Aug. 8, 1967 M. F. SMITH ET AL 3,334,657

ADJUSTABLE FLUID MIXING DEVICES

Filed Oct. 28, 1963 2 Sheets-Sheet 1

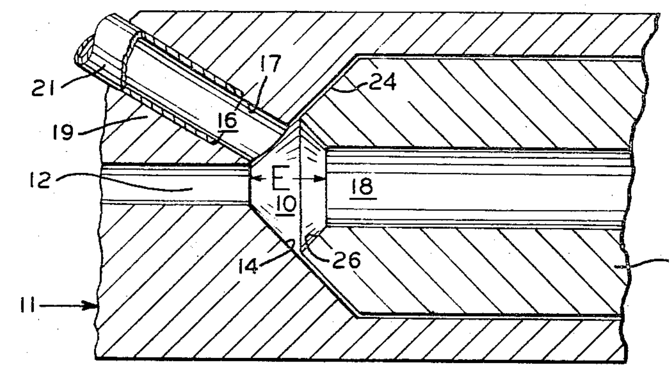

FIG. 1

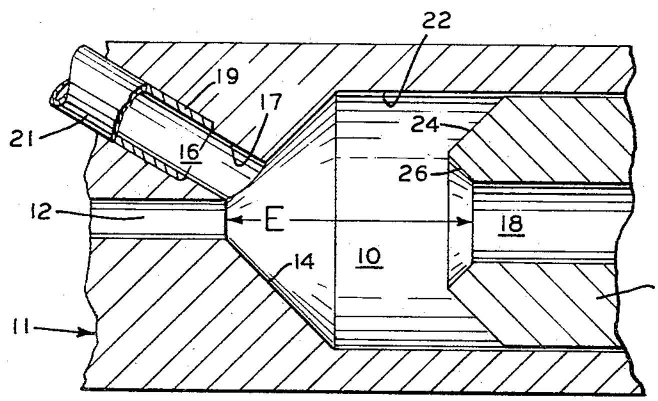

FIG. 2

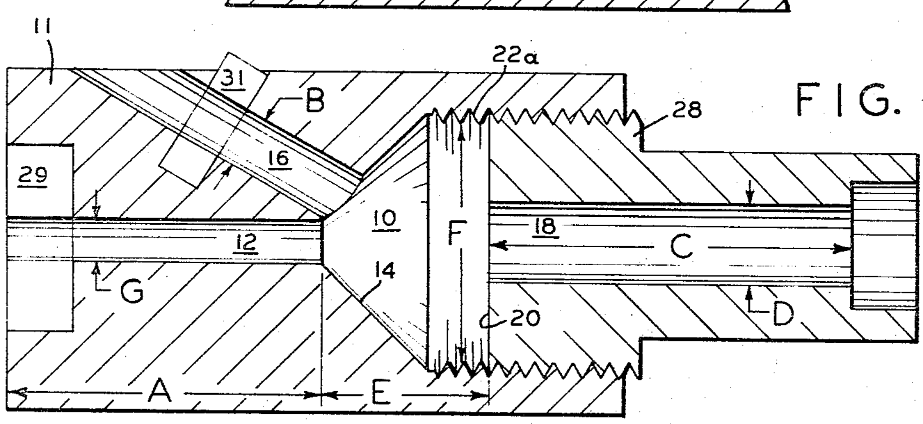

FIG. 3

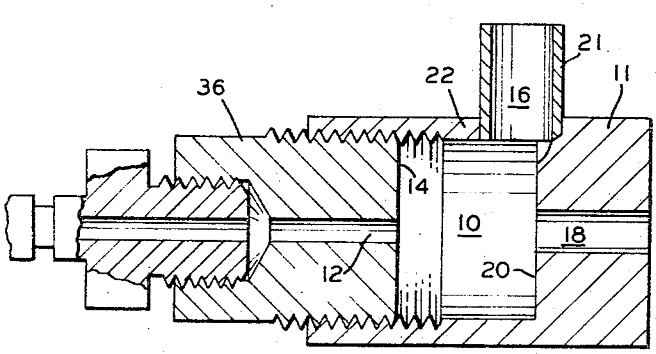

FIG. 4

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ADJUSTABLE FLUID MIXING DEVICES

