United States Patent

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[15] **3,660,045**

[45] **May 2, 1972**

[54] SMOKE CLARIFIER

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[22] Filed: **Feb. 20, 1970**

[21] Appl. No.: **13,004**

[52] **U.S. Cl.** .....**23/277 C,** 261/17, 261/118, 261/126, 110/119, 55/222, 55/240, 23/2 C

[51] **Int. Cl.**.....**F23g 7/06,** B01d 47/06

[58] **Field of Search** .....23/277 C, 2; 55/DIG. 30, 222, 55/240, 223, 230; 110/119, 120; 261/117, 115, 126, 17, 118, DIG. 9

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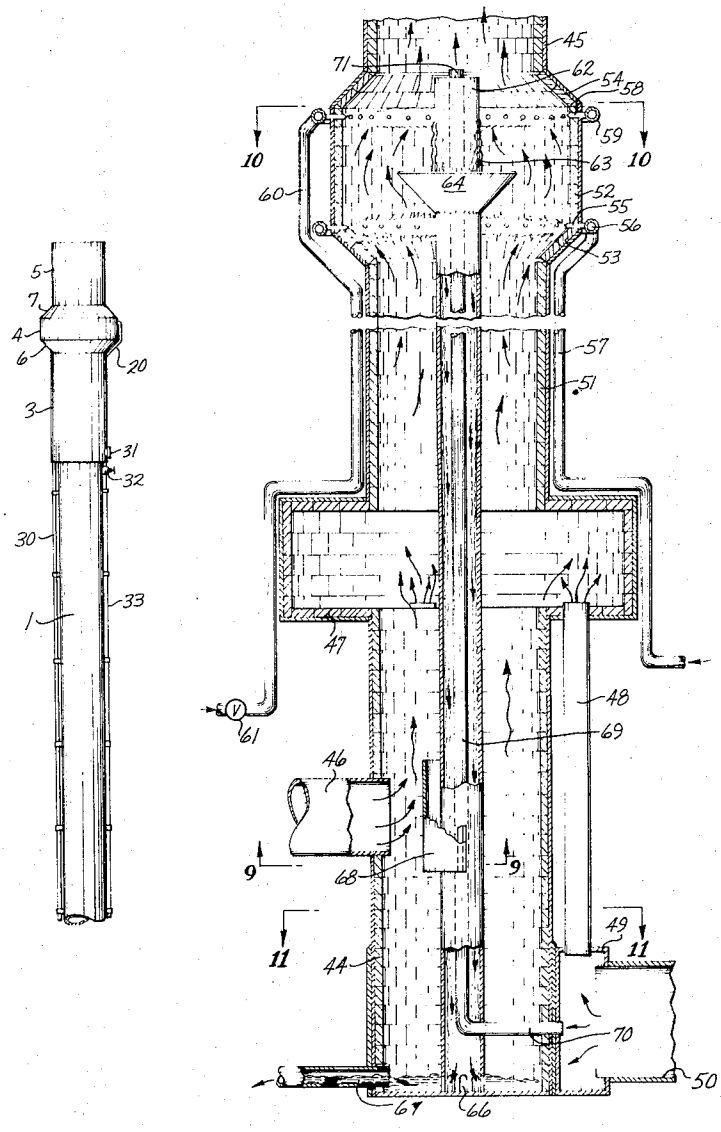
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[57] **ABSTRACT**

Water sprays projected in the form of a curtain through smoke rising through a smokestack transversely of the direction of smoke movement entrain particulate material in the smoke and carry it away. The sprays may cooperate with a baffle which aids precipitation of particles and creates turbulence to facilitate such separation further. Additionally, combustible impurities may be burned by flame jets preceding the spray washing operation, and supplemental air may be mixed with the smoke preceding the flame zone.

11 Claims, 13 Drawing Figures



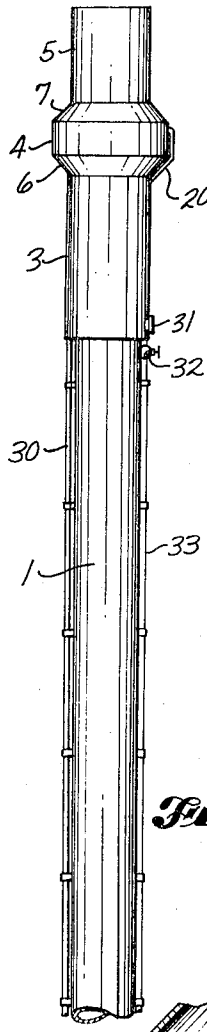


Fig. 1.

