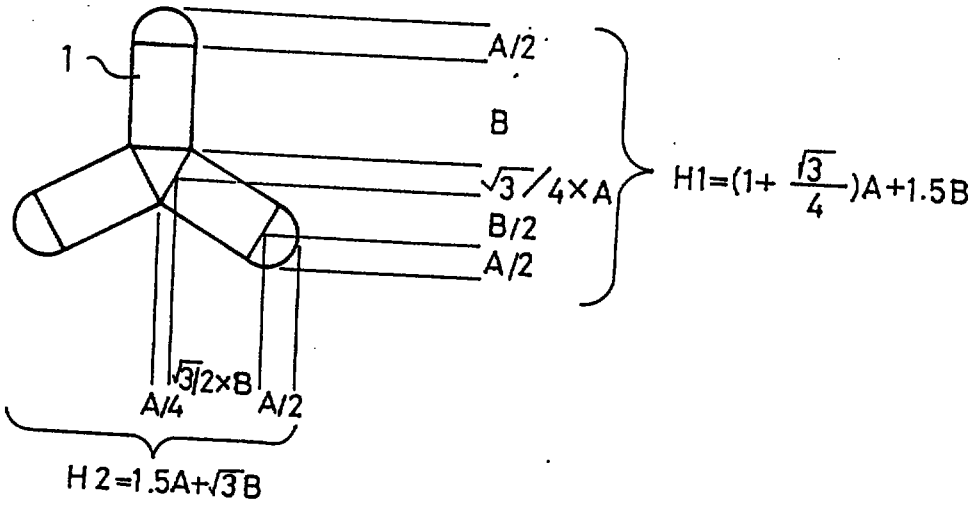


FIG. 2 D



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FIG. 3



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FIG. 4

