May 18, 1937. J. C. HAYES 2,080,713

GAS CLEANING MEANS

Filed Jan. 27, 1936 3 Sheets-Sheet 1

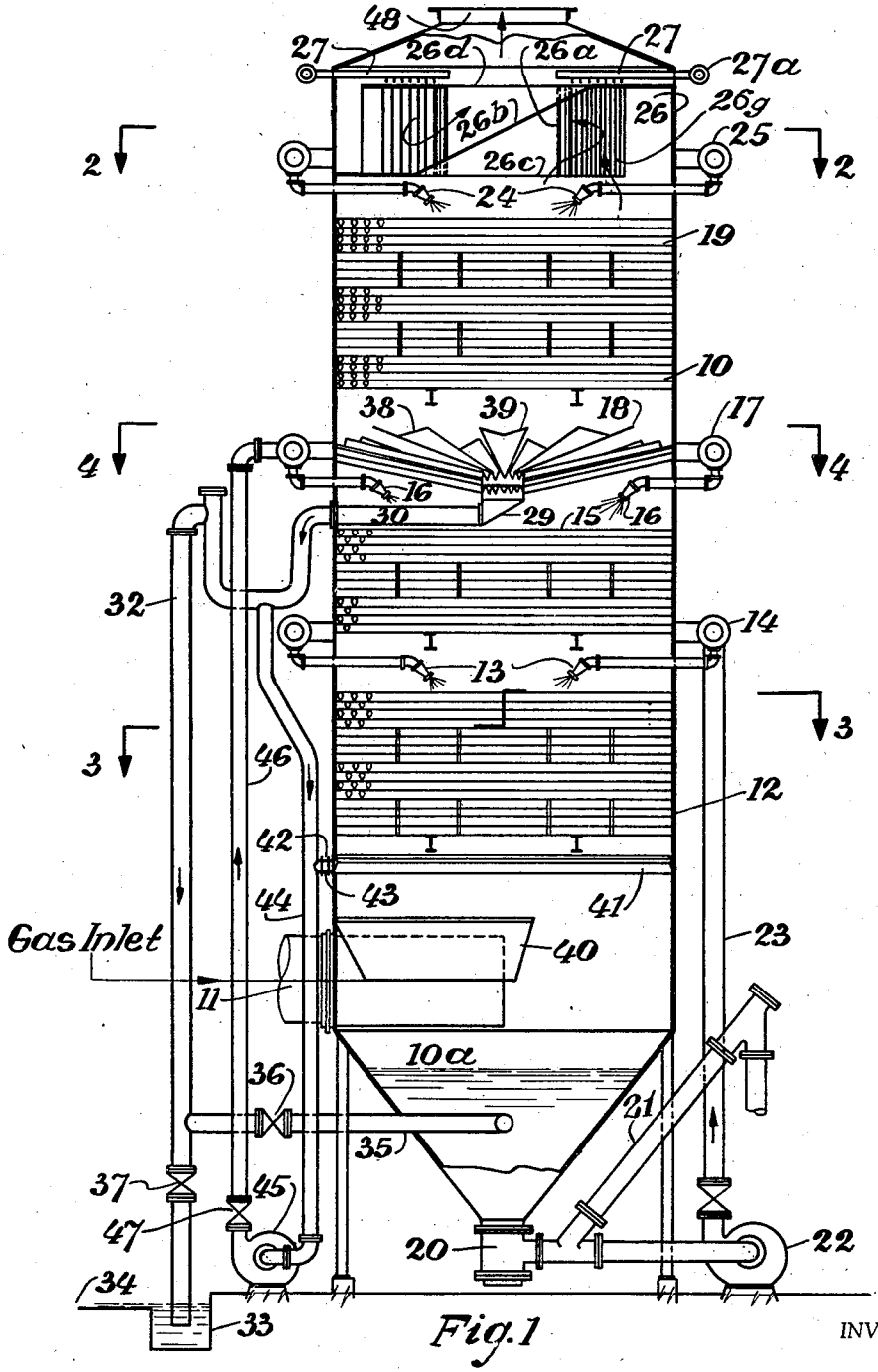


Fig. 1

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May 18, 1937. J. C. HAYES 2,080,713

GAS CLEANING MEANS

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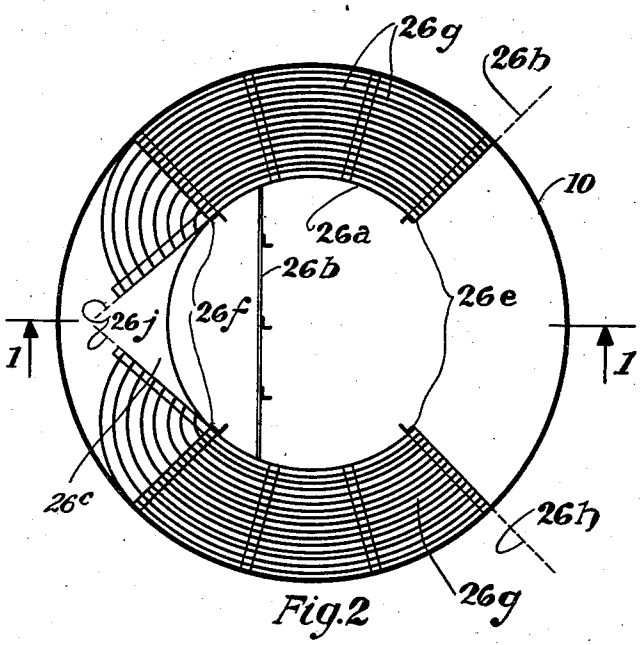


Fig.2

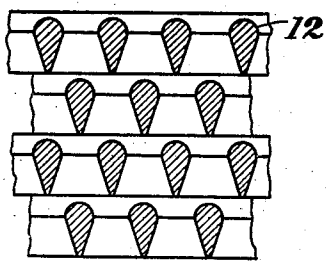


Fig.7

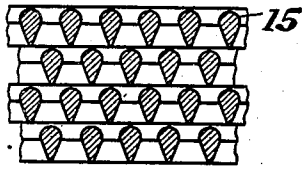


Fig.8

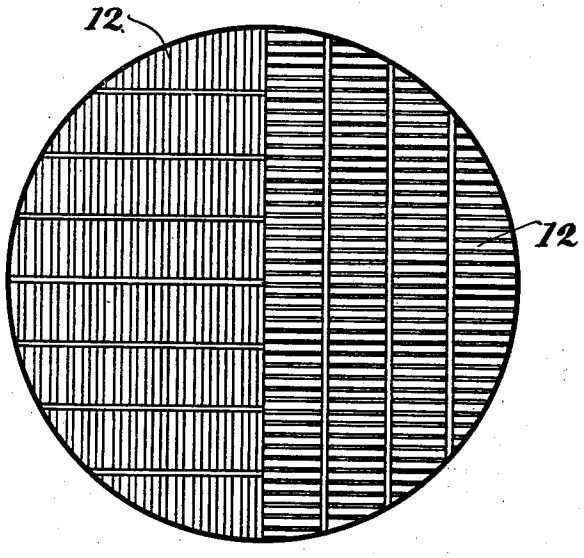


Fig.3

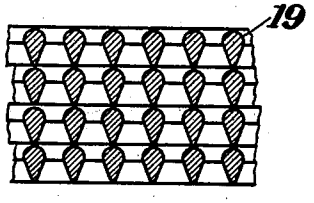


Fig.9

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May 18, 1937. J. C. HAYES 2,080,713

GAS CLEANING MEANS

Filed Jan. 27, 1936 3 Sheets-Sheet 3

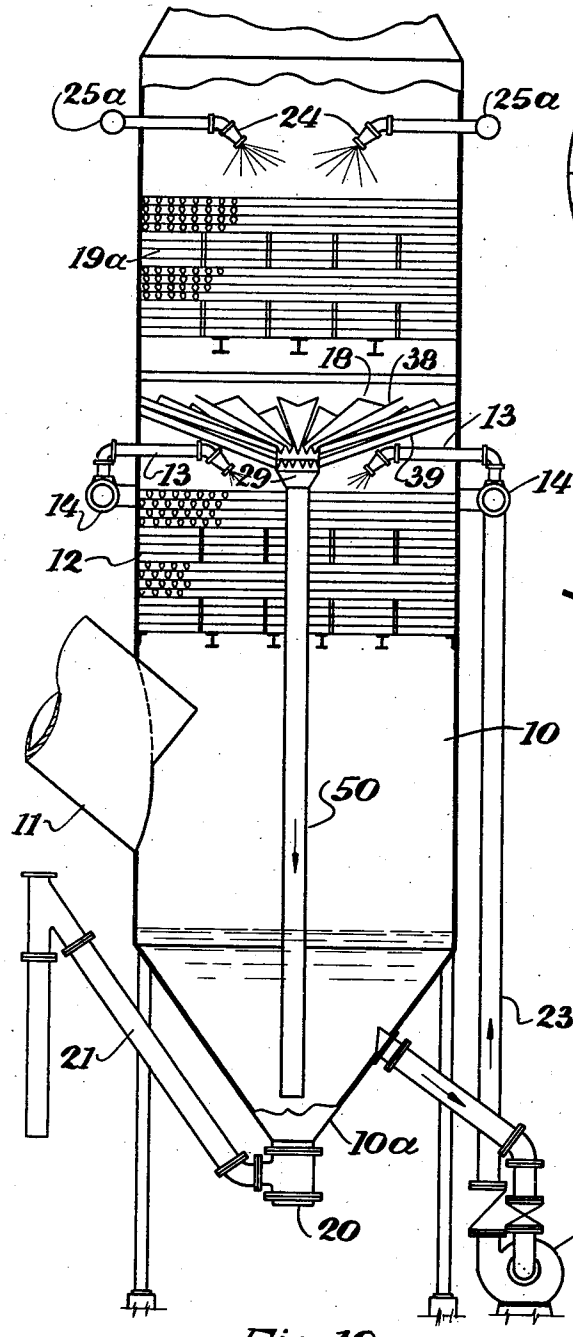


Fig. 10

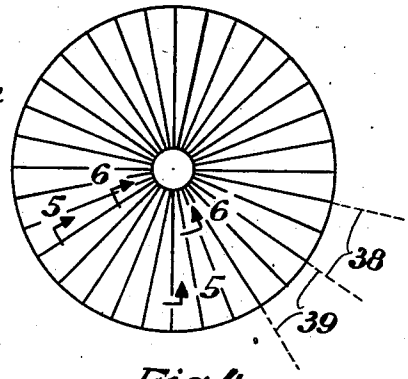


Fig. 4



Fig. 5



Fig. 6

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Patented May 18, 1937 2,080,713

UNITED STATES PATENT OFFICE

2,080,713

GAS CLEANING MEANS

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Application January 27, 1936, Serial No. 60,948

19 Claims. (Cl. 261—110)

The present invention relates to improvements in gas cleaning means.

Speaking generally, the present invention relates to means for removing dust and other solid matter from combustible gas such as that discharged from blast furnaces. In blast furnace practice it is common to pass the blast furnace gas through a dust catcher, which discharges the gas, freed of many of its heavier particles, at a temperature considerably above the boiling point of water. In addition to the dirt and the gas delivered from the dust catcher, a certain amount of moisture is contained in the gas, which, however, is in superheated condition. In the practice of the present invention the high temperature of the raw gas and the moisture content thereof are utilized. An object of the present invention is to provide gas cleaning means which will conserve the amount of ground space necessary in an installation for this purpose.

A further object is to provide efficient means for cleaning gas which is relatively inexpensive in initial cost. A further object is to provide an installation of the kind referred to in which the pressure drop in the gas through said installation is minimized.

A further object is to provide gas cleaning means of improved efficiency which can be embodied in the casings of gas washing towers as now known and used.

Further objects will appear as the description proceeds. Referring to the drawings—

Figure 1 is a diagrammatic view illustrating one embodiment of the present invention;

Figure 2 is a sectional view taken along the plane indicated by the arrows 2—2 of Figure 1;

Figure 3 is a sectional view taken along the planes indicated by the arrows 3—3 of Figure 1;

Figure 4 is a sectional view taken along the plane indicated by the arrows 4—4 of Figure 1 and illustrating a water diverter forming part of the present invention;

Figure 5 is a sectional view, developed along a plane, taken along the curved surface indicated by the arrows 5—5 of Figure 4, the parts being shown on an enlarged scale in Figure 5;

Figure 6 is a sectional view, developed along a plane, taken along the curved surface indicated by the arrows 6—6 of Figure 4, the parts being shown on an enlarged scale in Figure 6;

Figures 7, 8 and 9 are enlarged sectional views illustrating the preferred contour and arrangement of the hurdles in the hot water recirculating stage, the water preheating stage and the condenser stage, respectively; and

Figure 10 is a view similar to Figure 1 but showing a simplified construction.

Referring first to Figures 1 to 9, the numeral 10 indicates a tower preferably of cylindrical form but having the cone-shaped bottom 10*a*. Gas is admitted to the tower 10 through the pipe 11. Said pipe 11, in blast furnace service, will as a usual proposition lead from a dust catcher (not shown). The numeral 12 indicates generally a stage of hurdles, to be referred to more particularly hereinafter. Above said hurdles are a plurality of water sprays, indicated by the numerals 13—13. Said sprays are preferably disposed at spaced regions around the inside of the tower and are connected to the water supply pipe 14, which encircles the tower 10 through most of its periphery. Above the water sprays 13—13 is the stage of hurdles 15, and above said stage of hurdles 15 are the water sprays 16—16 distributed at spaced regions around the inside of the tower 10. Said sprays 16—16 are connected to the water pipe 17, which encircles the tower 10 through most of its periphery. Disposed above the water sprays 16—16 is the water diverter, indicated by the numeral 18, which diverter will be referred to more particularly as the description proceeds. Located above the water diverter 18 is the stage of hurdles 19.

For convenience of description, the lowermost stage of hurdles 12 may be referred to as the hot water recirculating stage. The next stage of hurdles 15 may be referred to as the water preheating stage, and the uppermost stage of hurdles may be referred to as the condenser stage. The hurdles of each one of the stages 12, 15 and 19 have been illustrated as having a cross-sectional contour of an enlarged inverted teardrop. The hurdles in each of the three stages are elongated bars. As illustrated, a series of bars or hurdles in each of the stages 12 and 15 has other series of bars or hurdles adjacent thereto disposed in right-angular relationship therewith. Preferably the hurdles in the stage 12 will be largest in cross section, the hurdles in the stage 15 will be of intermediate size, and the hurdles in the condenser stage 19 will be the smallest of the three stages. The hurdles in stages 12 and 15 extending in a common direction will preferably be staggered vertically relative to one another. In stage 19, adjacent hurdles are symmetrically disposed one above another and in substantial contact whereby to provide extended

surfaces for water films without danger of excessive splashing or turbulence.

The bottom of the tower 10 is provided with the outlet assembly 20 for permitting the exit of dirty water therefrom while preventing the escape of gas therethrough. Assemblies suitable for the purpose are well known in the art and need not be described in detail. Forming part of said assembly is the pipe 21, which, through a valve (not shown), may lead to a settling device for settling out dirt from water discharged from the tower before said water is delivered to the sewer or re-used. Also connected to the assembly 20 is the hot water recirculating pump 22, which delivers a portion of the water from the bottom of the tower to the hot water line 23, which connects with the circular supply pipe 14, which supplies the spray nozzles 13—13 above the stage 12 of hurdles.

Disposed above the hurdles of the condenser stage 19 are a plurality of water sprays 24—24 supplied by the water pipe 25, which may be connected to a source of clean, relatively cool water supply. Disposed above the water sprays 24—24 is a fine dust collector, indicated by the numeral 26. Said fine dust collector may embody the principles disclosed in the patent to Bleibtreu and Eberlein No. 1,933,699, granted November 7, 1933. The fine dust collector 26 is supplied with water by a plurality of water sprays 27—27, which are supplied with clean, cool water from the water pipe 27*a*.

Disposed below the hurdles of the condenser stage 19 and above the hurdles of the water preheating stage 15 is the water diverter 18. The water diverter 18 has the function of intercepting water which has dropped down through the condenser stage 19. Said diverter is so constructed that it permits the upward flow of gases from the water preheating stage 15 to the condenser stage 19.

The water diverter 18 includes the central thimble or hub 29, from the bottom of which leads the pipe 30, which through the U-connection 31 connects with the downwardly extending pipe 32 leading to the water seal 33, which through the outlet 34 may be connected to the sewer. The downwardly extending pipe 32 may have a connection through the pipe 35 with the lower portion of the tower 10, whereby water from the downwardly extending pipe may be conducted to the lower portion of the tower 10 to make up, in part, for evaporation which will occur in service, and to make up, in part, for the water discharged from the tower 10 through the pipe 21. The pipe 35 may be controlled by means of the valve 36. The downwardly extending pipe 32 may be provided with the valve 37 located between the pipe 35 and the water seal 33. By manipulation of the valves 36 and 37, the proportion of flows of water to the bottom of the tower 10 and to the water seal 33 may be controlled.

A preferred construction of the water diverter 18 is illustrated in Figures 1, 4, 5 and 6. By reference to these figures it will be noted that the central thimble or hub 29 is provided with two sets of radially disposed troughs. The troughs of the uppermost set are indicated by the numerals 38—38 and the troughs of the lowermost set are indicated by the numerals 39—39. The troughs 38 are staggered with respect to the troughs 39, and there may be a certain amount of overlapping between said troughs 38 and 39 so that water dropping vertically is certain to fall into one or the other of these sets of troughs. However, due to the vertical spacing between the two sets of troughs, it is possible for the gas which has passed upwardly through the hurdles of the water preheating stage 15 to pass through said water diverter 18 into the condenser stage 19. If preferred, the troughs 38 and the troughs 39 may be spaced circumferentially, so that a fraction of the water dropping vertically will pass through the diverter into the bank of hurdles therebelow, in this way supplying make-up water, which is heated by the upflowing gas and which would cause a gradual dilution of the hot water in the base of the cone of the tower. Said troughs 38 and 39 all incline downwardly toward the thimble or hub 29 and deliver to said thimble or hub the water which they catch, which water passes outwardly through the pipe 30.

As indicated above, gas is conducted into the lower region of the tower 10 below the hurdles of the hot water recirculating stage 12 through the gas inlet 11. Disposed in the lower region of the tower 10 adjacent to the gas inlet 11 is the apron 40 of arcuate form, coaxially disposed with reference to the tower 10. Said apron 40 directs the gases entering through the gas inlet 11 in a more or less circular path. Disposed above the apron 40 is the annular member 41 disposed coaxially with respect to the tower 10 and spaced a short distance from the inner surface of the cylindrical wall of the tower 10. Said annular member 41 decreases in diameter upwardly. Water is admitted to the outer periphery of the annular member 41 through the pipe 42, which is controlled by the valve 43. Said pipe 42 connects with the water supply pipe 44, the functions of which will be referred to more in detail presently. Water delivered to the outer tapered surface of the annular member 41 provides an annular curtain of dropping or flowing water disposed around the inner surface of the tower 10 below said annular member 41.

The water supply pipe 44 is connected to the bottom portion of the U-connection 31. Water delivered from the hub or thimble 29 passes down through the water supply pipe 44 and is delivered at relatively high pressure by means of the pump 45 to the pipe 46, which supplies water to the spray nozzles 16—16 located above the hurdles of the water preheating stage 15. Said pump 45 is illustrated as being located adjacent to the bottom of the tower 10 for the purpose of simplifying the matter of servicing said pump. The pipe 46 is controlled by the valve 47. At the top of the tower 10 is the gas outlet 48, through which the cleaned gas may be conducted either to storage or to gas utilizing devices.

The fine dust collector 26 may be described briefly as follows: Said dust collector 26 operates upon the principle of centrifugal action and provides a plurality of circuitous passages for the gases which have passed the sprays 24—24. Said dust collector 26 includes the tubular member 26*a*, which tubular member has located therein the dividing partition 26*b* positioned diagonally with reference to said tubular member 26*a*. Said dividing partition 26*b* extends from a region adjacent to the bottom of the tubular member 26*a* on one side thereof to a region adjacent to the top of said tubular member at the other side thereof. Said tubular member 26*a* is open at its bottom to the condenser stage 19 located therebelow and is open at its top to the gas outlet 48. A plate 26*c* in the form of a section of an annulus is disposed between the tubular member 26*a* at

the bottom thereof and the wall of the tower 10. An annular plate 26d is located at the top of the tubular member 26a and extends from said tubular member 26a to the wall of the tower. The tubular member 26a is provided with the opening 26e and with a corresponding opening 26f diametrically opposite to the opening 26e. Said openings 26e and 26f extend preferably throughout the length of the tubular member 26a between the plates 26c and 26d. The section of an annulus 26c is provided with an opening corresponding in size and location to the opening 26e. The boundaries of said opening in the plate 26c are indicated by the lines 26h—26h. It will be obvious that gas entering the tubular member 26a will travel through the opening 26e and through the opening just referred to in the plate 26c, and will have two substantially semi-circular routes of travel to the opening 26f, which communicates with the gas outlet 48. Disposed between the tubular member 26a and the wall of the tower 10 are a plurality of arcuate walls 26g, preferably disposed, through the greater part of their length, coaxially with the tower 10. The extremities of said arcuate walls 26g—26g adjacent to the opening 26e may be disposed along planes indicated by the lines 26h—26h, which diverge outwardly with reference to the axis of the tower 10. The other end portions of the arcuate walls 26g—26g may be given a sharper curvature than the other portions of said arcuate walls 26g, and the extremities of said arcuate walls 26g—26g adjacent to the opening 26f may be located in planes indicated by the numerals 26j—26j, which converge toward the outer wall of the tower 10.

The dust collector 26, as indicated above, operates upon the principle of centrifugal force. To this end, the velocity of the gases through the passages provided by the arcuate walls 26g—26g should be decidedly greater than the velocity of the gas vertically through the condenser stage 19. Accordingly, the tubular member 26a has a decidedly smaller diameter than the diameter of the tower 10, and the total cross-sectional area of the passages provided by the walls 26a—26a will be sufficiently restricted to ensure the gas velocity referred to. The surfaces of the arcuate walls 26g and other surfaces within the dust collector 26 which are contacted by the gases to be cleaned are preferably rubber-covered and may be wetted or flushed by the sprays 27—27. The gas which is passed upwardly through the condenser stage 19 will have the very fine dust particles therein wetted, so that in passing around the dust collector 26, the wetted particles will, by reason of centrifugal force, be directed against the wetted rubber-coated surfaces of the dust collector 26. In other words, the gases entering the tubular member 26a have been given a thorough preliminary wetting in the treatment before said gases have reached said tubular member 26a and in their wetted condition are carried along the curvilinear courses at decidedly higher velocities than were had in the tower 10 below said tubular member 26a. The gas stream within the dust collector 26 is deflected from straight line movement and is carried along through a plurality of radial spaced curved courses, or laminations, with the effect that the dust particles remaining in the gas are disposed upon the curved partitions or upon the wall of the dust collector. As mentioned hereinabove, the dust collecting surfaces of the dust collector 26 are preferably of rubber or other material which is highly wettable, which material is particularly well adapted for the purpose of collecting the wetted dust particles and of shedding such dust particles due to the flushing effect either of the water carried along in the gas stream or to the water from the water sprays 27—27. By reason of the fact that the curved passages or laminations are relatively narrow in a radial direction, the dust particles need travel only a relatively short distance radially of the apparatus before impinging upon the dust collecting surfaces. The dust and water particles deposited upon said dust collecting surfaces and the water from the sprays 27—27 will drain over the edges of the plate 26c, defined by the lines 26h—26h, down through the tower 10.

The sprays 27 need be located only at points adjacent to the entrances of the channels between the arcuate walls 26g—26g, so that the dust collector 26 will be effective not only in removing fine dust particles but water particles as well, delivering clean dry gas.

The structure disclosed in Figure 10 differs from that above described, first, in the fact that said structure is simplified, and, second, in the fact that it provides a structure which may be readily embodied in the towers of gas washers or scrubbers now in service. In Figure 10, the cleaning stage above the water diverter 18 is indicated by the numeral 19a and may take the form of the usual scrubber elements which are designed to provide agitation and turbulence of water with gas. Figure 10 shows water sprays 24a—24a for supplying water to the stage 19a, which sprays are supplied through a pipe 25a. According to the disclosure in Figure 10, the stage of hurdles 15 is omitted, together with the water sprays 16—16 above the stage 15. In the disclosure of Figure 10, the water diverter 18 is connected through the pipe 50 directly to the lower portion of the cone 10a of the tower 10. The pipe 50 is vertically disposed and conducts water which has been caught by the diverter 18 to a point directly above the lowermost portion of said cone 10a. The troughs 38—38 may be so proportioned relative to the troughs 39—39 that one or the other of the sets of troughs referred to will catch substantially all of the water passing down through the stage 19a, or, if preferred, the troughs 38—38 and/or the troughs 39—39 may be sufficiently narrow to permit the passage of a certain amount of water from the stage 19a down between said troughs onto the hurdles of the hot water recirculating stage 12. In Figure 10 the outlet pipe leading from the bottom of the tower connects with said tower at a point above the lower extremity of the pipe 50. This arrangement has the advantage that the cooler water which has flowed down through the pipe 50 is discharged through the pipe 21 to the sewer, while allowing the hotter and cleaner water in the bottom of the tower to be recirculated.

The principles of the present invention as illustrated in Figures 1 to 9 may be described as follows: For the purpose of illustration it may be considered that the gas entering through the inlet 11 has a temperature of about 350 degrees F. This superheated gas may, for example, contain about 30 grains of moisture per cubic foot. Said gas enters tangentially and is directed circumferentially of the tower 10 around the interior of the base of the tower before passing upward through the lowermost stage of hurdles 12. Due to the whirling motion of the gas, the largest particles of dirt are thrown, by centrifugal force,

against the wall of the chamber down which water is flowing from the annular member 41. In this stage the gas is given a preliminary centrifugal separation and the gas is distributed to the hot water recirculating stage 12.

In passing upward through the first hurdle stage 12, said gas impinges on wetted surfaces. It is also more or less immersed in spray and splash, resulting from the passage of a considerable quantity of water downward through this stage of hurdles. The conditions are such as to cause turbulence, intermingling of gas and water, and impingement of the gas against the wetted surfaces. This first stage of hurdles 12 is more or less inundated with water from the water sprays 13—13 located immediately above it. This water is near boiling temperature and by reason of this high temperature has minimum surface tension. Therefore there is the least possible resistance to the entry of dust particles into the water drops or upon the wet surfaces.

Because of the fact that the water in this stage is of approximately boiling temperature, a large amount of evaporation takes place. The heat for the evaporation is supplied by the incoming gas, that is—the sensible heat of the gas and the superheat of its contained water vapor. In this stage the incoming gas is cooled from its incoming temperature of say 350 degrees F. to a temperature slightly above the boiling point of water at approximately atmospheric pressure; that is, said incoming gas may be said to be cooled to about 220 degrees F. The heat thus given up by the gas is sufficient to raise the temperature of all of the water in this stage to the boiling point and to evaporate about 10 to 15 grains of additional moisture per cubic foot of gas. Therefore the gas leaving this stage is about 220 degrees F. and contains about 30 plus 13, or 43, grains of moisture per cubic foot, standard conditions.

Because of the considerable quantities of dirt involved in this stage of gas cleaning, it is necessary that a large amount of flushing water be used. As has been stated above, the water should be at or about boiling temperature. To meet this requirement the present invention contemplates the recirculation of the wash water in the first stage of the cleaning. By doing so, the heat in the water is conserved. According to the present invention, a considerable proportion of the water drawn from the bottom of the tower 10 is pumped back up to the water sprays 13—13. Because of the continuous deposition of dirt in this recirculated water, the water, in the absence of precautions, would soon become very concentrated and the bottom of the tower would clog with dirt To prevent such concentration, the present invention, in the embodiment illustrated in Figures 1 to 9, contemplates the recirculation of only a portion of the water from the bottom of the tower 10. According to practice which is at present preferred, about one-fifth of the discharge from the bottom of the washer 10 is delivered through the pipe 21 to a thickener or clarifier (not shown) before delivery to a sewer or before re-use. This fraction of the water required in the tower 10 is made up of relatively clear water, from the pipe 25 and the pipe 27a. The practice as at present preferred results in a concentration in the first stage of cleaning in the tower 10 of about 1400 grains per gallon. This concentration is not sufficient to cause difficulty in pumpage or in the spray nozzles 13—13 provided said spray nozzles are relatively coarse. The spray delivered by the nozzles 13—13 need not be very fine. Of course the concentration of the dirty water within the stage 12 may be chosen as desired, the degree of concentration being controllable by proportioning the flow of discharge from the tower 10 to the outlet pipe 21 and that back through the pipe 23 to the spray nozzles 13—13.

The question may arise as to why water delivered through the pipe 23 to the spray nozzles 13—13 may not be water which has been clarified after delivery through the pipe 21. In the first place, it is necessary, in order to provide proper settling, that the water remain in the thickener or clarifier for a considerable number of hours, in which period of time it will lose much of its heat. In this stage of the cleaning the water should preferably be maintained close to its boiling temperature, so that the advantages of low surface tension and maximum extent of evaporation may be utilized. In the second place, it is preferable to discharge an effluent of relatively high concentration to the thickener or clarifier for the purpose of conserving space and cost of the thickener or clarifier. The size of a thickener or clarifier depends largely upon the quantity of fluid and is not greatly influenced by the percentage of dirt in the effluent. With the relatively high concentration of effluent discharged through the pipe 21, a thickener or clarifier need occupy only a fraction of the space heretofore considered necessary in installations of capacities similar to those contemplated in the present invention.

In making up the one-fifth (which fraction was taken by way of example) of the effluent from the tower 10, it is not desirable to use ordinary cold water, since the temperature of the water in the first hurdle stage 12 would be too greatly reduced and much of the sensible heat in the gas would be utilized in bringing up the temperature of the water in this stage. This would hinder evaporation in this stage and would hold down the moisture content in the gas delivered from this stage.

As indicated above, it is desirable to use only a minimum of the sensible heat in the gas above 212 degrees F. in heating the water in the hurdle stage 12. This is desirable in order that a maximum of the heat in the gas may be available for evaporation. There is, however, no objection to the use of the sensible heat still remaining in the gas for preheating water. To this end, the second stage of hurdles 15 is disposed above the water sprays 13—13. This second stage of hurdles serves a triple purpose. First, it constitutes a stage of impingement cleaning for the gas for removing particles of dust which have escaped the hurdles in the first stage; second, the gas in the second stage of hurdles, in giving up sensible heat to the water in said second stage, acts as a preheater of the make-up water delivered to the first stage 12; and third, the second stage of hurdles 15 serves to partially cool the gas.

In the second stage of hurdles 15 the individual hurdles will be smaller and more closely spaced than in the first stage of hurdles 12. Because the gas is now relatively clean, and because the amount of dirt deposited in stage 15 is relatively small, a relatively small amount of water will suffice. This amount of water can be regulated to that required as make-up for the first stage.

Since this make-up water is of relatively small amount and since it will be relatively clean water, it can be pumped without excessive cost to a rela-

tively high pressure and be delivered through relatively small spray nozzles. This practice will result in even distribution of this relatively small amount of water over the hurdles in the second stage of hurdles 15. It will also serve to give extra cleaning and wetting of the gas. The gas leaving the second stage of hurdles 15 will have its dirt content very considerably reduced relative to the gas leaving the first stage of hurdles 12.

It might seem that the intermingling of warm gas with the relatively cool water from the water jets 16—16 would cause condensation to take place in the second stage of hurdles 15. Extensive condensation will not occur at this stage, for the following reasons: According to the example given above, the gas entering the second stage 15 of hurdles contains about 40 to 45 grains per cubic foot of moisture. The dew point of such gas is about 125 to 130 degrees F., whereas the temperature at this point is much higher, possibly 220 degrees F. Condensation will not take place until the gas reaches its dew point. It is possible and practicable to control the quantity or the temperature, or both, of the water supply to this stage in such manner as to control the temperature of the gas leaving the stage. The water supply for the stage of hurdles 15 comes from the pipes 25 and 27*a*, dropping down through the condenser stage 19 through the diverter 18, pipe 44, pump 45 and pipe 46 to the water sprays 16—16. The water which has passed down through the condenser stage 19 will, by reason of its contact with the gas which has passed up through the diverter 18, have had its temperature raised.

The diverter 18, as above described, catches the water (or a part of the water) dropping down through the condenser stage 19 without interfering materially with the passage of gas upwardly through the tower 10. The water (or a part thereof) which has passed downwardly through the condenser stage 19 is caught by the troughs 38—38 or the troughs 39—39 and is delivered to the hub or thimble 29, from which the water is delivered to the U-connection 31. A certain portion of this water may be allowed to go through the pipe 32 to the water seal 33 and to the sewer. A portion of the water from the U-connection 31 will pass downwardly through the pipe 44 to the pump 45, which is preferably located at the bottom of the tower as a matter of convenience. The water passing through the pump 45 is delivered under pressure to the water sprays 16—16. If preferred, part or all of the water passing down through the pipe 32 may be diverted through the pipe 35 to the conical bottom 10*a* of the tower 10. Valves 36 and 37 may be manipulated to control the passage of water from the pipe 32 either to the water seal 33 or to the bottom of the tower 10. The water for delivery to the annular member 41 may be conducted from the pipe 44 to the pipe 42, which pipe is controlled by the valve 43.

The moisture laden gas which has passed up through the hurdle stage 15 and the diverter 18 passes on to the condenser stage 19, passing between the hurdles of said condenser stage. The hurdles of the condenser stage 19 are of smaller cross-section and are more closely spaced than are the hurdles of stage 15. As stated above, the hurdles in stage 19 are so disposed as to reduce splashing and turbulence to a minimum. By reason of the symmetrical arrangement of said hurdles, a film of water may flow downward from each hurdle to the one immediately below it, forming passageways or channels of extended surface, bounded by smooth films of water. Water from the water sprays 24—24 flows down the surfaces of the hurdles in stage 19. This water comes from a source of clean water supply and will be relatively cool. Accordingly, the surfaces of the hurdles in the stage 19 are cooled. The gas entering the condenser stage 19 will give its heat to these cooled surfaces by convection and radiation. The gas, therefore, is cooled below its dew point and condensation takes place. This condensation causes a fog to be formed in the lanes between the hurdles in the condenser stage 19. In condensing, some of the moisture will form directly upon the cool walls of the hurdles. In the lanes between hurdles there will be relatively few drops of water originating from the sprays 24—24, said water tending to cling to the surfaces of the various hurdles in the condenser stage 19. The velocity of gas flow through the lanes between the hurdles of stage 19 will in practice not be high. This velocity will be so chosen that the water will not be blown off from the hurdles in the stage 19, and the quantity of water delivered by sprays 24—24 will be such as to cause only thin streams to flow down the hurdles in stage 19. Such streams are not easily blown off from the surfaces. Because of the moderate velocity, the gas will not be highly turbulent.

The fog formed in the lanes between the hurdles of stage 19 will use the dust particles as nuclei, since all of the larger dust particles have already been removed by impingement before reaching the condenser stage 19. Only the small particles remain as nuclei for the fog. Because of the substantial amount of fog formed, practically all of the small dust particles remaining in the gas will be coated with moisture. Some of these moist particles will adhere together, forming droplets and drops, and will attach to the condensing surfaces of the hurdles in stage 19. Some of the wetted particles will be so small and light in weight that they will be carried up and out of the condenser stage 19 and into the fine dust collector 26.

As indicated above, the water supplied to the hurdles of the condenser stage 19 will be relatively cold. For this reason it will be possible to reduce the temperature of the gas emerging from the condenser stage 19 to nearly the temperature of the incoming water, inasmuch as the water and the gas are flowing in opposite directions. A substantially constant temperature difference will exist between the water and the gas throughout the condensing stage. Such a substantially constant temperature difference is conducive to substantial reduction in area of the necessary condensing surface. By way of example, it may be stated that in the condensing stage the gas is cooled from about 140 degrees F. to 80 degrees F. (assuming water at 70 degrees F.). Even with this moderate range of cooling, considerable surface is required. If the gas were to enter at 220 degrees F., a much greater amount of cooling and condensing surface would be required. Thus it is evident why the pre-cooling in the hurdle stage 15 and the fine spray delivered by the water sprays 16—16 effects substantial economy in the condensing surface required in the condenser stage 19, where intimate intermingling of the gas and the water drops must be avoided in order that the dust particles alone may serve as nuclei for moisture condensation.

The gas, after passing the water sprays 24—24,

still must pass through the centrifugal dust collector 26. This centrifugal collector functions very effectively because the smallest dirt particles have been wetted much more completely than is possible in certain types of tower washers heretofore known and used, and, furthermore, the velocity of gas flow therethrough is decidedly greater than up through the condenser stage 19. The thorough wetting to which the very fine dust particles of the gas have been subjected has added greatly to the weight of these particles, and they are therefore particularly susceptible to centrifugal separation and deposition upon the curved rubber water-wetted surfaces of the centrifugal dust collector. Moreover, since the particles have been pre-conditioned by wetting, they will attach themselves to the water on the water-wetted rubber surfaces referred to very readily, and will gradually drift down these surfaces.

In view of the detailed explanation, appearing above, of the mode of operation of the embodiment of the invention disclosed in Figures 1 to 9, inclusive, it will not be necessary to recite in detail the mode of operation of the embodiment of the invention illustrated in Figure 10. In the construction illustrated in Figure 10, most of the relatively cool water which has been caught by the diverter 18 and delivered through the pipe 50 will pass directly out of the tower through the outlet assembly 20. A small portion of this relatively cool water may intermingle with the hot water at the base of the tower, thereby supplying the necessary make-up to take care of evaporation and the loss due to discharged hot dirty water through the outlet assembly 20. This intermingling of the relatively cool water from the pipe 50, together with the water which may be permitted to pass downwardly from the stage 19a directly to the hot water recirculating stage 12, will result in the dilution of the dirty water in the recirculating stage 12, preventing clogging of the system. Moreover, the water passing down through the pipe 50 to the bottom of the tower 10 will act, to a certain extent, in the nature of an ejector to flush the dirt from the base of the tower 10. The outlet to the pump 22, being connected to the tower 10 at a point above the lower extremity of the pipe 50, will cause the recirculation of the hotter water in the base of the tower.

Though preferred embodiments of the present invention have been described in detail, many modifications will occur to those skilled in the art. It is intended to cover all such modifications that fall within the scope of the appended claims.

What is claimed is—

1. In cleaning apparatus, in combination, a tower, means for admitting hot dirty gas to the bottom of said tower, means for admitting water to said tower above said gas admitting means, means for drawing off a mixture of dust and water from the bottom of said tower, means for recirculating a portion of said mixture through said tower in contact with said gas, a condenser stage within said tower, said water admitting means including means for admitting clean cool water to said condenser stage, a water preheating stage within said tower, and means for directing water, under pressure in the form of spray, from said condenser stage to said water preheating stage, said water preheating stage being positioned to deliver water to said recirculated mixture.

2. In cleaning apparatus, in combination, a tower, three stages of cleaning means within said tower, said three stages being disposed one above another, means for admitting hot dirty gas to said tower below the lowermost of said three stages, means for drawing off a mixture of dirt and water from the bottom of said tower and recirculating said mixture through the lowermost of said three stages, the uppermost of said three stages comprising a condenser stage, means for delivering cool clean water to said condenser stage, the intermediate of said three stages comprising a water preheating stage, and means for delivering water which has passed through said condenser stage, under pressure in the form of spray, to said water preheating stage, said water preheating stage being positioned to deliver water to said lowermost stage.

3. In cleaning apparatus, in combination, a tower, three stages of cleaning means within said tower, said three stages being disposed one above another, means for admitting hot dirty gas to said tower below the lowermost of said three stages, means for drawing off a mixture of dirt and water from the bottom of said tower and recirculating said mixture through the lowermost of said three stages, the uppermost of said three stages comprising a condenser stage, means for delivering cool clean water to said condenser stage, the intermediate of said three stages comprising a water preheating stage, and means for delivering water which has passed through said condenser stage, under pressure in the form of spray, to said water preheating stage, said water preheating stage being positioned to deliver water to said lowermost stage, said last-mentioned means including a water diverter disposed between said condenser stage and said preheating stage for catching water which has passed through said condenser stage while permitting the upflow of gas through said diverter.

4. In gas cleaning apparatus, in combination, a tower including a hot water recirculating stage, a water preheating stage above said recirculating stage and a condenser stage above said water-preheating stage, means for admitting hot gas below the lowermost of said three stages, means for recirculating a mixture of hot water and dirt through said hot water recirculating stage, means for delivering water at the top of said condenser stage, and means for catching water which has passed through said condenser stage and delivering said water under pressure in the form of spray to said water preheating stage, said tower having access for the passage of gas from said gas admitting means to the top of said tower.

5. In gas cleaning apparatus, in combination, a tower including a hot water recirculating stage, a water preheating stage above said recirculating stage and a condenser stage above said water preheating stage, means for admitting hot gas below the lowermost of said three stages, means for recirculating a mixture of hot water and dirt through said hot water recirculating stage, means for delivering water at the top of said condenser stage, and means for catching water which has passed through said condenser stage and delivering said water under pressure in the form of spray to said water preheating stage, said tower having access for the passage of gas from said gas admitting means to the top of said tower, said water catching means including spaced overlapping members which will permit the flow of gas up-

wardly from said water preheating stage to said condenser stage while restricting the flow of water directly from said condenser stage to said water preheating stage.

6. In cleaning apparatus, in combination, a tower, three stages of dust collecting means within said tower, the lowermost of said three stages being a hot water recirculating stage, the intermediate of said three stages being a water preheating stage and the uppermost of said three stages being a condenser stage, means for admitting hot dirty gas to the bottom of said tower and means for discharging gas from the top of said tower, means for recirculating a mixture of dirt and water through said hot water recirculating stage, means for delivering clean water to said condenser stage, means for catching water which has passed down through said condenser stage, and means including a pump for delivering water caught by said water catching means under pressure to said water preheating stage.

7. In cleaning apparatus, in combination, a tower, three stages of dust collecting means within said tower, the lowermost of said three stages being a hot water recirculating stage, the intermediate of said three stages being a water preheating stage and the uppermost of said three stages being a condenser stage, means for admitting hot dirty gas to the bottom of said tower and means for discharging gas from the top of said tower, means for recirculating a mixture of dirt and water through said hot water recirculating stage, means for delivering clean water to said condenser stage, means for catching water which has passed down through said condenser stage, means including a pump for delivering water caught by said water catching means under pressure to said water preheating stage, and pipe means connected to said water catching means for delivering water, independently of said pump, from said water catching means to the bottom of said tower.

8. In apparatus for cleaning gas of a temperature higher than the boiling point of water, a tower, means for admitting gas to the bottom of said tower, means for subjecting said gas to a recirculation of dirty water which has absorbed a portion of the heat from said gas, means disposed intermediate the height of said tower for further treating said gas with water and thereby preheating said water before delivery to said recirculating stage and condenser means above said intermediate stage, means for delivering clean water to said condenser stage, and means for delivering water which has passed through said condenser stage, under pressure, to said intermediate stage.

9. In apparatus for cleaning gas of a temperature higher than the boiling point of water, a tower, means for admitting gas to the bottom of said tower, means for subjecting said gas to a recirculation of dirty water which has absorbed a portion of the heat from said gas, means disposed intermediate the height of said tower for further treating said gas with water and thereby preheating said water before delivery to said recirculating stage, condenser means above said intermediate stage, means for delivering clean water to said condenser stage, and means for delivering water under pressure which has passed through said condenser stage to said intermediate stage, said water delivering means including a water catcher disposed below said condenser stage, said water catcher being capable of passing gas upwardly therethrough.

10. In means for cleaning gas of a temperature above the boiling point of water, a tower, three cleaning stages within said tower, means for admitting hot dirty gas to the bottom of said tower, means for recirculating a mixture of hot water and dirt through the lowermost of said stages, means for applying water under pressure to the intermediate of said stages, which water is adapted to drop down onto the lowermost of said stages, a condenser stage above said intermediate stage, means for applying clean water to said condenser stage, and a diverter for catching water which has passed through said condenser stage and delivering said water under pressure to said intermediate stage.

11. In means for cleaning gas of a temperature above the boiling point of water, a tower, three cleaning stages within said tower, means for admitting hot dirty gas to the bottom of said tower, means for recirculating a mixture of hot water and dirt through the lowermost of said stages, means for applying water under pressure to the intermediate of said stages, which water is adapted to drop down onto the lowermost of said stages, a condenser stage above said intermediate stage, means for applying clean water to said condenser stage, and a diverter for catching water which has passed through said condenser stage and delivering said water under pressure to said intermediate stage, said diverter comprising a plurality of troughs for catching water which has dropped down from said condenser stage but which permits the upward flow of gas through said diverter.

12. In a gas cleaning system, in combination, a gas washing tower, means for admitting hot dirty gases to the bottom of said tower, water sprays for admitting water to said tower at a region above said bottom, means for recirculating water from the bottom of said tower through said sprays, water delivery means for making up losses in said recirculated water, said water delivery means being positioned to deliver water to a region where it will be subjected to gas which has passed through said recirculated water whereby to raise the temperature of the water delivered by said water delivery means, condenser means in said tower, means for delivering clean water to said condenser means, and a water diverter for delivering water which has passed through said condenser means under pressure to said water delivery means.

13. In a gas cleaning system, in combination, a gas washing tower, means for admitting hot dirty gases to the bottom of said tower, water sprays for admitting water to said tower at a region above said bottom, means for recirculating water from the bottom of said tower through said sprays, water delivery means for making up losses in said recirculated water, said water delivery means being positioned to deliver water to a region where it will be subjected to gas which has passed through said recirculated water whereby to raise the temperature of the water delivered by said water delivery means, condenser means in said tower, means for delivering clean water to said condenser means, and a water diverter for delivering water which has passed through said condenser means under pressure to said water delivery means, said diverter comprising a plurality of troughs for catching water which has dropped down from said condenser stage but which permits the upward flow of gas through said diverter.

14. In cleaning apparatus, in combination, a

tower, means for admitting hot dirty gas to the bottom of said tower, means for admitting water to said tower above said gas admitting means, means for drawing off a mixture of dust and water from the bottom of said tower and recirculating a portion of said mixture through said tower in contact with said gas, an upper cleaning stage within said tower in position to receive water from said admitting means, and means for catching water which has passed through said upper cleaning stage and directing it to the bottom of said tower.

15. In cleaning apparatus, in combination, a tower, two stages of cleaning means within said tower, said two stages being disposed one above the other, means for admitting hot dirty gas to said tower below the lower of said two stages, means for drawing off a mixture of dirt and water from the bottom of said tower and recirculating said mixture through the lower of said two stages, means for delivering water to the upper of said stages, and means for catching water which has passed through said upper stage and delivering said water directly to the bottom of said tower.

16. In cleaning apparatus, in combination, a tower, two stages of cleaning means within said tower, one disposed above the other, means for admitting hot dirty gas to said tower below the lower of said two stages, means for drawing off a mixture of dirt and water from the bottom of said tower and recirculating said mixture through the lower of said two stages, means for delivering water to the upper of said stages, and means for catching water which has passed through said upper stage and delivering said water directly to the bottom of said tower, said water catching means being adapted to allow a certain amount of the water from said upper stage to pass therethrough into said lower stage.

17. In gas cleaning means, in combination, a tower, means for admitting gas to the lower portion of said tower, a stage of hurdles within said tower above said gas admitting means, an upper cleaning stage disposed above said lower stage, means for recirculating hot dirty water through said lower stage, means for applying water to said upper stage, a water diverter between said stages, said water diverter including a plurality of troughs for catching water dropping thereon, and a pipe leading from said diverter to a region in close proximity to the bottom of said tower.

18. In gas cleaning means, in combination, a tower, means for admitting gas to the lower portion of said tower, a stage of hurdles within said tower above said gas admitting means, an upper cleaning stage disposed above said lower stage, means for recirculating hot dirty water through said lower stage, means for applying water to said upper stage, a water diverter between said stages, said water diverter including a plurality of troughs for catching water dropping thereon, and a pipe leading from said diverter to a region in close proximity to the bottom of said tower, said water diverter being adapted to pass part of the water from said upper stage directly through said diverter to said lower stage.

19. In gas cleaning means, in combination, a tower, means for admitting hot dirty gas to said tower adjacent to the bottom of said tower, a lower stage of hurdles in said tower located above said gas admitting means, an upper cleaning stage in said tower above said lower stage of hurdles, means for recirculating hot dirty water through said lower stage of hurdles, and a water diverter including water catching means disposed between said stages and having a conduit leading to a point adjacent to the bottom of said tower, said recirculating means including an outlet pipe communicating with said tower at a region spaced a short distance above the outlet of said conduit.

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