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FIG. 5

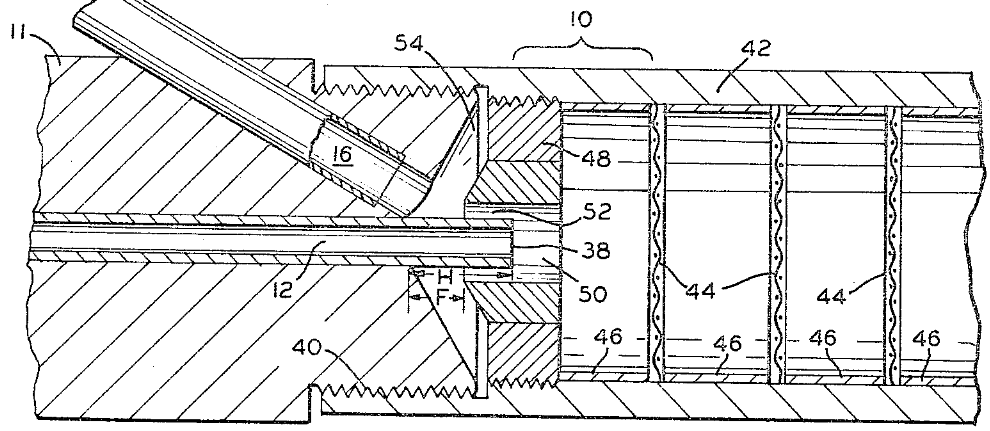


FIG. 6

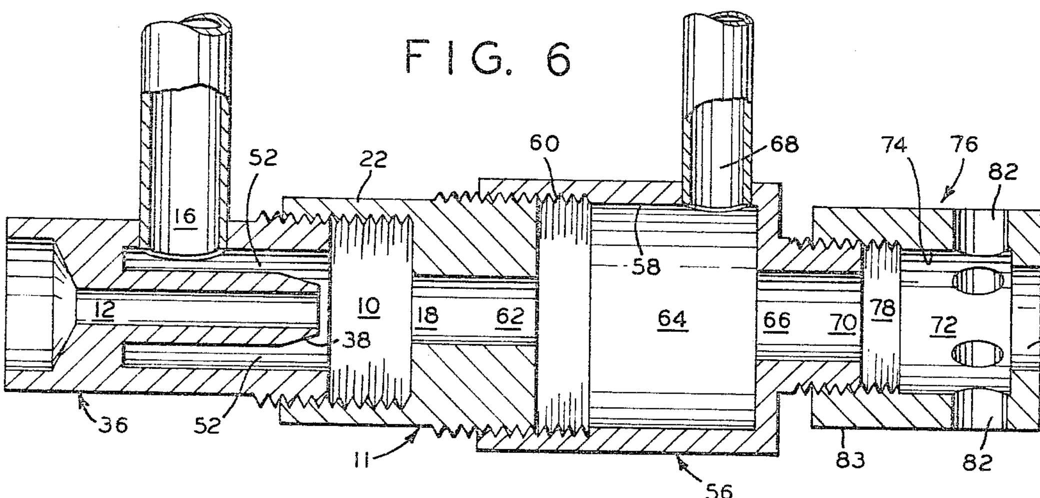


FIG. 7

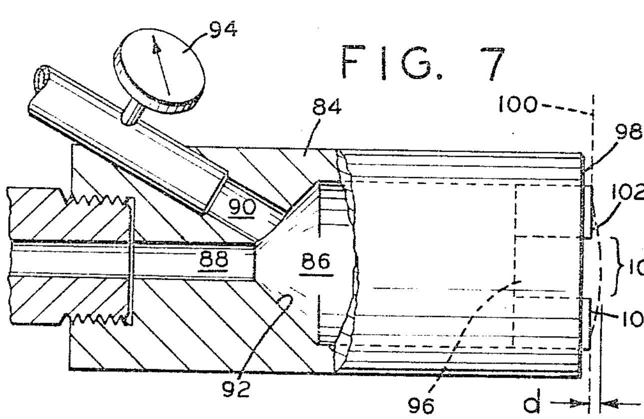
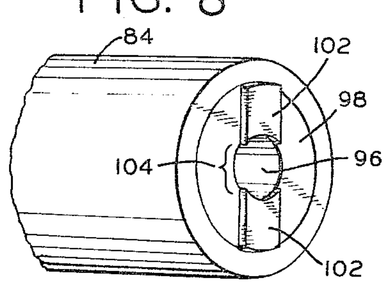


FIG. 8



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3,334,657
ADJUSTABLE FLUID MIXING DEVICES

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10 Claims. (Cl. 137—604)

This application is a continuation-in-part of the copending sole application of Millard F. Smith, Ser. No. 255,601, filed Feb. 1, 1963, and issued as United States Patent 3,291,631 on Dec. 13, 1966.

This invention relates to injectors, aspirators and fluid-mixing devices, and more particularly to an improved fluid-mixing device incorporating a mixing chamber of variable size. These variable injectors may be used as aspirators for drawing a partial vacuum through an intake portal; they may be used as fluid mixing devices employed in carburetion systems, fuel burners and similar systems; and they may be used as sensitive indicating devices.

The devices of the present invention somewhat resemble conventional injectors and fluid-mixing devices, but they all incorporate adjustable mixing chambers or "tunable" cavities which are variable in size or shape, and can be adjusted to produce optimum pressure, volume, mixing, sensing or other desired characteristics.