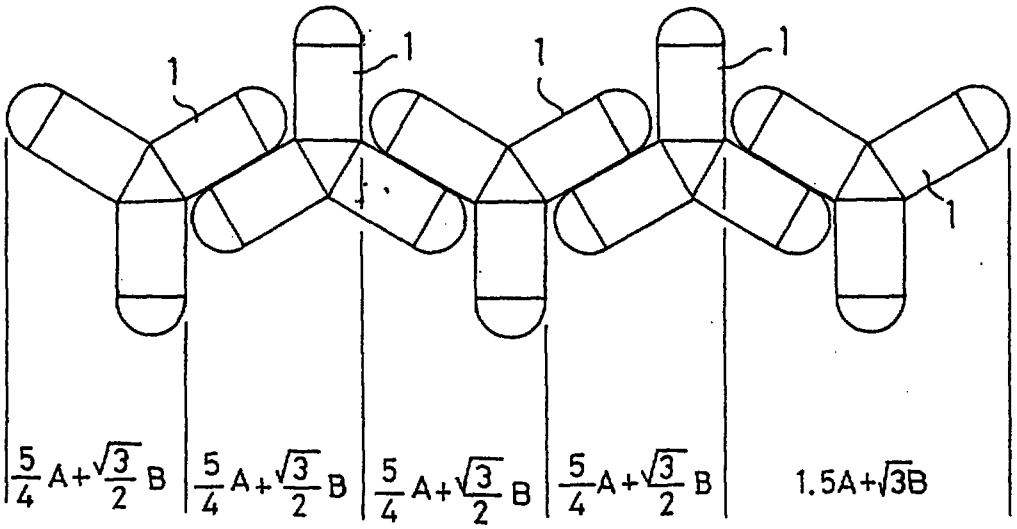


FIG. 5

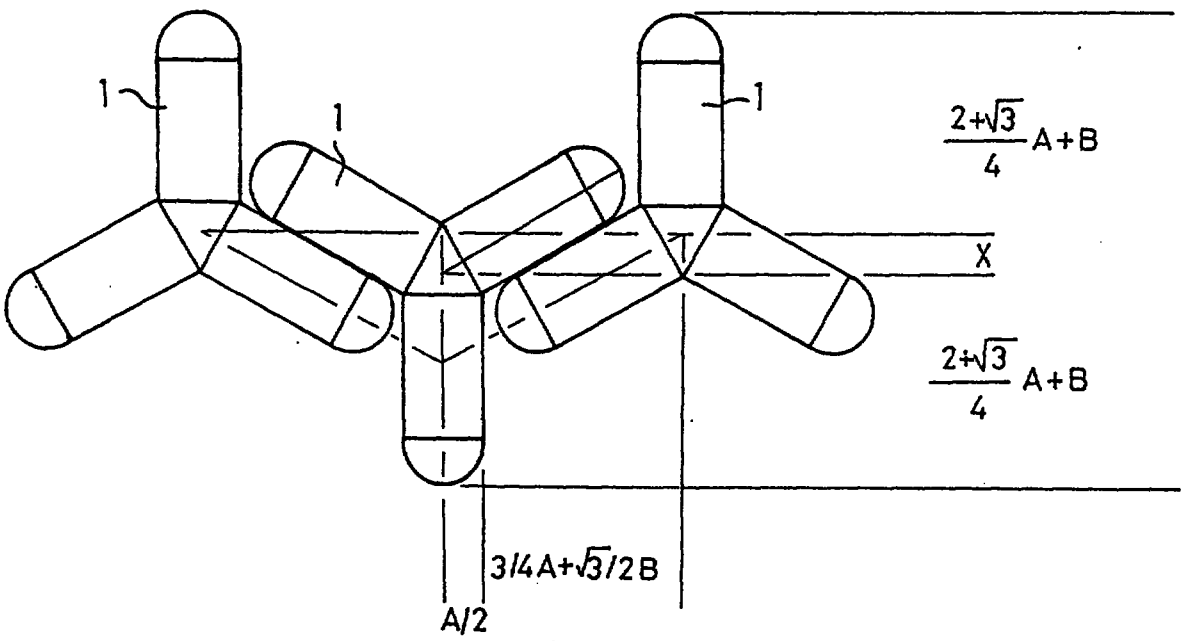
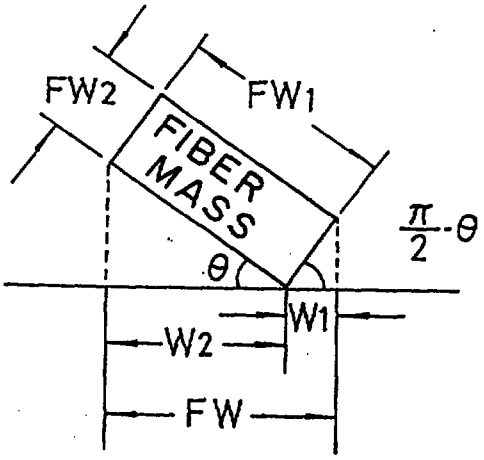


