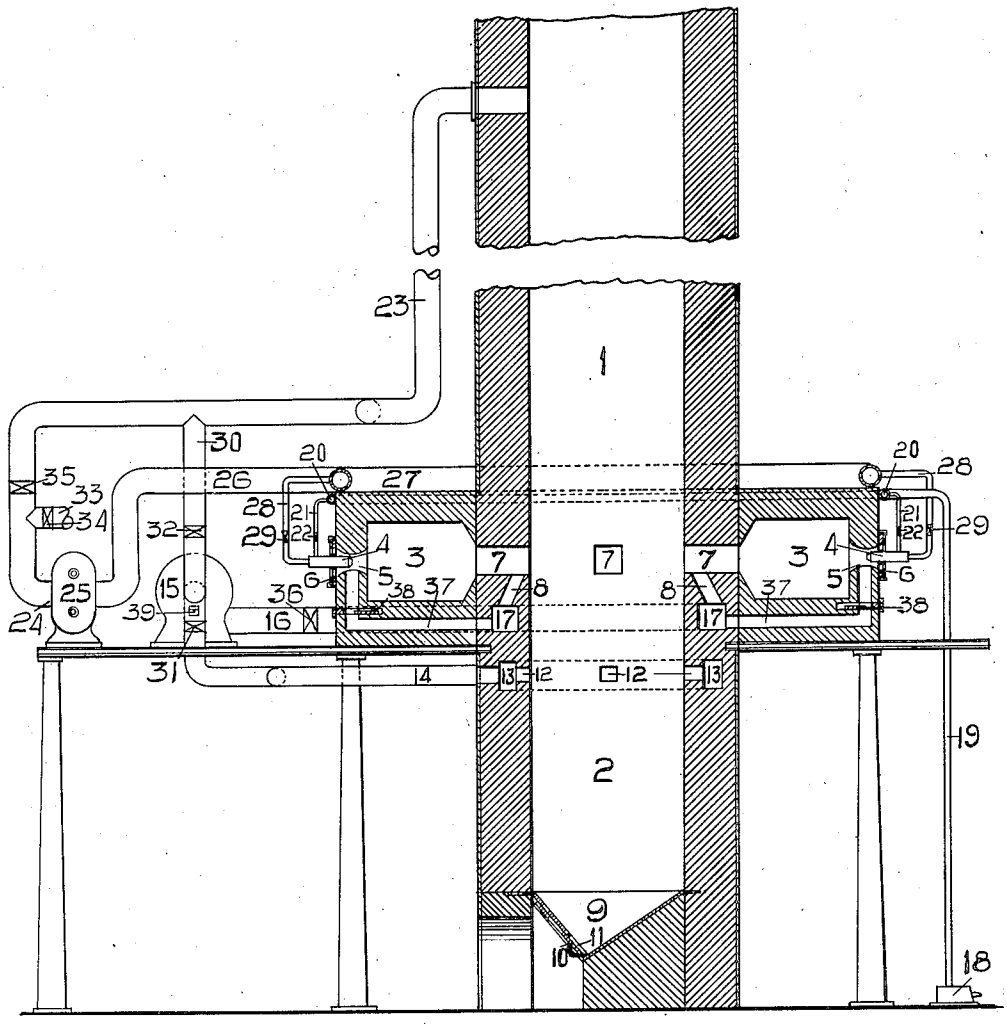
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PROCESS OF BURNING LIQUID FUELS.

APPLICATION FILED APR. 13, 1911.

1,101,790. Patented June 30, 1914.



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PROCESS OF BURNING LIQUID FUELS.

1,101,790. Specification of Letters Patent. Patented June 30, 1914.

Application filed April 13, 1911. Serial No. 620,862.

To all whom it may concern:

Be it known that I, HENRY L. DOHERTY, a citizen of the United States, and a resident of New York city, in the county of New York and State of New York, have invented certain new and useful Improvements in Processes of Burning Liquid Fuels, of which the following is a specification.

This invention relates to processes of burning liquid fuels and, in particular, to the burning of such fuels in connection with lime kilns, brick kilns, furnaces, etc., in which the air for combustion may be preheated either by the heat of the waste combustion gases or by contacting it with the burned charge to cool the same.

The object of my invention is to provide an improved method of burning liquid fuels in such furnaces with a comparatively smokeless flame with the use of preheated air in such a manner that the flame temperature may be thoroughly controlled, whereby I am able to restore to the furnace a large part of the heat that would otherwise be wasted by transferring such heat to the air supply of the furnace without the production of an injuriously high temperature in the combustion.

