Oct. 5, 1937. J. W. HAYS 2,095,065

SURFACE COMBUSTION PROCESS

Filed Jan. 25, 1933 3 Sheets-Sheet 1

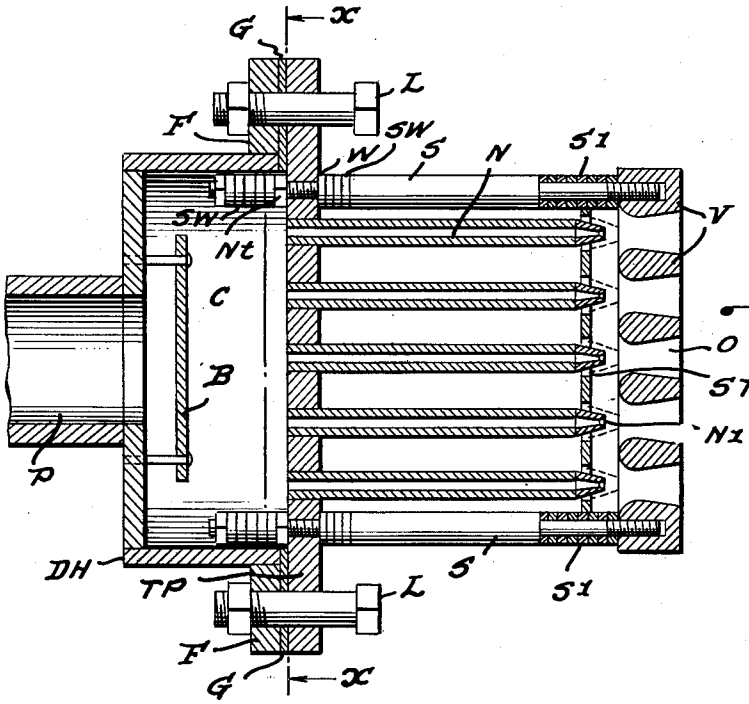


Fig. 1.

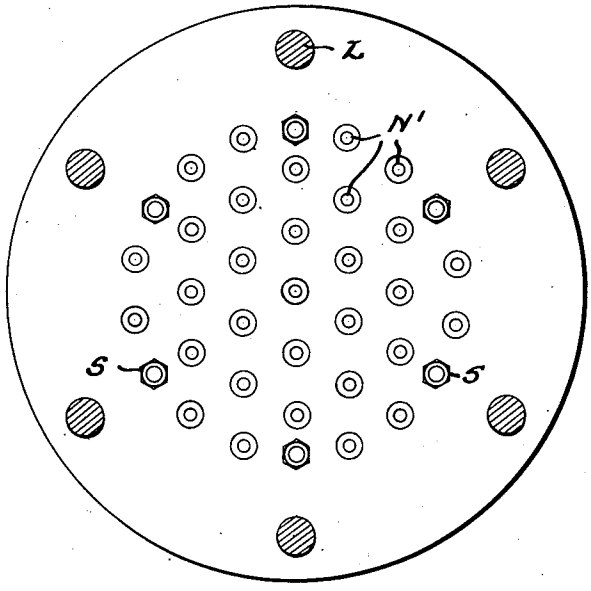


Fig. 3.

Fig. 2.

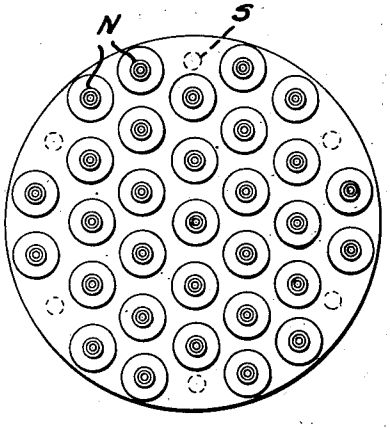
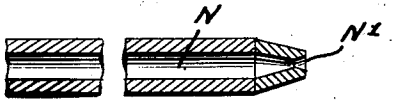


Fig. 4.



