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Sawyer

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[54] **GAS SCRUBBER**

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[52] **U.S. Cl.** **261/53,** 261/109, 261/112, 261/113, 261/DIG. 54

[51] **Int. Cl.** **B01f 3/04**

[58] **Field of Search** 261/53, 62, 108–113, 261/DIG. 54

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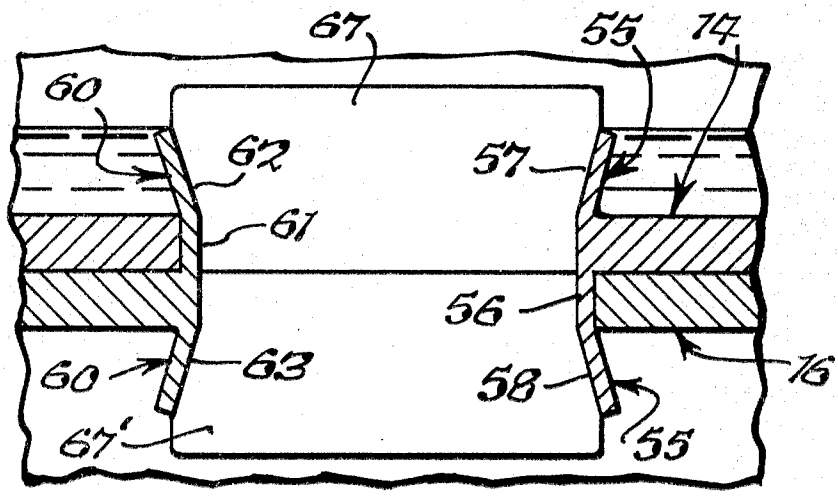
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Primary Examiner—Tim R. Miles
Assistant Examiner—Steven H. Markowitz
Attorney—Christel & Bean

[57] **ABSTRACT**

Apparatus for removing particulate material from a gas stream traveling through a duct comprising a pair of members each provided with a corresponding plurality of passages and arranged to cooperatively define a corresponding plurality of venturi passages extending generally parallel to the direction of flow of the gas stream and spaced around the axis of the duct. The members are relatively movable for varying the size of the venturi throats and for completely closing the passages when desired. Opposed sidewalls shaped to cooperatively define each venturi passage are carried by corresponding ones of the movable members whereby the configuration of the venturi passages is maintained throughout the entire range of adjustment. Liquid is supplied to the upstream member and the venturi inlets defined thereby are of a configuration effecting a substantially uniform distribution of the liquid to the passages.

9 Claims, 5 Drawing Figures



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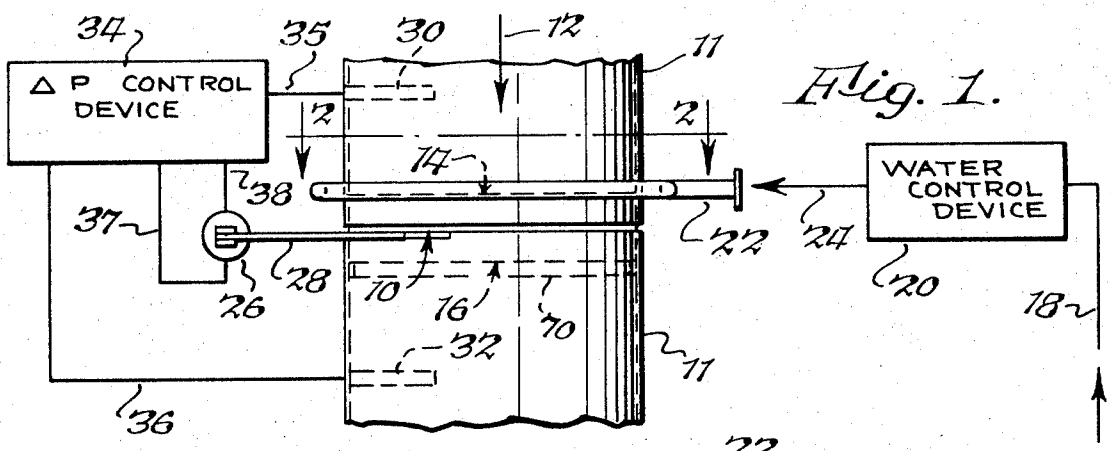


Fig. 1.

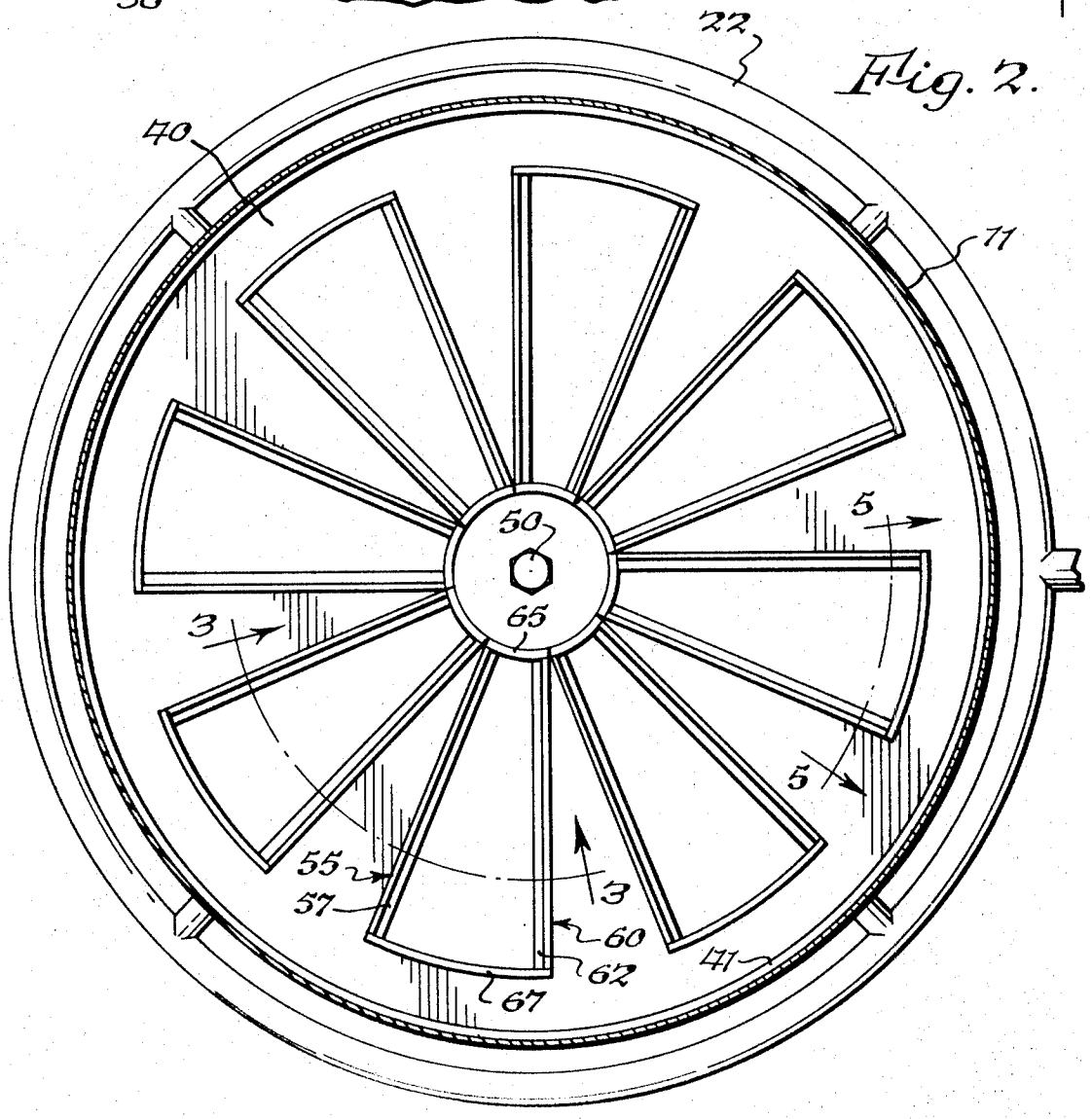


Fig. 2.

Fig. 3.

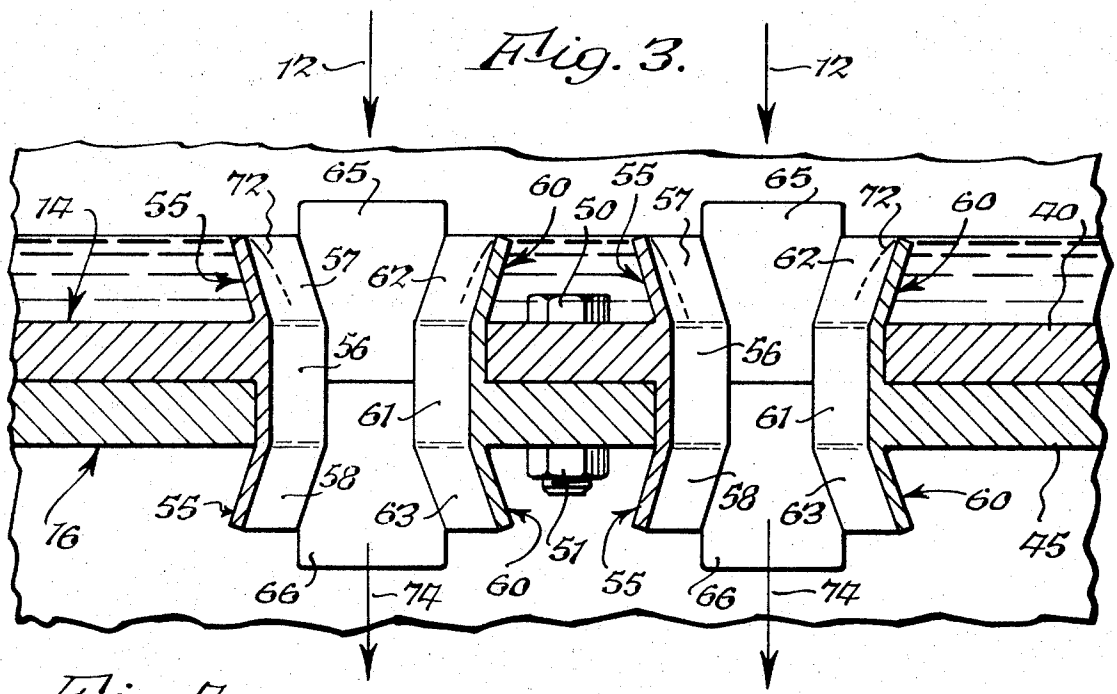
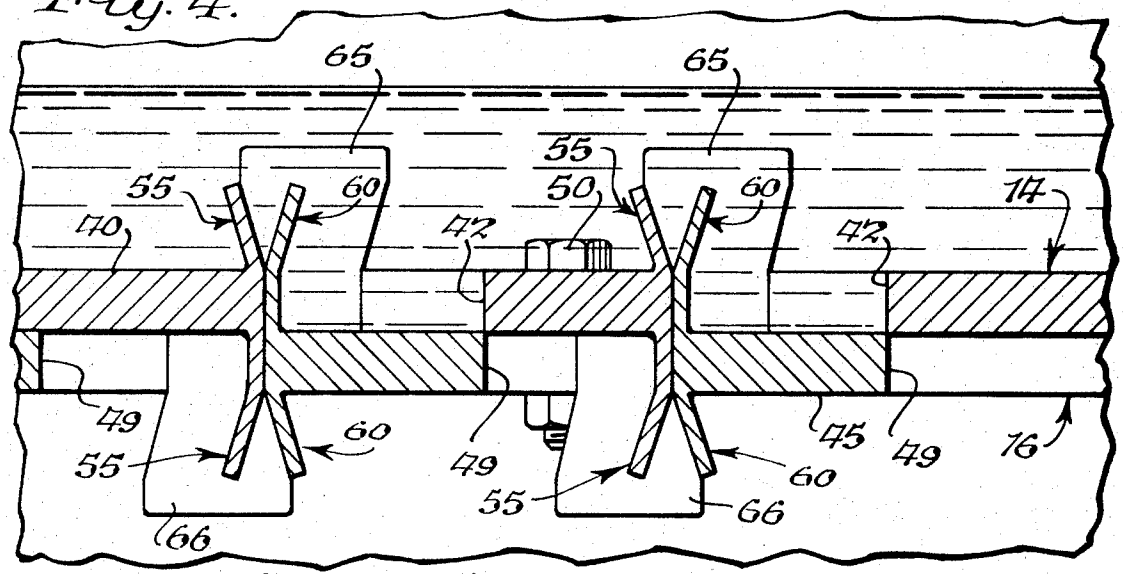


Fig. 4.



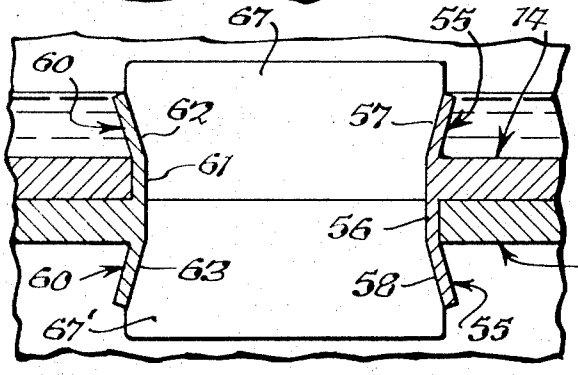


Fig. 5.

GAS SCRUBBER

BACKGROUND OF THE INVENTION

This invention relates to the gas scrubber art, and more particularly, to a new and improved wet collector advantageously including various desirable attributes of both the orifice and venturi types.

Wet collectors of the orifice type are well known and offer the advantages of relative simplicity and low cost. However, these capabilities are limited, making them unsuitable for many installations. Wet collectors of the venturi type are capable of higher collection efficiencies, the collection efficiency increasing with higher pressure drops, and some venturi type collectors are designed with adjustable throats to allow a range of pressure drops for a given gas volume. Further adjustment and regulation of the pressure drop to achieve effective agglomeration has been accomplished by the provision of movable dampers in conventional venturi type scrubbers, but only with the expenditure of considerable energy. Also, such venturi scrubbers are relatively large and expensive.

A wet collector constructed to advantageously include various desirable attributes of both the orifice and venturi types is taught by Selway in U.S. Pat. application Ser. No. 102,817 filed Dec. 30, 1970 and assigned to the assignee of the present invention. Briefly, the wet collector of that application utilizes first and second relatively movable members having corresponding passages which cooperatively define venturi passages in a manner permitting variation in the size of the venturi throats with a relatively small expenditure of energy. The members are identical in construction and are relatively movable between a full open position and a full closed position. Liquid is supplied at the periphery of a surface of one of the members and rises to the level of one of the venturi passage inlet openings, the inlet openings being arranged so as to create a pressure differential which distributes the liquid uniformly into the openings.

In the operation of the wet collector of the foregoing application, the configuration of the venturi passage defining walls is altered slightly as the members are moved between full open and full closed positions. While this usually will be of little or no concern under some operating conditions, it is believed desirable to provide such a wet collector having the additional capability of maintaining the same configuration in the venturi passage defining walls as the members are moved to vary the passage size.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to combine the various desirable features of the orifice and venturi types in a new and improved wet collector wherein the venturi passages can be varied with a relatively minimal expenditure of energy and in a manner maintaining the passage configuration throughout the range of adjustment.

It is a further object of this invention to provide such a gas scrubber of the web collector type which is relatively small, simple in construction and operation, and relatively inexpensive.

It is a further object of this invention to provide such a wet collector wherein the pressure drop can be varied to provide effective agglomeration for various particle sizes and wherein a particular pressure drop can be maintained despite varying flow conditions, all with a relatively minimal expenditure of energy.

It is a further object of this invention to provide such a wet collector wherein the pressure drop can be varied over a significantly large range and can accommodate a wide range of gas flow conditions.

It is a further object of this invention to provide such a wet collector capable of effecting a water seal when needed and in a relatively simple matter.

The present invention provides apparatus for removing particulate material from a gas stream utilizing first and second relatively movable members having corresponding passages which cooperatively define venturi passages in a manner permitting variation in the size of the venturi throats with a relatively small expenditure of energy. Each of the venturi passages is defined, in part, by first and second walls carried by said first and second movable members, respectively. Each of the walls has a configuration for cooperatively defining, one with the other, the corresponding venturi passage, and the configuration is exactly maintained when the members are moved to vary the size of the venturi throats. Liquid is supplied at the periphery of a surface of one of the members and rises to the level of the venturi passage inlet openings, the inlet openings being of a shape creating a pressure differential which distributes the liquid uniformly into the openings.

The foregoing and additional advantages and characterizing features of the present invention will become clearly apparent from the ensuing detailed description together with the included drawings wherein:

BRIEF DESCRIPTION OF THE DRAWING FIGURES

FIG. 1 is a fragmentary elevational view, partly schematic, showing the apparatus of the present invention as it would appear in use;

FIG. 2 is a horizontal cross sectional view on an enlarged scale taken about on line 2—2 of FIG. 1;

FIG. 3 is a developed vertical sectional view on a further enlarged scale taken about on line 3—3 of FIG. 2 showing the apparatus in a full opened condition;

FIG. 4 is a developed vertical sectional view similar to that of FIG. 3 but showing the apparatus in a full closed position; and

FIG. 5 is a developed vertical sectional view similar to that of FIG. 3 but taken about on line 5—5 of FIG. 2 and on a somewhat reduced scale.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

FIG. 1 illustrates apparatus 10 of the present invention arranged to remove particulate material from a gas stream traveling through a duct 11. The direction of flow of the gas stream is indicated by the arrow 12. The gas can be the effluent from a blast furnace, in which case the upstream end of duct 11 is suitably connected to the furnace exhaust, but it will be appreciated that apparatus of the present invention has the capability of scrubbing gas obtained from any of a wide variety of sources.