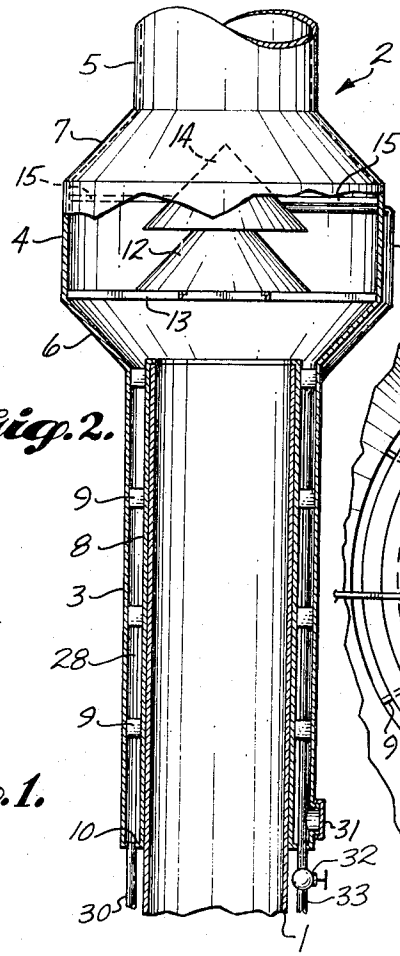
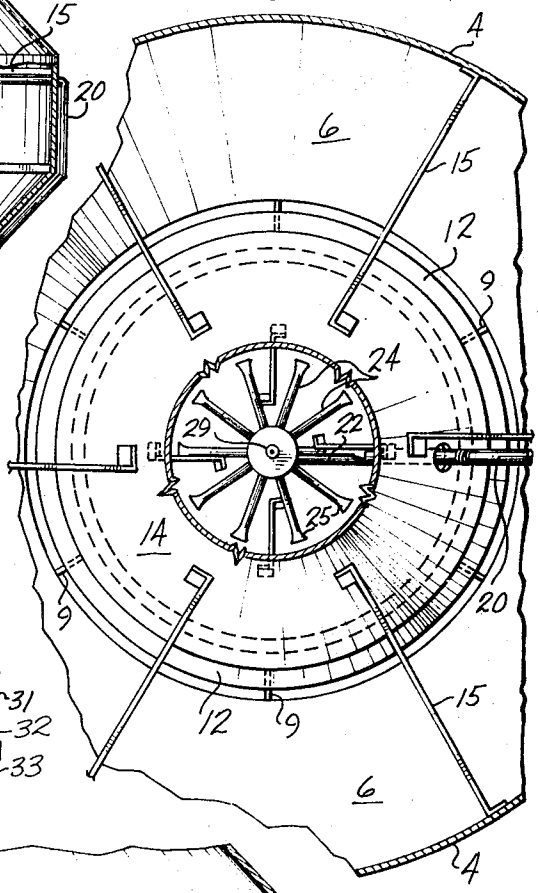


Fig. 2.

Fig. 4.



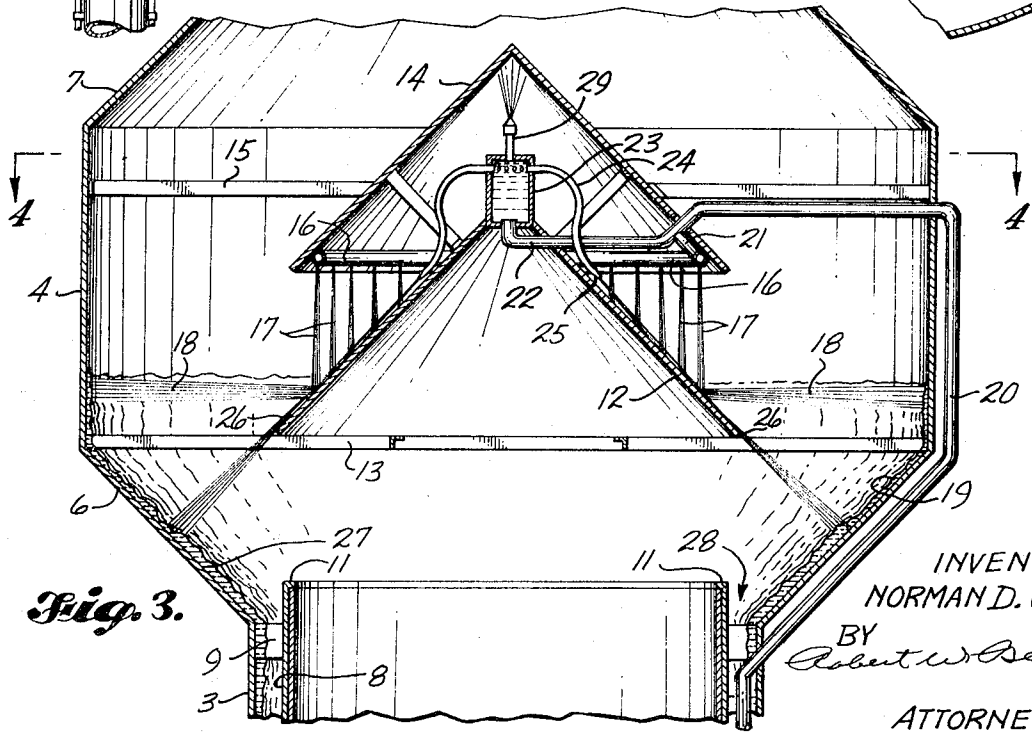


Fig. 3.

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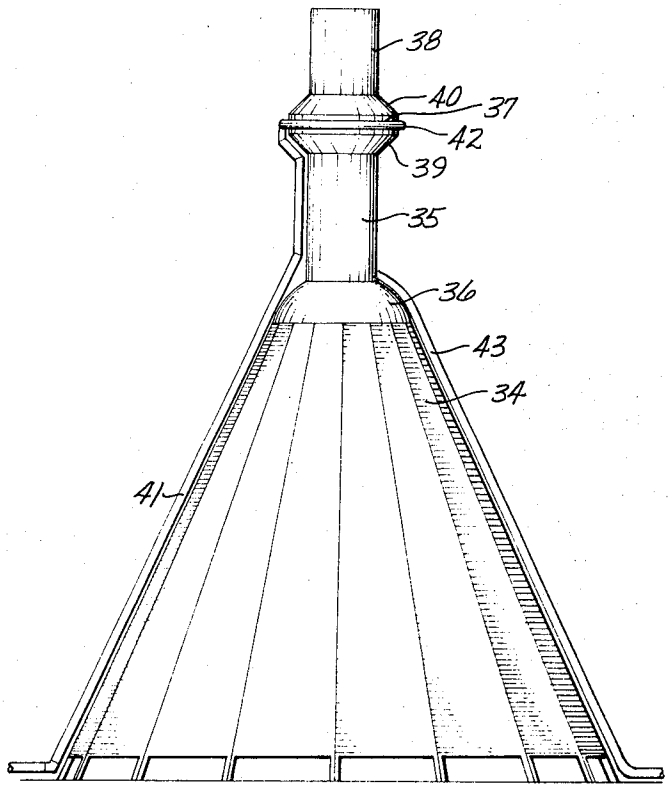


Fig. 5.