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by his attorneys

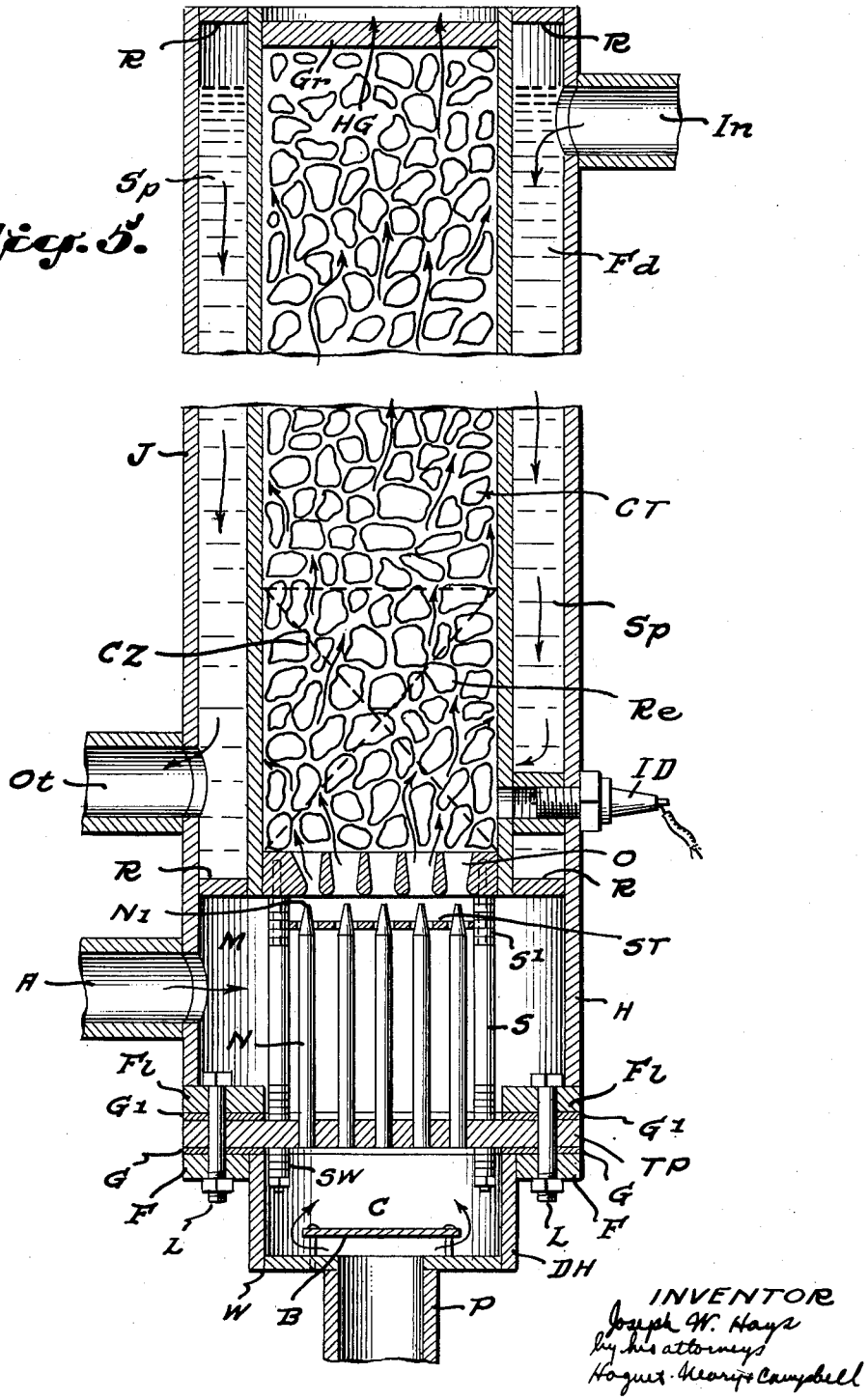
Hoguet, Neary & Campbell

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SURFACE COMBUSTION PROCESS

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Fig. 5.