The mixing devices of the prior art present many problems, whether they are used to mix liquids, gases, gas-entrained liquid particles or powdered solids, or combinations of these substances. Conventional mixers do not adequately mix the converging streams of fluid to provide finely-divided and homogeneous mixtures. The mixing characteristics of the prior art devices are subject to further deterioration when their outlet passages become clogged or obstructed, as by accumulations of entrained powder. The volumes which can be drawn through such piror art devices when they are employed as aspirators, and the negative pressures produced by such devices, are both severely limited.

Prior art surface softness sensing indicators are not sufficiently sensitive, and they often damage or destroy the surface whose softness is being measured. These conventional sensing devices are therefore useless in clinical medicine, and awkward techniques are required to measure pulse rate, blood pressure, and softness of various body tissues. Fluid removal aspirators and vacuum pumps employed in oxygen tents produce another serious medical problem, for these devices must avoid the danger of sparks and explosions in the concentrated oxygen atmosphere. The mixing, aspirating and sensing devices of the present invention provide highly improved performance in all these situations.

Accordingly, a principal object of the present invention is to provide highly effective devices for mixing streams of fluid. A further object is to provide mixing devices capable of atomizing or finely dividing a stream of fluid in a stream of gas. Another object of the invention is to provide mixing devices producing unusually homogeneous mixtures of finely divided solid particles in a stream of gas.

A further object of the invention is to provide a high efficiency source of partial vacuum actuated by a flowing stream of fluid and having no moving parts. Another object of the invention is to provide a vacuum source instantaneously actuated to provide sensitive on-off vacuum pickup operation for lifting sheets of paper, bundles or other objects.

A further object of the invention is to provide mixing devices which may be adjusted to draw high volumes of material through their intake conduits. Another object

of the invention is to provide aspirating and mixing devices for flowing streams of fluids which are well adapted to provide high volume input streams for flow straightening means, such as serially arrayed transverse mesh screens. A further object of the invention is to provide a highly efficient powder mixing and conveying system.

Another object of the invention is to provide highly sensitive surface softness indicators.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combinations of elements, and arrangements of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a fragmentary sectional side elevation view of a fluid mixing device of the present invention, with its adjustable core member telescoped inwardly to reduce the size of its mixing chamber to the smallest possible volume.

FIGURE 2 is a similar fragmentary sectional side elevation view of the fluid mixing device shown in FIGURE 1, with the adjustable core member partially withdrawn to increase the size of the fluid mixing chamber.

FIGURE 3 is a sectional side elevation view of a modified embodiment of the invention, in which the fluid mixing chamber is provided with an adjustable flat end surface whose position is changed by rotation of a threaded outlet cap.

FIGURE 4 is a sectional side elevation of a different embodiment of the invention employing a rotatably adjustable threaded inlet cap.

FIGURE 5 is a sectional side elevation view of a modified embodiment of the invention, employing a protruding inlet tube telescoping within an apertured movable transverse cap to form a different type of adjustable mixing chamber, co-operating with outlet flow-straightening devices shown as successively arrayed transverse mesh screens.

FIGURE 6 is a sectional side elevation view of a three-stage fluid mixing device incorporating the present invention.

FIGURE 7 is a side elevation view, partially in section, of a surface softness indicator incorporating the present invention; and

FIGURE 8 is a fragmentary end perspective view of the device shown in FIGURE 7.

In the mixing devices of this invention the effectiveness of mixing, the aspirating negative pressure and the aspirated volumes drawn through the intake conduit are all adjustable, to permit selection of optimum values, through variations in the size of the mixing chamber, in the amount of powdered material entrained in the intake stream, and in the nature of the outlet and the successive outlet conduits, all of which factors change the resonant characteristics of the mixing chambers. It is believed that standing waves of audible or ultrasonic frequencies are established in the flowing streams by the passage of fluids through the mixing chambers of this invention, and that these standing waves are composed of basic resonant frequencies plus harmonics and other frequencies, with at least two principal vibration frequencies being mixed in most situations.

Thus the fluid mixing devices of this invention incorporate a mixing chamber of adjustable size, having a pressure inlet opening therein through which a fluid stream, such as a slow moving stream of compressed air, is introduced into the chamber. An outlet is formed in the chamber opposite the pressure inlet, and generally the inlet and outlet are axially aligned. Alternatively, subsequent outlet passages may be altered to vary the size of the mixing chamber. An additional opening in the form of an intake conduit is also provided through which a stream of air or other fluid is drawn into the mixing chamber, to be mixed with the main stream introduced through the pressure inlet.

In all cases, the stream of gas entering the mixing chamber through the intake conduit is thoroughly and turbulently mixed with the stream of gas entering through the pressure inlet. When a powdered material is entrained in the fluid stream entering the chamber through the intake conduit, this thorough and turbulent mixing produces an unusually homogeneous suspension of powdered material in the stream of fluid leaving the chamber through the outlet.

The converging streams of fluid entering the mixing chamber through the pressure inlet and the intake conduit both traverse the successive condensations and rarefactions forming the standing waves which are believed to be present in the mixing chamber. By the time these fluid streams reach the outlet, they are completely and thoroughly mixed together in a homogeneous exit stream.

