United States Patent

[11] **3,601,133**

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[73] Assignee **Said Van Eck, by said Jewett**

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[54] **TOBACCO SMOKE FILTERING DEVICE**
27 Claims, 24 Drawing Figs.

[52] **U.S. Cl.** ..... **131/261 B,**
131/210, 131/212 A, 131/212 R, 131/213
[51] **Int. Cl.** **A24d 1/04,**
A24f 7/04, A24f 13/06
[50] **Field of Search** 131/10.5,
211, 212, 212 A, 213, 218, 261 B

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Primary Examiner—Samuel Koren
Assistant Examiner—J. F. Pitrelli
Attorney—Delio and Montgomery

ABSTRACT: This disclosure relates to a tobacco smoke filter which removes tars through condensation and precipitation. An inlet nozzle protrudes into a smoke expansion chamber of predetermined size. Smoke exits from the nozzle at high velocity and disperses and expands in the chamber with a resultant turbulence and temperature drop. Water vapor precipitates on the chamber surfaces and tars coalesce thereon. The filter is constructed and arranged to prevent blockage by coalesced tars and to operate within a predetermined range of pressure loss while efficiently removing tars from the tobacco smoke.

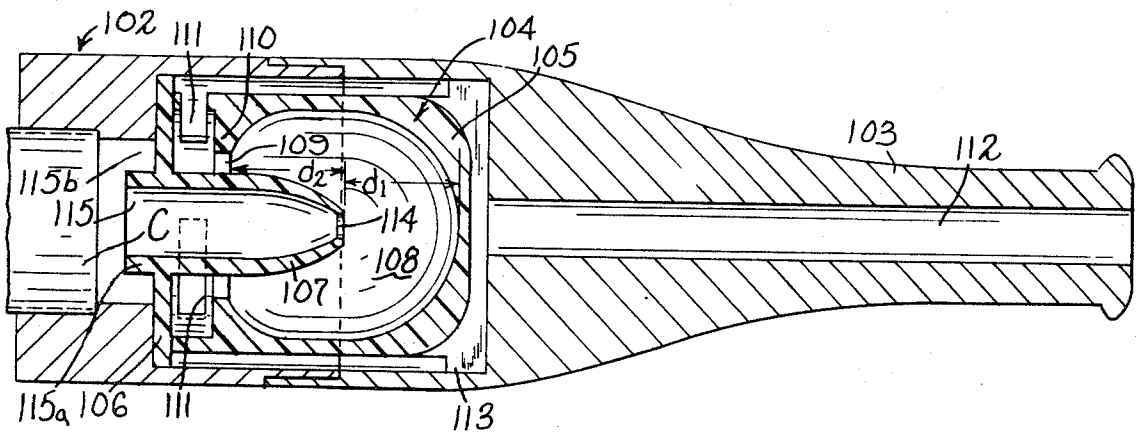

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Fig. 1.

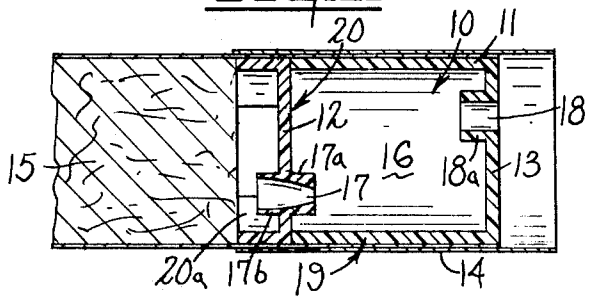


Fig. 2.

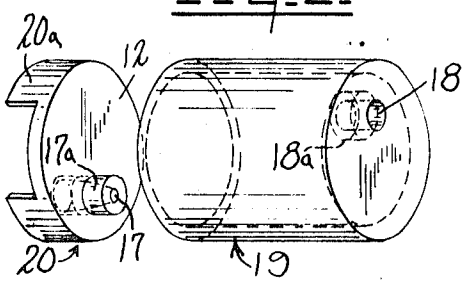


Fig. 3.

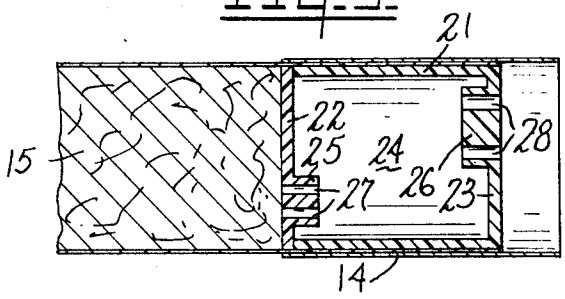
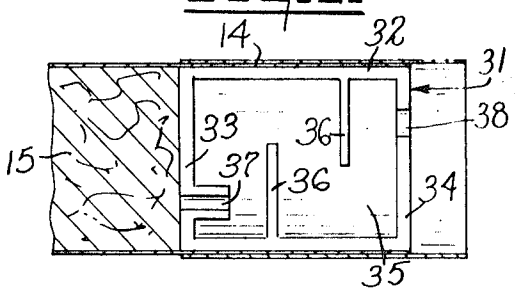


Fig. 5.



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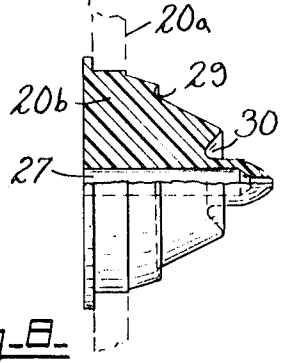

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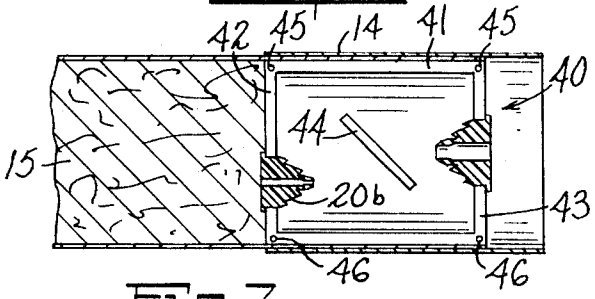

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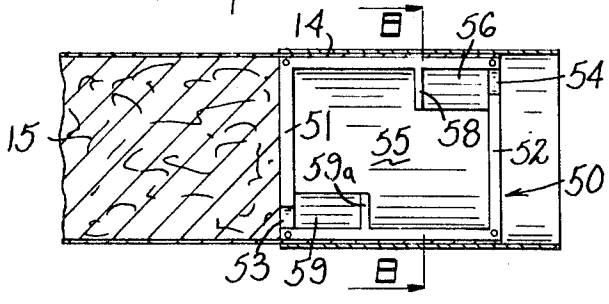

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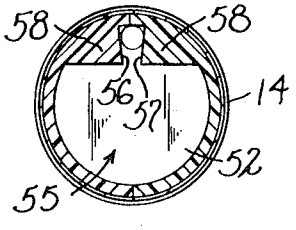

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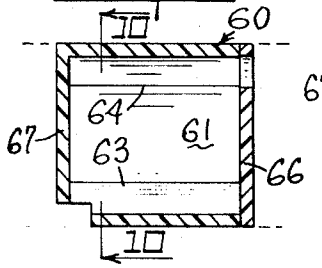
Fig. 9.



