# United States Patent

**Millman**

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[54] **SONIC NEBULIZER**


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[73] Assignee: **The Bendix Corporation**



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[52] **U.S. Cl.** .....**128/194,** 239/102, 310/8.3

[51] **Int. Cl.**.....**A61h 1/00,** A61m 15/00

[58] **Field of Search**.....128/194, 193, 188, 173, 172, 128/186, 191, DIG. 2; 239/338; 310/8.1, 8.7, 8.9, 8.3


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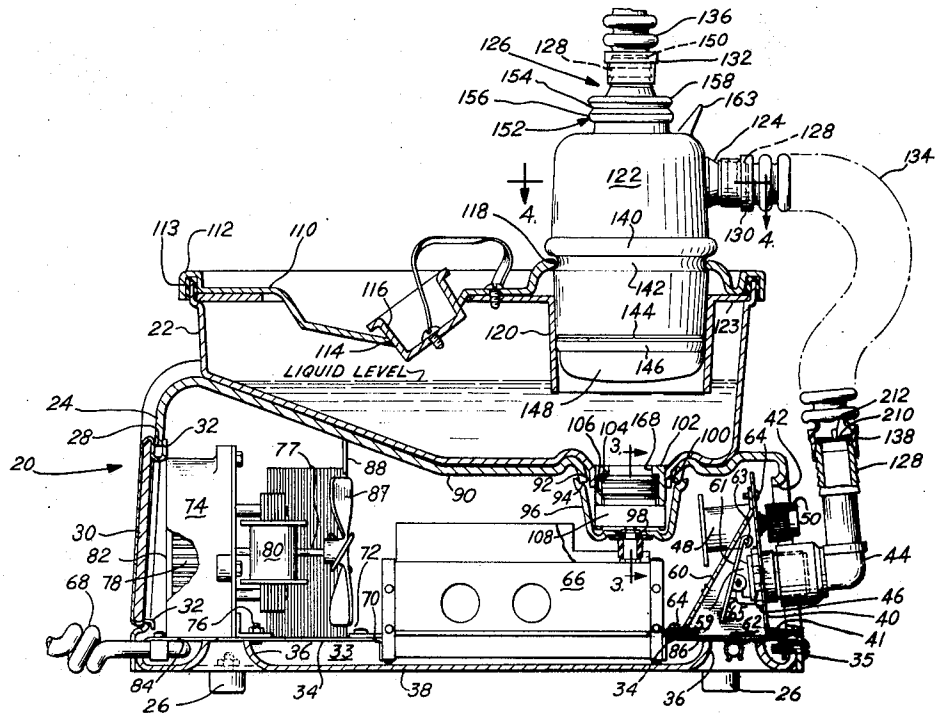
[57] **ABSTRACT**


A sonic nebulizer having an electronic powered piezo-electric crystal to produce mechanical vibrations which are transmitted through a coupling fluid and focused on a second fluid contained in a chamber having a tangentially directed pressurized air inlet and a central opening whereby the nebulized second fluid is entrained by the vortex air flow generated in the chamber and the resulting fluid mixture carried through the outlet. The coupling fluid, electric power oscillator, piezo-electric crystal and associated control apparatus are contained by a portable casing which presents a compact, lightweight and rugged unit particularly adapted for short or long term use in supplying medicated air or oxygen to a patient undergoing medical care. The chamber containing the nebulized second fluid is made of an inexpensive, transparent material which is quickly and easily mounted to the casing and attached to inlet and outlet hoses. The inlet and outlet hoses, like the chamber, may be made from inexpensive material and together with the chamber constitute a disposable portion to avoid contamination between patients.


