

Feb. 16, 1971

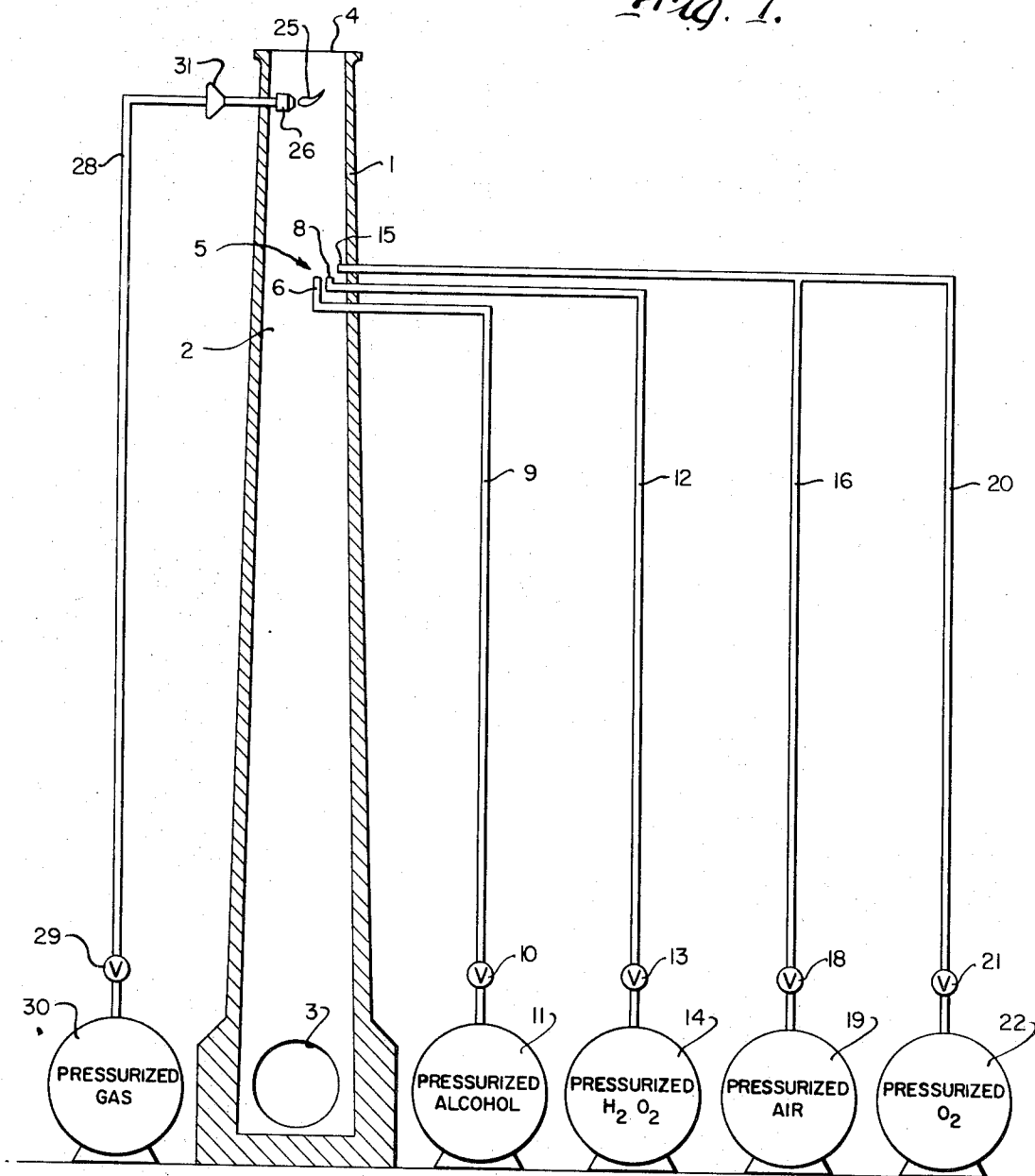
R. F. DE CASTRO
SMOKE ABATEMENT PROCESS

3,563,697

Filed Oct. 13, 1969

2 Sheets-Sheet 1

Fig. 1.