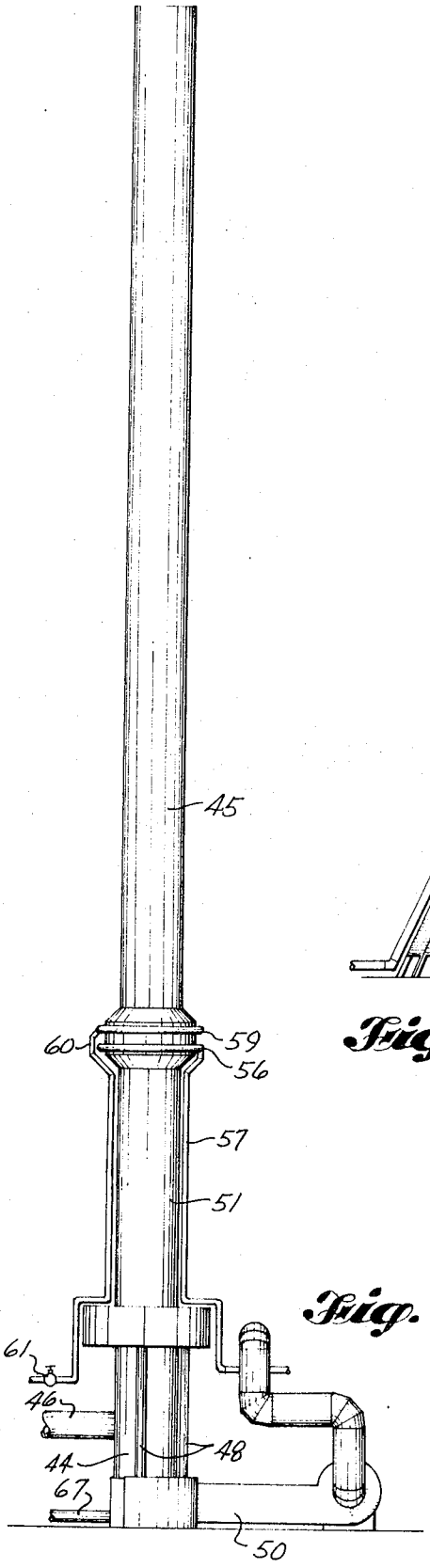


Fig. 6.

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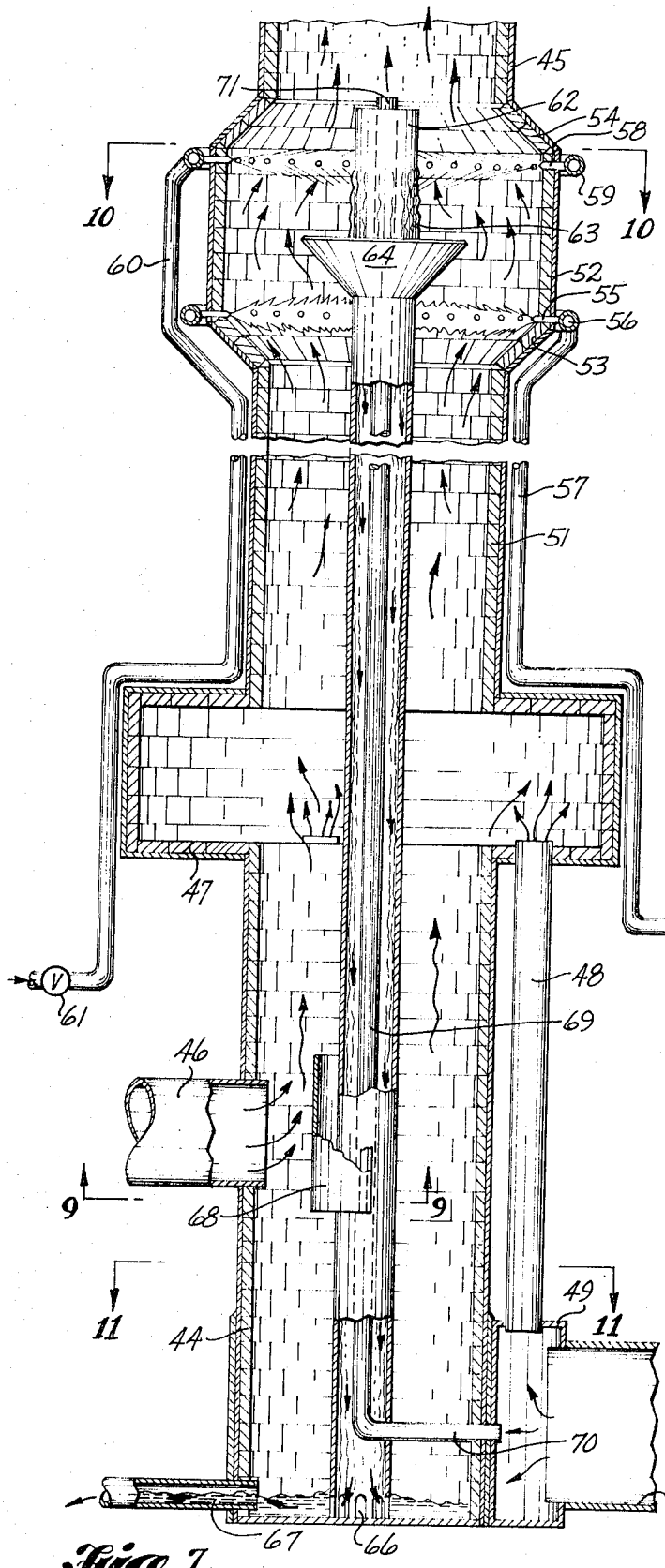


Fig. 7.