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SURFACE COMBUSTION PROCESS

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Fig. 8.

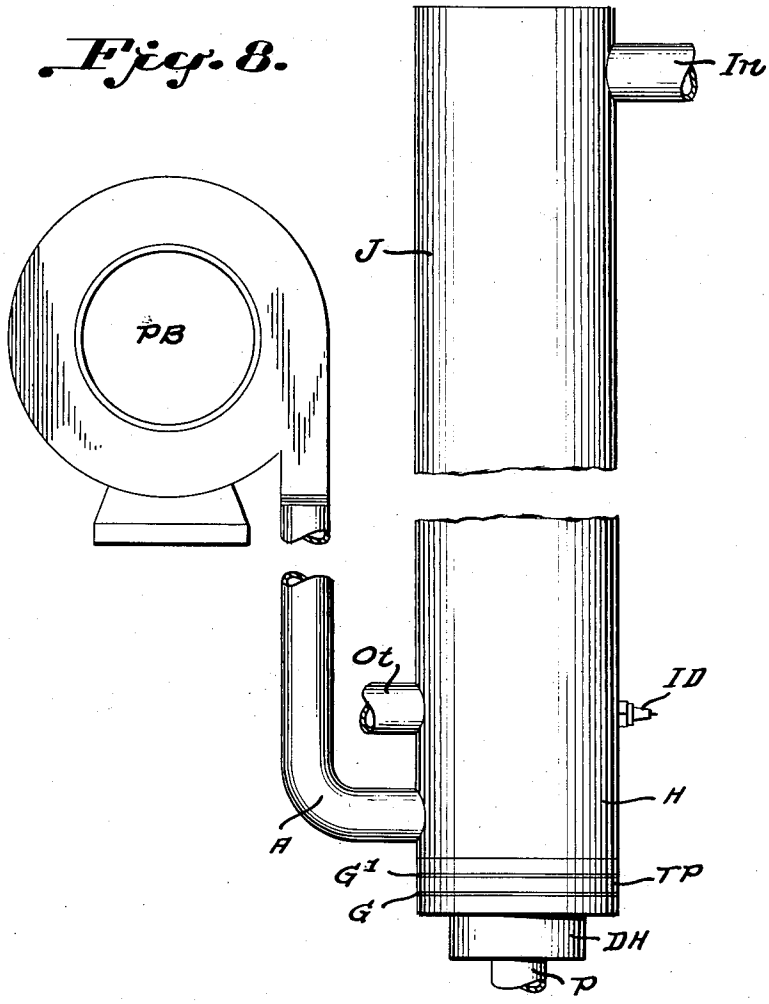


Fig. 6.

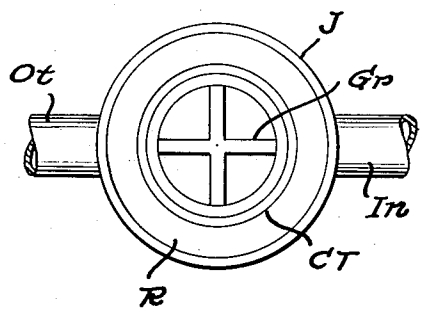
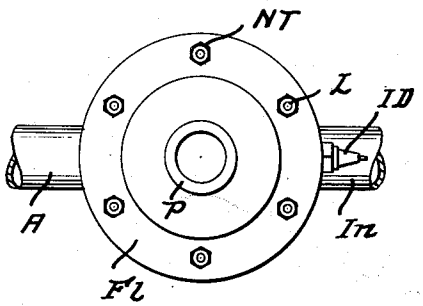


Fig. 7.