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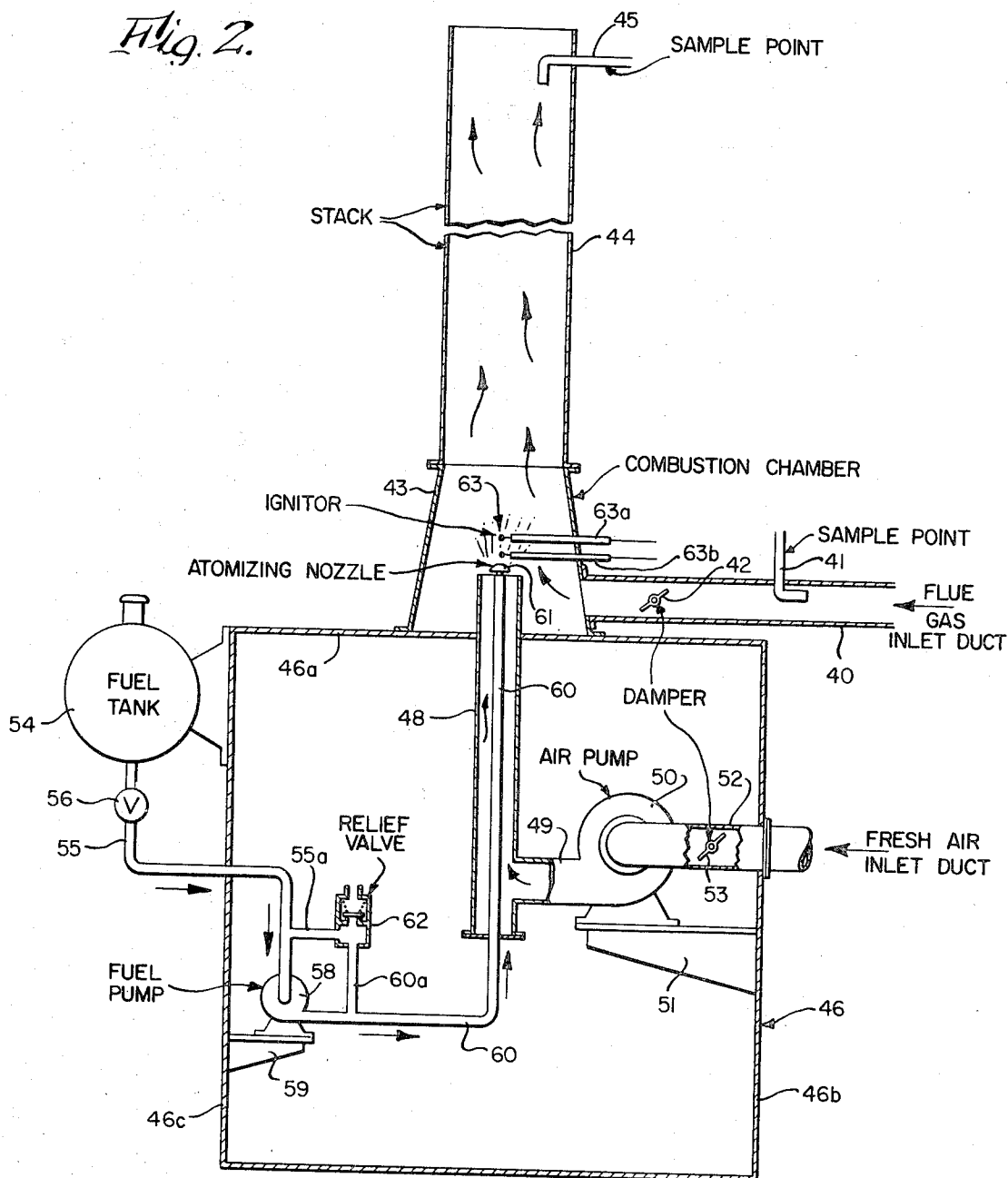
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2 Sheets-Sheet 2

Fig. 2.



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SMOKE ABATEMENT PROCESS

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Continuation-in-part of application Ser. No. 558,018, June 16, 1966. This application Oct. 13, 1969, Ser. No. 865,555

Int. Cl. B01d 53/34

U.S. Cl. 23—2

9 Claims

ABSTRACT OF THE DISCLOSURE

A process of eliminating noxious elements from a confined stream of smoke before being discharged from an outlet into the atmosphere, includes injecting an oxidizing agent and a monohydric alcohol containing not more than four carbon atoms into the confined stream to insure mixture of the noxious elements with the oxidizing agent and alcohol, and igniting such mixture to consume the noxious elements.

This application is a continuation-in-part of my co-pending application Ser. No. 558,018, entitled Method of Eliminating Noxious Elements From a Stream of Smoke, filed June 16, 1966, and now abandoned.

This invention relates to improvements in smoke abatement processes, and more particularly to a new and improved process or method of eliminating, removing or abating noxious elements from a gaseous atmosphere, such as a confined stream of smoke before being discharged through a conduit such as a flue, stack, chimney, or an automotive exhaust pipe, preferably but not necessarily through an open end thereof into the atmosphere. By smoke is meant the gaseous products of combustion or other physical and/or chemical reaction, whether or not made visible by the noxious elements therein. By noxious elements is meant those products of combustion or other physical and/or chemical reaction which cause noxious air pollution to some degree and can produce effects which are noticeably harmful to people, animal and plant life, and which, while excluding certain products such as water, stable oxides and completely burned ash, include a wide variety of substances, whether in liquid, gaseous or solid form, whether normally visible or invisible, and whether chemically referred to as elements or mixtures or compounds thereof, such as carbon monoxide, oily particles, soot, incompletely burned ash, sulfur compounds, hydrocarbons, oxides of nitrogen and the like.

A primary object is to provide a low cost process which reduces such noxious elements to an acceptable level by means which forms at least part of or can be readily installed in or on a conduit such as a chimney or automotive exhaust pipe and operates reliably to effect admixture of the active ingredients with the noxious elements of the smoke, as well as reaction therebetween, preferably by ignition and combustion thereof, to consume the noxious elements. Other objects are to provide such method which does not substantially alter or change the normal course of the smoke as it travels through the conduit wherein the reaction occurs, does not impede the flow of the smoke by passing it through any mechanical structures, does not compress, force, or substantially change the course of the smoke in any way, and does not use any solid catalysts.

I have found that by introducing a monohydric alcohol, (R—OH) preferably one having not more than about four carbon atoms, such as ethyl or methyl alcohol, because of cost, into a gaseous atmosphere, such as a confined stream of smoke traveling in normal manner as by

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rising up through a chimney or stack type conduit toward the open top end thereof, along with an oxidizing agent in such a manner as to insure intimate mixture thereof and by causing a reaction between such noxious elements, alcohol and oxidizing agent, preferably by igniting such mixture, the noxious elements of the smoke are consumed or reduced to an acceptable level before being discharged, preferably into the atmosphere, although a closed receptacle could be used. The oxidizing agents which have been found adequate include hydrogen peroxide or pure oxygen propelled or injected into the confined stream of smoke by means of compressed air, which also may be used by itself. I have found that such injection produces an effective mixture so that ignition thereof will effect the desired elimination of noxious elements. Water can be used to slow down the process, and the amount of water in the aqueous solution of alcohol, and hydrogen peroxide, if used, will have such a slowing down effect. Normally, not more than 90% aqueous solution of alcohol would be used.

FIG. 1 is a diagrammatic representation of a chimney equipped with apparatus for carrying out my inventive process, particularly as applied to abatement of smoke from a coal burning furnace.

FIG. 2 is a diagrammatic representation of another and more preferred apparatus for carrying out my inventive process, particularly as applied to the abatement of smoke from a nitric acid plant.

Referring now to FIG. 1, chimney 1 has a flue 2 leading from a furnace duct 3 to an open upper end 4 through which the products of combustion are discharged into the atmosphere. At a distance down from the open upper end 4, preferably not less than about 3 feet or a workable distance is an injector 5 comprising one or more nozzles for the liquid agents and one or more nozzles for the gaseous agents. As shown, the injector has a nozzle 6 arranged to discharge an aqueous solution of alcohol and a nozzle 8 arranged to discharge an aqueous solution of hydrogen peroxide upwardly into the flue 2 at one side thereof. The nozzle 6 can be supplied with ethyl or methyl alcohol via a line 9 containing a valve 10 from a pressurized source 11 of such alcohol solution. The nozzle 8 can be supplied with hydrogen peroxide via a line 12 containing a valve 13 from a pressurized source 14 of such hydrogen peroxide solution. The gas nozzle 15 of the injector 5 is shown as arranged to discharge compressed gas against the outlet ends of nozzles 6 and 8 so as to form the liquids issuing therefrom into a fine mist so as to condition the liquid for intimate mixture with the incompletely burned solid and gaseous phases of the smoke. This nozzle 15 can be supplied with air via a line 16 containing a valve 18 from an air pressure source 19. Alternatively or concurrently, this nozzle 15 can be supplied with oxygen in purer form than in air via a line 20 containing a valve 21 from an oxygen pressure source 22. Obviously, the injector 5 can take many forms and the particular agents used will depend on cost and availability.

The apparatus also includes a pilot or ignitor shown as being in the form of a flame 25 from a burner 26 in the flue 2 above the injector 5. This burner 26 can be supplied with gas, with or without air via a line 28 containing a valve 29 from a pressurized gas source 30. A conventional air mixer 31 can be used to supply the air necessary for maintaining the flame 25. Desirably the flame 25 is about twenty-five feet or a workable distance above the injector 5 and about 3 feet or a workable distance below the open top 4 of the chimney so as to both permit proper mixture of the oxidizing agents and alcohol with the incompletely consumed constituents of the smoke, and also to insure that the flame 25 will not be blown out by atmospheric wind currents or downdrafts.

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In use, the smoke from the furnace duct 3 with incompletely consumed solid and gaseous noxious phases or elements, such as carbon monoxide, oily particles, soot, incompletely oxidized sulfur compounds and incompletely oxidized fly ash, travels as a confined stream up the flue 2 of the chimney 1. On passing the injector 5, the compressed air or oxygen from the nozzle 15 is directed against the nozzles 6 and 8 to force the alcohol and any hydrogen peroxide issuing therefrom toward the center of the flue 2 as a fine mist which is quickly sorbed or occluded by the unburned or partly oxidized noxious components or elements of the smoke. These components, so loaded with both alcohol and also loaded with or being in the presence of one or more oxidizing agents then travel into contact with the flame 25 as an intimate mixture. Immediate ignition takes place, the alcohol combined with the reduced and partly oxidized components of the smoke as well as with the oxidizing agent or agents, providing an intimate mixture which continues reduction and oxidation of the smoke components to such extent as to render them acceptable to be discharged into the air.

In actual practice, if the results are not adequate, more alcohol and/or oxidizing agents are used. If too much alcohol is used, the level of active combustion will lower to the injector 5, die out, and reignite when a fresh mixture reaches the pilot flame 25, this resulting in an easily detectable pulsating combustion which the operator can correct by reducing the alcohol supplied. If too little alcohol is used, the smoke will bear a corresponding quantity of visible unburned particles. The level of combustion is that which admixture of the alcohol, oxidizing agent and noxious elements is complete and will stay at the equilibrium level until a change occurs, such as increased draft, which will raise the level.

In an actual installation where soft coal was used to generate 60 kw. of electricity from soft coal by means of a boiler and steam engine, the metal stack 1 was 47 feet high and had an inside diameter of about 18 inches. The pilot flame 25 was 3 feet from the open top 4 of the chimney and was served with butane gas. The injector 5 was placed about twenty-five feet below the flame 25. Air from 19 and a small amount of oxygen from 22 was used at about 60 p.s.i., the air constituting about 90% of the gas discharged from 15 across the top of the nozzle 6 from which a 20% to 50% aqueous ethyl alcohol solution was discharged, the supply line 9 having a one-eighth inch inside diameter. At a cost of about \$8.00 a month, the smoke was rendered unobjectionable.

Turning to FIG. 2, the apparatus diagrammatically shown therein is particularly adapted for use in carrying out the inventive process as applied to removing the various noxious oxides of nitrogen from smoke emanating from a tail or flue gas stack of a nitric acid plant (not shown), and includes a flue gas inlet duct 40 leading from such tail gas stack (not shown) and provided with a conventional sample extracting tube device 41 and an adjustable damper 42. The outlet end of duct 40 is connected to a combustion chamber 43 supporting the lower end of a stack or flue 44 which is provided adjacent its upper end with another sample extracting tube device 45 like device 41 in duct 40. Combustion chamber 43 is supported on a hollow base or housing 46 which may or may not be portable, as desired, and through the upper end wall 46a of which projects a fresh air duct 48 opening at its upper end into combustion chamber 43 at about the level of the top of flue gas inlet duct 40. Adjacent its open lower end, which may be supported in any suitable manner in housing 46, duct 48 is connected to the outlet duct 49 of an air pump 50 suitably supported on shelf 51 in housing 46 and provided with a fresh air inlet duct 52 projecting through side wall 46b of the housing and provided with a damper 53.

On the outside of the upper end of the opposite side wall 46c of housing 46 is supported an alcohol fuel tank 54 connected by supply line 55 having a shut off valve 56

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and extending through wall 46c to the inlet of fuel pump 58 suitably mounted on another shelf 59 in the housing. The outlet of pump 58 is provided with a fuel feed line 60 suitably passing upwardly through and secured in fresh air duct 48 and provided at its upper end with an atomizing nozzle 61 located just above the open upper end of duct 48. A relief valve 62 is connected to lines 55 and 60 on the inlet and outlet sides of pump 58 by branch lines 55a and 60a respectively. The apparatus is completed by an ignitor generally indicated at 63 and preferably of the electrical spark type, with the two electrodes 63a and 63b being located closely above nozzle 61.

In carrying out the inventive process with the apparatus of FIG. 2, which is preferred over that of FIG. 1 because the mixture is sufficiently intimate upon injection by reason of atomizer nozzle 61, so as to permit substantially instantaneous ignition, without significant travel of the stream being required, the flue gas enters combustion chamber 43 through duct 40 and mixes with the fuel from atomizing nozzle 61 and with fresh air from duct 48. This intimate mixture is substantially immediately ignited by ignitor 63 and burned, with the abated products of combustion exiting up through stack 44 to the atmosphere. The alcohol from fuel tank 54 is pumped through lines 55 and 60 to nozzle 61 by fuel pump 58, while fresh air from the atmosphere is pumped to combustion chamber 43 by air pump 50 through ducts 52, 49 and 48. Damper 42 in duct 40 controls the flow rate of flue gas to combustion chamber 43 and damper 53 in duct 52 controls the flow of fresh air thereto, while relief valve 62 maintains constant fuel pressure to atomizing nozzle 61, all to ensure the desired intimate mixture of these fluidic components.

In an actual installation, the diameter of stack 44 was six inches; the diameters of ducts 40 and 48 were about four inches each; the diameter of line 60 was about .25 inch; the overall length of stack 44 and combustion chamber 43 was about 6 feet, and the ignitor 63 was spaced about one inch above nozzle 61. The flow rate of the dark yellow smoke or flue gas from a nitric acid plant was approximately 200 cubic feet per minute at a temperature of about 700° F., an approximately 50% aqueous methyl alcohol solution was introduced into combustion chamber 43 at a rate of approximately one gallon per hour and fresh air at ambient temperature was introduced to provide the oxidizing agent at a pressure of about 1 to 2 inches H₂O and at a flow rate of about 2 to 8 cubic feet per minute. The flue gas entering duct 40 was sampled by device 41, and upon analysis, indicated approximately 3600 parts per million of noxious oxides of nitrogen present, while the abated gas was sampled by device 45, and upon analysis, indicated approximately 200 parts per million of such oxides of nitrogen present therein. This represented approximately a 95% reduction in such noxious oxides of nitrogen; other similar tests resulted in almost 99% abatement of such nitrogen oxides, and in each instance a reading of zero was obtained on the Ringleman scale, (i.e. colorless smoke).

While the inventive process has been described and illustrated herein by reference to but two embodiments, this is to be taken as illustrating rather than as limiting the scope of the invention, which scope is to be determined by the appended claims. For example, either apparatus may be employed for smoke abatement purposes generally, and they are not restricted to the particular types of gaseous atmospheres described in connection therewith. Also, the inventive process may be carried out by any other suitable apparatus, such as one installed in or forming at least part of an automotive exhaust system.

What is claimed is:

1. A process of eliminating noxious elements from a gaseous atmosphere comprising introducing a monohydric alcohol (R—OH) containing not more than about four carbon atoms and an oxidizing agent into said atmosphere in such a manner as to insure mixture of said

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noxious elements with said alcohol and oxidizing agent, and causing a reaction between said noxious elements, oxidizing agent and alcohol by igniting said mixture to consume said noxious elements.

2. The process of claim 1 wherein said gaseous atmosphere is a confined stream of smoke, said oxidizing agent and alcohol are introduced by injection into said confined stream, and said reaction is caused by igniting said mixture before said confined stream is discharged from an outlet.

3. The process of claim 1 wherein said alcohol is not more than about 90% aqueous solution.

4. The process of claim 1 wherein said oxidizing agent includes compressed air.

5. The process of claim 4 wherein said oxidizing agent also includes hydrogen peroxide or oxygen or both.

6. The process of claim 1 wherein said gaseous atmosphere is a confined stream of coal gas smoke, said alcohol and oxidizing agent are introduced by injection into said confined stream, said reaction is caused by igniting said mixture before said stream is discharged from an outlet.

7. The process of claim 6 wherein said confined stream is permitted to travel toward said outlet a sufficient distance to insure intimate mixture of said noxious elements with said alcohol and oxidizing agent before igniting the

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same, said alcohol is not more than about a 50% aqueous solution of ethyl alcohol, and said oxidizing agent includes compressed air and oxygen.

8. The process of claim 1 wherein said gaseous atmosphere is a confined stream of flue gas smoke from a nitric acid source, said alcohol and oxidizing agent are introduced by injection into said confined stream, said reaction is caused by igniting said mixture before said stream is discharged from an outlet.

9. The process of claim 8 wherein said mixture is ignited substantially immediately following said injection, said alcohol is not more than about a 50% aqueous solution of methyl alcohol, and said oxidizing agent is compressed air.

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EARL C. THOMAS, Primary Examiner

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