**7 Claims, 5 Drawing Figures**



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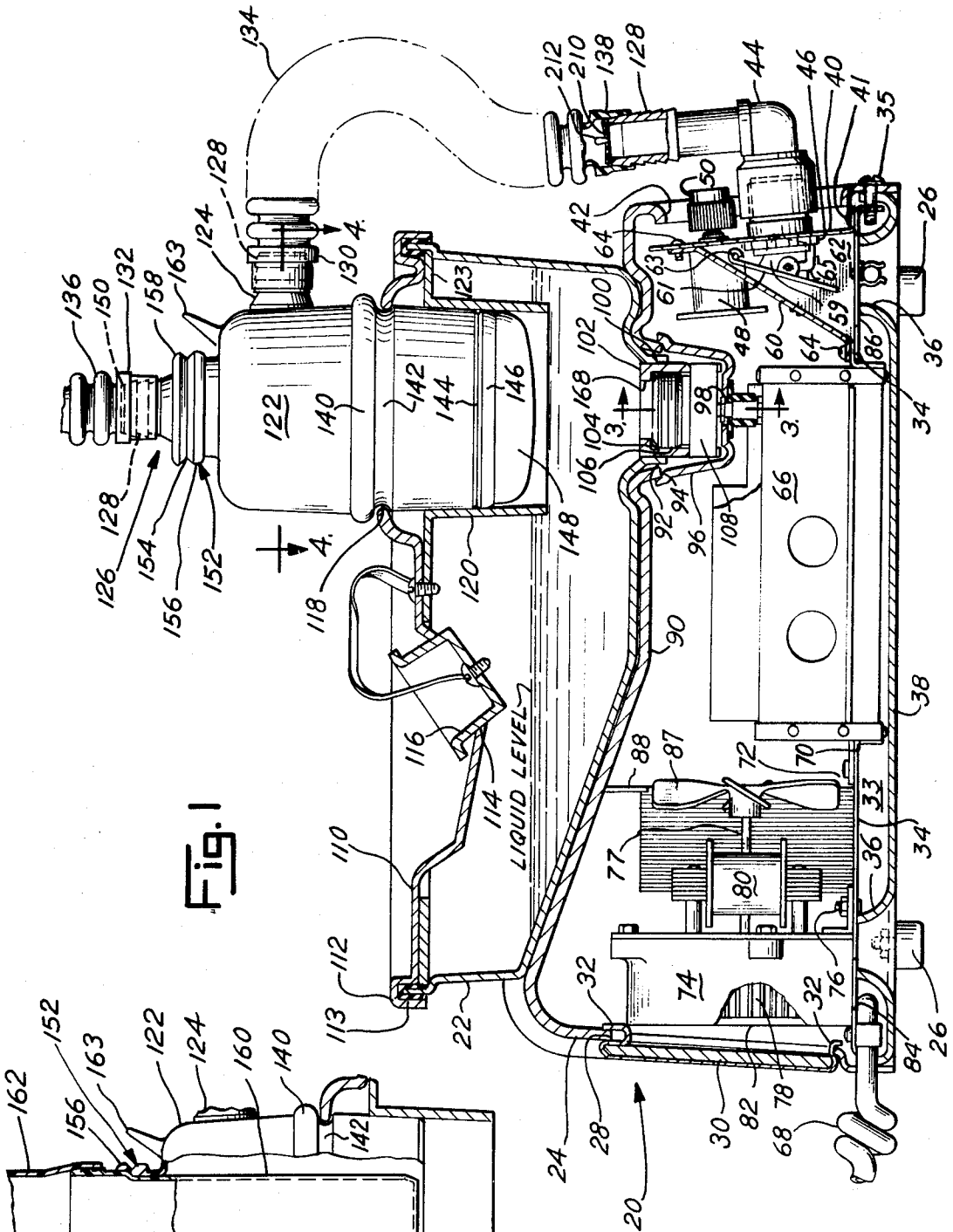