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Patented Oct. 5, 1937

2,095,065

UNITED STATES PATENT OFFICE

2,095,065

SURFACE COMBUSTION PROCESS

Joseph W. Hays, Tulsa, Okla.

Application January 25, 1933, Serial No. 653,469

1 Claim. (Cl. 158—117.5)

The accompanying drawings and some of the written matter of the present specification are the same as in my co-pending application, Serial Number 653,468 and of even date herewith, in which said application I disclose and claim the structural means by and through which the processes herein described and claimed are made possible and actually are accomplished.

My discovery relates particularly to all those applications of gas, oil and other burners where combustible mixtures of air and gas or air and vapor, or air and a powdered combustible, are burned under pressure, whether high or low, and where it is desirable to mix the fluid, or suspended, combustible and the air in the proper proportions before ignition. While my invention is designed primarily for the so-called "surface" or "flameless" combustion burners wherein the combustion takes place in a bed of refractory material, whether said refractory material is packed in a tube or otherwise, and while all of my references and the drawings herewith relate to burners of the above type, I do not limit myself to them. My process can be advantageously employed in all cases where thorough premixture is required prior to ignition, regardless of the pressure, whether positive or negative, under which the combustion takes place. While I refer especially to gas fuel in this specification, I do not hold myself limited in any way to gas. My invention is applicable to vaporized oil, powdered fuel, or any other fuel which may be mixed with air in any sort of combining proportion.

U. S. Patent No. 1,015,261 referring to "Surface combustion", as it is now known, was granted to W. A. Bone, of Leeds, England, on January 16, 1912, upon an application filed December 3, 1910. This patent discloses an application of the process to steam boilers, water-heaters and the like. The drawings show tubes packed with granular material, the inflow end of each tube being stopped with a plug through which there is a centrally located 5/8" hole for the admission of the air-gas mixture. The outflow end of the tube was left open, except for a wire-mesh screen which was used to hold the packing material in place. Air under a pressure of 20 inches (water gauge) was used, and this, together with the gas with which it was mixed, was forced through the 5/8" tube. It will be seen very readily that the combustion capacity of a tube so equipped is limited by the 5/8" inflow tube and the pressure applied to the air-gas mixture. Dr. Bone states in his specification that he has burned 100 cubic feet of 560 B. t. u. coal gas per tube per hour at a pressure of 20 inches, water gauge, (about 11½ ounces). By means of my invention I have been able to burn 165 cubic feet of 1050 B. t. u. gas per tube per hour at a pressure of 3½ ounces. I have burned 400 cubic feet per hour at a pressure of 8 ounces, and I have burned from 500 to 680 cubic feet per hour at a pressure of one pound. My invention enables me to obtain these extraordinary capacities because it does not restrict me to the use of an inflow tube of small capacity. On the contrary, I do not make use of an "inflow" tube at all. The gas-air mixture is introduced into the open end of the combustion tube itself, the only restriction to the free flow of gas through the tube being that of the frictional resistance of the refractory packing and the expansion of the gases in the hot combustion zone. The capacity limits of a combustion tube equipped with my invention are fixed only by the pressure applied to the air-gas mixture and the ability of the refractory materials used to withstand high temperatures. I have used tubes ranging in diameter from 1½ inches up to six and more inches.

One object of my invention, therefore, is the attainment of high rates of combustion in surface combustion tubes; and another object is safety.

In the Bone patent, above referred to, reference is made to "back-firing" in the tube leading from the mixing chamber, where the gas and air are commingled, to the tube in which the combustion takes place. This tendency has been offset by Bone in various ways, viz.: (*a*) by making the inflow tube of such length and of such small diameter, and by giving the explosive mixture such velocity through this small tube, that the velocity of flame propagation (velocity of flashback) is exceeded; (*b*) by admitting the air and gas separately until temperature has been established in the combustion tube, whereupon an air-gas mixture is introduced from a mixing chamber; (*c*) by igniting at the rear, or outflow, end of the combustion tube and relying upon the refractory packing to retard the tendency to backfire until temperature has been established; and (*d*) by increasing the pressure applied to the combustible mixture until a velocity is attained exceeding the velocity of flame propagation. As an insurance against disastrous explosions, Bone provides an "explosion door" in the mixing chamber wall.