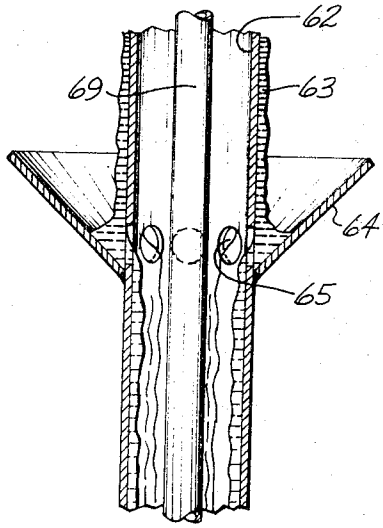


Fig. 8.

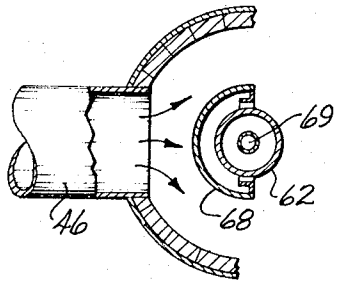


Fig. 9.

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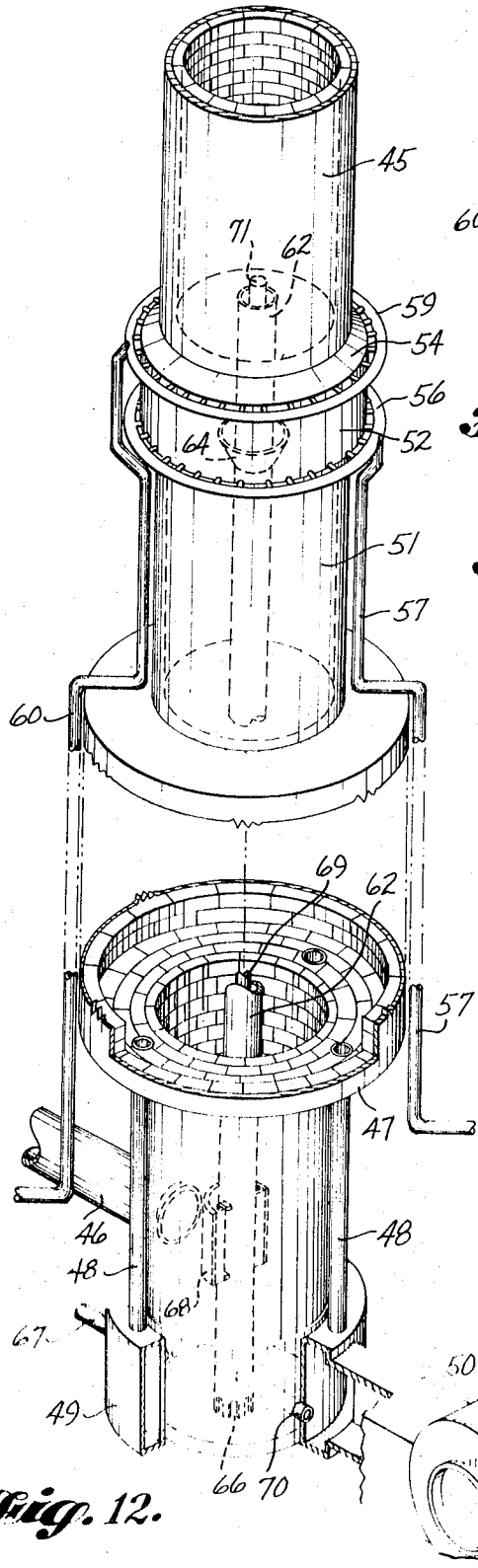


Fig. 12.

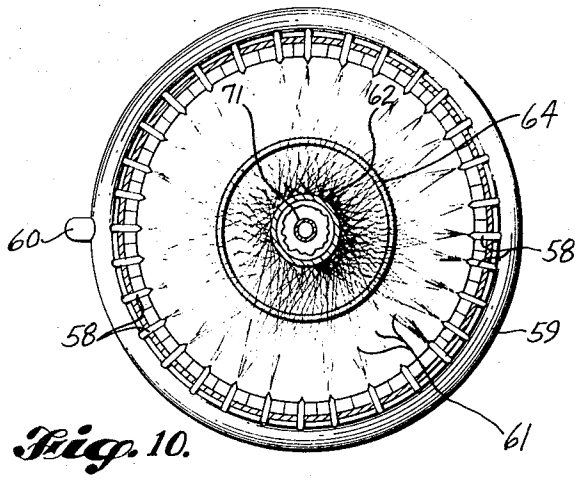


Fig. 10.

Fig. 11.

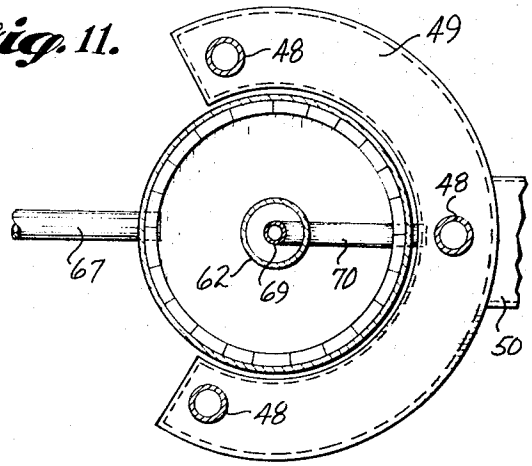
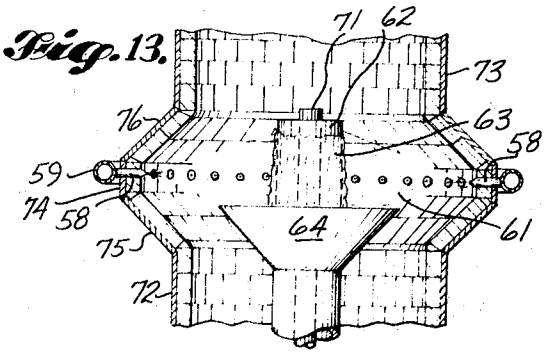


Fig. 13.