FIG. 6



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FIG. 7

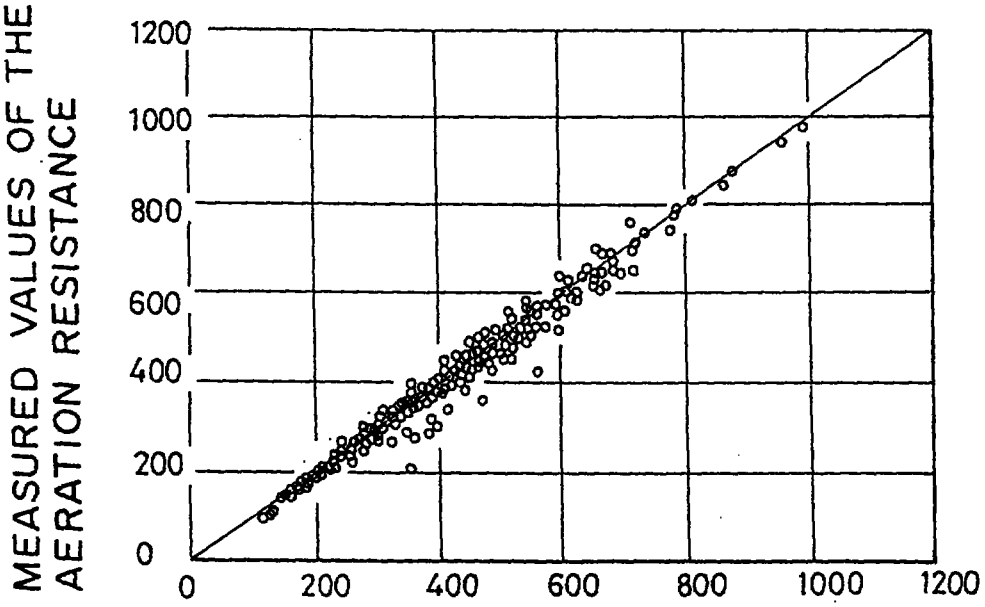
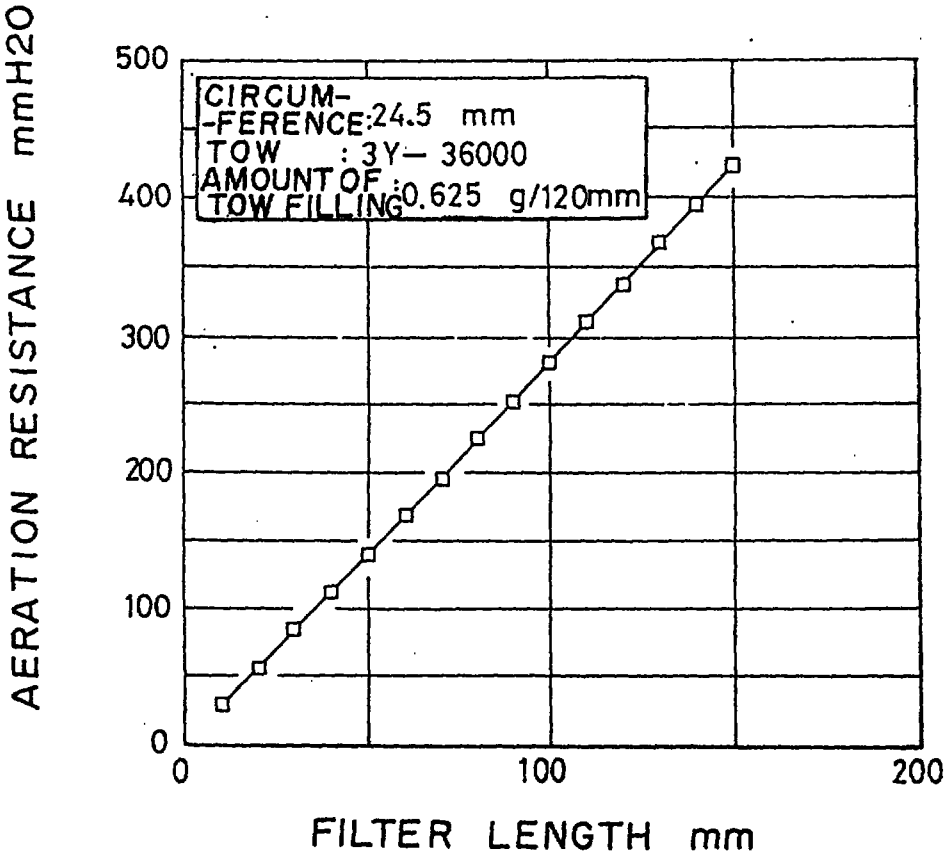