Fig. 1



Fig. 5

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Fig. 2

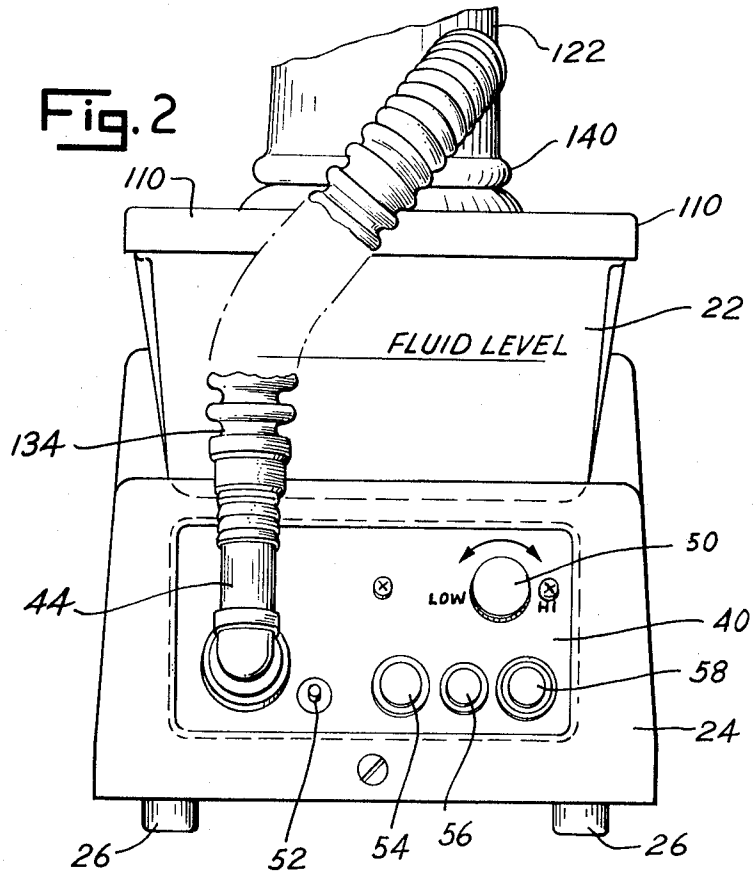



Fig. 3

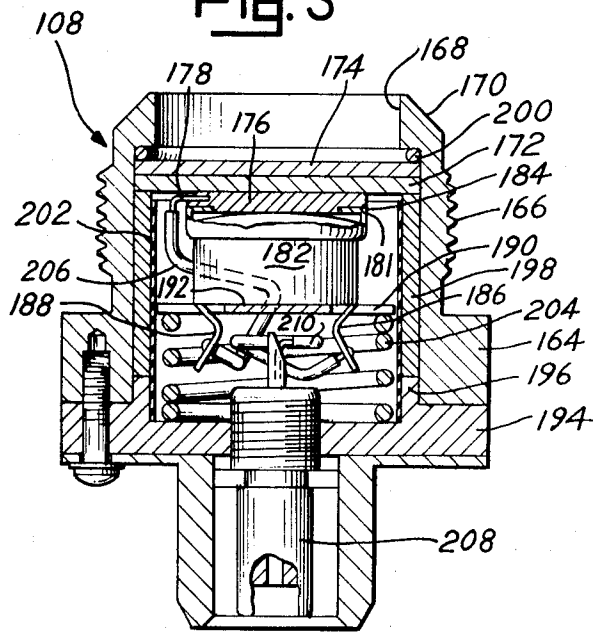
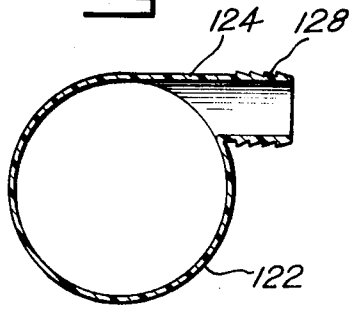



Fig. 4

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# SONIC NEBULIZER

## BACKGROUND OF THE INVENTION

In general, nebulizers for medical treatment are not new and various forms thereof exist for hospital or home use. However, the nebulizers of which I am aware have a number of serious disadvantages including high cost, lack of simplicity and attendant maintenance problems as well as need for skilled therapists, limited life and lack of reliability due to inability to withstand repeated shock and the like resulting from rough handling and/or other mistreatment, susceptibility to contamination of hoses, etc., as a result of being exposed to a patient's breath and subsequent need for disassembly to permit sterilization before use on another patient. Other undesirable characteristics include disassembly problems involved in replacing critical parts subject to deterioration and replacement under normal usage.

In particular, the design of prior art nebulizers precludes accurate control over the quantity of medicament nebulized over a given period of time so that a specified medicant-air and/or oxygen mixture can be maintained to a patient over a short or long time period.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a sonic nebulizer characterized by structural simplicity, compactness and lightweight which renders the same readily portable for use at substantially any desired location in a hospital or home.