In each embodiment of this invention, changes in the size of the mixing chamber produces changes in the flow characteristics of the fluid stream entering the mixing chamber via the intake conduit. Thus in every mixing device of FIGURES 1 through 6, the intake negative pressure or the intake volume may be adjusted to optimum values through predetermined variation in the size of the mixing chambers.

The standing wave phenomena are thought to enhance this adjustability, since the mixing chamber can be changed in size to vary the frequencies and harmonics for which it is tuned to resonance.

In the embodiment shown in FIGURES 7 and 8, a similar change in mixing chamber size is produced by a resilient deformation of the surface against which the end of the indicating device is placed, with such deformation being produced by the force of the outlet stream deflected by the depressible surface. This will induce corresponding changes in the negative pressure within the intake conduit, which may be calibrated in terms of the softness of the surface being tested.

Adjustable mixing chambers

The fluid mixing devices of the present invention incorporate a mixing chamber **10** which may be formed by drilling or boring a hole of suitable diameter in a block **11** as indicated in FIGURES 1, 2 and 3. A pressure inlet **12** generally opens into mixing chamber **10** through an inlet face **14**, which may be the conical surface remaining after the drilling operation which produces the mixing chamber **10** as shown in FIGURES 1–3, or which may be a flat surface, as shown in FIGURES 4, 5, and 6.

Outlet **18** opens into the chamber **10** opposite pressure inlet **12**, and is aligned substantially coaxially with inlet **12**. In all cases, the outlet **18** is larger than the pressure inlet **12**.

In FIGURES 1, 2, 3 and 5 the intake conduit **16** is shown converging toward the centerline of the pressure inlet **12** at an acute angle, so that the fluid stream entering the mixing chamber **10** through the intake conduit **16** converges with the fluid stream entering through the pressure inlet **12**. In the devices shown in FIGURES 4 and 6, on the other hand, the intake conduits **16** are shown entering the mixing chamber **10** along differently oriented axes, as explained more fully below. Thus for example in FIGURE 4, the intake conduit **16** enters mixing chamber **10** near the outlet surface **20** in which the outlet **18** is formed, and passes radially through the peripheral wall **22** of the mixing chamber **10**. In this embodiment, the pressure inlet **12** enters the mixing chamber through the transverse

flat inlet face **14**, which is substantially parallel to the flat outlet face **20**.

As indicated in FIGURES 1 and 2, the intake conduit **16** may be formed of a bored hole **17** entering the mixing chamber **10** at an acute angle coverging with the axis of pressure inlet **12**, with an enlarged counterbored section **19** accommodating a length of tubing **21** whose inside diameter corresponds substantially with the inside diameter of the bored hole **17**, providing a smooth walled intake conduit **16** of substantially constant diameter. The opposite end of the tubing **21** may then be employed for piping connections, or coupling to gas or powder reservoirs or the like.

Variable size of the mixing chamber

In the embodiment of the invention shown in FIGURES 1 and 2, the outlet surface is formed of two separate sectors, an outer convex conical sector **24**, formed as a conical surface substantially mating with the concave conical inlet face **14**, and an inner concave sector **26**. These surfaces **24** and **26** are formed on the end of an axially adjustable core member **28** which is mounted for movement within the concave mixing chamber **10**. As shown in FIGURE 1, the core member **28** is fitted for telescoping movement within the chamber **10** to extreme inward position in which the outer convex sector **24** of the outlet surface is closely juxtaposed to the inlet face **14**. Thus as shown in FIGURE 1, the mixing chamber **10** is substantially bounded by the inlet face **14** and the concave inner conical sector **26** formed on the core member **28**.

In FIGURE 2, the core member **28** is shown withdrawn from the mixing chamber **10** to leave a chamber of considerably larger volume bounded by both end sectors of the core member **28** as well as the peripheral wall **22** of block **11** and the conical inlet face **14**.

This axial adjustment of the core member **28** moving telescopingly out of the mixing chamber **10** enlarges the size and length of the mixing chamber **10** correspondingly. Axial adjustment of core member **28** may be varied to produce the optimum volume or pressure characteristics at the intake conduit **16**.

When a fluid such as compressed air is introduced through pressure inlet **12** to pass through the chamber **10** and out the outlet **18**, the resulting expansion of the compressed air as it enters the mixing chamber **10** produces a negative pressure for partial vacuum at the intake conduit **16**. Intake conduit **16** may be connected to a vacuum shoe, to a supply of gas or liquid, or to a reservoir of powdered material, for example. In each of these cases a fluid stream is drawn through intake conduit **16** to be mixed in mixing chamber **10** with the fluid stream entering through the pressure inlet **12**, and the mixed stream is then expelled through the outlet **18**.

When intake conduit **16** is connected to a reservoir of powdered material, this material is drawn through intake conduit **16** together with the gas forming its ambient atmosphere, and is mixed in chamber **10** with the fluid stream entering through pressure inlet **12**.