FIG. 8



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FIG. 9

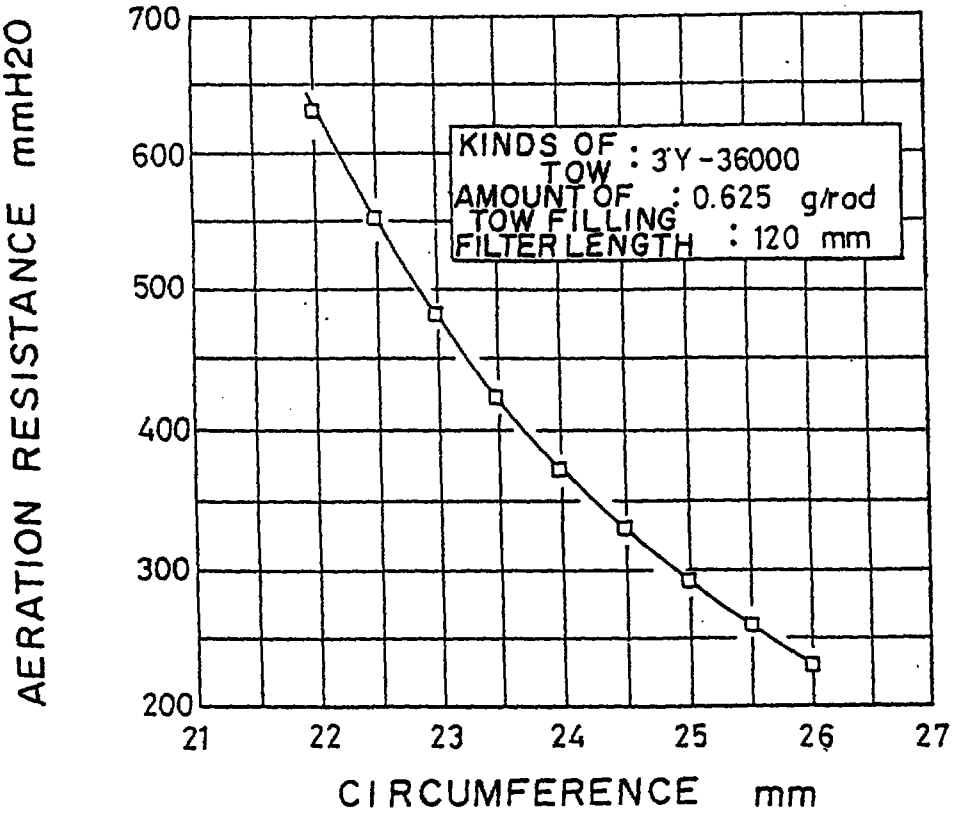
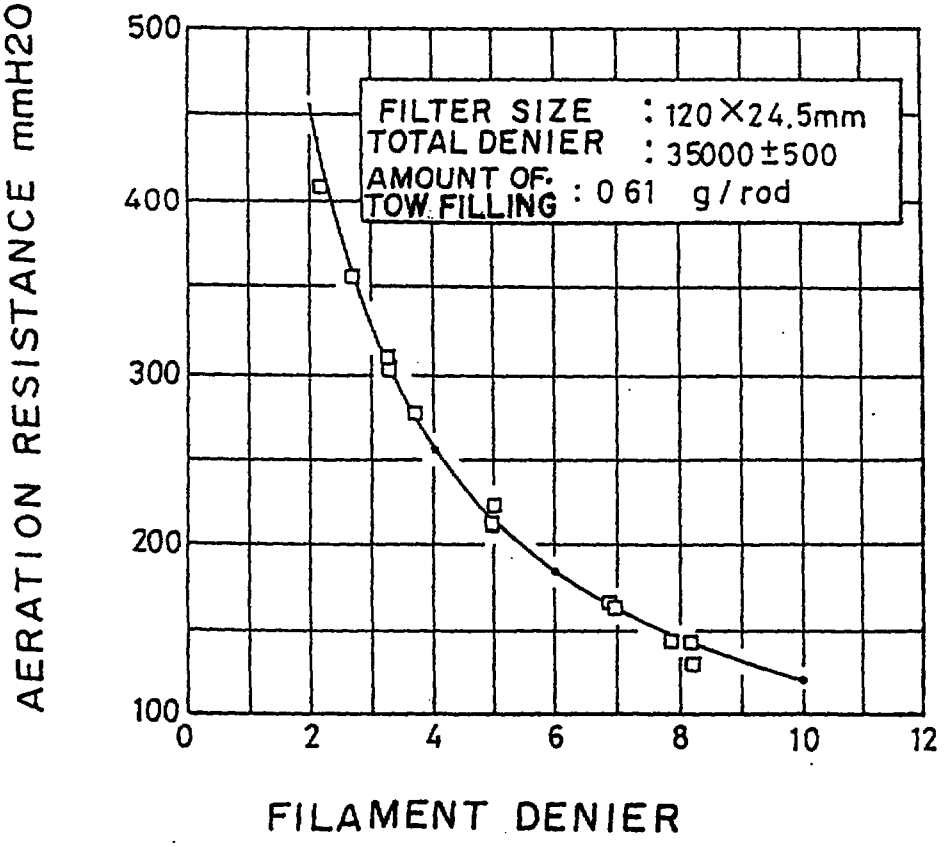