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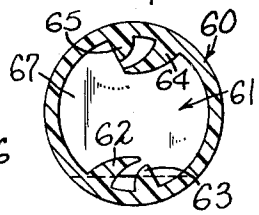

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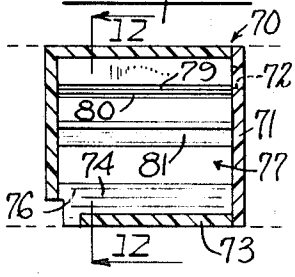

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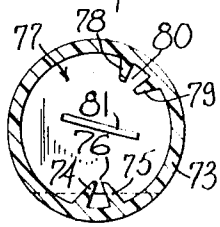

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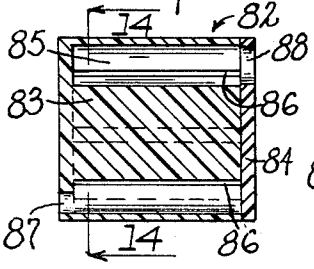

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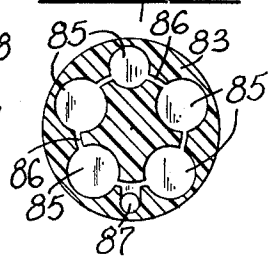

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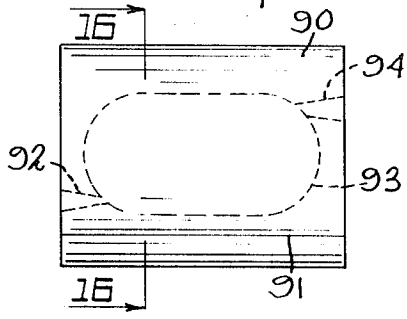

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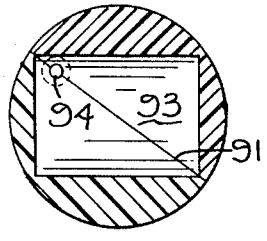

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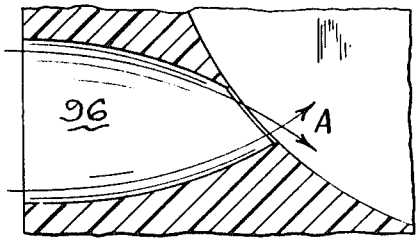

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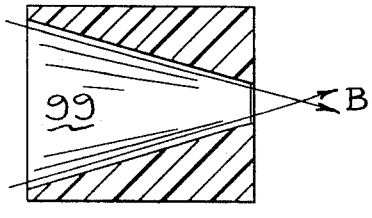

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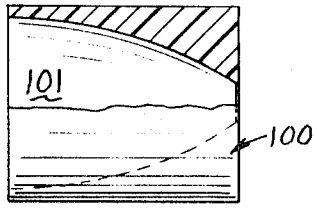

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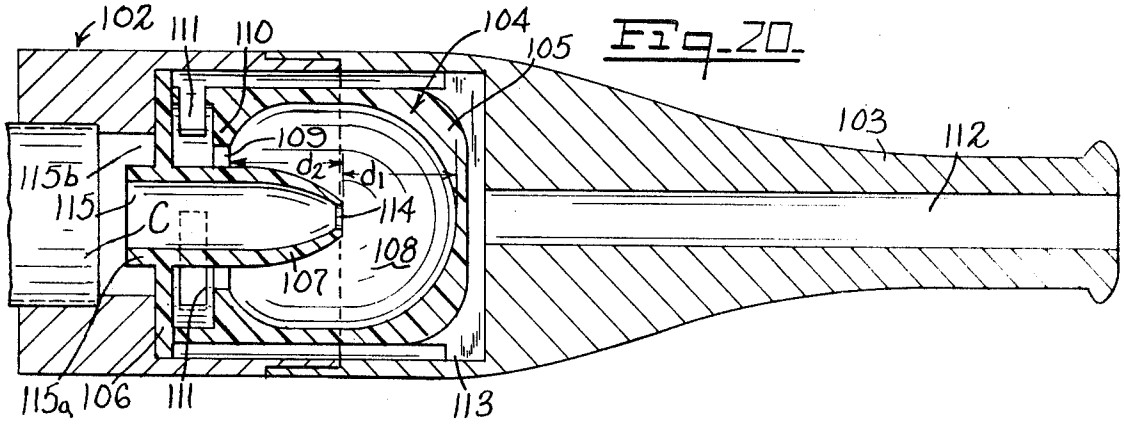
Fig. 20.



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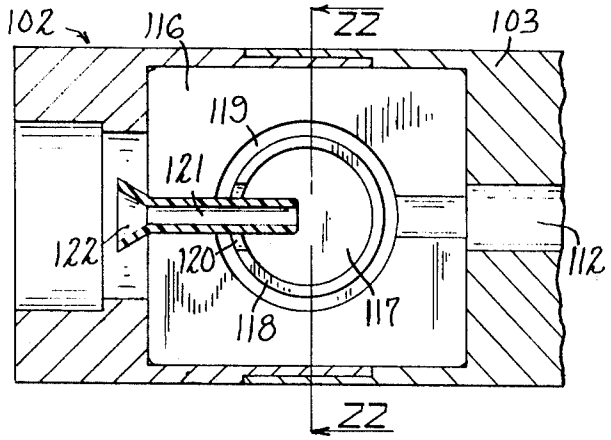

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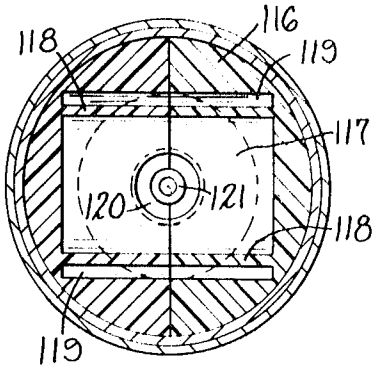