To this end my invention consists, briefly stated, in, first, atomizing the liquid fuel by means of a jet of combustion or other gases containing carbon dioxid under pressure; second, conducting the mixture of atomized fuel and CO_2-containing gases into a primary combustion chamber and there subjecting the atomized liquid to a partial combustion with a limited supply of air, whereby the said atomized liquid is subjected to a temperature sufficiently high to split up that portion of the original heavy hydrocarbons of the liquid which was not consumed in the said partial combustion, in the presence of the CO_2 of the gas used in the atomization of the liquid, whereby the carbon liberated in the breaking down of the hydrocarbons is caused to react with the CO_2 present to form CO according to the well known gas producer reaction,

$$CO_2 + C = 2CO,$$

and the atomized liquid is wholly converted into gaseous products practically free from suspended carbon or soot; and, third, in burning the combustible constituents of the gas mixture from the primary combustion, with a second portion of air (which may or may not be mixed with gases which are non-supporters of combustion), whereby the hydrocarbons are burned with the production of a comparatively smokeless flame of easily regulated temperature.

In the accompanying drawings I have shown, in rather diagrammatic form, an apparatus capable of carrying out my invention in the burning of limestone.

The drawing represents a vertical diametral section through two of the furnaces of the limekiln.

1 is the kiln shaft, of which the lower portion, 2, I designate the "cooler" of the kiln.

3, 3, etc., are the primary combustion chambers, 4 the atomizing nozzles, which may be of any approved construction.

5 are the injector passages through which the jets from the nozzles 4 discharge, thereby inducing an inflow of air through the dampered air inlet passages 6.

7, 7, etc., are the passages through which the gases generated in chambers 3 discharge into the kiln-shaft 1.

8, 8, etc., are the passages through which the air for supporting the secondary combustion is introduced into the gases from the primary combustion, in one method of operating my apparatus.

9 is the discharge hopper of the kiln, having a gate, 10, for the discharge of the burned lime from the cooler 2.

11 is an air damper on 10 by means of which air in regulated volume may be permitted to enter 9.

12 are hot air off-take ports, connected with the collecting-flue 13.

14 is the suction pipe of blower 15 whereby the blower is enabled to draw off from cooler 2 air which has entered through damper 11 and been heated by its passage upward through cooler 2 in contact with the hot lime therein.

16 is the discharge pipe of blower 15 which communicates with the air-distributing flue 17.

18 is an oil pump which draws the oil from a suitable storage tank and forces it through the pipe 19 to the oil distributing-pipe 20. An elevated tank may of course be substituted for pump 18.

21 are the oil pipes to the nozzles 4, having valves, 22.

23 is a down-comer for drawing off a portion of the kiln gases from the upper

part of shaft 1 and which communicates with the suction connection 24 of positive blower 25.

26 is the discharge pipe of blower 25 which discharges into the bustle-pipe 27.

28, 28 are the connections from bustle-pipe 27 to nozzles 4.

29 are valves on connections 28.

30 is a connection from the suction pipe 14 of blower 15 to the down-comer 23.

31 and 32 are blast gates or valves on 14 and suction-pipe connection 30, respectively.

33 is an air inlet on suction connection 24, of blower 25 having the valve 34.

35 is a valve on downcomer 23.

36 is a valve on pipe 16.

37, 37 are flues connected with distributing flue 17 which permit of the diversion of a portion of the heated air passing through distributing flue 17 to the passage 5 of each furnace of the kiln.

38, 38 are dampers on flues 37 connecting with distributing flue 17. By manipulating the dampers on air inlets 6 and dampers 38 it is readily seen that either or both cold or heated air may be used for supporting the primary combustion.

39 is a dampered air port on suction pipe 14 of blower 15, so that the blower 15 may draw the air directly from the atmosphere, if this is for any reason desired.

The preferred method of operating my invention is as follows: In beginning operations, the blower 25 is started and at first air alone forced through discharge pipe 26, bustle-pipe 27 and pipes 28 to the nozzles 4. Oil is now turned on by opening valves 22 and ignited in the passages 5.