FIG. 10



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FIG. 11

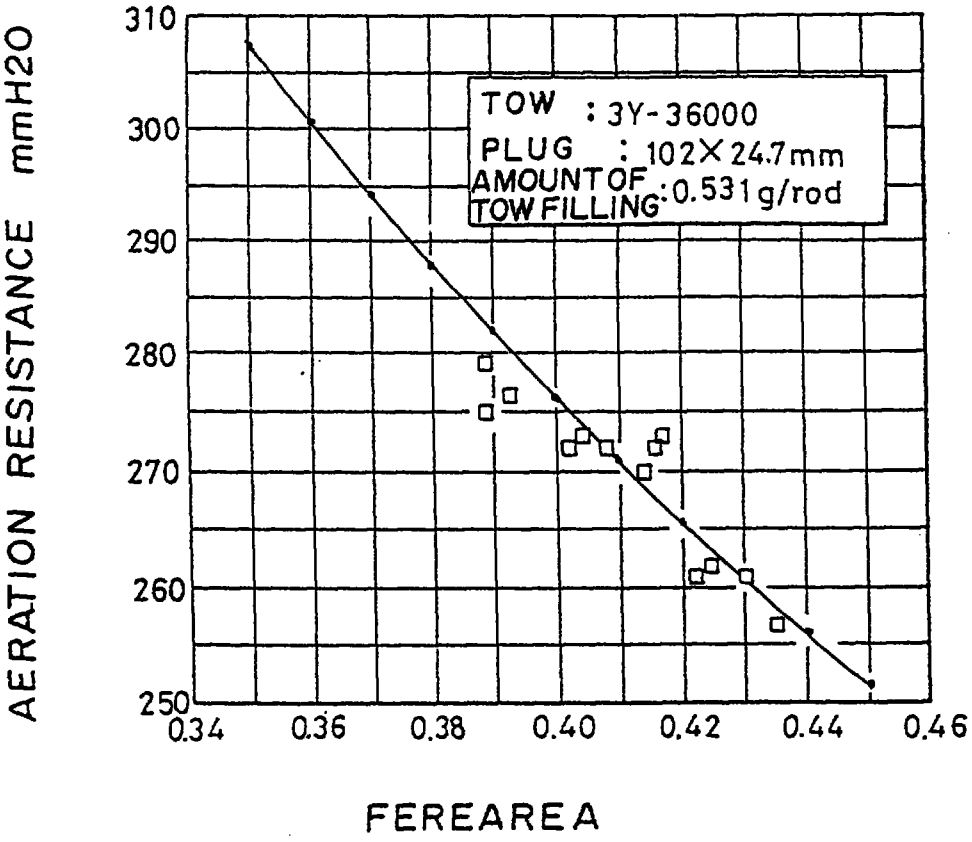
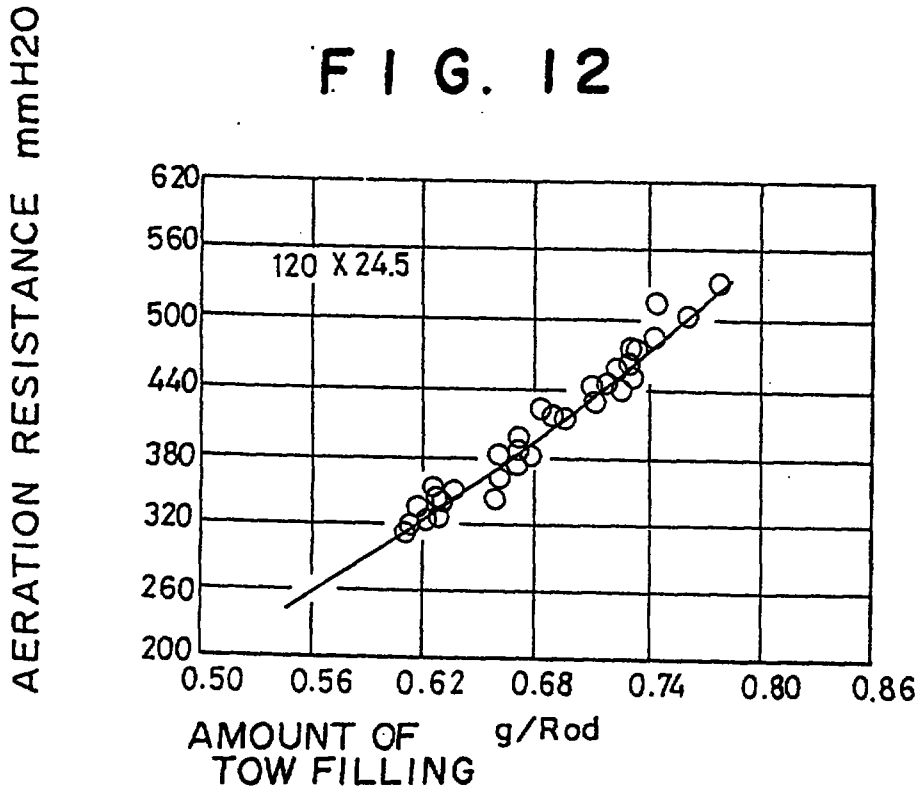


FIG. 12



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METHOD OF ESTIMATION OF AN AERATION RESISTANCE IN A FILTER PLUG

ABSTRACT

The aeration resistance of a cigarette filter plug filled with tow is estimated as a sum of a friction resistance and a fluid resistance by a formula 17.

Figure 1