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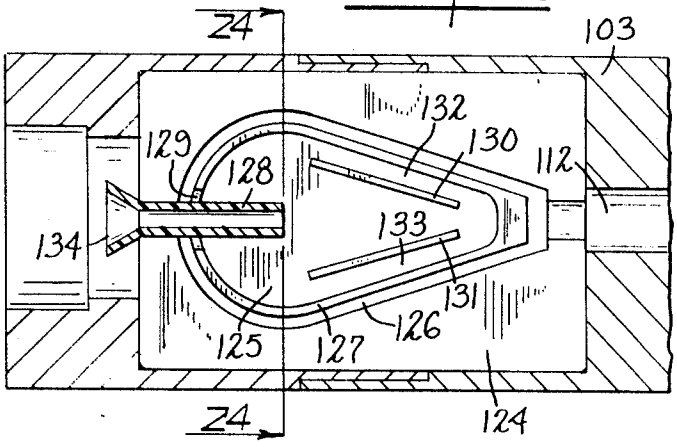
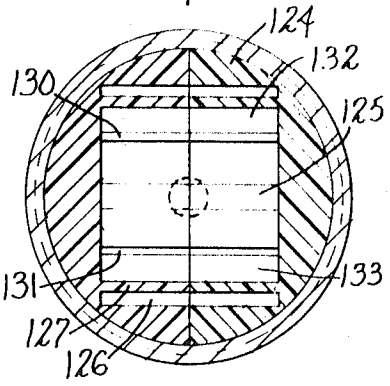


Fig. 24.



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TOBACCO SMOKE FILTERING DEVICE

This invention relates to the removal of tars and other particulate substances from tobacco smoke, and more particularly relates to new and improved devices for precipitating tars from tobacco smoke.

At the present time, by far the great majority of tar filtering arrangements use cellulose filaments in various amounts, with various binders and additives. The purpose of such filters either in cartridge form or as filter tips on cigarettes is to trap or collect the tar by virtue of the maze formed by the filaments. The path the smoke travels in passing along the length of the filter tip may be up to approximately nine-sixteenths of an inch.

Such filters attempt to precipitate the tar by providing a large number of contacting surfaces. However, such filament type filters provide a large through air passage as may be exemplified by rolling the filter and finding it will decrease from approximately a five-sixteenths inch diameter filter tip into a one-eighth inch diameter bundle or rod. It may readily be appreciated that to make the filament type filter more effective, the bundle of filaments would have to be packed tighter. This decreases the effective air passage and increases the resistance, which is highly objectionable to the smoker.

Another type of filter which appears to be more effective than the common fiber filter is one in which the smoke drawn from a cigarette is passed through a small orifice to substantially increase the velocity and direct it onto an impingement wall or baffle placed a very small distance behind such orifice, perhaps 0.030 inch. In such structure, the smoke from the cigarette may pass through the orifice at a speed in excess of 100 feet per second. When the smoke impinges on this wall, the heavier particles therein will tend to collect on the wall and further will be released from the gas stream as the gas stream changes direction to go around the wall. This type of filter may be considered a fairly effective arrangement for removing the heavier tars from tobacco smoke. However, it adds a static pressure loss which may be uncomfortable or unacceptable to the smoker. This may easily be appreciated when it is considered that the impingement barrier is substantially in contact with the orifice and just enough clearance is allowed to attempt to prevent the tar formed by impingement from blocking further flow of gas. Measurements on one such device as shown in U.S. Pat. No. 2,954,779 have shown the static pressure loss to be normally on the order of 28–40 mm. Hg. This pressure loss may increase where several cigarettes are smoked with some time intervals in between. During the intervening time, the deposited tars will tend to thicken and partially block the narrow gap. This results in increased resistance to air flow.

Other techniques include cooling the smoke through conduction while using metal parts. This type of filter construction has been used predominantly in pipe stems and has further included the use of a spiral path. However, if the smoke is cooled too great an extent, the smoker finds this objectionable.

Another way of removing entrained particles from tobacco smoke would be through expansion cooling and allowing the heavier particles to precipitate from the gas. These devices, so far as is known, have heretofore been rather elongated and required considerable length, and therefore have not been acceptable. Additionally, such devices as have been known have not been efficient in the removal of tars.

So-called tars from tobacco smoke exist in gas form or micro droplets. Tobacco smoke, because of its composition of micro droplets of tar, water and other particles in suspension may be considered an aerosol. Tar precipitation from smoke is a complex, multifactored process. One of the factors involved is turbulence which is produced by resistance to air flow. Other considerations are surface characteristics; sudden changes in the volume or direction of gas flow; condensation of water vapor produced by turbulence and a cooling effect as, for example, through expansion of the smoke. The transport of tar and smoke is, in effect, similar to a steam distillation phenomenon, and condensation of water reduces the kinetic energy of the tar particles sufficiently to coalesce. This requires that a solid surface be present in order for the tar to adhere thereto. Otherwise, the tar will remain in the gaseous vehicle and will be aspirated by the smoker.

The present invention provides tobacco smoke filters which generally operate on the principle of precipitation of tars. Due to the products of combustion when smoking a cigarette or other tobacco, water is generated. If the cigarette smoke containing such water vapor is expanded or decompressed under suitable conditions, a drop in the temperature of the gas results which can lead to condensation of water vapor therein. This reduces the kinetic energy of the gas system and micro tar droplet or particles coalesce upon contact with a solid or liquid surface. This provides liquid surfaces upon which the particles may further coalesce. Tar precipitators or filters embodying the present invention generally operate on the principle of the decompression or expansion of the gas to release entrained or suspended particles.

It has been determined that in a tar precipitator or filter it is quite important that the resistance introduced by such filter be held to a minimum. If the resistance to puffing becomes too great, the filter will be discarded. I find that the precipitation qualities of the filter are greatly improved by introducing turbulence into the gas flow. However, such turbulence must be so introduced that it does not increase the resistance to an unacceptable value.

It has also been determined that the relative volume of the expansion chamber to the smoke introduced therein is determinative of the amount of tar that may be precipitated. This, in turn, has a relation to the amount of surface area defining the chamber. If the chamber is too small, an undesired static pressure loss is presented. If the chamber is too large, the particles remain in suspension and do not precipitate. There must be some pressure loss across the filter device.

In the present invention, moderate turbulence is introduced in a condensation or expansion chamber by increasing the velocity of the smoke through a nozzle into the chamber to effect rapid deceleration of the smoke and resultant increase in volume against a pressure within the condensing chamber. This produces a drop in the temperature of the expanded smoke and resulting condensation of water vapor on the walls defining the chamber.

The present invention further preferably utilizes a nozzle which protrudes into the condensation chamber to prevent coalesced tars from collecting on the tip of the inlet opening or from flowing along the walls of the chamber to the inlet opening and effecting a partial stoppage or blocking thereof which would lead to a greater pressure drop to the system. The present invention further utilizes tobacco smoke inlet nozzles of preferred shape and longitudinal contour to accelerate the gas towards the condensation chamber without introducing any objectionable pressure drops across the nozzle.

An object of this invention is to provide new and improved devices for precipitating tars and other particulate matter from tobacco smoke.