At first, dampers on air inlet 6 or dampers 38 are so adjusted that the air admitted through them, in addition to that entering through atomizing nozzle 4, will be sufficient for perfect combustion of the oil. The products of the combustion pass from the chambers 3 through gas passages 7 into the kiln-shaft 1 and thence ascend through the latter. By partially closing valve 33 and opening valve 35 the blower 25 may now be made to draw in more or less combustion gases from shaft 1 and force the same to the nozzles 4. When the chambers 3 have been heated up to a suitable temperature—say 1800° to 2000° F.—the apparatus is in condition to start operating on my process proper. At this time, the charge in the kiln shaft (which latter should have been filled with limestone before starting the operation), opposite the ports 7, should have been heated to a temperature sufficiently high to insure the ignition of any combustible gases entering the shaft from ports 7. When this condition has been established the blower 15 is started (the damper 11 being properly adjusted to admit the quantity of air required for the secondary combustion) and air forced through discharge-pipe 16, air distributing flue 17 and passages 8 into the gaseous current passing through gas passages or ports 7. At the same time, the valve 34 is closed, whereby the pressure fluid supplied to the nozzles 4 is made to consist wholly of kiln gases, and dampers on air passages 6 and dampers 38 adjusted so that only the proper proportion of air to effect the complete gasification of the liquid fuel is admitted to chambers 3. The gaseous currents leaving the chambers 3 now contain a large proportion of combustible gases. These are burned in the shaft 1 by the secondary air entering through the passages 8.

In the primary combustion, it is my aim to use only sufficient air to effect the proper and thorough gasification of the fuel. In this operation the combustion proper is chiefly to CO, only a relatively small proportion of the hydrogen of the hydrocarbons burning owing to the presence of free carbon liberated in the breaking down of the hydrocarbons. That portion of the fuel which does not react directly with the oxygen of the limited quantity of air used in the primary combustion, is subjected to reaction with the CO_2 present in the chamber 3, and to direct dissociation by the heat of the flame, into permanently gaseous compounds and free hydrogen. Since the heavy petroleum oils and the heavy residual oils of petroleum and coal tar, have an exceedingly complex composition and the reactions vary also with the temperature of the flame in the primary combustion chambers, as well as with the proportion of CO_2 in the draft current, I do not limit myself to the use of any specific proportion of CO_2 to fuel. I use, in any case, that proportion of CO_2-bearing gas which, in connection with the primary air, will convert the hydrocarbon liquids into gaseous compounds and free hydrogen that will burn in the furnace chamber, with a slight excess of secondary air, with the production of little or no soot.

A reaction, typical of those which I aim to bring about between the hydrocarbon constituents of the primary flame and the CO, would be in the case of dodecane,

$$(b)\quad C_{12}H_{26} + 12CO_2 = 24CO + 13H_2.$$

I, of course, do not claim that I can cause any given hydrocarbon compound present in the original fuel to react wholly with the CO_2 in a manner similar to that given in equation (*b*) above. As is well known, the oxygen of the primary air would be divided between the various hydrocarbons of the fuel in accordance with the principles of mass action whereby a re-agent capable of reacting with all of the components of a mixture of substances, when introduced into

the mixture in quantity insufficient to satisfy all of the components, will be distributed among them in proportion to their relative reactive avidities and mass. I may state that I aim to so carry out the primary combustion as to cause the reaction with the hydrocarbons of the greatest possible quantity of CO_2 without having an undue quantity of the latter in the gas. The proportion of air used in the primary combustion is therefore adjusted to that which will best favor the accomplishment of the above-stated object, *i. e.* to develop the quantity of heat and the temperature in the primary combustion chamber which will best favor the maximum degree of reaction between hydrocarbons and CO_2. In any given case, the proper regulation of the supply of air and kiln gas to the primary combustion may be determined with fair accuracy by the operator from the appearance of the primary flame. This should be of a golden yellow color and should show but little, if any, smoke.

It is manifest that, with the comparatively great variation in composition which exists in the oils (including coal tars) which are in common use as fuel oils, and the widely different percentages of CO_2 which are contained in kiln and combustion gases from different sources, it is impossible to prescribe any specific relative proportions for oil, kiln gas and primary air. In the case of the application of my invention to a lime kiln the proportions of the several substances in the primary draft current, might, advantageously, be fixed per gallon of oil as follows, viz., kiln gas 100 cu. ft. (at normal temperatures and pressure) and primary air 400 cu. ft. With these proportions the temperature in the primary chambers should be maintained uniformly at about 1800° F. Since the quantity of air theoretically required for the complete combustion of the oil considered above (which is a petroleum residue) would amount to about 14.1 lb. per lb. of oil, or about 1350 cu. ft. (normal) per gallon of oil, the air used in the primary current, in the example given above, would be somewhat less than 30% of the theoretical air. While not limiting myself to this proportion, I may say that, with most fuel oils and for ordinary combustion uses, I find it advantageous to use in the primary current an amount of air equivalent to about one-third, or less, of the air theoretically requisite for the complete combustion of the oil.

Since the dissociation of CO_2 by carbon does not take place actively below 1300° F. and practically ceases below 1200°, while most of the hydrocarbons occurring in the ordinary heavy oils are "cracked" readily at the latter temperature, it is readily seen that I may, when I have no objection to carry on the primary combustion at 1300°–1400°, inject into the primary current a much greater proportion of the kiln gases. When this is done the combustible gas produced in the primary combustion is diluted by the excess of the kiln gas so that its calorific value is reduced. The relatively large volume of inert gases present in the combustible gas in this case proportionately reduces the intensity of the secondary combustion as well as the flame temperature. Instead of the "oil-producer-gas" burning with a comparatively short flame of high temperature, as is the case when only the proportion of CO_2 is introduced into the primary chamber that can be dissociated therein, when an excess of kiln gases is used, the gas burns with a long voluminous, slow burning flame of comparatively low temperature. Therefore by varying the excess of kiln gas (or other CO_2-bearing gas) introduced into primary chamber I may, without varying the secondary air supply, vary the temperature in the kiln (or other furnace) at pleasure. This is, of itself, important in that it permits of the burning of liquid fuels in kilns or furnaces which require a flame of moderate temperature but of high heat-carrying capacity. Besides this advantage, the use of an excess of kiln gas in the primary combustion permits of the preheating of the secondary air. It thus enables me to effect a great economy in fuel in that I am enabled to return to the kiln (or other furnace) a large part of the otherwise wasted heat contained in the effluent products of the kiln, using the air as the vehicle for transferring the heat. In the apparatus figured the air is heated only by contact with the burned lime. It is obvious that by passing through suitable recuperators, which are common in the art and need no specific description to enable one skilled in the art to install them, that portion of the kiln gases not returned to the combustion a portion of the air may be heated by the otherwise wasted heat carried out of the kiln by the effluent gases. The quantity of heat in these gases, however, is usually low, and such modification I do not herein claim specifically as a part of my invention.

In the at present known methods of burning liquid fuels, it is seldom possible to use preheated air for sustaining the combustion owing to the intensity of the combustion thereby engendered. Oil burned by preheated air in the apparatus known to me as being in industrial use at present would quickly burn out the most refractory firebrick. According to my present invention, on the other hand, I may (and indeed prefer to) use air preheated to the highest practicable temperature, by such otherwise wasted heat as may be available. In the case of the primary combustion, the higher

the temperature of the air, the greater is the quantity of heat available for sustaining the dissociation of the CO_2 introduced in the kiln gas into the primary chamber, and therefore the greater the quantity of combustible gas reaching the kiln for any given volume of air used in the primary combustion. It is evident that all of the carbon monoxid formed from the CO_2 of the kiln gas by the aid of the heat so recuperated and returned to the kiln in the primary air is so much fuel saved to the operation of burning.

Instead of securing the presence of diluent gas in the draft current supplied for the secondary combustion by introducing an excess of kiln gas into the oil-producer-gas formed in the primary combustion I may instead mix the diluent gas with the secondary air. This is accomplished by simply opening the valve 32 to the proper extent and partially (if necessary) closing the air valve or damper 31. The blower 15 would now draw in more or less of the kiln gases from the pipe 23 through the pipe 30. These would mix with the secondary air drawn in from the cooler 2 through the pipe 14 thus diluting the oxygen of the air. Substantially the same result will be secured whether the diluent gas is introduced into the air or oil-producer-gas, *i. e.* the production in the kiln of a long slow-burning flame of moderate temperature but, owing to its relatively great volume, carrying a large quantity of heat.

When deemed desirable, the blower 15 may be omitted and the air admitted at air damper 11 simply permitted to ascend through the kiln shaft until its meets with the gas issuing from the passages 7. I, however, do not consider this method of operation as desirable as the one first described since it is more difficult, in this case, to secure a uniform distribution of the flame across the horizontal section of the kiln. The air and gas do not mix uniformly at the level of the ports 7 and there is therefore a considerable irregularity in the temperatures to which the material in the region of the ports 7 is exposed. The combustion takes place very gradually as the air and gas currents mix and is extended over a considerable region. For the above reasons therefore I prefer the first-described method of operation in which the secondary air is drawn off from the kiln shaft below the gas inlets and injected into the gas near its point of entry into the kiln shaft. In this way I secure a uniform mixture of gas and air and a more uniform temperature across the kiln shaft in the high temperature zone.

Having described my invention, what I claim is:

1. The process of burning liquid fuels which comprises atomizing the said fuel, mixing the atomized liquid fuel with carbon dioxid and air, regulating the relative proportions of said carbon dioxid and air to supply sufficient of said constituents to effect the gasification and breaking up of heavy hydrocarbons of the liquid fuel with the minimum liberation of free carbon, and subjecting the said mixture to reaction to produce fixed gaseous products with the formation of a minimum quantity of soot.