It is an important object of the present invention to provide a sonic nebulizer characterized by reliability of operation and ruggedness even under continuous usage.

It is another object of the present invention to provide a sonic nebulizer which is relatively inexpensive to manufacture and operate and capable of providing a wide range of aerosol output with or without medicaments.

It is another object of the present invention to provide a sonic nebulizer which is easy to clean and sterilize and wherein the portions thereof normally exposed to contamination by a patient temporarily using the same are disposable to prevent cross contamination to a subsequent patient using the same.

It is another object of the present invention to provide a sonic nebulizer characterized by a wide range of aerosol output flow thereby adapting the same for medical use with a face mask or tent.

It is still another object of the present invention to provide an inexpensive, disposable nebulizer chamber including medicant cup which is rugged, efficient and easily attached to or removed from associated nebulizer apparatus.

Other objects and advantages will be apparent from the following description taken with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 represents a sectional view of a sonic nebulizer embodying the present invention;

FIG. 2 represents an end view of the apparatus of FIG. 1;

FIG. 3 represents a sectional view of a piezo-electric transducer assembly;



FIG. 4 represents a sectional view taken on line 4—4 of FIG. 1.

FIG. 5 represents a portion of FIG. 1 modified to provide greater output flow for tent use.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, FIG. 1 in particular, numeral **20** designates a generally rectangular shaped, multi-section casing having an upper section **22** defining a fluid reservoir and a lower section **24** housing various control elements as will be described. The upper section **22** rests upon the lower section **24** and is readily separable therefrom. Preferably, the casing **20** is constructed from any suitable plastic material which may be easily and quickly formed to the required shape and having desirable characteristics including low cost, strength as well as being impact resistant, lightweight, electrically non-conductive and corrosion resistant.

The lower section **24** is supported by a plurality of spaced-apart legs generally indicated by **26** suitably secured thereto. An air inlet **28** in lower section **24** is provided with an air filter element **30** secured therein by integral flexible clips **32** which engage casing **20**. A floor or platform **34** is positioned on a plurality of spaced apart supports **36** integral with casing **20** by fasteners **35**, only one being shown. The supports **36** hold the platform **34** a uniform distance from the base **38** to form a passageway **33** therebetween.

A control panel **40** fixedly secured to platform **34** by suitable fastening means such as screws **41** is held in spaced-apart relationship to an air outlet **42** in lower section **24** through which pressurized air is discharged from the interior of lower section **24**. An air outlet opening is defined by a fitting **44** fixedly secured to control panel **40** by a lock nut **46** threadedly engaged therewith. Various control members including a power regulator **48** having an adjustable control knob **50** movable between low and high power settings, an air control push to operate control member **52**, a fuse block **54**, an ON-OFF push button switch **56** and a timer **58** for indicating elapsed time of operation are suitably connected to panel **40** for control purposes.

The air inlet of fitting **44** is isolated from air flowing to air outlet opening **42** by partition means including a wall **60** extending at an angle to panel **40** and provided with suitable integral end wall portions **62** only one of which is shown. A truncated plug or valve member **59** fixed to a plate **61** is adapted to move relative to the inlet of fitting **44** to vary the effective flow area of fitting **44**. The plate **61** is secured to a shaft **63** suitably mounted for rotation and actuated by a link **65** connected to air control member **52**. The wall **60** is suitably flanged to permit opposite edge portions thereof to be fixedly secured to control panel **40** and platform **34** by suitable fastening means such as screws **64**.

A power control unit generally indicated by **66** is connected to a source of electric power via insulated power cord **68**. The power control unit **66** is provided with suitable flange members **70** fixedly secured to platform **34** by any suitable means such as rivets **72** to thereby provide support for power control unit **66**. The power control unit **66** including internal electronic circuitry thereof is fully described as well as claimed in copending application Ser. No. 45,163 filed June 10,

1970 now U.S. Pat. No. 3,648,188 in the name of H. Ratcliff, owned by the common assignee of this application and incorporated by reference. In general, the power control unit **66** is adapted to receive an electric input via lead **68** and control the same to a desired oscillating electric output of predetermined frequency and amplitude. To that end, the power regulator **48** is electrically connected to power control unit **66** such that any desired electrical power output within the established range may be selected by rotating control knob **50** to the proper position.