Another object of this invention is to provide new and improved devices of the type described which offer no objectionable static pressure loss.

Another object of this invention is to provide devices of the type described which include new and improved nozzle means for dispersing tobacco smoke to enhance decompression thereof and precipitation of matter therein.

Another object of this invention is to provide devices of the type described having new and improved dimensional relationships to maximize precipitation of tars and other particulate matter.

A further object of this invention is to provide devices of the type described wherein the surface area for precipitation of tars ad other particulate matter is enhanced.

A still further object of this invention is to provide new and improved devices of the type described having new and improved means for producing a slight degree of turbulence therein to enhance precipitation without producing an objectionable static pressure loss.

The features of the invention which are believed to be novel are particularly set forth and distinctly claimed in the concluding portion of this specification. The invention, however, both as to its organization and operation, together with further objects and advantages thereof may best be appreciated by reference to the following detailed description taken in conjunction with the drawings, wherein:

FIG. 1 is a longitudinal view in half section of a device embodying the invention;

FIG. 2 is a view in perspective exploded showing one manner of construction of the device of FIG. 1;

FIG. 3 is a view in longitudinal section of a modified embodiment of the device of FIG. 1;

FIG. 4 is a view partially in half section of a nozzle-defining device which may be utilized with a filtering device embodying the invention;

FIG. 5 is a view in longitudinal half section of another device embodying the invention;

FIG. 6 is a view in longitudinal half section of still another embodiment of the invention and utilizing the nozzle-defining member of FIG. 4;

FIG. 7 is a view in longitudinal half section of another embodiment of the invention;

FIG. 8 is a view of the device of FIG. 7 seen in the plane of lines 8—8 of FIG. 7;

FIG. 9 is a longitudinal half section of another device embodying the invention;

FIG. 10 is a cross-sectional view seen in the plane of lines 10—10 of FIG. 9;

FIG. 11 is another embodiment of the invention shown in longitudinal half section;

FIG. 12 is a view seen in the plane of lines 12—12 of FIG. 11;

FIG. 13 is a view in longitudinal half section of a multicavity device embodying the invention;

FIG. 14 is a sectional view seen in the plane of lines 14—14 of FIG. 13;

FIG. 15 is a longitudinal view of another device embodying the invention;

FIG. 16 is a view seen in the plane of lines 16—16 of FIG. 15;

FIG. 17 is an enlarged sectional view of a nozzle defined in the device of FIGS. 15 and 16;

FIG. 18 is a view in longitudinal half section of a nozzle defining member which may be utilized with various embodiments of the invention shown;

FIG. 19 is a longitudinal view partially cut away and in section showing another nozzle defining member which may be utilized in various embodiments of the invention;

FIG. 20 is a longitudinal half section view of a cartridge type device shown in a mouthpiece.

FIG. 21 is a longitudinal view of another cartridge type device within a holder;

FIG. 22 is a view seen in the plane of lines 22—22 of FIG. 21;

FIG. 23 is a longitudinal view of another cartridge device embodying the invention; and

FIG. 24 is a view seen in the plane of lines 24—24 of FIG. 23.

In FIGS. 1 and 2 are shown a first tar precipitator embodying the invention. This tar precipitator or filter 10 comprises a general cylindrical housing 11 having oppositely disposed end walls 12 and 13 which are shown as received within the conventional filter wrapper 14 on a cigarette 15.

As smoke is drawn from the cigarette 15, it enters the chamber 16 through nozzle 17. Nozzle 17 is selected to protrude into chamber 16 for reasons hereinafter described. The smoke leaves chamber 16 through opening 18 defined in end wall 13. The walls 18*a* defining opening 18 also project into chamber 16. Nozzle 17 is provided with an exterior extension 17*b* and spacer tabs 20*a* are provided for spacing the filter a small distance from the end of the cigarette.

As smoke is drawn through nozzle 17 it enters chamber 16, substantially decreases in velocity and is decompressed, or expands. Upon expansion, the smoke cools and the water vapor therein precipitates which collects the tars on the walls defining chamber 16. The degree of relative expansion would be greater with the nozzle 17 being made smaller. However, this would also increase the air flow resistance.

The average smoker aspirates about 35 ml. of air and smoke in one puff, which has a duration of close to 2 seconds. With this volume of smoke and air in approximately 2 seconds, the inlet port or opening 17 should have a diameter of from approximately 0.025 inch to 0.033 inch. The opening must not be so small that an undue resistance to air flow is created.

Excellent tar precipitation is obtained by a chamber volume of about a numerical factor of 100 to 300 times the cross-sectional area of the inlet opening where the units of measure are in millimeters.

In the filter shown in FIGS. 1 and 2, the outlet opening 18 should have an area which is substantially twice as great as the area of the inlet opening. The inlet and outlet openings are offset with respect to each other so that there will be no straight line or direct flow of smoke from inlet to outlet openings.

The openings 17 and 18 are defined by nozzlelike projections 17*a* and 18*a* into chamber 16. The condensation of water droplets and precipitation of tar could occur on the inside end walls 12 and 13 and, due to gravity or handling of the cigarette, such precipitates could block or tend to block the passages 17 and 18, which would result in increased resistance to air flow and a higher static pressure drop. In order to prevent such action the projections 17*a* and 18*a* defining nozzles are provided. The projection 18*a* prevents the suctioning of any precipitated and coalesced tars into the outgoing air stream.

The actual cigarette is spaced from the filter by the tabs 20*a* which could also take the form of a complete cylindrical extension. The purpose of this spacing is to trap any tars precipitated by turbulence at the end of the cigarette and prevent entrance into nozzle 17.

The device of FIGS. 1 and 2 is shown as a two-part structure comprising a cylindrical containerlike member 19 which provides both sidewall 11 and end wall 13 and a closure member 20 which provides end wall 12. Such a filtering device may be made in this manner or may be made in two semicylindrical pieces with the centerline of openings 17 and 18 residing in the same plane but offset from each other.

An alternative embodiment of FIGS. 1 and 2 is shown in FIG. 3 and comprises a cylindrical housing 21 having oppositely disposed end walls 22 and 23 defining a chamber 24. The end walls 22 and 23 have projections 25 and 26, respectively, thereon. Such projections define nozzlelike inlet openings 27 and nozzlelike outlet openings 28. The overall dimensional relationship of the device of FIG. 3 with respect to the chamber volume and the cross-sectional area of the inlet and outlet openings would be substantially the same. However, a compensating factor would have to be introduced for the greater resistance through the smaller openings.

To further guard against the accumulation of precipitated tars about the inlet nozzle, the end piece 20*a* may be formed with an opening adapted to receive a nozzle defining member 20*b*, as shown in FIG. 4, defining an inlet opening and nozzle into the chamber 16. This provides traps 29 and 30 which further aid in preventing the creep back of any precipitated tars from blocking or restricting the inlet opening.