By varying the position of core member **28**, a maximum negative pressure will be developed at intake conduit **16**. This maximum negative pressure apparently results from the standing wave characteristics produced merely by the passage of the fluid streams through passages **12** and **16**, and through chamber **10**. Combined frequencies, including a low frequency between one and six cycles per second, mixed with a principal high frequency in the neighborhood of 14,000 cycles per second, have been observed, and the component frequencies may be changed by adjustment of core member **28**, somewhat in the manner that a trombone is tuned by moving its slide. In addition, standing waves of the desired frequencies may be induced or resonantly reinforced by energizing at the desired frequencies mechanical, piezo-electric or electromagnetic transducers, such as the transducers **29** and **31** incorporated in the modified embodiment of FIGURE 3. These transducers are respectively positioned adjacent to passages **12** and **16** where they can inducec resonant vibrations in the streams of fluids passing therethrough.

Different adjusted positions of core member **28** will produce either maximum negative pressure or maximum fluid volume drawn through intake conduit **16**, and the observed performance characteristics of the various embodiments of the invention indicate that the theoretical application of Boyle's Law must be substantially modified when sonic standing wave phenomena are produced in flowing fluid streams.

A convenient method of adjusting the core member **28** is also illustrated in FIGURE 3, where a threaded core member **28** is rotatably engaged in the threaded peripheral wall **22*a*** of the block **11**, enclosing the mixing chamber **10**. Rotation of core member **28** relative to the block **11** thus produces threading retraction of core member **28**. In FIGURE 3 the part dimensions are identified as follows:

A: Length of pressure inlet **12**
B: Diameter of intake conduit **16**
C: Length of outlet **18**
D: Diameter of outlet **18**
E: Length of mixing chamber **10**
F: Diameter of mixing chamber **10**
G: Diameter of pressure inlet **12**

Table I shows representative dimensions for these various features in two versions of the embodiment shown in FIGURE 3:

TABLE I

A	B	C	D	E	F	G
0.750″	0.125″	0.375″	0.101″	Variable	0.312″	0.041″
0.750″	0.125″	0.375″	0.076″	Variable	0.312″	0.062″

In this embodiment of the invention, shown in FIGURE 3, the outlet surface **20** is a flat plane surface, as contrasted with the conical surfaces **24** and **26** shown in FIGURES 1 and 2.

A different embodiment of the invention is shown in FIGURE 4 where the mixing chamber **10** is adjusted in size by the threaded telescoping movement of an inlet cap **36** within the threaded side wall **22** of the block **11**. The pressure inlet **12** passes axially through the inlet cap **36**, and rotary threading adjustment of cap **36** in block **11** thus brings pressure inlet **12** and inlet wall **14** in cap **36** closer to outlet **18** in outlet surface **20** on the opposite wall of mixing chamber **10**. In this embodiment of the invention, the intake conduit **16** is formed as a radial opening entering mixing chamber **10** near the outlet surface **20** through peripheral wall **22**.

Table II shows the volume in cubic feet per minute of air drawn through inlet conduit **16** for a series of different compressed air pressures supplied to the pressure inlet **12** of the device shown in FIGURE 4.

TABLE II

Supply Pressure, p.s.i.g.	Supply Volume, c.f.m.	Intake Volume, c.f.m.	Total Volume, c.f.m.
15	.96	1.63	2.59
20	1.06	1.95	3.01
35	1.30	2.45	3.75
40	1.37	2.57	3.94
45	1.42	2.74	4.16
50	1.50	2.85	4.35

In this embodiment, shown in FIGURE 4, pressure inlet diameter was 0.059 in., the intake conduit diameter was 0.250 in., and the outlet diameter was 0.157 in.

Table II shows the surprisingly large volumes delivered by the fluid stream mixing devices of this invention with very small input pressures; between 2½ and 3 times the input volume of air is expelled by the device, and this emphasizes the high efficiency of its aspirating action.

In the embodiments of the invention shown in FIGURES 5 and 6, an annular shield or hood **38** extends from the pressure inlet **12** toward the mixing chamber **10**, requiring the stream of fluid entering from the intake conduit to pass along and around this hood **38** as an annular stream, joining the stream entering from the pressure inlet to be mixed in the mixing chamber. In the embodiment shown in FIGURE 5, the pressure inlet **12** and intake conduit **16** passageways are formed in a block **11** provided with external threads **40** on which a tubular sleeve **42** is threaded. Serially arrayed inside the tubular sleeve **42** are a series of flow-straightening transverse mesh screens **44**, spaced apart by spacer rings **46** and all fitting within the sleeve **42**.

This assembly of transverse screens **44** and spacer rings **46** is held against an internal end cap **48** threaded inside tubular sleeve **42** inside the end threads joining it to portion **40** of the threaded block **11**. End cap **48** is provided with a central mixing aperture **50** aligned to receive in telescoping fashion the protruding hood **38** projecting from the pressure inlet **12**, as shown in FIGURE 5.