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SMOKE CLARIFIER

A principal object of the present invention is to provide an effective washing mechanism and operation for the purpose of entraining particulate material of the smoke and removing the particles from the gas. Specifically, an object is to remove from the smoke the maximum amount of particulate material while minimizing the back pressure created by such clarifying action.

In particular it is an object to be able to clarify a large volume of smoke rising through a stack at high temperature and velocity, and to clarify effectively smoke at different temperatures rising at different velocities and of different compositions.

Another object is not only to entrain particulate matter from smoke, but to remove such entrained matter quickly and easily from the clarifying apparatus.

It is also an object to remove impurities from fumes or smoke by heating or burning them so as to convert them to a less noxious form and/or to remove such impurities from the smoke in addition to particulate material which the smoke or fumes may contain.

A further object is to provide apparatus capable of performing such a smoke-clarifying operation which is adaptable to different types of smokestack installations, and which can be incorporated in various types of existing stack installations.

FIG. 1 is a side elevation of a typical stack installation to which the smoke clarifier of the present invention has been applied.

FIG. 2 is a side elevation of a portion of the smoke clarifier on an enlarged scale with parts broken away.

FIG. 3 is an enlarged vertical central section through a portion of the clarifier, and

FIG. 4 is a transverse section taken on line 4—4 of FIG. 3.

FIG. 5 is a side elevation of a refuse burner to which the smoke clarifier has been applied.

FIG. 6 is a side elevation of a smokestack installation incorporating a flame and washer type of clarifier.

FIG. 7 is a longitudinal vertical section through such clarifier with parts broken away.

FIG. 8 is a vertical section through a portion of such clarifier.

FIG. 9 is a horizontal section through another portion of such clarifier on line 9—9 of FIG. 7.

FIG. 10 is a transverse horizontal section through the clarifier, taken on line 10—10 of FIG. 7.

FIG. 11 is a horizontal section through the clarifier taken on line 11—11 of FIG. 7.

FIG. 12 is a top perspective of a portion of the clarifier shown in FIGS. 6 and 7, parts being broken away.

FIG. 13 is a vertical section through a portion of a modified type of clarifier.

One of the most objectionable types of air pollution in populated areas is the emission of black smoke from a smokestack. Whether such emission is from a sawmill, a plywood plant or other type of woodworking factory, or from a coal-burning furnace installation such as in a steel mill, or some type of steam-producing or heat-producing installation, the black smoke phenomenon indicates a condition of incomplete combustion evidenced by a large quantity of particulate material entrained in the hot stack gases. Such particulate material is carried in the smoke a greater or lesser distance from the smokestack depending upon the temperature and velocity of the smoke, and eventually is deposited in the surrounding neighborhood.

Attempts have been made to reduce the resulting nuisance by increasing the height of the smokestack, but this has simply resulted in increasing the area in which the entrained particulate material is deposited, so that the same quantity of material is less concentrated in a greater area. Efforts have been made to remove particulate material from such smoke, but either the equipment required has been very expensive, or considerable back pressure has been produced which adversely affects the operation of the furnace, or the amount of such particulate material removed from such smoke has not warranted the expense or other adverse factors of the clarification.

The clarifier shown in FIGS. 1 to 4, inclusive, can be installed on the upper end of a conventional smokestack 1 which may be of sheet steel construction. The smoke clarifier unit 2 includes a skirt 3 fitting over and encircling the upper end of the smokestack. Such clarifier includes a washing zone 4 between the skirt fitted over the upper end of the smokestack and a discharge duct 5 extending upward from the washing zone. Preferably the washing zone is enlarged in cross-sectional area over the cross section of the smokestack and is joined to the skirt 3 by an expansion transition piece 6 and to the discharge duct by a contraction transition piece 7.

The skirt 3 does not fit snugly onto the smokestack 1 but includes an inner wall 8 connected to and spaced from the outer wall of the skirt by spacer blocks 9. Such inner wall should fit the outer wall of the smokestack 1 snugly, or suitable calking material should be inserted between the smokestack and the inner wall of the skirt to prevent smoke from passing up through the stack 1 and down between the inner wall 8 of the skirt and the outside of the smokestack to escape into the atmosphere. A lower annular wall 10 closes the annular chamber between in the inner and outer walls of the clarifier skirt. An inwardly directed flange 11 on the upper end of the inner skirt wall 8 overlies and bears on the upper end of the stack 1, as shown in FIG. 3, to support the clarifier on the smokestack.

A lower precipitation and turbulence conical baffle 12 of sheet material is mounted in the lower portion of the washing zone by bars 13 extending transversely of the washing zone. As shown, the sides of such baffle, which are inclined relative to the direction of smoke flow through the smokestack, have edge portions which project generally upstream relative to the smoke flow and are spaced from the wall of the smokestack. The apex angle of the cone as shown in FIG. 3 is approximately 90°. Also, the diameter of the downwardly opening hollow cone base is preferably at least approximately as great as the diameter of the upper end of the smokestack received in the clarifier. By utilizing a baffle of this size the inertia of the smoke would drive it into the interior of the cone, and the smoke would billow into the washing chamber around the skirt of the cone to produce the dual effect of tending to precipitate particles from the smoke and of creating turbulence facilitating intimate contact of washing sprays in the washing chamber with the smoke.