The introduction of turbulence into the system has been found to substantially aid in the precipitation of tars. A two-part filter element 31, as shown in FIG. 5, of generally cylindrical shape, only one-half of which is shown, comprises a cylindrical housing portion 32 having oppositely disposed end walls 33 and 34 affixed to the end of a cigarette 15, then covered with a filter wrapper paper 14. A projection or box

extending into the chamber **35** defines a nozzlelike inlet opening **37**. Extending from the sidewalls are baffles **36** which define an elongated path between inlet opening **37** and outlet opening **38** in end wall **34**.

The baffles **36** are spaced from opening **37** and **38**, respectively, a sufficient distance such that there is no impingement effect, or essentially any resistance to gas flow. The purpose of the baffles **36** is to make the gas flow change direction to prevent any straight-through effect, to provide surfaces for precipitation of water vapor and tars, and introduce some turbulence to aid in precipitation of tars.

The positioning or the shape of the baffling means, as exemplified by the turbulence introducing means is not critical so long as it is spaced a sufficient distance from the inlet opening so that expansion of the gases occurs without high velocity impingement thereon.

In FIG. **6**, a filter **40** comprising sidewalls **41** and end walls **42** and **43** has arranged therein a bafflelike member **44** which is angularly disposed with respect to both the inlet and outlet opening and whose function is to make the gas change directions between the inlet and outlet openings without introducing any substantial static pressure loss. The filter **40** of FIG. **6** is provided with the type of nozzle defining member **20***b* shown in FIG. **4**, defining both the inlet and outlet openings. Again the inlet and outlet openings reside in a common plane through the centerlines of the inlet and outlet openings so that the filter **40** may be made in two mating halves. Preferably, this device is made in two halves by any acceptable molding or forming process. The device may be made of any acceptable plastic material which may be cast, such as acrylics, nylons, teflons, etc. Such plastic parts may be easily cast, vacuum or injected molded or otherwise formed in high volumes at extremely low per unit cost, then may easily be assembled from two mating parts into the whole. If desired, the two parts may be provided with mating pegs **45** and holes **46** for alignment purposes, and when so joined the half nozzles defined in each filter half and the half baffles would be in alignment, and then form a baffle across the expansion chamber and complete openings into and out of the expansion chamber.

Another embodiment is shown in FIG. **7** and comprises a generally cylindrical filter cartridge **50** having end walls **51** and **52**. An inlet opening **53** is defined in end wall **51** and outlet opening **54** is defined in end wall **52**. To prevent any tendency for straight-through flow of tobacco smoke and to introduce a slight degree of turbulence, the entrances into the defined chamber **55** are made essentially radial.

The filter cartridge **50** is formed with upstanding walls **56** and **57** on either side of outlet opening **54** as viewed in FIG. **8**. A backwall or baffle **58** joins sidewalls **56** and **57** to define a passage which is essentially radially directed out of chamber **55**. Similarly, sidewalls **59** and a backwall **59***a* (only one shown) define a similar channel leading from the inlet opening **53**.

It will be noted that the walls **56** and **57** are so inclined toward each other as to provide a nozzle effect and reduce turbulence. The walls **59** are similarly positioned. The backwall **59***a* is sufficiently spaced from the opening **53** so that essentially no precipitation from impingement occurs at this point.

If desired, backwalls **58** and **59** could be made of greater length to provide a more tortuous path, and would appear as the baffles **35** ad **36** in FIG. **5**.

Still another embodiment of the invention is shown in FIGS. **9** and **10** wherein a generally cylindrical cartridge **60** defines an expansion chamber **61** and is so formed that the inlet port and a nozzle is defined by walls **62** and **63** which direct the incoming smoke away from the longitudinal centerline of the cartridge **60**. Similarly, the upstanding walls **64** and **65** receive exiting smoke in a path extending away from the axis.

In this embodiment, the filter cartridge is formed in two parts which comprise end wall **66** and the remainder **67** of the cartridge **60**. If the nozzles were directed towards the centerline of cartridge **60**, a baffle (not shown) could be displaced between the inlet and outlet opening to change the direction of the incoming tobacco smoke and, accordingly, introduce some turbulence therein. Such baffle, if utilized, would of course be sufficiently spaced from the inlet opening so as not to create an impingement precipitation effect and resulting static pressure loss. Such an arrangement is shown in FIGS. **11** and **12** and comprises a generally cylindrical cartridge **70** formed in two parts with an end wall **71** defining an outlet opening **72**. The larger cylindrical portion **73** is formed with internal walls **74** and **75** which define an inlet nozzle **76** into chamber **77**, and walls **78** and **79** which define an outlet channel **80** to opening **72**. A baffle **81** is disposed between the inlet and outlet openings to block any straight-through flow of tobacco and, also, to change the direction of the incoming flow of smoke and create a small degree of turbulence to aid in the precipitation of the tars.

FIGS. **13** and **14** illustrate another filter cartridge **82** formed in two parts **83** and **84**. The cylindrical portion **83** has a plurality of longitudinally extending cavities **85** therein connected by passages **86** to inlet opening **87** and outlet opening **88** in end wall **84**. With this arrangement the incoming smoke will be subject to plural expansions in the various cavities or chambers **85** to provide a multicycle expansion or distillation process which will very effectively remove the tars in the tobacco smoke.

In all of the foregoing embodiments of the invention, for most efficient precipitation, the volume of the precipitation or decompression chambers should bear the ratio of 100 to 400 numerically to the area of the inlet opening when the dimensions are measured in millimeters cubed and squared. If this ratio should be greatly exceeded, only minimal precipitation of the tars will take place. The inner surfaces of the filter cartridge should be maximized in area to provide the maximum surface area for precipitation of the water vapor and accompanying coalescing of the tars. However, I have found that if the volume of the expansion is made too large, precipitation of the water vapor will not occur.

This is believed to be due to the fact that as the volume of the expansion chamber increases, the relation thereof to the amount of gas pulled through the inlet port becomes such that free expansion of the smoke occurs and very little cooling of the smoke occurs. Therefore, the amount of water vapor precipitated decreases and the effectiveness of the filter is decreased.

On the other hand, when the smoke entering the chamber expands in a constrained area it expands against the pressure therein or a back pressure and also experiences the internal work of separating its own molecules. This results in efficient cooling of the water vapor and resultant coalescing of tars.

The actual size of the outlet opening is not critical, except that it must not reach a size which would give the chamber the effect of a large volume. Otherwise stated, the outlet opening must have some pressure drop thereacross to maintain some back pressure in the chamber against which the incoming smoke expands.