Charles E. Lucke, in Patent 1,259,029, issued March 12, 1918, describes and claims a form of screen to prevent back-flashes. The same inventor, in Patent 1,313,196, claims another form of

screen for the same purpose, and in this patent he refers to two other patents, Numbers 1,113,171 and 1,113,174, both dated October 6, 1914, to himself and Frank Creelman in which devices for the same purpose have been covered. Other previous inventors have recognized the back-flash as a bad feature of forced-draft surface combustion and have sought to obviate the consequences in various ways, but always either by devices for increasing the velocity of flow of the unignited mixture or by interrupting the progress of flame backwards through the mixture toward the mixing chamber. In the specification of Patent 1,259,029, previously referred to, the inventor states:

"Back-flash may be prevented by the cooling action of the walls of small or narrow passages through which the mixture is caused to flow, or by causing the mixture to approach the zone with a velocity greater than the rate of propagation of inflammation."

This, so far as my knowledge goes, summarizes the state of the art prior to my invention.

For a number of years past I have experimented with surface combustion in tubes and in diaphragms, using coal gas, water gas, vaporized oil, natural gas and even coal. I have operated such tubes both with induced draft and with forced draft. When suction or induced draft is used to promote flow through the refractory bed the gas and air may be delivered through one or more nozzles, or pipes, directly against the cold surface of the refractory materials, or the gas may be delivered separately and the air drawn in around the gas pipe or pipes, or vice versa. Ignition in either case is a very simple matter, as a torch or a match may be used. The mixture may be allowed to burn at or near the surface of the refractory materials until the latter become heated for some distance below the surface, whereupon the gas may be turned off for a few moments, and, when turned on again, the gas will ignite and combustion will proceed entirely below or beyond the surface of the refractory materials. There can be no "back-flash" in such cases.

I have found forced draft to be more efficient than induced draft in surface combustion tubes. When induced draft is used there is a tendency toward "short-circuiting", "channeling", or "laning" of the gases through the refractory bed, because of the negative pressure. But when the pressure is "positive", as in the case of forced draft, the combustible mixture and the gaseous products of combustion are forced into all of the interstices of the packing. This results in a better combustion and a higher efficiency.

Hitherto the objections to the use of forced draft in surface combustion tubes have been those relating to dangerous back-flashes and the difficulties of securing ignition. My invention makes it impossible for back-flashes to occur, regardless of the velocities of the gas and the air and the "rate of propagation of inflammation" of the mixture. This, I believe, is new to the art and very highly useful, as it makes the internally fired surface combustion tube both safe and practicable. I have also discovered a practicable means of igniting the mixture in the closed combustion tube, but this I am making the subject of a separate patent application.

The simplest and most obvious way of producing the desired mixture of air and gas where a fan is used to produce forced draft, is by introducing the gas with the air at the intake of the fan. The mixture in such case is necessarily thorough, regardless of air and gas ratios. The best results with surface combustion are attained when the mixture is at, or very close to, the chemical requirements and such a mixture is very easily attained by the method referred to, as it is necessary merely to increase the volume of gas delivered until the desired point is reached. But this method is subject to very serious hazards, especially if the explosive mixture is delivered from a common "wind-box" to a number of surface combustion tubes. A flash-back into such wind-box, or mixing chamber, would result in a terrific and perhaps destructive explosion. While I have prevented "flash-backs" by the use of screens and other devices I have always been obsessed by the thought of what would happen if the screen, for any reason, should fail to function. Assuming the use of a perfect anti-flash-back screen, or other device, it is proper to consider what would happen if the explosive mixture in the "wind-box", or mixing chamber, should be ignited by a spark or some cause other than that of a flash-back. The results would be precisely the same in the one case as in the other.

There can be no explosion where no explosive mixture exists. I attain the principal object of my invention by mixing the gas and the air in the proper proportions at, or very close to, the point where it is desirable to ignite the mixture, at which point, and beyond, combustion necessarily proceeds normally and continuously so long as the mixture is provided in the proper proportions.

Reference may now be had to the accompanying drawings which illustrate the principles of my invention.

Figure 1 is a cross-sectional view of the mixing device without its housing, the latter, which carries the intake for the air, being preferably, but not necessarily, an integral part of the tube, J, Figure 5.

Figure 2 is an end view showing the gas supply tube tips and nozzles.

Figure 3 is a sectional view on the line, *x*—*x*, Figure 1.

Figure 4 is a detail of one of the tubes, N, Figure 1.

Figure 5 is the complete assembly of combustion tube with its accessories and the mixing device, all shown in cross-section.

Figure 6 is an end view of the discharge end of the combustion tube showing the grid holding the refractory in the tube.

Figure 7 is a bottom plan view of the mixer and its accessories, together with the combustion tube and its accessories.

Figure 8 is an assembly view in side elevation, showing a mixer, combustion tube, etc., together with a pressure blower.

In Figure 1, P is a gas-supply pipe through which gas is preferably furnished under a pressure in excess of the operating pressure and in excess of the air pressure. Should the static pressure of the gas be less than that of the air no gas could flow to the mixer. On the other hand, the air, owing to its much greater volume, (the proportions being about 10 of air to 1 of gas when natural gas is used) may have a pressure in ounces while the gas pressure is in pounds. High gas pressures, when available, are to be desired because they contribute to the capacity of the combustion tube. C is a distribution chamber for the gas before it enters the nozzle tubes, N. B is a baffle to insure distribution of the gas

at common pressure to all of the tubes, N, but it is not a basic part of my invention. The tubes, N, are set gas-tight in the plate, TP, and the latter is secured by the bolts, L, to the flange of the detachable housing, DH, of the chamber, C. G is a gasket of any suitable material to make the chamber, C, gas-tight. V is a Venturi orifice plate with orifices, O, of the well-known Venturi type. The nozzles of the tubes, N, are aligned, as shown in the drawings, with the orifices, O. The adjustable spacers, S, are used to fix the nozzles, *Nl*, of the tubes, N, at the desired distance from the orifices, O. These spacers may be of any form to satisfy the requirements. In the drawings I show them as rods turned at each end to provide shoulders, one of the turned-down ends being threaded to screw into the plate, V, and the other passing through TP to which it is secured by the nut, *Nt*, as shown. W is a gasket of the washer type to prevent leakage of gas from C. *St* is an equalizer, or straightener. Its use will be explained later in this specification. Should it be desired to change the distances of the nozzles, *Nl*, from the orifices, O, the nuts, *Nt*, may be removed and the spacer-washers, SW, or some of them, shifted to the opposite side of TP, thereby bringing *Nl* into a closer or more distant position with respect to O, as desired.

The above letters and numerals are used throughout the several drawings.

The complete assembly of mixer and combustion tube is shown in the drawings, Figure 5, in which CT is the combustion tube and *Re* the refractory material with which the tube is packed. *Gr* is a casting, in the form of a grid, which serves to retain the refractory material in the tube while providing sufficient space for the escape of the waste gases. *Gr* may be secured in place by any practicable means. J is a jacketing tube surrounding CT and spaced apart therefrom at any desired distance. Flat metal rings, R, are welded to J and CT so that the space between the two tubes, (*Sp*), is completely enclosed, except for the inlet pipe, *In*, and the outlet pipe, *Ot*. The fluid to be heated, *Fd*, whether water, oil, vapor or any fluid or liquid, is caused to flow through *Sp*, preferably, as shown, in a direction contrary to the flow of the hot gases, through CT.

In the preferred form of construction, which is shown in the drawings, the tube, J, extends a short distance beyond one end of CT and forms a housing, H, for the mixer, illustrated in Figures 1, 2, 3 and 4. *Fl* is a flange which is welded to J and at the extreme end thereof. *Fl* is provided with bolt-holes, corresponding to those in F and TP, and *Gl* is a gasket to render the mixer, M, air-tight. Air under the desired pressure, whether in ounces or in pounds, is admitted to M through the inlet, A. ID is an igniting device, which may be a spark plug, as shown, or any other suitable contrivance.

My invention will be best understood if I next explain the method of its operation.

Air in sufficient volume and at the desired pressure may be supplied by a suitable blower, a compressor or in any other manner. I prefer a pressure-volume blower, PB, which is indicated in Figure 8. Whatever means may be employed to provide a flow of air, it is highly desirable that the air be delivered in constant volume and at constant pressure.

Gas is delivered through the pipe, P, at a pressure which should be constant and preferably in excess of that at which the air is supplied. The higher the gas pressure the better for the following reasons:

1. In order to secure the best possible distribution of the gas and the best possible air-gas mixture, I prefer to deliver the gas through a multiplicity of nozzles, *Nl*. I have found that the best results are secured when the orifices or vents of these nozzles do not exceed $\frac{1}{32}$nd or $\frac{3}{64}$ths of an inch in diameter. Such small openings under low pressure operation might become clogged with dust or other foreign material carried by the gases, but if the latter are under a considerable pressure head this will be less likely to happen.

2. The higher the pressure of the gases the greater the velocity of the air-gas mixture flowing through the orifices, O, and, likewise, the greater the mushrooming effect when the mixture impinges upon the refractories, *Re*. Such "mushrooming", or spreading, promotes a thoroughness of air-gas mixture.

3. Gas for industrial uses can usually be secured at high pressures without increase of cost. Pressure gas, therefore, represents an available amount of kinetic energy, costing nothing, and this should be utilized whenever possible. High pressure gas reduces the load on the air blower and thereby lowers the cost of operation.

It will be understood that the drawings are illustrative, and the number and spacing of tubes N or orifices O can be varied as desired.

Air is delivered to the chamber, M, through the inlet, A. The air circulates in the space between the housing, H, and the nozzle tubes, N, and from this space enters the tubebank from all sides. To avoid turbulence at, and an unequal distribution of air to, the numerous nozzles, the "straightener", *St*, is used to straighten the air flow and break it up into a series of currents running parallel with the tubes, N, which are severally aligned with the orifices, O. *St* serves to equalize the distribution of the air and air pressure and prevent "short-circuiting" to the nearest orifices. *St* is merely an orifice plate with holes in alignment with the orifices, O. It is adjustable as to position by means of the spacers, *Sl*, which are washers of various thicknesses, and the space desired may be arrived at by increasing or decreasing the number of washers. I find, in practice, that very satisfactory results are secured by positioning the "straightener" approximately as shown in my drawings. The "straightener" may be considered as a desirable accessory, but by no means a basic part of my invention.

The air and gas are mixed in the orifices, O. The gas, being under relatively high pressure, is projected at high velocity and in a diverging cone into each orifice, drawing air with it from the surrounding stream of air. The air, being under pressure, flows under its own velocity head into the gas stream. The velocity in the orifice is, therefore, a composite of the velocities of the air and the gas, and this velocity is accentuated by the Venturi effect of the orifice. Mixture is completed to a point of extreme thoroughness because of the multiplicity of the gas-air streams, and because of the "mushrooming" effect when these streams impinge upon the broken surfaces of the refractory materials, *Re*. The gases are ignited in the vicinity of this point of impingement by means of an ordinary spark-plug, or other igniting device, ID. It will be seen that a "flash-back" is impossible for the reason that the point of ignition lies in, or near to, the very locality where the gas and the air are brought

together to form a combustible mixture. There is no reason for a screen or other anti-flashback device, because there can be no flash-back into an atmosphere consisting entirely of air or entirely of gas.