A housing **74** is fixedly secured to platform **34** by suitable fastening means including a plurality of nut and bolt combinations **76**. The housing **74** houses a conventional air blower **78** rotatably supported therein and driven by an electric motor **80** suitably connected to lead **68**. The housing **74** is provided with an air inlet **82** exposed to filtered air from air inlet **28** and an air outlet **84** for discharging pressurized air to an air channel partially defined by platform **34** and base **38** between which the air flows to an opening **86** in platform **34** thence to air outlet fitting **44**. A fan **87** driven by shaft **77** of electric motor **80** receives air from air inlet **28** and urges the same through lower section **24** to air outlet **42** to thereby provide cooling air flow which passes over power control unit **66** to dissipate heat generated thereby. A shroud **88** suitably mounted around fan **87** confines the incoming air to passage through fan **87**.

The lower section **24** is provided with a dished upper wall portion **90** provided with an opening **92** having a flanged edge **94**. A cup-shaped receptacle **96** flanged to mate with flanged edge **94** is fixedly secured thereto by any suitable means such as an adhesive or the like. An opening **98** in the base of receptacle **96** is provided for a purpose to be described.

The upper section **22** is contoured to mate with dished upper wall portion **90** and has a flanged opening **100** formed therein. A sleeve **102** having a shoulder **104** formed in the upper end thereof is received by flanged opening **100** to which the sleeve **102** is fixedly secured by any suitable means such as an adhesive providing a fluid seal. The inner wall of sleeve **102** is threaded as at **106** and adapted to threadedly receive an energy transducer or piezo-electric crystal assembly generally indicated by **108**. The upper section **22** is provided with a cover **110** having a channeled edge section **112** adapted to engage a resilient seal **113** secured to the wall of upper section **22** to thereby hold cover **110** in position securely. An opening **114** in cover **110** is adapted to receive a standard U.S.P. bottle, not shown, for supplying fluid to the reservoir defined by upper section **22**. A cap **116** suitably secured in opening **114** serves to plug the same in the event a conventional U.S.P. bottle is not used as will be described. An opening **118** in cover **110** is aligned with a sleeve **120** having a radially extending wall **123** fixedly secured to cover **110** by any suitable means such as adhesive or the like. The sleeve **120** is aligned with sleeve **102** containing the piezo-electric crystal assembly **108** and extends below the level of fluid in upper section **22**.

A nebulizing chamber is defined by a container **122** preferably circular in form and molded from any suitable relatively inexpensive thermoplastic material. The container **122** is provided with an integral tubular extension **124** defining an air inlet located to direct pressurized air tangentially into container **122** as indicated in FIG. **4**. An integral two diameter tubular extension **126** centrally located in the top of container **122** provides an air outlet for container **122**. The tubular extensions **124** and **126** are provided with corrugations **128** adapted to engage respective mating coupling members **130** and **132** suitably fixed to one end of flexible inlet and outlet hoses **134** and **136**, respectively. The opposite end of inlet hose **134** is provided with a coupling **138** suitably fixed thereto which is adapted to engage a corrugated portion **128** of fitting **44**. The opposite end of outlet hose **136** is adapted to be removably attached to a conventional breathing mask, not shown. The container **122** has an integral outwardly extending annular rib **140** and an adjacent integral annular recess **142** molded therein and located at approximately the midportion of container **122**. An annular recess **144** is defined by an outwardly extending annular rib **146** formed in a reduced diameter which transitions into a substantially flat base portion **148** of container **122**. The base portion **148** and, in particular, the portion thereof exposed to the piezo-electric crystal assembly **108** is carefully controlled during molding thereof for a purpose to be explained. It will be noted that the container **122** is received by sleeve **120** and securely held in position therein by the edge portion of opening **118** which snap fits into recess **142**.

Referring to the two diameter extensions **126**, the smaller diameter portion **150** thereof is adapted for connection to hose **136** which, in turn, connects to a breathing mask. However, the above-described apparatus may be readily modified for tent use in which case the air flow volume as well as the volume of nebulized fluid must be increased significantly over that required for mask use. To that end, the base portion of container **122** is adapted to be cut off at the annular recess **144** to expose the interior of container **122** to the liquid reservoir in upper section **22**.

The larger diameter portion **152** of extension **126** is provided with an annular recess **154** defined by spaced-apart annular ribs **156** and **158**. The extension **126** may be cut off at recess **154** thereby providing an enlarged diameter outlet for the container **122** as indicated in FIG. **5**. A sleeve **160** attached to one end of a corresponding relative large diameter flexible hose **162** leading from a tent, not shown, is slidably received by the larger diameter portion **152** and extends axially through container **122** to approximately the open end thereof. A shoulder **162** formed on sleeve **160** engages the rib **158** to thereby locate the axial position of sleeve **160**.

The container **122** may be provided with an integral nipple **163** which is snipped off in the event that oxygen enrichment is desired. To that end, a source of pressurized oxygen, not shown, is provided with an outlet hose adapted to be secured to the inlet opening defined by the snipped off nipple **163**.

Referring to FIG. **3**, the piezo-electric crystal assembly **108** is shown in section. An annular housing **164** preferably formed from an electrically non-conductive material is provided with a threaded section **166** and a reduced diameter end portion defining an opening **168** and shoulder **170**. A flat piezo-electric

crystal assembly is defined by a disc **172** of suitable piezo-electric material such as a lead-zirconate-titanate composition of suitable thickness which is polarized to vibrate in an axial direction. A stainless steel disc **174** ( ½) thick is suitably bonded to the disc **172** by means of an epoxy to thereby establish a well-known resonant system. In general, the stainless steel disc **174** functions to load the piezo-electric disc **172** to prevent self destruction thereof when a high electrical input is applied thereto and further functions to store energy thereby increasing the mechanical Q operation as will be recognized by those persons skilled in the art. An electrically conductive slug or disc **176** bears against the disc **172** and has a terminal **178** fixedly secured thereto which receives a wire lead **180**. The slug or disc **176** is securely mounted on an annular flange **181** of a conventional thermostat assembly **182** by means of an adhesive **184** or the like. The thermostat assembly **182** is provided with terminals **186** and **188**, each of which extend through an associated opening of a plurality of openings **190** in insulating disc **192** of electrically non-conductive material.

A cap **194** is provided with an annular extension **196** which extends into the interior of housing **164** into engagement with one end of a sleeve **198** slidably engaged with the interior wall of housing **164**. The opposite end of sleeve **198** bears against piezo-electric disc **172**. An O ring seal **200** trapped between shoulder **170** and disc **174** is compressed thereby establishing a fluid seal between disc **174** and annular housing **164** which compression also serves to force load piezo-electric disc **172** into engagement with sleeve **198** and maintain positive electrical contact therebetween. An insulating sleeve **202** of suitable electrically non-conductive material is inserted within sleeve **198** to electrically insulate the thermostat assembly **182**, slug **176** and associated mechanism from sleeve **198**. A compression spring **204** interposed between cap **194** and insulating disc **192** loads the thermostat assembly **182** and thus slug **176** to thereby maintain positive electrical contact between slug **176** and piezo-electric disc **172**. A wire **206** connects terminal **188** with slug **176**.

A conventional RF connector plug **208** threadedly engaged with cap **194** is suitably connected via a wire **210** to terminal **186** of thermostat assembly **182**. Current flow passes through thermostat assembly **182** to terminal **188** then via wire **206**, slug **176**, piezo-electric disc **172**, sleeve **198** and cap, in that order, to plug **208**. It will be noted that the sleeve **198** and cap **194** are necessarily made from electrically conductive material. Also, it will be recognized that the thermostat assembly **182** and piezo-electric disc **172** are in series flow relationship such that current flow through the disc **172** is automatically interrupted by the thermostat assembly **182** in response to a predetermined temperature condition.

The housing **164** is adapted to be screwed into mating threads **106** in sleeve **102** attached to upper section **22**. The RF connector plug extends through opening **98** in receptacle **96** into a mating socket, not shown, provided in power control unit **66**.