The material of the filters is selected to preferably have a low coefficient of heat transfer so that heat will not be radiated from the walls thereof and produce too much cooling of the smoke. Many smokers find very cool smoke to be objectionable. The volume of the cartridge is selected in accordance with the inlet opening so that the cooling effect for precipitation purposes is achieved through controlled expansion through the chamber and heat transfer to and through the walls of the cartridge is minimized.

The embodiment thus far disclosed are to be considered only as exemplary of various forms and configurations in which the invention may be embodied. In particular, the nozzles disclosed thus far are for illustrative purposes only.

A cigarette filter cartridge constructed in accordance with the present invention introduces a moderate amount of turbulence into the tobacco smoke entering the condensation chamber so as to produce a desired energy loss in the system and resulting condensation of water vapor and coalescing of

tars without introducing an objectionable pressure drop across the system. This is achieved by providing a nozzle of decreasing cross-sectional area which protrudes into the expansion or condensation chamber. The tobacco smoke is accelerated through the nozzle of decreasing cross-sectional area with essentially laminar flow at high velocity. The average volume of smoke which is aspirated by a smoker is 35 milliliters during a puff of 2-second duration. The nozzle orifice is so sized that the resulting velocity through the nozzle is increased, and then suddenly decreased as the smoke enters the expansion chamber. The nozzle is preferably shaped so as to disperse the smoke upon exiting therefrom and enhance expansion of the smoke in the chamber and resultant condensation of water vapor.

The volume of the expansion chamber is further so selected that the water vapor will condense on the walls defining the chamber and provide wetted surfaces for coalescing of the tars as the smoke loses its kinetic energy.

It is preferred to use materials of relatively poor heat conductivity, especially in the inlet and outlet openings into the chamber. The materials of good heat conductivity, particularly in the input nozzle, might cause condensation of tars therein resulting in full or partial obstruction and greatly increased pressure drop across the system. It is further preferred that the material defining the expansion chamber be of relatively poor heat transfer characteristics so that the condensation of water vapor and tars is due essentially to the cooling effect of expansion and not by the transmission of heat to the walls of the chamber.

In avoiding precipitation of any tars in the member defining the inlet nozzle, it is highly advantageous to have such member extend part way into the cigarette receiving chamber. There is always found some little tar precipitation in this space due to turbulence. However, if the nozzle defining member extends into this space a trap is defined thereabout the tobacco or protrudes slightly and any precipitation due to such turbulence will not be easily drawn into the inlet nozzle. In this embodiment the chamber is defined by the cartridge holder and spaces the cigarette from the cartridge.

The shape of the nozzles, and particularly the inlet nozzles, may contribute to the precipitation efficiency of the unit. Where the inlet is defined by a nozzlelike passage which converges toward the inlet opening of the chamber, the smoke entering the chamber has better immediate dispersion and the pressure loss due to the nozzle is reduced.

A device with such inherently built-in opening is shown in FIGS. **15** and **16** and comprises a cartridge **90** formed in two parts and joined along a line **91**. An inlet passage or nozzle **92** is defined in the material of the cartridge leading to the chamber **93**.

The outlet opening is also shown as an inverted nozzle **94**. However, the outlet passage may be cylindrical. The cartridge of FIG. **15** may be cast in two parts and then joined together as explained in conjunction with FIG. **6**.

Another and preferred form of the inlet nozzle is shown in FIG. **17** and comprises a passage **96** of converging cross-sectional area. The contour of this nozzle along the longitudinal section line thereof is generally ellipsoid in nature. Such shape decreases the pressure loss through the nozzle and, further, by the shaping of the walls thereof reduces an immediate diverging effect on the smoke entering the chamber as indicated by the arrows A. This produces some turbulence which aids in the precipitation of the water vapor and the coalescing of the tars.

The input nozzles may be defined in separate members which protrude into the expansion chamber as heretofore shown in FIG. **6**. FIG. **18** illustrates a nozzle defining member **98** defining a nozzle **99** generally of frustoconical configuration. Such member may be made independently and assembled with any cartridge. The divergent effect of such nozzle is exemplified by the arrows B. Similarly, in FIG. **19** a nozzle defining member **100** may define the nozzle **101** with an ellipsoid contour. With the use of the nozzle defining members, the inlet opening into the chamber should be on the order previously described, that is, 0.025 inch to 0.033 inch to optimize the precipitation of tars and not introduce an undue pressure loss. It is preferred that the inlet diameter to the nozzle be on the order of 0.050 inch and the nozzle defining members of FIGS. **18** and **19** may range from 0.09 inch to 0.045 inch in length.

The invention may be embodied in filter cartridges in which the direction of flow of the smoke after expansion thereof is caused to reverse. This provides the advantage of accelerating the particles through change of direction, thus causing the forces due to such acceleration to drive the particles toward the chamber walls.

A preferred cartridge so formed is shown in FIG. **20** as embodied in a cigarette or cigar holder **102** which includes a mouthpiece portion **103**. It is to be understood that the cartridge **104** may be included in a filter wrapper **14** as shown in FIG. **1** and, similarly, the filter cartridges show in FIGS. **1–16** could be made in cartridge size for a cigar or cigarette holder **102**, as shown in FIG. **20**. The cartridge **104** is shown as comprising a chamber defining member **105** and an end piece **106** carrying a nozzle **107**. The chamber **108**, as shown, is formed partially cylindrical and terminating at one end in a substantially hemispherical dome. The nozzle **107** is formed as shown in FIG. **19** to obtain maximum dispersion of the smoke as it exits therefrom into chamber **108**. The smoke upon entering the hemispherical portion of the chamber expands accompanied by a decrease in temperature which precipitates moisture and tars from the smoke. The remaining gas then reverses direction and flows towards the suction or low pressure area created in mouthpiece **103** through an opening **109** defined about the nozzle **107**. The opening **109** is defined by the nozzle together with an inwardly extending flange **110**. Defined in the sidewall of the cartridge are openings **111** to permit exit of the gas about the exterior of portion **105** and the holder to the passage **112** in stem portion **103**. For support and spacing purposes, a plurality of vanes **113** may be provided on the outer walls or any convenient portion of member **105**.

The opening **109** is made of a size which will maintain a back pressure in chamber **108** to permit the desired loss of temperature upon expansion of the smoke without producing an objectionable static pressure drop. The size of the openings **111** in this form of the invention presents no criticality.

The total volume of the chamber **108** is greater than the effective volume for purposes of expansion. Essentially all expansion of smoke and gases takes place between the nozzle orifice **114** and the hemispherical wall of chamber **108**, and the ratio of effective volume for expansion purposes to the orifice area as previously set forth also remains true in this embodiment.

It has been determined that the distance d_1 of the end of the nozzle **107** from the backwall of chamber **108** is not critical except to the extent that air flow resistance and, hence, pressure loss increases if the nozzle is too close. In a cartridge as shown in FIG. **20**, where the radius of the hemisphere was 0.125 inch, there was no significant difference in tar yield where the dimension d_1 was 0.093 inch, 0.125 inch, and 0.156 inch. However, increased air flow resistance was detected at the smaller dimension.