Immediately after ignition the mixture burns in the interstices of the refractory packing and in a short time the refractories become heated to a point of incandescence, whereupon the mixture burns without flame and a very high temperature is reached, the heat being produced, very largely if not entirely, in the radiant form. Combustion is practically instantaneous. This being so, the capacity limits of such a combustion tube are fixed by the free area of the interstitial spaces of the refractory packing and by the pressures used to force the gases into and through the tube.

The combustion zone, or "hot-spot", is indicated in Figure 5 by the dotted lines, CZ. The transfer of heat from the incandescent refractories, *Re*, in CZ to and through the tube, CT, to the fluid, *Fl*, is almost instantaneous, the heat being in the radiant form. CT may be packed with the refractories, *Re*, throughout its entire length, if considered advisable. The hot gases leaving CZ are "baffled" by these refractories and brought into contact repeatedly with CT, giving up their heat as they flow. Furthermore, these gases heat the refractories themselves and the heat is transferred by radiation and conduction from one refractory element of the packing to another and finally to the tube, CT, through which it is conveyed to the fluid in the space, *Sp*. In this way a very rapid and very complete transfer of heat is effected.

The positioning of the combustion zone, CZ, is a very important consideration in all cases where such combustion tubes are employed. The advantages of counter-flow in effecting heat exchanges are well known. The fluid to be heated should, in all cases where possible, flow in a direction contrary to that of the hot gases. This is best accomplished, as in the present instance, by fixing the location of the combustion zone at the extreme end of the combustion tube, CT, and approximately adjacent to the place where the heated fluid reaches its outlet. In this way the fluid, when in its hottest state, is exposed to the highest temperature and, when in its coolest state, on entering the heater, is exposed to the lowest temperature. Thus the highest heater capacities and efficiencies are obtained.

It can easily be seen that if the combustion zone should be established at the opposite end of the combustion tube, or midway of the tube, there would be a marked loss of heat energy with the waste combustion gases, and this would be reflected adversely upon the heating device, both as to its efficiency and its capacity.

Previous inventors, as already explained, have ignited the air-gas mixture at the discharge outlet of the combustion tube, relying upon a balancing of the velocities of mixture flow and of flame propagation to fix the location of the combustion zone, but I have found that the combustion zone is likely to remain fixed at, or close to, the spot where it is first established. The tendency of the "hot-spot" to remain stationary is influenced to some extent by the state of the refractory packing, as to coarseness or fineness, by the length of the tube and by the temperatures attained in the "hot-spot" as well as by the velocities. There is an enormous increase in gas volume in the combustion zone, due to the high temperature, and this acts as a brake upon the flow of the gases through the tube.

My invention enables me, among other things, to fix the combustion zone at the forward end of the combustion tube, or at any other point where I may prefer to ignite the mixture, and to maintain said zone substantially in its original location and position.

While I have shown tubes in my drawings and referred to them as such in this specification, I do not hold myself as limited to tubes. Any form of chamber or receptacle may be used to hold the refractory materials or the fluid which is to be heated, whether that form be tubular or otherwise, as it is plain that I can vary the size, shape and materials of any and all of the structures shown and claimed without departing from the spirit of my invention.

I claim:—

The process of surface combustion of explosive mixtures of air and combustible fluid fuel freely miscible with air which comprises discharging the fuel in jets, discharging air in streams around said jets to mix with the fuel, impinging the fuel and air while partially mixed upon a fixed porous body, spreading the partially mixed air and fuel over the surface of said body to complete mixture of the fuel and air, then flowing the completed mixture through the pores in said body and burning the mixture in said body.

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