Referring to the fitting **44**, reverse air flow therethrough is obstructed by a flexible wall or flapper **210** suitably enclosed as by member **212** at its center to fitting **44**. The flexible wall **210** allows pressurized air to pass therethrough to hose **134**. However, in the event of a patient coughing or the like in his mask, the resulting back flow through container **122** and thus hose **134** is prevented from entering fitting **44** by closing of flexible wall **210** thereby eliminating contamination of the structure upstream from the fitting **44**.

## OPERATION OF THE PREFERRED EMBODIMENT

Applicant's nebulizer apparatus may be easily and quickly set up for operation in any suitable location relative to a patient requiring aerosol therapy. To that end, the upper section **22** is positioned on lower section **24** with the connector plug **208** engaged with the power control unit **66**. The therapist may then fill the upper section **22** defining the liquid reservoir to the indicated level by removing cap **116** and inserting standard U.S.P. bottles containing water or saline solution in opening **114**. When the liquid in upper section **22** reaches the desired level, the neck of U.S.P. bottle is immersed thereby blocking air flow into the bottle and controlling the liquid level accordingly.

The container **122** or nebulizing chamber is inserted into opening **118** and secured in position therein by cover **110** which snaps into recess **142**. The desired quantity of a liquid medicant to be nebulized is poured into container **122** through extension **126**. The coupling members **130** and **138** on opposite ends of flexible hose **134** are snapped in position on corrugations **128** of extension **124** and fitting **44**, respectively. The coupling member **132** on one end of flexible hose **136** is snapped in position on the corrugations **128** of the smaller diameter portion **150** of extension **136**.

The power cord **68** is plugged into a suitable electrical receptacle and the push button switch **56** actuated to the ON position. The power control knob **50** is adjusted to the desired power setting and the air control **52** set to position valve member **59** which, in turn, establishes the effective flow area of fitting **44** and thus air volume to the container **122**.

The setting of power control knob **50** determines the electrical output impressed on piezo-electric disc **172** and thus resulting sonic energy generated thereby which sonic energy is directed through opening **168** causing the liquid reservoir or coupling liquid in upper section **22** to pile up into a fountain shaped wave. The created sonic energy will be concentrated at a flat peak of the fountain shaped wave causing the tip of the wave to be dispersed as droplets into the surrounding space. However the base portion **148** of container **122** is placed in the fountain shaped wave. The base portion is carefully molded of a thickness which will not affect the transmission of sonic energy from crystal assembly **108**. A thickness for the base **148** equal to one quarter wave length or less of the acoustic wave imposed on the base portion **148** will be acoustically transparent to the sonic energy passing therethrough permitting the formation of the fountain shaped wave in the medicament. The resulting agitation of the medicament causes the same to be dispersed into a mist defined by small particles of the medicant.

The pressurized air introduced into the container **122** via inlet hose **134** is directed tangentially into container **122** and follows a vortex path in passing to the outlet extension **126**. The nebulized medicament in container **122** is entrained by the air flow which causes

the larger particles of medicament to move radially outwardly in container **122** in response to the centrifugal force imposed on the particles by virtue of the vortex action such that only thoroughly dispersed relatively small particles of medicament are carried by the air flow through outlet extension **126** to the outlet hose **136** for subsequent inhalation by the patient. Treatment is discontinued when the medicament in container **122** is used up following which the power unit **66** is shut off whereupon upper and lower sections **22** and **24** may be transferred to another location for use by a second patient if desired. The inlet and outlet hoses **134** and **136** are disconnected from fitting **44** and the inhalation mask, respectively, and the container **122** detached from cover **110**, all of which may be discarded and replaced by an unused container **122** and unused inlet and outlet hoses **134** and **136** thereby preventing cross contamination between patients. The sections **22** and **24** including the liquid reservoir are not contaminated and may be used repeatedly since the sections are not exposed to a patient.

The nipple **163** is located adjacent air inlet extension **124** such that oxygen introduced therethrough to container **122** tends to be entrained by the air flow through extension **124**.

Applicant's nebulizing apparatus may be set up for tent therapy quickly and conveniently. To that end, the base portion **148** of container **122** is removed by cutting along recess **144** and the smaller diameter portion **150** of extension **126** removed by cutting along recess **154**. The sleeve **160** may then be inserted into larger diameter portion **154** of extension **126** as shown in FIG. **5**. The sonic energy derived from the piezo-electric crystal assembly **108** is imposed on the liquid reservoir in upper section **22** creating a fountain-like mass of liquid particles adjacent the lower end of sleeve **160** which particles are swept along by the vortex air flow through container **122**, which exits through sleeve **160** and hose **162** attached thereto to the tent. In this manner, the large liquid reservoir supplemented by standard U.S.P. bottles attached to cover **110** and replaced as required permits hours of continuous fog in suitable volume for tent therapy.

The upper and lower sections **22** and **24** may be readily cleaned as desired by removing the cover **110** and unplugging the upper section **22** from the lower section **24** which cover **110** and section **22** may be easily and thoroughly washed and sterilized since there are no small, inaccessible places to contend with therein.

With the upper section **22** unplugged from lower section **24**, the piezo-electric crystal assembly **108** may be removed therefrom simply and quickly by unscrewing the same from sleeve **102** and screwing in a replacement crystal assembly if required.

I claim:

**1**. A portable sonic nebulizing apparatus for use in treating an individual with a respiratory problem requiring conditioned air, said apparatus comprising:

a first housing having an inlet port, a first outlet, a second outlet and a third outlet, said first housing having a flange around said first outlet, said housing retaining an electrical power control adjacent said first outlet;

fan means adjacent the inlet port in said first housing for moving air along a first path to said second outlet and a second path to said third outlet, said air moving in said first path removing thermal energy from said electrical power control;

a filter member located in said inlet port to remove impurities from the air received by said fan means, a second housing positioned on said first housing having a first opening, a second opening and a third opening, said second and third openings being in axial alignment with said first outlet port of the first housing, said second opening having a sleeve extending inwardly toward said third opening a predetermined distance;

sonic energy means sealed in said third opening of said second housing having an extension passing through said first outlet in the first housing connecting said sonic energy means with said electrical power control;

cylindrical container means resiliently retained in said second opening and sleeve of the second housing having a substantially flat base which is in axial alignment with said sonic energy means, said flat base extending into the sleeve a predetermined distance from said second opening, said container means retaining a fluid medicament which aids in relieving said respiratory problem, said container means having a tangential entrance passage and an axial exit passage, said tangential entrance passage being connected to said third outlet in the first housing for delivering all of the filtered air from said fan means in said second path, said tangential entrance causing the filtered air to follow a vortex flow path in said cylindrical container, a coupling fluid located in said second housing; and

control means connected to said electrical power control for activating the sonic energy means for creating a fountain shaped energy wave in said coupling fluid, said base of the cylindrical container means being located in said fountain shaped energy wave, said fountain shaped energy wave passing through said base unobstructed causing the medicament to be dispersed as droplets in said vortex flow path of the filtered air, said droplets being suspended in said air, said exit passage being connected to the patient for delivering the medicament droplets in the filtered air.

**2**. The apparatus as recited in claim **1** wherein the control means further includes:

flow control means in said second path adjacent the third outlet in the first housing for regulating the quantity of filtered air delivering said tangential entrance into the cylindrical container means to selectively establish said vortex flow path corresponding to the need of the individual user.

**3**. The apparatus as recited in claim **2** wherein the thickness of the base of said fluid container is less than h/4 wave length of the vibrating frequency of the sonic energy means to prevent destruction of the cylindrical container means by thermal energy.

**4**. The apparatus as recited in claim **3** wherein the control means further includes:

temperature responsive means for interrupting the operation of the sonic energy means when the sensed thermal level in said sonic energy means corresponds to a predetermined value.

5. The apparatus as recited in claim 2 wherein said third opening in said second housing and the sonic energy means are threadedly engaged to permit easy removal thereof from the sonic energy means.

6. The apparatus as recited in claim 5 further including:

flow restricting means adjacent the third outlet in the second flow path for preventing backflow from the container means.

7. The apparatus as recited in claim 6 wherein said container means further includes:

an additive entrance downstream from said tangential entrance passage connected to a source of oxygen to further condition the filtered air by enriching the oxygen content therein.

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