It has further been determined that when the dimension d_2 is lengthened the yield of precipitated tars is increased. This is believed to be due to the increase in the volume with increase in d_2 which provides a plenum chamber effect and the gas pressure therein has less variation during aspiration of smoke and a more uniform back pressure is developed in the chamber against which the incoming smoke expands. In these tests it was noted that all precipitated tars collected in in the hemispherical surfaces, indicating that precipitation of tars due to expansion of the smoke and resulting energy loss of the system occurred in the immediate expansion volume subsequent to entering the chamber.

The length of protrusion of the nozzle **107** into chamber **108** must not be so shortened that it provides a short circuit path from the nozzle to the opening **109**.

The cartridge **104** may be further modified to eliminate the flange **110** and, therefore, the opening **109**. In such modification, the openings **111** are then properly sized to maintain the necessary back pressure in chamber **108**.

This arrangement, providing the reverse flow, offers the advantage that there is no possibility of a straight-through flow of gases without expansion thereof and, further, a greater amount of surface area for precipitation in coalescing of tars is provided. In tests it has been found, however, that by far the greatest amount of tars will precipitate immediately upon expansion thereof on the walls defining the hemispherical portion.

The nozzle defining member extends without the cartridge to define a short passage **115** defined by walls **115***a*. This prevents any tars precipitated in the areas **115***b* from entering nozzle **107**. Where the filter is carried in a holder, the spacers for the cigarette may be defined in the holder.

Another cartridge operating on this principle is shown in FIGS. **21** and **22** and comprises a housing **116** defining a cylindrical chamber **117** with a wall **118** therein defining with the housing a passage **119**. The wall **118** has an aperture **120** therein which together with nozzle **12** defines an outlet opening. The nozzle **121** is shown as a cylindrical passageway for simplicity of illustration. However, it will be understood that it will preferably take the same form as the nozzle shown in FIGS. **19** and **20**. Upon entrance of the smoke into the chamber **117**, it expands primarily between the end of nozzle **121** and the walls of the chamber therebehind. Thereafter, the gas will flow towards the opening **120** in passage **112** in stem **103**. The nozzle defining member **121** may have an externally protruding extension **122** for the purposes previously described. Such extension may itself be tapered to enhance essentially laminar flow in the nozzle.

Still another embodiment of the invention utilizing the same reverse flow principle is illustrated in FIGS. **23** and **24**. In this embodiment, a housing member **124** defines an expansion chamber **125** and an outlet passage **126** thereabout separated by the wall **127**. Wall **127** together with nozzle **128** defines an outlet opening **129** about the nozzle. Vanes or baffles **130** and **131**, straight or curved, are provided to define gas directing passages **132** and **133**, respectively, and present more surface for condensation. The nozzle **128** is shown as defining a cylindrical passage for simplicity of illustration. However, it is to be understood that the preferred nozzle is shaped as shown in FIGS. **18** or **19** and **20**. Upon entrance of the smoke through nozzle **128** into chamber **125**, it expands upon leaving the nozzle with the resulting decrease in energy and loss of temperature which results in precipitation of moisture and coalescing of the tars. The gas then proceeds between baffles or vanes **130** and **131** and reverses flow through passages **132** and **133** towards opening **129**. Hence, it is drawn through passages **126** into the passage **112** in stem **103**. The nozzle defining member **128** may be provided with an external extension **134** for reasons previously described.

It will be apparent that the filter cartridges shown in FIGS. **20–24** may readily be disposed of and replaced in the holder. Tests have shown that such filter cartridges are effective for use with five or more cigarettes of the so-called king size.

Tests have further shown that cartridges of the type disclosed operating on the expansion and precipitation principle are 30 to 50 percent more effective in the yield of tars and other matters from tobacco smoke than the commercially available filters of the type described in U.S. Pat. No. 2,954,779, which operates on the impingement principle, and where the pressure drop through the filter is the same. It has been determined that devices embodying the present invention may be sized to produce an approximately 25 percent lower pressure drop than the commercially available filters of the type shown in the aforementioned patent and still produce the same yield as such commercially available device.

Comparative tests were made on a Kent king size cigarette with its included filter removed between a cartridge as shown in FIG. **20** and one known as Tar-Gard constructed in accordance with U.S. Pat. No. 2,954,779.

These tests were made under the following conditions:

a. Each puff was 35 milliliters.

b. Each puff has a duration of 2 seconds.

c. The puffs were produced by sinusoidal pressure changes.

d. One puff per minute.

e. Total of eight puffs.

The tests revealed that the filter, as shown in FIG. **20**, removed, on the average, at least 50 percent more tar than the one constructed in accordance with U.S. Pat. No. 2,954,779.

It may thus be seen that the objects of the invention set forth above, as well as those made apparent from the foregoing description, are efficiently attained. While a preferred embodiment of the invention has been set forth for purposes of disclosure, other embodiments of the invention as well as modifications to the disclosed embodiments may occur to those skilled in the art which do not depart from the spirit and scope of the invention. It is therefore intended in the appended claims to cover all embodiments of the invention as well as modifications to the disclosed embodiments of the invention which do not depart from the spirit and scope of the invention.

We claim:

1. A device for removing tars from tobacco smoke passing therethrough comprising means defining a chamber having internal walls, means defining an inlet nozzle extending into said chamber, said nozzle having an opening diameter of from 0.025 inch to 0.033 inch, an outlet opening defined in said chamber, said nozzle opening being spaced from said walls and said chamber having a volume sufficient to permit substantial expansion of smoke therein entering from said nozzle prior to the smoke contacting said walls, said nozzle being constructed and arranged to produce dispersion of smoke entering therethrough to said chamber, said outlet opening having an area at least twice as large as the area of said nozzle opening and being sized in relation to the volume of said chamber to produce a pressure drop thereacross as smoke is drawn through said device so that expansion of the smoke in said chamber produces a drop in temperature of the smoke in said chamber causing precipitation of tars in the smoke on said walls and said outlet opening being positioned intermediate the ends of the passage defined by said nozzle.

2. A device for removing tars from tobacco smoke passing therethrough comprising means defining a hollow chamber having internal walls, means defining an inlet nozzle extending into said chamber, said nozzle being so shaped as to cause dispersion of smoke in said chamber as the smoke enters the chamber through said nozzle, said nozzle having an opening diameter of from 0.025 inch to 0.033 inch, an outlet opening defined in said chamber, said chamber having a volume sufficient to permit expansion of smoke therein entering from said nozzle so as to precipitate tars from the smoke, said nozzle opening being spaced from said walls a sufficient distance so that substantial expansion of smoke entering said chamber occurs prior to the smoke contacting said walls, said outlet opening having an area at least twice as large as the area of said nozzle opening, said outlet opening being defined in said chamber upstream the opening of said nozzle in said chamber so that smoke entering said chamber reverses direction between the inlet and outlet openings, said outlet opening being sized to produce a pressure drop thereacross as smoke is drawn through said device so that expansion of smoke in said chamber produces a drop in temperature of the smoke in said chamber causing precipitation of tars in the smoke on said walls.