The inner diameter of aperture **50** is greater than the external diameter of hood **38**, leaving an annular space **52** between them. The intake conduit **16** opens into a portal chamber **54** formed between the block **11** and the end cap **48**, and the annular hood **38** extends through this portal chamber **48**. The fluid stream entering through intake conduit **16** passes through the portal chamber **54** and the annular space **52** into the mixing aperture **50**, where it mixes with the fluid stream entering through the pressure inlet **12** via the hood **38**. In this embodiment of the invention, shown in FIGURE 5, the mixing chamber lies partially within the mixing aperture **50** and partially within the contiguous open region inside tubular sleeve **42** traversed by the mixing streams before they reach the first screen **44**.

In this device, rotary adjustment of tubular sleeve **42** relative to block **11**, producing unthreading telescoping separation of these two elements and enlarging the portal chamber **54** between them, also produces diminishing telescoping overlap of the annular hood **38** within the mixing aperture **50**, thus changing the size of the mixing chamber **10** as well as the flow characteristics of the intake stream passing through intake conduit **16**, portal chamber **54** and annular space **52**.

The assembly of FIGURE 5 is particularly useful in producing a homogeneous suspension of powder in a flowing stream of air, which then passes through the screens **44**, smoothing the otherwise turbulent flow and producing a substantially laminar flow stream of entrained powder which is highly useful in powder-coating installations. In such systems, some of the air-entrained powder may tend to be deposited upon screens **44**, partially clogging their apertures and progressively reducing the volume of air passing through the tubular sleeve **42**. Any such clogging has the effect of reducing the size of the mixing chamber **10**, and confining it effectively between the annular hood **38** and the first of the screens **44**.

Any such clogging effect may be counteracted by rotational threaded adjustment of sleeve **42** relative to block **11**. The relative unthreading of these two members withdraws the annular hood **38** from mixing aperture **50**, progressively enlarging the mixing chamber **10**. This adjustment may be continued until a mixing chamber **10** of optimum proportions is reached, producing the maximum volume of air passing through the device for any partially clogged condition of the screens **44**.

Plural mixing chambers

A three-stage modification of the invention is shown in FIGURE 6. There the first pressure inlet **12**, formed in inlet cap **36**, is again provided with a long annular hood **38** protruding toward the first mixing chamber **10**. The first intake conduit **16** enters an elongated annular space **52** surrounding the hood **38**, and the intake stream flows into the mixing chamber **10** through this annular space **52**, around hood **38**. In this embodiment, the inlet cap **36** is provided with external threads engaging internal threads inside peripheral wall **22** of the first mixing chamber block **11**, in which are formed the first mixing chamber **10** and an enlarged outlet **18**.

The second stage of the device shown in FIGURE 6 is provided by a second mixing chamber block **56** formed in the shape of a hollow cylinder having a bore **58** with an internally threaded portal **60**. This portal **60** accommodates the threaded outlet end of block **11** incorporating first outlet **18**, the exit of which forms a second pressure inlet **62**, opening into a second mixing chamber **64** formed by portal **60** and hollow bore **58** in the second block **56**.

A second, enlarged outlet **66** opens from the second mixing chamber **64** opposite second pressure inlet **62**, and a second intake conduit **68** enters the second mixing chamber **64** near this outlet **66**.

The exit of the second outlet **66** forms the third pressure inlet **70** opening into a third mixing chamber **72** formed within a central bore **74** in a third mixing chamber block **76**. The bore **74** has an internally threaded portal portion **78** engaged with external threads surrounding the passage **66–70** at the outlet end of the second mixing chamber block **56**. A third further enlarged outlet **80** opens from third mixing chamber **72** opposite third pressure inlet **70**, and a plurality of intake conduits **82** pass radially through the peripheral walls **83** of the block **76** near outlet **80**, forming a multiple intake conduit for the third mixing chamber **72**.

As shown in FIGURE 6, the inlet cap **36** is capable of rotary adjustment relative to the block **11**. The blocks **11**, **56** and **76** are likewise capable of relative rotary adjustment, respectively varying the size of the second and third mixing chambers. The three mixing chambers **10**, **64** and **72** are thus each adjustable in size until optimum flow characteristics are produced in each chamber.

The highly efficient aspirating action produced by all three of these mixing chambers draws a high volume of gas through the various intake conduits, producing a highly effective aspirator or vacuum pump as well as a convenient mixing device. The flow of a stream of gas, for example, through first pressure inlet **12** creates a negative pressure in intake conduit **16**, drawing a second stream of gas therethrough to be mixed with the first stream and expelled as a combined stream through passage **18–62** into the second mixing chamber **64**, creating a negative pressure in second intake conduit **68**. This draws a third stream of gas through intake conduit **68** which is thoroughly mixed with the previously combined stream in chamber **64**. The newly combined stream is expelled through passage **66–70** into third mixing chamber **72**, drawing a fourth stream of gas through third intake conduits **82**, and thoroughly mixing it with the combined stream of gas. Streams of liquids may likewise be mixed, with equal effectiveness.