Spaced above the lower cone 12 and located concentric with it is an upper hollow cone 14 opening downward. Preferably the apex angle of this cone is approximately 90° like the apex angle of the lower cone 12. It is preferred that such upper cone be mounted by bars 15 extending radially of the washing zone so that the lower edge of its skirt is located below the apex of the lower cone 12, as shown best in FIG. 3. The diameter of such cone skirt may be somewhat less than the diameter of the skirt of the lower cone so as not to obstruct the flow of smoke upwardly from such lower cone.

Within the rim of the upper cone 14 and suitably connected to it, such as by welding or by pipe clamps, a washing spray pipe ring 16 is mounted. The lower side of such ring has perforations spaced circumferentially through which downwardly-directed jets 17 are projected. Such spray ring is located in vertical registry with the lower portion of the lower cone 12 so that the jets impinge on the exterior surface of the lower cone i.e. the smoke outflow side of the baffle, to induce atomization. Since such surface slopes downward and outward at an angle of 45° to the vertical jets 17, the jet streams will impinge against the conical baffle wall at a glancing angle of 45° and be reflected from the baffle surface at angles of approximately 45°; to produce sprays 18 directed substantially horizontally radially outward through the washing zone 4 toward the cylindrical wall of such zone. The water will then flow in a sheet 19 inward and downward along the wall of the frustoconical transition piece 6.

Water is supplied to the spray ring **16** through a supply pipe **20** extending upwardly alongside the washing zone **4** and then radially inwardly through such washing zone. Such supply pipe is connected to the washing ring **16** by a branch conduit **21**. A second branch conduit **22** of the spray supply pipe is connected to a header **23** mounted on the apex of lower cone **12** to supply water to spray pipes **24** extending generally radially outward from such header.

From the flattened ends of spray pipes **24** additional fan-shaped jets are projected substantially in radial planes of the washing zone downward along the outer surface of the lower conical baffle **12**. Such sprays wash from the upper surface of such baffle any residue which may tend to collect there from smoke curling upward around the rim of the lower cone and are then projected from the rim in jets **26** downwardly and outwardly through the washing zone to impinge against the wall of the transition piece **6**. The water then joins the drain sheet **19** from the sprays **18** and forms the composite drain sheet **27** which flows downward into and through the annular space **28** in the clarifier skirt **3** between its outer wall and its inner wall **8**.

In addition, a nozzle **29** may be mounted on top of the header **23** to project a jet upwardly into the hollow upper cone **14** for general cleansing and scavenging purposes. Water from this jet eventually falls onto the upper side of lower cone **12** and mingles with the water from the jets of spray ring **16** and spray pipes **24**. The jets **17** are spaced sufficiently closely so that the substantially horizontal radial sprays **18** form generally a barrier spray sheet of water for particulate material entrained in the smoke. Also the pipes **24** are located sufficiently close together and their nozzle ends **25** provide sprays sufficiently fan-shaped so that the composite sheet sprays **26** also provide generally a sheet spray curtain through which the smoke rises.

Projection of the smoke flowing upward through the stack **1** into the downwardly opening conical baffle **12** tends to precipitate particulate matter, principally fly ash, from the smoke. The smoke then billows around the rim of the conical baffle outward and upward into the washing zone **4**. Passage of the smoke around the lip of the baffle creates turbulence which further tends to precipitate particulate matter from the gaseous component of the smoke. In such turbulent zone the smoke passes first through the curtain of downwardly directed sprays **26** and then through the curtain of radially directed sprays **18**, which entrain the particulate matter from the smoke and carry it outward to the drain sheets **19** and **27** flowing downward along the walls of the washing zone to the annular drain duct **28** of the clarifier skirt.

From the bottom wall **10** of the annular drain duct a drain pipe **30** extends downward for removing spray water and the particulate material washed from the smoke and entrained in the water. One or more cleanout openings **31** may be provided in the lower portion of the skirt, through which any accumulations of particulate matter can be removed from the lower portion of the drain duct.

The amount of particulate matter, such as fly ash or soot, in the smoke will vary depending upon the type of fuel being burned, the type of furnace installation, the temperature of the smoke and its velocity. The amount of water projected from the spray ring **16** and from the spray pipes **24** may be regulated by a valve **32** located between the pipe **33** leading to the valve and the pipe **20** connecting such valve to the spray pipes. The amount of water also may be regulated in accordance with the temperature of the smoke and, if desired, the valve **32** can be controlled thermostatically by temperature-sensing means responsive to the temperature of the smoke.

The water spray curtains through which the smoke passes not only entrains particulate material from the smoke, but cools the smoke appreciably. A substantial amount of such water would be evaporated, and the resulting vapor or steam would mingle with the smoke. The smoke would be cooled to the extent that heat would be absorbed by heating of the spray water and by the latent heat required to convert such water into steam. Such cooling of the smoke would correspondingly reduce its volume and in turn the velocity of the smoke. Such reduction in velocity also contributes to precipitation of particulate matter from the smoke. The hotter the smoke the wider will valve **32** be opened to increase the supply of water to the sprays.

While the installation of the smoke clarifier shown in FIGS. **1** to **4** is on the top of a stack **1**, a clarifier of this general type is adaptable to various types of smoke-producing equipment. In FIG. **5** a clarifier unit is shown mounted on a conical refuse burner **34** of conventional type. Customarily, smoke is simply emitted from the open upper end of such a burner. Burners of this type are in general use for burning waste wood products from lumber mills, plywood plants and other woodworking operations. A lower stack **35** is mounted on the upper end of the burner by an adaptor or transition piece **36**. This clarifier includes a washing zone **37** from which a discharge duct **38** extends upwardly. Such washing zone is connected to the stack **35** by the expansion transition piece **39**, and such zone is connected to the discharge duct **38** by the contraction transition piece **40**.

The construction of the smoke washing mechanism used in this clarifier may be similar to that described in connection with FIGS. **1** to **4**. Water is supplied to the washing mechanism through a supply pipe **41**. Such pipe may supply water to spray means of the type shown in FIGS. **3** and **4**, or may supply water to a spray ring **42**, which may be of a type the details of which will be described below. From the washing zone water with entrained particulate material is discharged through the drain pipe **43**.

In FIGS. **6** to **12** the smoke clarifier is shown as being applied to a smokestack **44** near its base, so that a long discharge duct or stack section **45** extends upward from the clarifier. The smoke discharged into this smokestack from the furnace through the connection **46** is of the type which includes not only particulate matter but also odorous fumes, such as from a pulp mill, paper mill or smelter, for example. The clarifier apparatus shown in FIGS. **6** to **12** not only removes particulate material from the smoke, but also removes or converts odorous components of the smoke into unobjectionable fumes.

Such purification is accomplished by burning or heating the fumes in an afterburner type of arrangement. Supplemental air is supplied to the smoke in an enlarged air mixing zone **47** of the stack. Forced air is supplied to such zone through several pipes **48** distributed around the stack **44** from a plenum chamber **49** which receives air from the blower discharge duct **50**. The supplemental air and smoke mixture flows upward from the mixing zone **47** through the intermediate stack section **51**, where it is mixed further on its way to the expanded flame and washing zone **52**.

The flame and washing zone is connected to the intermediate stack portion **51** by the expansion transition piece **53** and is connected to the upper smokestack section **45** by the contraction transition piece **54**. Nozzles **55** project jets of combustible gas cooperatively forming a ring of tongues of flame. Gas is supplied to such individual nozzles from a pipe ring **56** carrying such nozzles and fed by the supply pipe **57**. Above the flame nozzles **55**, nozzles **58** project flat sprays of water radially inward which intersect as shown in FIG. **10** to form a spray sheet or a curtain of water through which the smoke rises. Such spray nozzles are carried by and project inward from a spray ring **59** encircling the washing zone, to which ring water is supplied through the supply pipe **60**. The supply of water to this pipe can be controlled by a manual or thermostatic valve **61**.

As the smoke rises through the lower stack section **44**, supplemental combustion air is added to it in the mixing chamber **47**, so as to support combustion of combustible gaseous components of the smoke in the flame area. Such heating and combustion will substantially complete the oxidation of carbon compounds of the gas and will substantially complete

either the oxidation or the conversion of other noxious and/or odorous components of the gas, such as those containing sulphur. Also, some of the carbonaceous particulate material may be burned in the flame area. As the smoke continues upward through the sheet or curtain of water spray produced by the jets from nozzles **58** projected radially inward, such spray curtain will entrain particulate material from the gas and will also dissolve to a greater or lesser extent water-soluble components of the smoke.

The water carrying such dissolved and entrained matter will impinge against the exterior of the drain pipe **62** extending concentrically upward through the stack, as shown in the upper portion of FIG. **7**, to induce atomization and form an annular drain water sheet **63**, which will flow downward into an upwardly opening, annular, frustoconical runoff catch trough **64** carried by the drain pipe. From such catch trough the water will flow through aperture **65** in the wall of the drain pipe and downward through its interior to be discharged from the pipe through apertures **66** in its bottom. The water then flows from the bottom of the stack outward through the drain **67**.

In order to prevent injury to the wall of the drain pipe **62** by impingement of hot smoke directly against it, a shield plate **68** shown in FIGS. **7** and **9** may be mounted on the drain pipe between it and the end of the furnace flue **46** opening into the smokestack **44**.

As in the operation of the smoke clarifier described in connection with FIGS. **1** to **4**, passage of the smoke through the curtain of spray from the water jets **58** will cool the smoke substantially despite the addition of heat to the smoke contributed by the ring of flame produced by the gas jets dispensed by the nozzles **55**. Such cooling of the smoke by heating and vaporization of the water dispensed by the jets will result in a decrease in smoke volume, and consequently a reduction in the velocity of the smoke. Under such circumstances, particularly where the smoke clarifier is installed at the base of a tall stack such as shown in FIG. **6**, it may be desirable to improve the draft up the stack portion **45** above the smoke clarifier.

In FIGS. **7**, **9**, **11** and **12** a supplemental air supply pipe **69** is shown extending concentrically upward through the central portion of the drain pipe **62**. A pipe **70** extending laterally through the wall of the lower stack section has its inner end connected to the lower end of the riser **69** and its outer end is in communication with the blower discharge duct **50**. The air received by pipe **70** from such blower discharge duct therefore flows upwardly through pipe **69** and is discharged from its upper end **71** projecting above the upper end of the drain pipe **62** for improving the draft through the stack.

The smoke clarifier shown in FIG. **13** as being installed between a lower section **72** and an upper section **73** of a smokestack, has features similar to the smoke clarifier shown in FIGS. **6**, **10** and **12** with respect to the smoke washing mechanism, but it does not have a flame zone. Consequently, the axial extent of this zone connected to the lower stack section by the expansion transition piece **75** and to the upper stack section **73** by the contraction transition piece **76** may be considerably less than the axial extent of the flame and washing zone **52** shown in FIG. **7**.

The washing zone **74** of the smoke clarifier shown in FIG. **13** has washing spray nozzles **58** projecting inwardly through the zone wall, as shown in FIG. **7**. Similarly, these nozzles are carried by and supplied with water from a nozzle ring **59**. Such ring may be the same as the ring **42** shown in FIG. **5**, and, in fact, the smoke clarifier of that figure can be like that shown in FIG. **13**.

As in the installation shown in FIG. **7**, the jets projected from the nozzles **58** cooperate to form a spray sheet or curtain through which the smoke passes and which impinges against the outer wall of the drain pipe **62**. The drain water sheet **63** then runs down the outside of the drain pipe into the runoff catch trough **64** and is carried away through the drain pipe.

I claim:

1. Smoke-clarifying apparatus comprising an upright smoke passage, a baffle in said smoke passage inclined downwardly and having a lower edge portion spaced from the wall of said smoke passage for flow of smoke upward around and past said baffle edge portion, a first row of water jet means at the upper side of said baffle projecting jets of water downward onto the upper side of said baffle at a substantial glancing angle thereto for impingement against said baffle and projection of spray therefrom at a substantial angle of reflection into the smoke flowing past said baffle edge portion in a direction transversely of the direction of such smoke flow, a second row of water jet means above said baffle projecting additional water jets downward substantially parallel to and alongside the upper side of said baffle and beyond its lower edge portion to mingle with the spray from said first water jet means for entraining in the water from said jet means material washed from the smoke, and means for removing the water of said jet means from said smoke passage with the material entrained thereby.

2. The apparatus defined in claim **1**, in which the reflected spray is projected from the baffle substantially radially of the smokestack.

3. The apparatus defined in claim **1**, in which the smoke passage has a circular cross section and the upper surface of the baffle is an upwardly tapered conical surface, the first row of water jet means includes an annular row of jets disposed above the conical surface of the baffle substantially coaxial therewith, spaced a substantial distance outward from the center of the baffle and projecting jets of water downward onto the upper surface of the baffle in a ring, and the water jet means of the second row being annular and located closer to the center of the baffle than such ring for projecting sprays through the ring of jets projected by the first row of water jet means.

4. Smoke-clarifying apparatus comprising an upright smoke passage having a circular cross section, a baffle in said smoke passage having an upwardly tapered conical upper surface and a lower edge portion spaced from the wall of said smoke passage for flow of smoke upward around and past said baffle edge portion, an annular row of water jets disposed substantially coaxially above said conical surface for projecting jets of water downward onto such conical surface at a substantial glancing angle thereto for impingement against said baffle surface and projection of spray therefrom at a substantial angle of reflection into the smoke flowing past said baffle edge portion in a direction transversely of the direction of such smoke flow, a hollow cone spaced upwardly from said baffle conical upper surface and carrying said annular row of jets, and means for removing the water of said jets from such smoke passage with the material entrained thereby.

5. Smoke-clarifying apparatus comprising an upright smoke passage having a circular cross section, a baffle in said smoke passage having an upwardly tapered conical upper surface and a lower edge portion spaced from the wall of said smoke passage for flow of smoke upward around and past said baffle edge portion, an annular row of water jets disposed substantially coaxially above said conical surface for projecting jets of water downward onto such conical surface at a substantial glancing angle thereto for impingement against said baffle surface and projection of spray therefrom at a substantial angle of reflection into the smoke flowing past said baffle edge portion in a direction transversely of the direction of such smoke flow, a hollow cone spaced upwardly from said baffle conical upper surface closely overlying said annular row of jets and having its walls disposed generally parallel to the conical upper surface of said baffle, and means for removing the water of said jets from said smoke passage with the material entrained thereby.

6. The apparatus defined in claim **5**, and additional jet means projecting a water jet upwardly against the underside of the hollow cone.

7. Smoke-clarifying apparatus comprising a smokestack including a lower expansion downwardly tapered transition piece, an upper contraction upwardly tapered transition piece

and means joining said transition pieces to form a washing zone having a cross section expanded from the cross section of said smokestack below said expansion transition piece and above said contraction transition piece, a drainpipe extending longitudinally upward through the central portion of said smokestack, a runoff catch trough carried by said drainpipe and having its upper edge disposed above the bottom of said expansion transition piece and communicating with the interior of said drainpipe for collection of water in said catch trough and passage into said drainpipe, and water jet means including a row of jets encircling said washing zone above said runoff catch trough and projecting water jets from substantially the periphery of said washing zone substantially radially inward for passage of gas upward around the upper portion of said runoff catch trough and through the spray of said water jets.

8. The apparatus defined in claim 7, a draft-inducing pipe extending upwardly through the drainpipe at least substantially to the upper portion of the contraction transition piece for supplying draft-inducing air to the interior of the smokestack, and means for supplying air to said draft-inducing pipe.

9. The apparatus defined in claim 7, and burner means, located below the water jet means and below the drain-pipe catch trough, projecting flame into the smokestack.

10. Smoke-clarifying apparatus comprising a smokestack including a washing and combustion zone having a cross section expanded from the cross section of said smokestack below said washing and combustion zone, water jet means projecting sprays into smoke rising through said washing and combustion zone in a direction generally transversely of the direction of movement of such smoke for entraining in the water of such sprays material washed from the smoke, runoff catching means below said water jet means for collecting and draining out of said washing and combustion zone water precipitated from said water jet means sprays, and burner means disposed below said water jet means and below the upper portion of said runoff catching means, disposed to project flame into smoke rising through said expanded washing and combustion zone generally transversely of the direction of movement of such smoke and in a direction corresponding to the direction of the water jet sprays.

11. The apparatus defined in claim 10, and supplemental air supply means including an enlarged smokestack portion larger than the portion of the smokestack therebelow and disposed below the expanded washing and combustion zone, and means for supplying air to said enlarged smokestack portion.

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