3. The device of claim **2** wherein the longitudinal cross-sectional contour of said nozzle defines a portion of an ellipsoid.

4. The device of claim **2** wherein the longitudinal cross-sectional contour of said nozzle is defined by lines converging from the inlet to outlet of approximately 30°.

5. The device of claim 2 wherein the outlet opening of said chamber is defined in said chamber between the inlet and outlet of said nozzle.

6. The device of claim 2 wherein the chamber wall opposite said nozzle is longitudinally concave in the direction facing the outlet portion of said nozzle.

7. The device of claim 2 wherein the means defining said nozzle is of a nonmetallic material.

8. A tobacco smoke filter comprising wall means defining a chamber for expansion of smoke therein, a nozzle extending into said chamber and defining an inlet passage therein, the opening in said nozzle in said chamber being spaced from said wall means in said chamber for defining with said wall means a volume sufficient to permit substantial expansion of smoke therein entering from said nozzle prior to the smoke contacting said wall means, an outlet opening from said chamber, said outlet opening being positioned intermediate the ends of the passage defined by said nozzle, said outlet opening being sized in relation to the volume of said chamber to produce a pressure drop thereacross as smoke is drawn through said device so that expansion of the smoke in said chamber produces a drop in temperature of the smoke in said chamber causing precipitation of the tars in the smoke on said wall means.

9. The filter of claim 8 wherein said outlet opening is coaxial with said nozzle.

10. The filter of claim 8 wherein said outlet opening has a cross-sectional area selected to create back pressure within said chamber and prevent unlimited expansion of tobacco smoke entering said chamber through said nozzle.

11. The filter of claim 8 wherein the wall defining said chamber opposite said nozzle is substantially hemispherical, said wall extending transversely across the outlet portion of said nozzle.

12. The filter of claim 8 further including wall means defining a passage with the outer walls of said chamber, said outlet opening of said chamber communicating with said passage.

13. The filter device of claim 8 wherein said nozzle has a length of 0.045 inch to 0.10 inch and a decreasing cross-sectional area along the length thereof toward the outlet opening.

14. The device of claim 13 wherein said nozzle has an opening into said chamber of 0.025 inch to 0.033 inch diameter.

15. The device of claim 13 wherein the diameter of the smoke intake end of said nozzle is approximately twice the diameter of the smoke outlet end.

16. The device of claim 13 wherein said nozzle defining means extends outwardly of said chamber defining means towards a smoke producing article.

17. A device for removing tars from tobacco smoke passing therethrough comprising means defining a hollow chamber having internal walls, means defining an inlet nozzle extending into said chamber, said nozzle being so shaped as to cause dispersion of smoke in said chamber as the smoke enters the chamber through said nozzle, said nozzle having an opening diameter of from 0.025 in. to 0.033 in., an outlet opening defined in said chamber, said chamber having a volume sufficient to permit expansion of smoke therein entering from said nozzle so as to precipitate tars from the smoke, said nozzle opening being spaced from said walls a sufficient distance so that substantial expansion of smoke entering said chamber occurs prior to the smoke contacting said walls, the volume of said chamber for expansion of smoke therein expressed in cubic millimeters being 100 to 400 times greater than the area of said nozzle opening expressed in square millimeters, said outlet opening having an area at least twice as large as the area of said nozzle opening, said outlet opening being defined in said chamber upstream the opening of said nozzle in said chamber so that smoke entering said chamber reverses direction between the inlet and outlet openings, said outlet opening being sized to produce a pressure drop thereacross as smoke is drawn through said device so that expansion of smoke in said chamber produces a drop in temperature of the smoke in said chamber causing precipitation of tars in the smoke on said walls.

18. The device of claim 17 wherein the longitudinal cross-sectional contour of said nozzle defines a portion of an ellipsoid.

19. The device of claim 17 wherein the longitudinal cross-sectional contour of said nozzle is defined by lines converging from the inlet of the nozzle to the outlet of the nozzle by approximately 30°.

20. The device of claim 17 wherein the outlet opening of said chamber is defined in said chamber between the inlet and outlet of said nozzle.

21. The device of claim 17 wherein the chamber wall opposite said nozzle is longitudinally concave in the direction facing the outlet portion of said nozzle.

22. The device of claim 17 wherein the means defining said nozzle is of a nonmetallic material.

23. A tobacco smoke filter comprising wall means defining a chamber for expansion of smoke therein, a nozzle extending into said chamber and defining an inlet passage therein, an opening on said nozzle in said chamber being spaced from said wall means in said chamber for defining with said wall means an volume sufficient to permit substantial expansion of smoke therein entering from said nozzle prior to the smoke contacting said wall means, the volume of said chamber for expansion of smoke therein expressed in cubic millimeters being 100 to 400 times greater than the area of said nozzle opening expressed in square millimeters, an outlet opening from said chamber, said outlet opening being positioned intermediate the ends of the passage defined by said nozzle, said outlet opening having a cross-sectional area selected in relation to the volume of said chamber to produce a pressure drop thereacross as smoke is drawn through said device so that expansion of the smoke in said chamber produces a drop in temperature of the smoke in said chamber causing precipitation of the tars in the smoke on said wall means.

24. The filter of claim 23 wherein said outlet opening is coaxial with said nozzle.

25. The filter of claim 23 wherein said outlet opening has a cross-sectional area sufficient to create back pressure within said chamber and prevent unlimited expansion of tobacco smoke entering said chamber through said nozzle.

26. The filter of claim 23 wherein the wall defining said chamber opposite said nozzle is substantially hemispherical, said wall extending transversely across the outlet portion of said nozzle.

27. The filter of claim 23 further including wall means defining a passage with the outer walls of said chamber, said outlet opening of said chamber communicating with said passage.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,601,133 **Dated** August 24, 1971

Inventor(s) William F. Van Eck - Warren R. Jewett

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 11, after "water" insert -- vapor --. Line 16, "droplet" should be -- droplets --. Line 75, "ad" should be -- and --. Column 3, line 61, "FIG. 2" should be -- FIG. 22 --. Column 6, line 67, "embodiment" should be -- embodiments --. Column 8, line 71, delete "in" (second occurrence). Column 9, line 25, "nozzle 12" should be -- nozzle 121 --. Column 12, line 33, "an" should be -- a --.

Signed and sealed this 14th day of March 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents