

Dec. 13, 1960

O. R. RICE

2,964,304

AUTOMATICALLY ADJUSTED ORIFICE PLATE BLAST FURNACE
GAS CLEANER AND BACK-PRESSURE SYSTEM

Filed Oct. 8, 1958

7 Sheets-Sheet 1

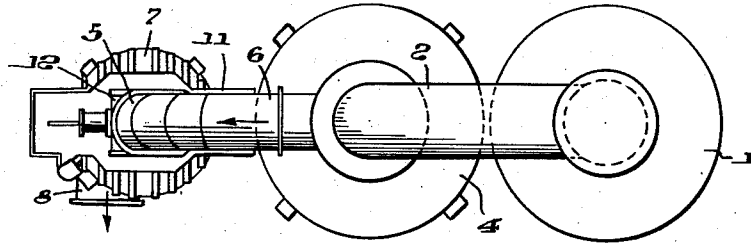


Fig. 2.

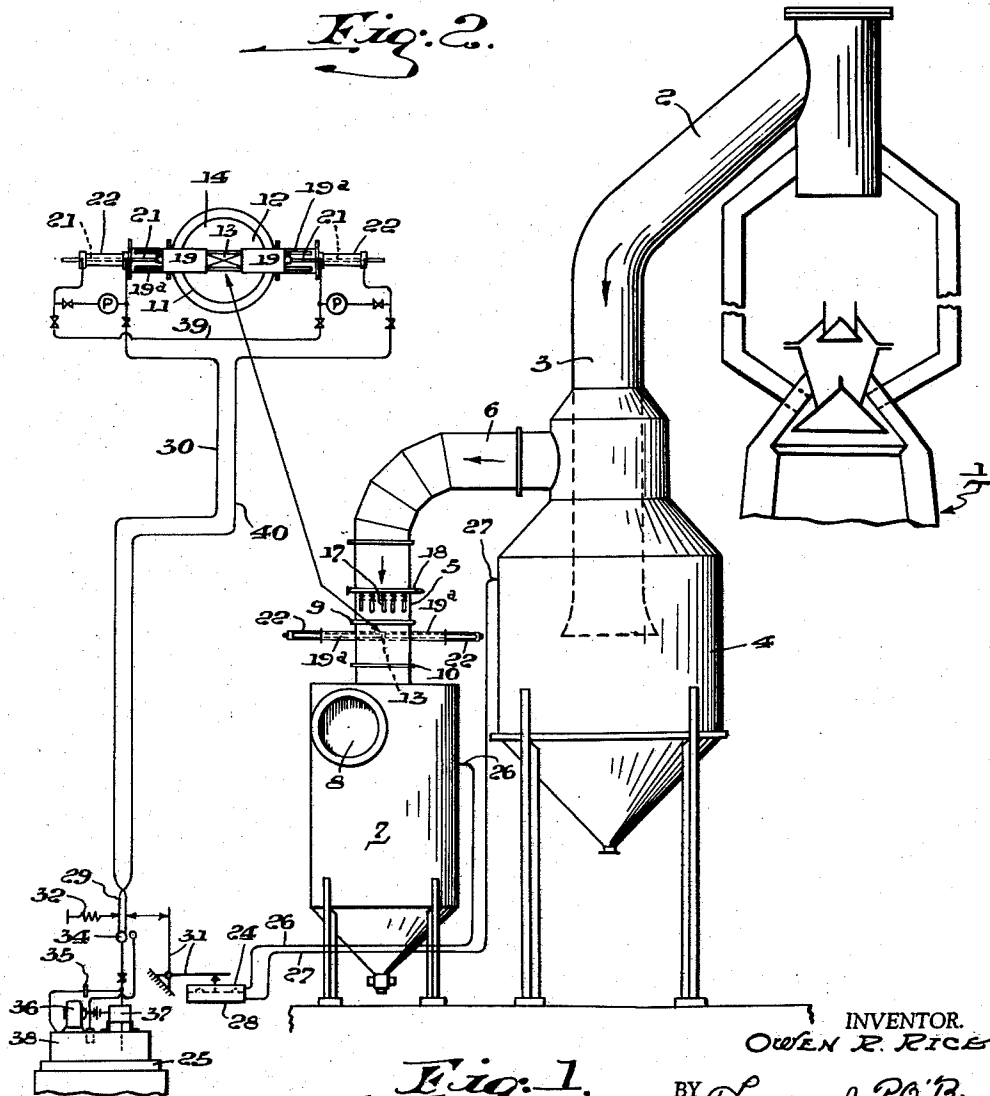


Fig. 1.

INVENTOR.
OWEN R. RICE.

BY Thomas J. P. O'Brien
his ATTORNEY.

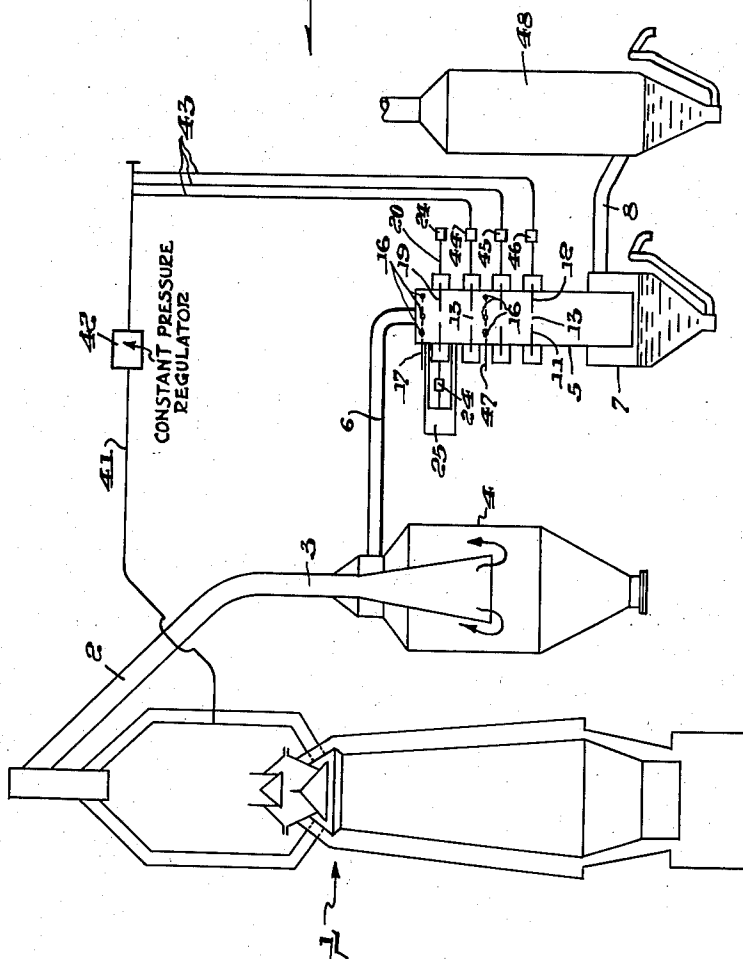
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1958

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Fig: 3.



INVENTOR.
OWEN R. RICE.

BY
Thomas J. PO'Brien.
his
ATTORNEY.

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O. R. RICE

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1250 AUTOMATICALLY ADJUSTED ORIFICE PLATE BLAST FURNACE
GAS CLEANER AND BACK-PRESSURE SYSTEM

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7 Sheets-Sheet 3



INVENTOR.
OWEN P. PRICE.

BY
Thomas J. P. O'Brien
his
ATTORNEY

Dec. 13, 1960

O. R. RICE

2,964,304

AUTOMATICALLY ADJUSTED ORIFICE PLATE BLAST FURNACE
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7 Sheets-Sheet 4

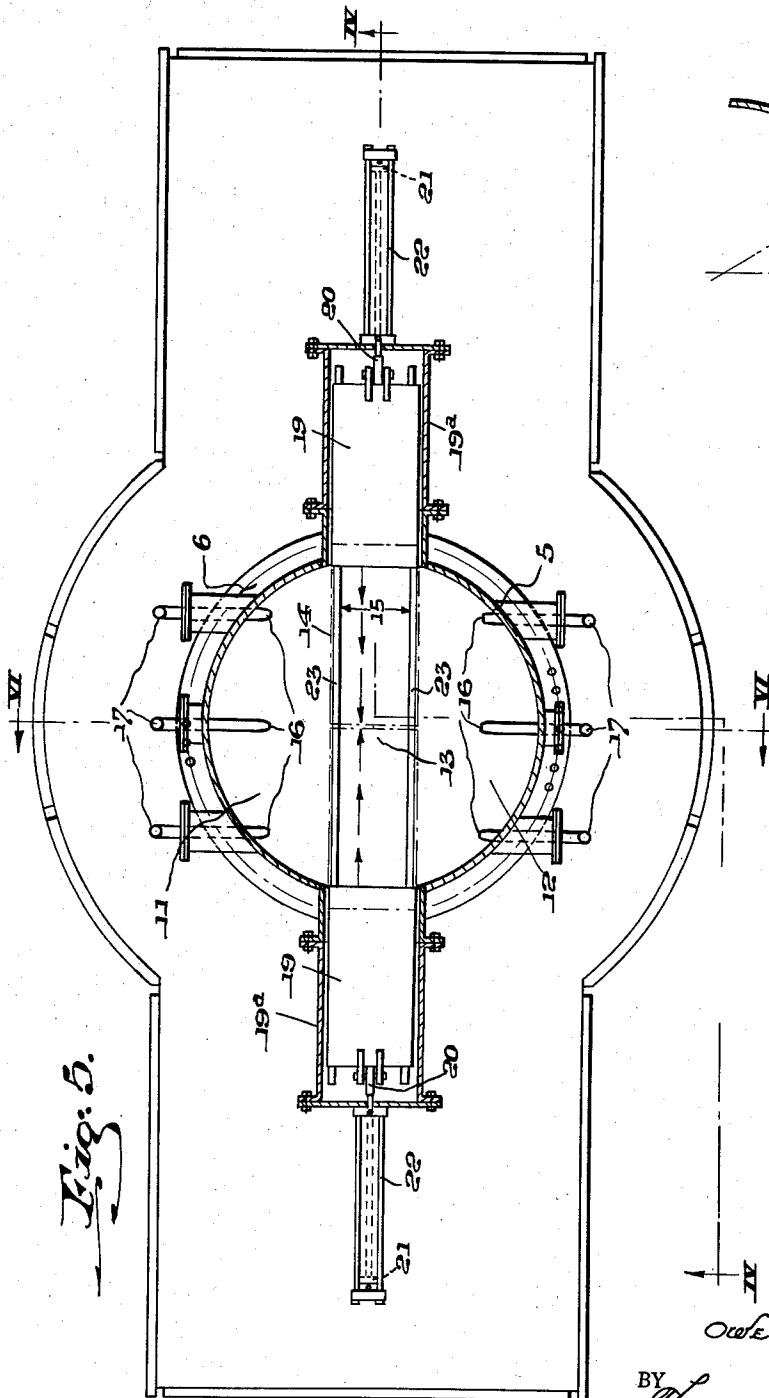


Fig. 5.

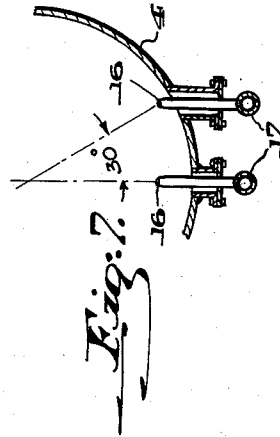


Fig. 7.

INVENTOR.
OWEN R. RICE

BY Thomas J. P. O'Brien.
his ATTORNEY.

Dec. 13, 1960

O. R. RICE
AUTOMATICALLY ADJUSTED ORIFICE PLATE BLAST FURNACE
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7 Sheets-Sheet 5

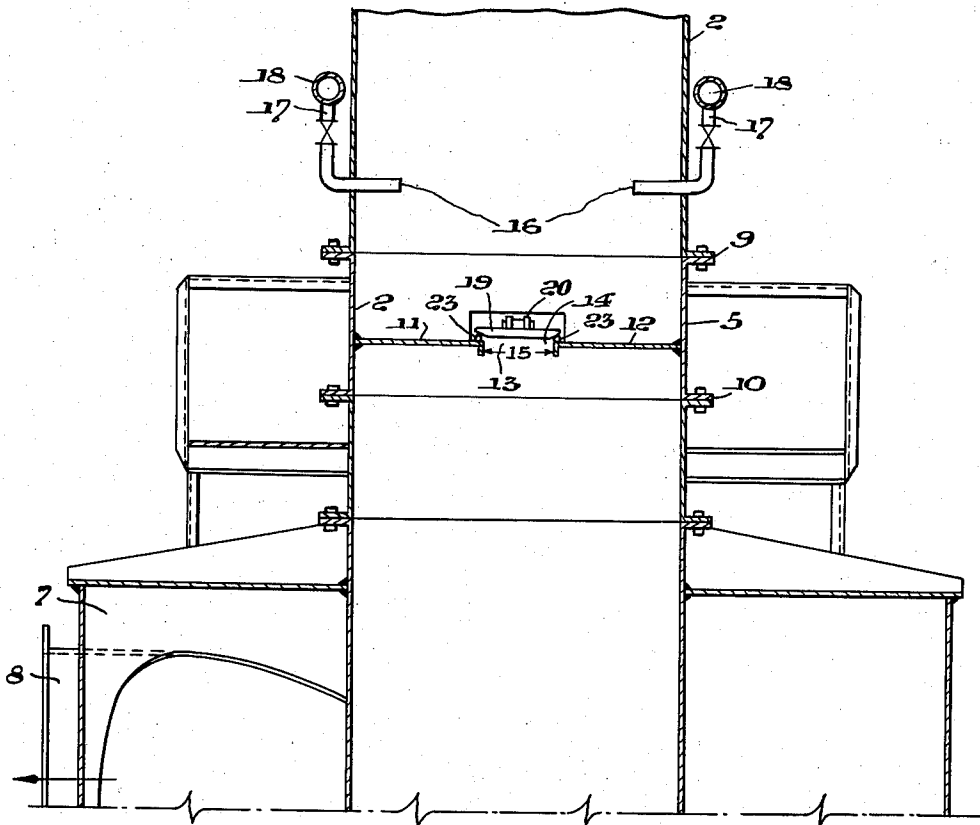


Fig. 6.

INVENTOR.
OWEN R. RICE.

BY
Thomas J. P. O'Brien
his
ATTORNEY.

Dec. 13, 1960

O. R. RICE
AUTOMATICALLY ADJUSTED ORIFICE PLATE BLAST FURNACE
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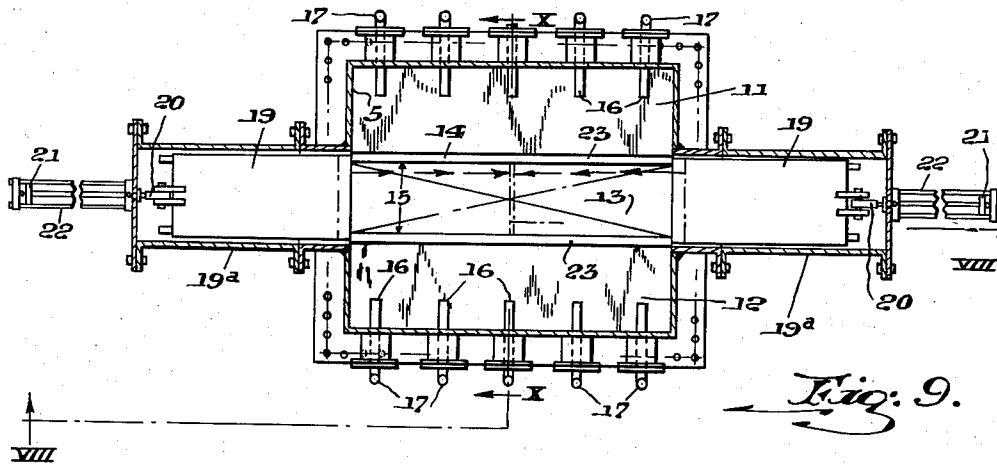


Fig. 9.

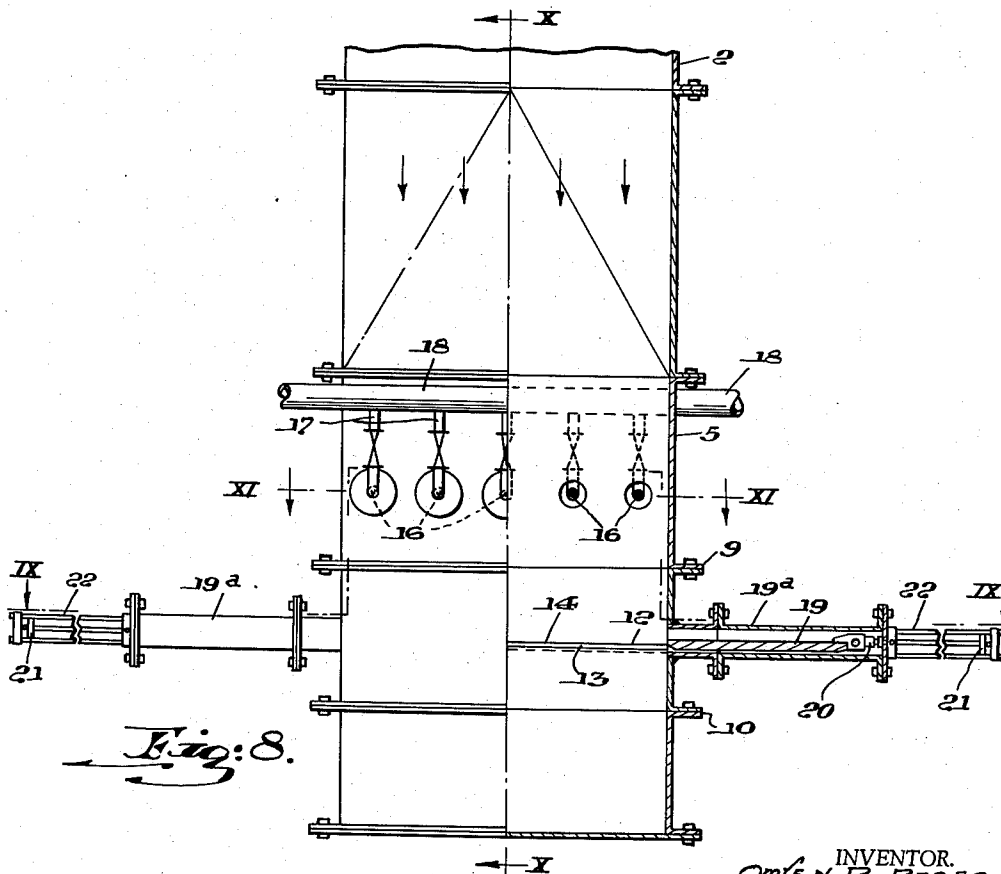


Fig. 8.

INVENTOR.
OWEN R. RICE.

BY Thomas J. P. O'Brien.
his ATTORNEY

Dec. 13, 1960

O. R. RICE
AUTOMATICALLY ADJUSTED ORIFICE PLATE BLAST FURNACE
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7 Sheets-Sheet 7

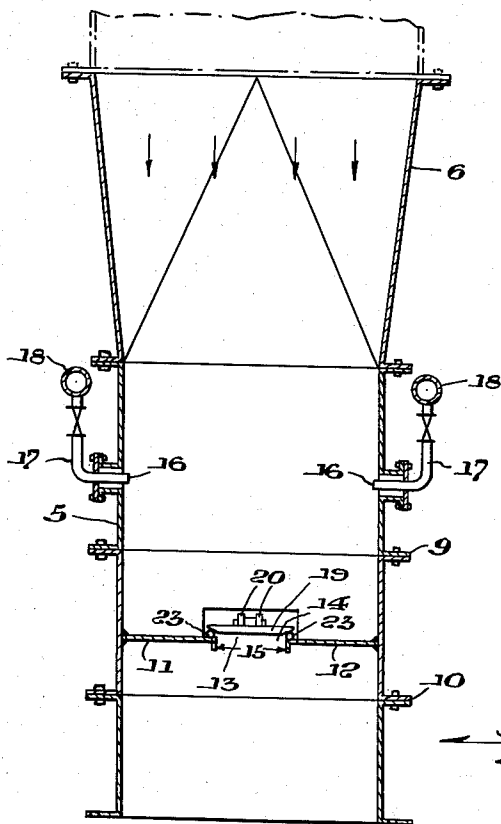
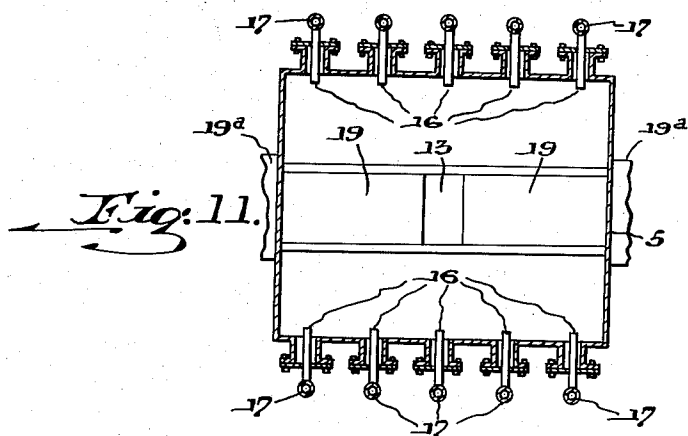


Fig. 10.

INVENTOR.
O. R. RICE

BY
Thomas J. P. O'Brien
his
ATTORNEY

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2,964,304

AUTOMATICALLY ADJUSTED ORIFICE PLATE BLAST FURNACE GAS CLEANER AND BACK- PRESSURE SYSTEM

Owen R. Rice, Pittsburgh, Pa., assignor to Koppers
Company, Inc., a corporation of Delaware

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9 Claims. (Cl. 261-118)

The present invention relates in general to improved apparatus for wet cleaning, and shutting off the flow, of furnace gases by means of orifice gas cleaners employing constrictions in the form of orifice plates. More particularly, the invention relates to improved apparatus for wet cleaning blast furnace gas with equal effectiveness at all the rates of gas flow at which the gases generally issue from such furnaces.

A primary object of the present invention is the provision of a wet orifice gas cleaner apparatus of this general type in which a constant intensity of liquid application is imparted to the gas stream in the orifice, and a constant pressure drop is maintained across the orifice, with varying rates of flow of gas from the furnaces, by automatically increasing and decreasing the size of the orifice by, and in correspondence with, the increase and decrease in rate of gas flow from the furnaces, thereby maintaining the same efficiency of gas cleaning notwithstanding the variations in volume of gas flowing from such metallurgical furnaces.

A further object of the invention is the provision of auxiliary like adjustable wet orifice gas cleaners in conjunction with a furnace top pressure controller for controlling the auxiliary orifices to serve as a furnace back-pressure device while contributing to the cleaning of the gas, thus also eliminating the need for the usual septum valve in a main through which the washed gas is to be passed.

In the wet orifice cleaning of gas, particularly blast furnace gas, one particular procedure has been to pass the gas through a constriction in the normal gas off-flow conduit, such as a Venturi throat or an orifice plate, and at the same time to apply forceful sprays so that the entrained particulate matter traveling in the high velocity gas stream is struck by the water particles in a violent and turbulent manner, thus assuring of their being enveloped and engulfed by the liquid and so removed from the gas. The prior art has taught that the higher the velocity of the gas, the more complete is the removal of particulate matter. Practical considerations put a limit upon the degree of gas velocity, and therefore upon the degree of conduit constriction because of the resulting loss in the static pressure of the gas, or because of the magnitude of back-pressure required to force the gas through the constriction. However, once a rate of gas flow has been established and an acceptable back-pressure or pressure drop has been designated, a constriction of appropriate magnitude is determined, and a certain degree of cleaning of the gas results.

Unfortunately, a Venturi throat, and also an orifice plate as heretofore used are of fixed dimensions, so that a change in the rate of gas flow results in a change in the constrictive effect upon the gas stream. For example, if the rate of gas flow decreases, the constrictive effect of the Venturi throat or the fixed orifice of an orifice plate decreases, and the degree of cleansing of the gas correspondingly decreases. Or, if the rate of gas flow increases, the back-pressure required to force the gas

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through the fixed constriction increases and may cease to be acceptable.

This invention presents an improvement in this art of cleaning gas by passing it through a constriction with the accompanying application of a liquid. This improvement comprises an elongated constriction of constant width and a length initially at least twice the width and of adjustable length as will be hereinafter-described with automatic adjustment of the length of the orifice by and in accordance with the changes in pressure and volume of the gas so as to conform to a wide range of rates of gas flow. This gas controlled adjustability feature also permits or lends itself to putting into effect by the operation of this gas cleaning element a change in the designation of an acceptable gas back-pressure or pressure drop, if so desired.

This feature of the invention is one which also lends itself to operation in a manner that the adjustability may be carried to such an extreme as to make possible also the complete closure of the gas passage thus accomplishing a shut-off of the gas flow as a continuous flow liquid seal which those skilled in the art will recognize as frequently desired in the transmission of gases, and particularly suitable to blast furnace operation.

Still another improvement presented by this invention resides in the rectangular shape of the constriction. Heretofore the constrictions employed, for instance, an orifice in a plate, usually have often been circular; the liquid sprays being located peripherally and directed generally toward the center. This arrangement is more satisfactory where a relatively small rate of gas flow is involved and where, in consequence, the constriction is of relatively small size. However, where a higher rate of gas flow is involved and where, in consequence, the constriction is of relatively large size, the situation is not entirely satisfactory. In such case, the central core area or region of the gas stream does not enjoy the same intensity of the liquid application or the same degree of cleansing as do area portions or regions of the gas stream nearer the periphery of the constriction and consequently nearer the origin of the sprays. This invention presents a rectangular constriction of constant width, more particularly a constriction that is considerably larger in one direction than in the other at 90 degrees thereto; in other words, a slot-like constriction of greater length than width. The sprays are arranged in a rank on either of the longer sides of the slot, the rank on one side being directed generally toward the rank on the opposite side. Thus, where the equipment is designed for a large rate of gas flow as compared to a small rate of gas flow, the length of the slot is merely increased, the width of the slot remaining the same. Thus there is no greater central core area or region of gas stream in a large installation than in a small one. Thus the cross-sectional area of the different volumes of the gas stream receives the same spray treatment and the same degree of cleansing where a high rate of gas flow is involved as where a small rate of gas flow is involved.

It is often desirable in blast furnace practice to introduce a back-pressure device in the gas main system for off-flow of gas from the top of a blast furnace so as to increase the pressure of reagent gases within the furnace. A group of butterfly valves, called a septum valve, is commonly used as the back-pressure device. The septum valve is commonly located in a part of the main through which gas that has already been washed is passed, to avoid the erosion which would result from exposing butterfly discs to dust-laden gas.

Accordingly, the present invention further provides the combination of the aforesaid adjustable orifice gas cleaner under control of the rate of flow of the gas and a back-pressure device comprising auxiliary-like orifice

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gas cleaners under control of the pressure of the gas at the top of the blast furnace in which the back-pressure device also jointly contributes to cleaning the gas.

Other objects and advantages of the invention will be apparent as it is better understood from the following description when considered in connection with the accompanying drawings illustrating the best mode of practicing the same:

Figure 1 is a schematic side elevational view of a part of the gas main embodying the present invention for off-flow of gas from the top of a blast furnace, with the auxiliary back-pressure orifice gas cleaners omitted;

Figure 2 is a top plan view of the portion shown in Figure 1;

Figure 3 is a view similar to Figure 1 but showing the auxiliary back-pressure orifice gas cleaners in coactive conjunction with the gas-volume-controlled wet orifice cleaner shown in Figure 1;

Figure 4 is an enlarged elevational view, with parts in section, of the orifice mechanism shown in Figure 1 showing the application of the invention to circular ducts, the view being also taken on line IV—IV of Figure 5;

Figure 5 is a horizontal sectional view taken on the line V—V of Figure 4;

Figure 6 is a vertical sectional view taken on line VI—VI of Figures 4 and 5;

Figure 7 is a horizontal sectional detail view of a part of Figure 4;

Figure 8 is an enlarged elevational view of the orifice mechanism shown in Figure 1, with parts in cross-section to show the application of the invention to rectangular orifices, the view being also taken on the line VIII—VIII of Figure 9;

Figure 9 is a horizontal sectional view taken on the line IX—IX of Figure 8;

Figure 10 is a vertical sectional view taken on the line X—X of Figures 8 and 9;

Figure 11 is a horizontal sectional view taken on the line XI—XI of Figure 8.

The same reference numerals are used for like parts in each of the several views.

Referring to Figures 1 and 2 in the main gas conduit 2 which is communicable with a source of gas to be cleaned, and more particularly, the top of a blast furnace 1, as shown in Figures 1 and 4, there is provided for off-flow of the hot furnace gases a downcomer conduit 3 which discharges the gas into a dust catcher 4 and from which the gas then passes out through a vertical section 5 of a branch 6 of the main gas conduit 2. From this upright conduit section 5 the gas then flows to a water separator 7 and thence by way of outlet 8 to the rest of the system wherein the usual septum valve (not shown) is generally contained for regulating the back-pressure on the source of gas, such as the top 1 of the blast furnace. The upright conduit section 5 is connected to the rest of the branch 6 between the dust catcher and the water separator 7 by flanges 9 and 10. This upright section 5 has mounted therein across the path of flow of gas there-through a pair of oppositely disposed plates 11 and 12 spaced to form between them an orifice 13 of greater length 14 than width 15 and of constant width throughout the length of the orifice. As shown, the orifice is preferably rectangular and initially of a length 14 at least twice the width 15 of the orifice.

The liquid for wetting and scrubbing is introduced to the gas in the conduit portion above the plates 11 and 12 and orifice 13 by means of spray heads 16 on valved branch pipes 17 from a header 18.

The effective cross-sectional area of the orifice 13 is adjustable by means of contractable and retractable orifice closure parts in the form of oppositely disposed sliding panels 19 mounted to move to and from each other over the orifice 13, to decrease and increase its effective length for passage of gas. Each panel 19 is also

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slidable into and out of a housing 19a respectively on diametrically opposite sides of the conduit section 5, and each is provided with a stem 20 operable by a piston 21 in an hydraulic cylinder 22 for operation of the panels to change the open area of the orifice 13 by and in accordance with changes in the rate of gas flow from the furnace source, to maintain the same drop in pressure across the orifice with each variation in volume of flow of gas out of the furnace.

Each of these sliding panels 19 and their stems 20 are of sufficient length to reach the center line of the conduit section 5, which position effects a complete closure of the orifice 13 to completely shut off the through flow of gas. The orifice 13 is lined along its longer sides above the top plane of the plates 11 and 12 with cylindrical bearing surfaces 23 which support the beveled sides of the panels 19. When it is desired to shut off the through flow of gas, the panels 19 are slid into the centerline of the section 5. To further seal off the gas flow, the spray heads 16 are operated to continue to supply liquid thus building up a liquid seal on the plates 11 and 12 to a depth reaching an overflow seal (not shown), thus effecting a completely gas tight closure. The overflow may be carried by the overflow seal (not shown) in the side wall of the section 5, but preferably this overflow may be effected by limiting the extent of inward movement of the panels 19 to leave a small opening for continuous drainage of the liquid during a gas shut off period.

In Figures 4 to 7 the invention is applied to a gas main system with a circular duct with the orifice plate system above-described therein.

In Figures 8 to 11, the invention is applied to a gas main system 2 with the scrubbing effected with the section 5 in the nature of a rectangular duct. As shown, the conduit section of the part of the main 2 ahead of the section 5 is converged toward the rectangular upright section 5 and this upright section 5 discharges into the larger area of the water separator chamber portion 7 of the gas main system 2. The cross-section of the orifice 13 containing gas conduit section 5 is rectangular thus providing the advantages of the combined effects of the action on the gas in a rectangular duct and the novel features of the present improvement.

In accordance with a further feature of the invention, the panels 19 are automatically operated through their pistons 21 by power operators responsive to changes in the rate of gas flow to the orifice 13 so as to maintain automatically a pre-set pressure drop in the orifice 13 with all rates of gas flow from the furnace source 1. To this end conventional regulator means 24 are employed operable by, and in accordance with fluctuations in the rate of flow of gas from the blast furnace, to actuate the pistons 21 for control of pressure drop in the orifice 13 and in accordance with any change in the rate of flow of gas to the orifice from the furnace source 1. Such regulator means 24 are interconnected to known or conventional actuating means 25 to operate the same whereby the actuating means 25 actuates the piston 21 to move the panels 19 in the direction and to the extent to adjust the panels 19 to a position to maintain the orifice area 13 such that the pressure drop in the orifice remains constant notwithstanding the change in rate of flow of gas from the furnace source 1 to the orifice plates 11 and 12.

As shown in Figure 1, the regulator 24 is of the type having impulse lines 26, 27 leading from points in the main at the dust catcher 4 and at the water separator 7 on opposite sides of the orifice plates 11 and 12 to the opposite sides respectively of a diaphragm 28. The diaphragm operates an actuating means 25 comprising a jet pipe 29 which controls a hydraulic circuit 30, 40 to reverse the direction of hydraulic fluid. As shown, the system comprises a lever system 31, counterspring 32, jet pipe oil supply 34, relief valve 35, motor 36, pump 37 and tank 38. When the rate of flow of gas from the blast furnace drops, impulse line 26 from the water separator

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rator 7 after the orifice 13, actuates the jet pipe 29 to flow oil to line 40 and open line 30 to discharge. When the rate of gas flow increases, impulse line 27 from the dust catcher 4 before the orifice 13 actuates the jet pipe to flow oil to line 30 and discharge oil from line 40.

Movement of oil in line 40 toward the cylinders 22 results in a closing movement of the panels 19, and movement of oil in line 30 toward the cylinders 22 effects an opening movement of the panels 19. Line 40 is connected with the right-hand cylinder, Figure 1, at its outer end that is remote from its panel 19 and line 30 is connected with the left-hand cylinder at its inner end that is closest to its panel 19. The outer end of the left-hand cylinder is connected by a closed oil line 39 with the inner end of the left-hand cylinder. This effects movement of the panels to and from each other in unison.

Referring to Figure 3, to accomplish blast furnace gas cleaning as above-described, the pressure drop across the orifice 13 may be in the category of 2 pounds per square inch. For combined further cleaning and control of the back-pressure at the source 1 of the gas, as in the blast furnace, auxiliary orifice plates 11, 12 with an orifice 13 therein under control of panels 19 as above-described are employed in series 44, 45, 46 after the orifice 13 that is controlled in accordance with the rate of gas flow. However, these auxiliary orifices are instead adjusted by, and in accordance with, the change in pressure of the source of the gas at the top 1 of the blast furnace, rather than in accordance with the rate of flow of the gas.

To this end, a pressure impulse line 41 actuates a conventional constant pressure regulator 42 which actuates through lines 43 actuators of the same type 25 above-described for operation of the cylinder 22 for the panels 19 for the auxiliary orifices 44, 45, 46 to control the furnace top 1 pressure in lieu of the aforesaid usual septum valve. In this manner, these members 44, 45, 46 jointly contribute to the cleaning of the gas as well as providing the necessary regulated back-pressure required to maintain a predetermined pressure back in the source of the gas, such as the top of the blast furnace, in lieu of said septum valves.

The auxiliary orifices 44, 45, 46 are so positioned downstream from the aforesaid rate of flow controlled orifice cleaner as to re-use water from the same and its spray heads together with possible additional water introduced below the same at 47.

The pressure drop across the orifices of members 44, 45, 46 is also regulated to be in the category of 2 pounds per square inch per orifice. The number of orifices is not limited to four as shown but can be more or less depending upon the total pressure drop or back-pressure desired at the source 1, such as at the top of the blast furnace.

In operation, the gas after scrubbing in upright section 5 passes to the water and moisture separator 7, thence to a cooling tower 48 to storage or use, in accordance with common practice.

It is quite practicable to apply the power operators to adjust the constriction of the orifices as previously disclosed, so that the first orifice is automatically adjusted by the rate of flow of the gas to maintain a pressure drop corresponding to the minimum degree of gas cleaning desired. The constrictions of orifices 44, 45, and 46 are then automatically adjusted by changes in the source pressure to maintain the total back-pressure desired, while each of their constrictions improves the degree of gas cleaning.

The power operators for orifices 44, 45, and 46 are controlled, in series or in parallel, from a conventional furnace top pressure controller. The furnace top pressure controller is set by the furnace operator, who can reduce the furnace top pressure to "normal" about 2 p.s.i.g. during the casting of the furnace or at other

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times, without prejudice to the minimum degree of gas cleaning established by the setting of the orifice of the first gas cleaner.

The invention is herein-above set forth as embodied in particular forms and manner but may be variously embodied within the scope of the claims as hereinafter made.

I claim:

1. Blast furnace gas cleaning apparatus, comprising:
 10 a gas main connected with the top of a blast furnace for off-flow of top furnace gas therefrom having an upright conduit section with a rate-of-flow controlled constricted orifice therein of greater length than width and of constant width throughout the length thereof; means for supplying cleaning liquid to said conduit section for flow with the gas through said orifice; oppositely disposed orifice closing panels mounted for movement toward and from each other lengthwise of the length of said rate-of-flow orifice for varying the effective length of the free area of said orifice; manipulating means for manipulating said panels in their movements toward and from each other; actuating means for actuating the manipulating means in accordance with changes in rate of flow of gas from said furnace top to said orifice to maintain a predetermined constant pressure drop across the orifice notwithstanding variation in the rate of gas flow; regulating means responsive to changes in the pressure differential across said orifice and operatively connected with said actuating means for regulating the operation of said actuating means by, and in accordance with, changes in rate of gas flow through said orifice; a back-pressure regulating constricted orifice in series in said conduit section with said rate of flow constricted orifice and likewise of greater length than width and of constant width throughout the length of the orifice; oppositely disposed orifice closing panels mounted for movement toward and from each other lengthwise of the length of said back-pressure orifice for varying the effective length of the free area of the same; manipulating means for manipulating said panels in their movements toward and from each other; actuating means for actuating the manipulating means in accordance with changes in the gas pressure at the top of the blast furnace to maintain a predetermined back-pressure therein; and regulating means responsive to changes of the top furnace gas pressure and operatively connected with said actuating means for regulating the operation of the actuating means for the panels for the back-pressure orifice by, and in accordance with, changes in gas pressure at the top of the blast furnace.

2. Apparatus as claimed in claim 1, and in which said constricted orifices are each of rectangular configuration.

3. Apparatus as claimed in claim 1, and in which said constricted orifices each are of a length at least twice their widths.

4. Blast furnace gas cleaning apparatus, comprising: a gas main connected with the top of a blast furnace for off-flow of top furnace gas therefrom having an upright conduit section with a rate-of-flow controlled constricted orifice therein of greater length than width and of constant width throughout the length thereof; means for supplying cleaning liquid to said upright conduit section for flow with the gas through said orifice; oppositely disposed orifice closing panels mounted for movement toward and from each other lengthwise of the length of said rate-of-flow orifice for varying the effective length of the free area of said orifice; manipulating means for manipulating said panels in their movement toward and from each other; actuating means for actuating the manipulating means in accordance with changes in rate of flow of gas from said furnace top to said orifice to maintain a predetermined constant pressure drop across the orifice notwithstanding variation in the rate of gas flow; regulating means responsive to changes in the pressure differential across said orifice and operatively connected with said actuating means for regulating the operation of

said actuating means by and in accordance with changes in rate of gas flow through said orifice.

5. Blast furnace gas cleaning apparatus, comprising: a gas main connected with the top of a blast furnace for off-flow of top furnace gas therefrom having an upright conduit section; means for supplying cleaning liquid to said upright conduit section for flow with the gas through said orifice; a back-pressure regulating constricted orifice in said conduit of greater length than width and of constant width throughout the length of the orifice; oppositely disposed orifice closing panels mounted for movement toward and from each other lengthwise of the length of said back-pressure orifice for varying the effective length of the free area of the same; manipulating means for manipulating said panels in their movements toward and from each other; actuating means for actuating the manipulating means in accordance with changes in the gas pressure at the top of the blast furnace to maintain a predetermined back-pressure therein; and regulating means responsive to changes of the top furnace gas pressure and operatively connected with said actuating means for regulating the operation of the actuating means for the panels for the back-pressure orifice by and in accordance with changes in gas pressure at the top of the blast furnace.

6. Gas cleaning apparatus, comprising: a gas main connectable with a source of gas for off-flow of gas therefrom having an upright conduit section with a rate-of-flow controlled constricted orifice therein of greater length than width and of constant width throughout the length thereof; means for supplying cleaning liquid to said conduit section for flow with the gas through said orifice; oppositely disposed orifice closing panels mounted for movement toward and from each other lengthwise of the length of said rate-of-flow orifice for varying the effective length of said orifice; manipulating means for manipulating said panels in their movements toward and from each other; actuating means for actuating the manipulating means in accordance with changes in rate-of-flow of gas from the source to said orifice to maintain a predetermined constant pressure drop across the orifice notwithstanding variations in the rate of gas flow; regulating means responsive to changes in the pressure differential across said orifice and operatively connected with said actuating means for regulating the operation of said actuating means by, and in accordance with, changes in rate of gas flow through said orifice; a back-pressure regulating constricted orifice in series in said conduit section with said rate of flow constricted orifice and likewise of greater length than width throughout the length of the orifice; oppositely disposed orifice closing panels mounted for movement toward and from each other lengthwise of the length of said back-pressure orifice for varying the effective length of the same; manipulating means for manipulating said panels in their movements toward and from each other; actuating means for actuating the manipulating means in accordance with changes in the gas pressure at the source to maintain a predetermined back-pressure therein; and regulating means responsive to changes of the source gas pressure and operatively connected with the actuating means for regulating the operation of the actuating means for the panels for the back-pressure orifice by and in accordance with changes in gas pressure at the source.

7. Gas cleaning apparatus, comprising: a gas main connectable with a source of gas for off-flow of gas therefrom having a conduit section with a rate-of-flow controlled constricted orifice therein of greater length than width and of constant width throughout the length thereof; means for supplying cleaning liquid to said conduit section for flow with the gas through said orifice; oppositely disposed orifice closing panels mounted for movement toward and from each other lengthwise of the length of said rate-of-flow orifice for varying the effective length of said orifice; manipulating means for manipulating

ing said panels in their movements toward and from each other; actuating means for actuating the manipulating means by, and in accordance with, changes in rate of flow of gas from the source to said orifice to maintain a predetermined constant pressure drop across the orifice notwithstanding variations in the rate of gas flow; regulating means responsive to changes in the pressure differential across said orifice and operatively connected with said actuating means for regulating the operation of said actuating means by, and in accordance with, changes in rate of gas flow through said orifice.

8. Gas cleaning apparatus, comprising: a gas main connectable with a source of gas for off-flow of gas therefrom having a conduit section with a back-pressure regulating constricted orifice in said conduit section of greater length than width and of constant width throughout the length of the orifice; means for supplying cleaning liquid to said conduit section for flow with the gas through said orifice; oppositely disposed orifice closing panels mounted for movement toward and from each other lengthwise of the length of said back-pressure orifice for varying the effective length of the same; manipulating means for manipulating said panels in their movements toward and from each other; actuating means for actuating the manipulating means by, and in accordance with, changes in the gas pressure at the source to maintain a predetermined back-pressure therein; and regulating means responsive to changes of the source gas pressure and operatively connected with the actuating means for regulating the operation of the actuating means for the panels for the back-pressure orifice by, and in accordance with, changes in gas pressure at the source.

9. Blast furnace gas cleaning apparatus, comprising: a gas main connected with the top of a blast furnace for off-flow top furnace gas therefrom having a conduit section with a rate-of-flow controlled constricted orifice therein; means for supply of cleaning liquid to said conduit section for flow with the gas through said orifice; contractable and retractable orifice closing parts for said rate-of-flow orifice for varying the effective area of said orifice; manipulating means for manipulating said parts; actuating means for actuating the manipulating means by, and in accordance with, changes in rate of flow of gas from said furnace top to said orifice to maintain a predetermined constant pressure drop across the orifice notwithstanding variations in the rate of gas flow from said furnace top; regulating means responsive to changes in the pressure differential across said orifice and operatively connected with said actuating means for regulating the operation of said actuating means by, and in accordance with, changes in the rate of flow of gas through said orifice; a back-pressure regulating constricted orifice in series in said conduit section with said rate-of-flow constricted orifice; contractable and retractable orifice-closing parts for varying the effective length of the free area of said back-pressure orifice; manipulating means for manipulating said parts; actuating means for actuating the manipulating means by, and in accordance with, changes in gas pressure at the top of the blast furnace to maintain a predetermined back-pressure therein; and regulating means responsive to changes in the gas pressure at the top of the blast furnace and operatively connected with said actuating means for regulating the operation of said actuating means by, and in accordance with, changes in the gas pressure at the top of said blast furnace.

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