2. The process of burning liquid fuels, which comprises, atomizing the said liquid fuel, mixing the atomized fuel with carbon dioxid and air, regulating the proportion of said carbon dioxid admixed with said atomized fuel to that proportion required to combine with nascent carbon produced in the combustion of the said liquid fuel, and regulating the proportion of air admixed with said liquid fuel to that proportion required to generate a temperature in excess of 1300° F. in the combustion of said liquid fuel but below the proportion required to completely burn said fuel, and subjecting the said mixture of liquid fuel, carbon dioxid and air to reaction to produce fixed gaseous products.

3. The process of burning liquid fuels, which comprises, atomizing the said liquid fuel, mixing the atomized fuel with carbon dioxid and air, regulating the proportion of said carbon dioxid admixed with said atomized fuel to that proportion required to combine with nascent carbon produced in the combustion of the said liquid fuel, and regulating the proportion of air admixed with said atomized liquid fuel to that proportion required to produce a temperature of between 1300° and 2000° F. on the combustion of said mixture, and subjecting the mixture to a temperature sufficient to insure ignition, to produce fixed gaseous carbon products.

4. The process of burning liquid fuel, which comprises forming a draft current of carbon-dioxid-containing gas and air, regulating the proportion of carbon-dioxid-containing gas in said draft current to that proportion required to supply the quantity of carbon dioxid necessary to substantially prevent the presence of free carbon in the gases during the combustion of said fuel, and regulating the proportion of air in said draft current to that proportion required to maintain the temperature during the combustion of said fuel at the desired point, disseminating the said liquid fuel through said draft current, subjecting the resulting mixture of liquid fuel, carbon-dioxid-containing gas and air to reaction to convert the said liquid fuel into a combustible gas, mixing the said combustible gas with a second portion of air, and burning the mixture.

5. The process of burning liquid fuel

which comprises disseminating said liquid fuel throughout a body of carbon-dioxid-containing gas, adding air to the fuel-laden carbon-dioxid-containing gas to that proportion required to generate sufficient heat by reaction with said liquid fuel to maintain the temperature of the gas mixture above 1300° F., subjecting the gas mixture containing the liquid fuel to reaction to cause partial combustion of the said mixture to convert the said mixture into combustible gas with a minimum separation of free carbon, mixing the so-formed combustible gas with a second portion of air and burning the mixture.

6. The process of burning liquid fuel which comprises disseminating said liquid fuel throughout a body of carbon-dioxid-containing gas, regulating the proportion of air added to the fuel-laden carbon-dioxid-containing gas to that proportion required to generate sufficient heat by reaction with said liquid fuel to maintain the temperature of the gas mixture between 1300° and 2000° F., subjecting the gas mixture containing the liquid fuel to reaction to cause partial combustion of the said mixture to convert the said mixture into combustible gas with a minimum proportion of free carbon, mixing the so-formed combustible gas with a second portion of air and burning the mixture.

7. The process of burning liquid hydrocarbon fuel to form a flame of moderate temperature and comparatively free from soot which comprises, atomizing said liquid fuel into a carbon-dioxid-containing gas, regulating the relative proportions of atomized liquid fuel and carbon dioxid in the resulting mixture so that the proportion of carbon dioxid present will be that proportion required to react with nascent carbon produced in the subsequent heating of the mixture, and subjecting the said mixture to a temperature of between 1300° and 2000° F. by the partial combustion of the liquid hydrocarbon of said mixture, to decompose said hydrocarbon and to cause reaction between the carbon dioxid of said mixture and nascent carbon liberated in the decomposition of said hydrocarbon, whereby said mixture is concerted into a combustible gas.

8. The process of burning liquid fuels, which comprises, atomizing liquid fuel by a body of combustion gas under pressure, mixing with the fuel-laden combustion gas a quantity of air approximating one-third of that theoretically required for the complete combustion of said liquid fuel, regulating the quantity of said combustion gas used in atomizing said liquid fuel to approximately one-fourth of the quantity of air added, subjecting the resulting mixture of liquid fuel, combustion gas and air to ignition to institute partial combustion thereof to convert said mixture into a body of permanent gases, and burning the so-formed permanent gases by a secondary air supply to generate heat.

Signed at New York city in the county of New York and State of New York this 12th day of April A. D. 1911.

HENRY L. DOHERTY.

Witnesses:
J. M. McMillin,
F. L. Blackburn.