In the illustrated embodiment apparatus 10 comprises a first member 14 and a second member 16 defining a plurality of venturi passages spaced around the axis of duct 11 and disposed generally parallel to the direction of flow of the gas stream as will be described in detail. The apparatus 10 further comprises means for

supplying liquid to the inlets of the passages, in particular to member **14**, in the form of a supply conduit indicated schematically at **18** connected to a liquid source (not shown), a water control device **20**, and a liquid distributing conduit **22** in communication with member **14** and connected through a conduit **24** to control device **20**. In a presently preferred form, member **14** includes a generally horizontal planar surface, and liquid is supplied to that surface at or near the periphery thereof by conduit **22** whereupon the liquid level rises to the passage inlets.

The apparatus **10** further comprises means operatively connected to at least one of the first and second members **14** and **16**, respectively, for causing relative movement of members **14**, **16** in generally parallel planes whereby the throats of the venturi passages defined thereby can be varied in cross sectional area. The means for causing relative movement can comprise an hydraulic cylinder **26** suitably mounted or attached to a fixed reference surface relative to duct **11** and apparatus **10**. The rod of cylinder **26** is connected to one end of an actuator arm or lever **28**, the other end of which is attached or joined to member **16**, member **14** being stationary in the illustrated embodiment. The operation of cylinder **26** is controlled as a function of the pressure drop across the apparatus **10** in duct **11** as determined by a first pressure sensing means **30** positioned in duct **11** upstream of apparatus **10** and by a second pressure sensing means **32** positioned in duct **11** downstream of apparatus **10**. A pressure sensitive control device indicated schematically at **34** in FIG. **1** is connected through a line **35** to sensor **30** and through a line **36** to sensor **32**. Device **34**, in turn, controls the flow of operating fluid to and from the rod and piston ends of cylinder **26** through lines **37** and **38**. The detailed construction of device **34** and of sensing means **30, 32** per se comprise no part of the present invention, and since they are readily commercially available in various suitable forms, all readily understood by those skilled in the art, a detailed description thereof is unnecessary.

Referring now to FIGS. **2–5**, member **14** is formed to include a generally planar surface **40** and a peripheral edge portion in the form of a skirt-like rim **41** disposed at about a right angle to the plane of surface **40**. When member **14** is in the operative position shown in FIG. **1**, surface **40** is disposed generally horizontally and rim **41** projects upwardly in an upstream direction therefrom. In addition, rim **41** is of an outer dimension and shape so as to provide a snug-fitting relationship or engagement with the inner surface of duct **11**. Member **14** is provided with a plurality of openings each designated **42** spaced around the center thereof and extending through surface **40**, which center coincides with the axis of duct **11**. In a similar manner, member **16** is formed to include a generally planar surface portion **45** and a peripheral edge portion in the form of a skirt-like rim (not shown) which is disposed at about a right angle with respect to the plane of surface **45**. This rim, like rim **41** of member **14**, is of a dimension and configuration so as to engage the inner wall surface of duct **11**. In addition, member **16** can be supported in duct **11** by a bearing band **70** (FIG. **1**) suitably attached to or formed on the inner surface of duct **11** and positioned whereby the lower or depending edge of the rim of member **16** is seated thereon. Member **16**, like member **14** and duct **11**, is circular and is provided with a corresponding plurality of openings, each designated **49**, spaced around the center thereof and extending through surface **45**, which center coincides with the axis of duct **11**.

When assembled in duct **11**, members **14** and **16** are rotatably connected at the centers thereof by suitable means illustrated in the present instance as a bolt **50** and nut **51**. Members **14** and **16** cooperate to define a plurality of venturi passages spaced around the axis of duct **11**, and each passage extends generally in the direction of flow of the gas stream. The total number of venturi passages is equal to the number of either of the openings **42** or **49** in the members **14** or **16**, respectively. Each venturi passage is defined in part by a first sidewall **55** carried by member **14** and extending from a corresponding opening **42**. Sidewall **55** comprises a middle portion **56** disposed generally perpendicular to the planar portion **40** of member **14** and first and second end portions **57** and **58**, respectively, separated by middle portion **56**. End portion **57** extends upstream from surface **40** of member **14** and is disposed at a relatively acute angle, for example, about **15** degrees, with respect to the direction of flow of the gas stream. End portion **58** extends downstream from surface **45** of member **16** and is disposed at a relatively acute angle, for example **15** degrees, with respect to the direction of the gas stream. Each venturi passage is further defined by a second side wall **60** carried by member **16** and including a middle portion **61** disposed generally perpendicular to planar portion **45** of member **16** and first and second end portions **62** and **63**, respectively. End portion **62** extends upstream from surface **40** of member **14** and is disposed at a relatively acute angle, such as **15** degrees, with respect to the direction of flow of the gas stream. End portion **63** extends downstream from surface **45** of member **16** and is disposed at a relatively acute angle, such as **15** degrees, with respect to the direction of flow of the gas stream. As a result, walls **55** and **60** present a region defined by the opposed sidewall end portions **57** and **62** which converges in the direction of flow of the gas stream toward a throat region defined by sidewall middle portions **56** and **61**. The throat region communicates with a region diverging from the throat in a downstream direction and defined by the opposed sidewall end portions **58** and **63**.

Each of the venturi passages is completed by opposed end walls which engage corresponding ends of the sidewalls **55** and **60**. In particular, end walls **65** are carried by member **14**, extend from openings **42**, and contact the radially innermost ends of sidewalls **55** and **60** relative to the center of member **14**. End walls **66** are carried by member **16**, extend from openings **49**, and are generally coplanar with end walls **65**. End walls **66** as a result contact the radially innermost ends of the sidewall end portions **58** and **63**. There also are provided end walls **67** carried by member **14**, extending from openings **42**, and contacting the radially outermost ends of sidewall portions **57** and **62**. In a similar manner corresponding and generally coplanar end walls **67'** are carried by member **16**, extend from openings **49**, and contact the radially outermost ends of sidewall end portions **58** and **63**. End walls **65, 66, 67** and **67'** are disposed in planes generally perpendicular to planar portions **40** and **45** of members **14** and **16**. The end walls preferably also are of a height or length (in the direction of gas flow) greater than that of sidewalls **55** and **60** whereby water flows only over the edges of sidewalls

55 and 60 into the passage inlet openings. It will be appreciated that side walls 60 have sliding contact with end walls 66 and 67'. Any spacing therebetween is quite sufficient to provide clearance for relative movement.

As a result, members 14 and 16 cooperate to define a plurality of venturi passages spaced around the axis of duct 11 and each extending generally in the direction of flow of the gas stream. When member 14 is located in duct 11 in the operative position of FIG. 1, each passage has an inlet opening defined by the edges of end walls 65 and 67 and by the edges of end portions 57 and 62 of sidewalls 55 and 60, respectively, which inlet opening is in communication with the dirty gas stream. Each of the passages, furthermore, is made to initially converge in the direction of flow of the gas stream or, in other words, in a direction from the inlet opening toward the plane of surface 40. Member 16 preferably is identical to member 14, and when placed in the position of FIG. 1 is inverted relative to member 14 whereby the corresponding passage defining walls in member 16 diverge in a direction away from member 14.

The number of venturi passages cooperatively defined by members 14 and 16 will vary depending upon the size of duct 11. The end walls of members 14 and 16 all are disposed generally parallel to the direction of gas flow thereby cooperatively defining relatively straight venturi passage end walls. Sidewalls 55 and 60 of members 14 and 16, respectively, include end portions 57 and 62 which converge in the direction of gas flow and end portions 58 and 63 which diverge in the direction of gas flow. As a result, there is provided a plurality of venturi passages each having a restricted throat defined by the middle portions 56 and 61 of sidewalls 55 and 60, respectively. In the present illustration member 16 is disposed so that planar portion 45 is generally horizontal, the rim or flange thereof contacts the inner surface of duct 11, and the depending edge of the rim rests on a bearing band 70 or other suitable supporting arrangement whereby member 16 is supported for rotation about the axis of duct 11. Member 14 is then placed on member 16 and supported thereby in a manner defining the venturi passages as described hereinabove. Rim 41 of member 14 should contact or engage the inner wall surface of duct 11 in a manner providing a fluidtight seal, and in some instances it may be necessary or desirable to enhance the seal such as by a peripheral weld between flange 41 and duct 11. The foregoing arrangement for positioning members 14 and 16 in duct 11 is illustrative, and other arrangements can be employed without departing from the spirit and scope of this invention.

Conduit 22 can be in the form of a manifold encircling duct 11, with multiple delivery conduits equally spaced therearound, and it has been found that adequate distribution can be obtained with the number of delivery conduits equaling one-half the number of venturi passages, as clearly illustrated in FIG. 2.