As a mixing device, this three-stage unit thus combines and thoroughly mixes as many as four different fluids, and it may also be used to mix several different varieties of gas-entrained powdered material respectively drawn through the different intake conduits **16**, **68** and **82**. This plural stage device thus forms an inexpensive and highly effective vacuum pump, aspirator or exhaust blower, and it is well suited for operation under enclosed oxygen tents or gas or dust collecting hoods, where sparks and moving parts might be dangerous or undesirable.

Surface softness indicator

Shown in FIGURES 7 and 8 is a modified embodiment of the invention adapted to indicate the softness or depressibility of an adjacent exposed surface, which forms an outlet face of the mixing chamber, and the chamber varies in size because of the depressible deformation "*d*" of this exposed surface caused by the pressure of the gas stream issuing from the device. The resulting adjusted mixing chamber size produces a corresponding change in the negative pressure produced at the intake conduit, which is measured and calibrated to indicate the softness of the depressible surface.

In this device, a casing **84** encloses the mixing chamber **86**, which has an axial pressure inlet **88** and a converging intake conduit **90**, both of which enter chamber **86** through a conical inlet face **92**. An indicator, such as the dial gauge **94**, is connected to intake conduit **90** to show the negative pressure therein.

An outlet **96** passes through casing **84** opposite the pressure inlet **88**, forming an exit aperture through a flat exit face **98** preferably formed on the end of the casing and adapted for juxtaposition with the resilient depressible surface **100** whose softness is to be measured. This may be the surface of any soft material, and in particular it may be body tissue or flesh whose softness is to be indicated or measured to determine pulse rate, blood pressure, internal condition of the eyeball, or other characteristics.

A pair of raised lands **102** protrude from the exit face **98** flanking outlet **96**, acting to space the exit face **98** away from the surface **100**, and forming gaps **104** between the lands and the surfaces **98** and **100**. Three, four or more lands **102** may be arrayed around outlet passage **96**, providing a series of platforms on which the casing **84** may rest against the surface **100**, and preferably leaving about half the circumference of outlet **96** in the form of gaps **104**.

The softness of the depressible surface **100** is measured by placing casing **84** with its lands **102** resting directly on the surface **100**, and supplying a stream of compressed air at low pressure to the pressure inlet **88**. This produces a low velocity stream of air traveling through outlet **96**, to exit through the gaps **104** between lands **102** and surfaces **98** and **100**. The resulting pressure and standing wave characteristics of the mixing chamber **86** influence and in turn are influenced by the extent of depressible deformation "*d*" of surface **100** (FIGURE 7), producing a negative pressure at intake conduit **90** which is indicated by gauge **94**. For any given inlet supply pressure, each reading of gauge **94** will correspond to a specific amount of deformation "*d*" of the surface **100**. The indications of gauge **94** can therefore be calibrated in terms of the softness or resilience of surface **100**, or in terms of such related variables as blood pressure. Fluctuations such as the changes in blood pressure caused by the beating of the heart will be indicated as periodic variations on the gauge **94**, permitting pulse rate to be observed or recorded, and similar fixed or variable softness characteristics of any object are easily measured or recorded by this embodiment of the invention.

In addition, the indicating devices of this invention can be used as sensitive gaging devices for indicating the distance between exit surface **98** and gaged surface **100**. High precision gaging of inside and outside diameters and other work surfaces during the course of machining operations are therefore made possible by this invention. In the case of a rigid nondeformable surface, the character and shape of the calibration curve of the device differs from those for resilient deformable surfaces, but the basic operation of the device is the same.

Mixing and carburetion

The enhanced mixing action of the mixing chambers of this invention provides one unusual advantage in the handling of powdered solid material: quick and effective drying action. The unusually homogeneous powder suspensions created by the invention expose all surfaces of the powder particles to the entraining air or other gas, and water or solvents in the powder particles are quickly vaporized. This drying action can be combined with conveyor operation, moving the powder from place to place and at the same time reducing its moisture content to the extent desired.

In addition to their highly effective and homogeneous mixing action, useful in producing suspensions of powder extrained in flowing gas, the mixing chambers of the present invention produce unusually finely divided droplets of liquid suspended as a fine mist when compressed gas is supplied to the pressure inlet and the intake conduit is connected to a source of liquid. The invention thus provides a highly effective atomizer for injection of liquid fuel into combustion chambers of engines, turbines or furnaces, and the plural stage devices such as that shown in FIGURE 6 afford excellent mixing of a second liquid fuel, an additive, injected water, or other additional liquids into the advancing fuel-air mixture.

Terminating and restoring the positive pressure supply to the pressure inlet produces nearly instantaneous stopping and starting of the negative pressure at the intake conduit, giving excellent control of the fuel-air mixture, particularly useful when interrupted or intermittent operation is desired, and mixture ratios are easily controlled by adjusting mixing chamber size.

These devices also mix soap, detergents and laundry additives into wash water so effectively that smaller quantities are needed and considerable savings are realized, particularly in commercial laundry operations. Proportions are easily controlled through adjusting the mixing chamber size, as explained above. The same fluid mixing efficiency is highly useful in dry-cleaning plants and many other manufacturing and processing operations.

Vacuum pumping and aspirating

In addition to these highly effective mixing functions, the devices of this invention make excellent aspirators which are powered only by flowing or compressed air, for example, and which produce desirably low negative pressures without moving parts. Being completely free of electric motors, sparks or friction-generated heat, they are well adapted for operation under fume exhaust hoods, inside oxygen tents, in explosive or combustible atmospheres, or in other critical locations.

In hospitals, aspirating removal of saliva or other fluids may be performed inside oxygen tents without danger of explosion, employing the devices of this invention powered by compressed air from compressors or aerosol tanks, or by the pressurized oxygen itself, for only small amounts of pressure fluid are used at high efficiencies in the devices of this invention. Indeed, the oxygen supplied to an oxygen tent may first be passed through one of the aspirators of this invention, and then released inside the tent, performing both aspirating and atmosphere-enriching functions successively.

Compressed gas from aerosol pressurized containers may be used to power the aspirators of this invention in remote locations, such as emergency bilge pumps aboard small boats, where air compressors are generally not found.

Any flowing stream of gas may be directed through the pressure inlet of this invention to produce such aspirating action. Thus the air passing an aircraft surface may be directed through the pressure inlet of an aspirator of this invention, and the resulting partial vacuum produced at the intake conduit may be varied easily by mixing chamber size adjustment and employed, for example, to produce the negative pressures utilized to control boundary layer effects and turbulence in slotted or "laminar-flow" type aircraft wings.

The nearly instantaneous control of the negative pressure achieved by connecting or disconnecting positive pressure to the pressure inlet makes the aspirators of this invention highly useful in precise vacuum-pickup systems, such as printing press paper delivery systems, materials handling conveyors, and vacuum chucks. Minimum control lead-time and optimum sensitivity make these aspirators excellent sources of partial vacuum for such applications.

Furthermore, the adjustable aspirators of this invention are well adapted to reduce ambient pressures by predetermined increments in hydrocarbon fractionation processes, permitting separation of successive volatile components at the same temperature. Processes for the conversion of brackish or salt water to fresh water by distillation also benefit from the precise pressure control produced by the aspirators of this invention.

The mixing and aspirating action of the variable-size mixing chambers of the present invention offer new solutions to many problems in materials handling, fuel-air mixing, medicine, powder coating, and many other fields. The optimum negative intake pressures and volumes, the precise adjustability and the high efficiency of the invention afford unique advantages in all these applications.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

We claim:

1. A device for moving and mixing a stream of intake fluid into an advancing stream of supply fluid comprising, in combination:

(A) means defining an enlarged, unobstructed mixing chamber having an inlet end and an outlet end,

(B) inlet conduit means terminating at the inlet end of the mixing chamber in a pressure inlet centrally opening into the mixing chamber,

(C) means forming an intake entering the inlet end of the mixing chamber closely adjacent to the pressure inlet,

(D) outlet conduit means forming a sharp-edged outlet portal in a substantially flat transverse outlet surface bounding and terminating the mixing chamber opposite the pressure inlet,

(E) with the mixing chamber being bounded peripherally by a cylindrical surface extending from the transverse surface toward the inlet conduit pressure inlet but axially spaced therefrom in non-overlapping relationship.

2. The combination defined in claim **1** wherein the pressure inlet is joined to the cylindrical surface by a conical inlet surface bounding the inlet end of the mixing chamber opposite the outlet surface, with the intake means forming an intake portal passing through the conical inlet surface.

3. The combination defined by claim **1** wherein standing wave phenomena are generated in the fluid passing through the device.

4. The combination defined by claim **1**, further including energizable transducer means positioned adjacent to the moving fluid to induce standing wave phenomena therein.

5. The combination defined by claim **1**, further including

(F) a first transducer positioned near the pressure inlet in operative juxtaposition with a first fluid stream passing through the pressure inlet,

(G) and a second transducer positioned near the intake, in operative juxtaposition with a second fluid stream passing through the intake,

whereby the transducers may be energized to induce standing wave phenomena in the fluid passing through the device.

6. The combination defined by claim **5** wherein the transducers are energized at different frequencies.

7. The combination defined in claim **1** wherein the intake and the inlet have axes intersecting in the mixing chamber.

8. The combination defined in claim **7** wherein the axes intersect at an acute angle of about 30 degrees.

9. The combination defined in claim **1** wherein the outlet conduit is perpendicular to the outlet surface, forming a sharp-edged right-angle shoulder defining the outlet.

10. The combination defined in claim **1** wherein the size of the mixing chamber is varied by adjusting the distance between the inlet and the outlet.

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