The apparatus of the present invention operates in the following manner. Liquid, usually water, is delivered by conduits 22 to member 14 at the periphery thereof and onto horizontal planar surface 40. The liquid fills the trough or reservoir defined by rim or flange 41 and the various end walls 65, 67 and sidewalls 55 and 60 defining the venturi passage portions in member 14. The level of the liquid rises until it reaches the height of sidewalls 55, 60 whereupon the liquid enters the inlet portions of the passages and flows generally in a direction indicated by the dashed lines 72 in FIG. 3. Sidewalls 55, 60 are of a height slightly less than that of the end walls 65,67 and function as weirs over which the liquid flows. The liquid is atomized in the venturi passages by the moving gas stream, in a manner familiar to those skilled in the art, and the liquid droplets agglomerate with the solid particles in the gas stream. The relatively clean gas together with the agglomerated liquid drops and particles leave the venturi passages generally in a direction indicated by the arrows 74 in FIG. 3 for subsequent separation of the liquid and agglomerated particles. In particular, separation of the agglomerated liquid drops and particles from the gas stream can be accomplished by gravity, by effecting an abrupt change in the direction of flow, or by other methods and apparatus well known to those familiar with the art.

Substantially uniform distribution of liquid or water along the entire length of end portions 57 and 62 of sidewalls 55 and 60, respectively, is accomplished by creation of a pressure differential in a radial direction across each of the venturi passage inlet openings. The pressure at or near the center of member 14 is made lower than the pressure at the periphery of member 14 by having each venturi passage inlet opening of a generally pie-shaped configuration as shown in FIG. 2. In other words, each of the passage inlet openings has spaced apart side edges extending generally radially outwardly relative to the center of member 14 which edges define therebetween an acute included angle. Therefore, the venturi passages are of progressively decreasing cross-sectional area, proceeding radially inwardly from the outer end walls 67, whereby the velocity of the gas passing through the passages increases progressively, again proceeding radially inwardly from end walls 67. This results in a pressure gradient or progressively decreasing, radially inward form across member 14, producing a pressure differential causing liquid to flow radially inwardly across surface 40 of member 14. In addition, it has been found that this configuration of the inlet openings adds more impetus to the fluid flow through the venturi throats.

To achieve the desired degree of agglomeration for optimum operation of apparatus 10 it is necessary that the atomized liquid droplets be of a size substantially equal to that of the particles to be removed from the gas stream. The size of the liquid drops is, in turn, a function of the pressure drop across apparatus 10, i.e. between the upstream side of member 14 and the downstream side of member 16. Accordingly, for a given size of particle present in the gas stream, it may be necessary to vary the pressure drop to form liquid drops of the required size. In addition, if a characteristic of the flow should happen to change, such as the volume, an adjustment most probably will be necessary to maintain the desired pressure drop.

According to the present invention, the throat of each venturi passage can be varied in size by a simple relative movement of members 14, 16, and this is accomplished with a relatively minimal energy expenditure arising from the action of essentially only shearing forces on members 14, 16. In addition, this variation is provided by the apparatus of the present invention in a manner maintaining the same configuration of the venturi passages throughout the full range of adjustment. Referring now to FIGS. 3 and 4, member 14 is

moved by rotation in a plane normal to the direction of gas flow to vary the throat size of the venturi passages cooperatively defined by members **14** and **16.** For example, member **16** can be rotated relative to member **14** between a fully opened position where sidewall portions **56, 61** are spaced apart as shown in FIG. **3** and a fully closed position where portions **56, 61** are in contact as shown in FIG. **4.** During such movement, the portion of each venturi passage configuration defined by sidewalls **55** and **60** is maintained the same throughout this range of adjustment by virtue of the fact that sidewall **55** is carried by member **14** and sidewall **60,** is carried by member **60** and these sidewalls do not change shape. When member **16** is rotated, each sidewall **60** is moved in its entirety toward and away from its associated sidewall **55,** such movement being in the region provided by openings **42** in member **14** and openings **49** in member **16.**

End walls **66** and **67'** do move relative to their associated end walls **65** and **66,** but without interrupting or otherwise altering the end wall configuration in the space between the side walls, whereby only the width of the venturi passage end walls changes.

In the embodiment illustrated in FIG. **1,** movement of member **16** is effected by an hydraulic cylinder **26,** and movement of the cylinder rod is transmitted through arm **28** to rotate the member **16.** Movement of member **16** to vary the size of the venturi throats is performed as a function of a pressure difference, under control of device **34** connected to cylinder **26** and to the pressure sensing means **30** and **32.** Accordingly, member **16** is moved automatically to vary the cross sectional size of the venturi passage throats as a function of the pressure drop existing between the region upstream of member **14** and the region downstream of member **16.** Of course, the relative positioning of members **14** and **16** to selectively vary the throat size can be accomplished manually.

When a liquid or water seal is desired, this is accomplished by the apparatus of the present invention in a convenient, easy and economical manner. Member **16** simply is moved or rotated to the position of full closure indicated in FIG. **4.** The supply of liquid to member **14** is continued, in a sufficient amount to effect a seal across the blocked throats of the passages notwithstanding spaces which may exist between members **14, 16** because of manufacturing tolerances. It should be noted that member **14** is in liquid-tight engagement with the duct wall, as by a welded seam or other means. Apparatus **10** of the present invention is suitable for use with ducts of various diameters and requires only slight modification. For use in a relatively small duct, it has been found desirable to provide four venturi passages cooperatively defined by members **14** and **16.** For relatively larger ducts the number of venturi passages is increased to as many as eight. It has been found that increasing the overall diameter of members **14, 16** requires a larger number of passages each of a relatively smaller included angle.

The apparatus **10** of the present invention is of a relatively simple construction, easily assembled and operated, and economical to manufacture particularly when members **14** and **16** are of identical construction. The apparatus has a high collection efficiency, approaching and sometimes exceeding that of a conventional venturi scrubber, while requiring a minimal expenditure of energy for varying the throat size of the venturi passages and requiring only a relatively small space. In addition, the configuration or shape of the venturi passages is maintained throughout the full range of variation in the throat size, without interruption in either side or end walls. Effective liquid distribution is obtained by a radial pressure differential across the upstream side of the scrubber. In addition, the apparatus permits a water seal to be provided in a convenient and easy manner for isolating the system in which it is included.

It is therefore apparent that the present invention accomplishes its intended objects. While a single specific embodiment has been described in detail, this has been done by way of illustration without thought of limitation.

I claim:

1 Apparatus for removing particulate material from a gas stream traveling through a duct, said apparatus comprising:

a. a first member positioned in said duct and provided with a plurality of openings;

b. a second member positioned in said duct adjacent said first member on the downstream side thereof, said second member being provided with a corresponding plurality of openings;

c. a plurality of walls carried by said first and second members for defining a plurality of venturi passages when the openings of said first and second members are brought into alignment;

d. said walls including first and second sidewalls for each of said venturi passages and carried by said first and second members, respectively, said sidewalls being shaped to cooperatively define therebetween the corresponding venturi passage;

e. means for causing relative movement of said first and second members thereby to vary the size of said venturi passages; and

f. means for delivering liquid to the inlets of said passages.

2. Apparatus according to claim **1** wherein each of said first and second members comprises a generally planar portion from which said passage defining walls extend and a peripheral edge portion adjacent the wall of said duct.

3. Apparatus according to claim **2** wherein each of said sidewalls includes first and second end portions separated by a middle portion disposed generally perpendicular to the planar portions of the corresponding first and second members, said first end portions extending in a direction upstream from said first member and disposed at a relatively acute angle with respect to the direction of the gas stream so as to be converging toward said middle portions, and said second end portions extending in a direction downstream from said second member and disposed at a relatively acute angle with respect to the direction of the gas stream so as to be diverging from said middle portions.

4. Apparatus according to claim **3** wherein one of each opposed pair of said sidewalls defining each of said venturi passages is moved in its entirety relative to the other thereof between an open position wherein said middle portions are spaced apart to a closed position wherein said middle portions are in contact in response to relative movement of said first and second members.

5. Apparatus according to claim **1** wherein said members are identical in construction, and are relatively

movable between a full open and a full closed position.

6. Apparatus according to claim 2 wherein said first and second members are disposed generally horizontally in said duct and wherein said liquid delivering means comprises conduit means positioned to deliver liquid to said planar portion of said first member near said peripheral edge portion thereof whereby liquid rises to a level corresponding to the height of said sidewalls and then flows into said passages defined by said walls.

7. Apparatus according to claim 6 wherein said walls defining each of said venturi passages are positioned relative to each other so as to define passage inlet openings having a configuration which gives rise to a pressure differential between the center of said planar portion and said peripheral edge portion of said first member for distributing liquid substantially uniformly to said passages.

8. Apparatus according to claim 7 wherein each of said passage inlet openings has spaced apart edges extending generally radially outwardly relative to the center of said planar portion which edges define an acute included angle.

9. Apparatus according to claim 1 further including:

a. first pressure sensing means positioned in said duct upstream from said first member relative to the direction of flow of said gas stream;

b. second pressure sensing means positioned in said duct downstream from said second member relative to the direction of flow of said gas stream; and

c. control means connected to said first and second sensing means and responsive to the pressure difference measured therebetween, said control means being connected in controlling relation to said means causing relative movement between said first and second members whereby the throats of said venturi passages are varied in response to changes in the pressure drop across said apparatus.

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