

May 28, 1963

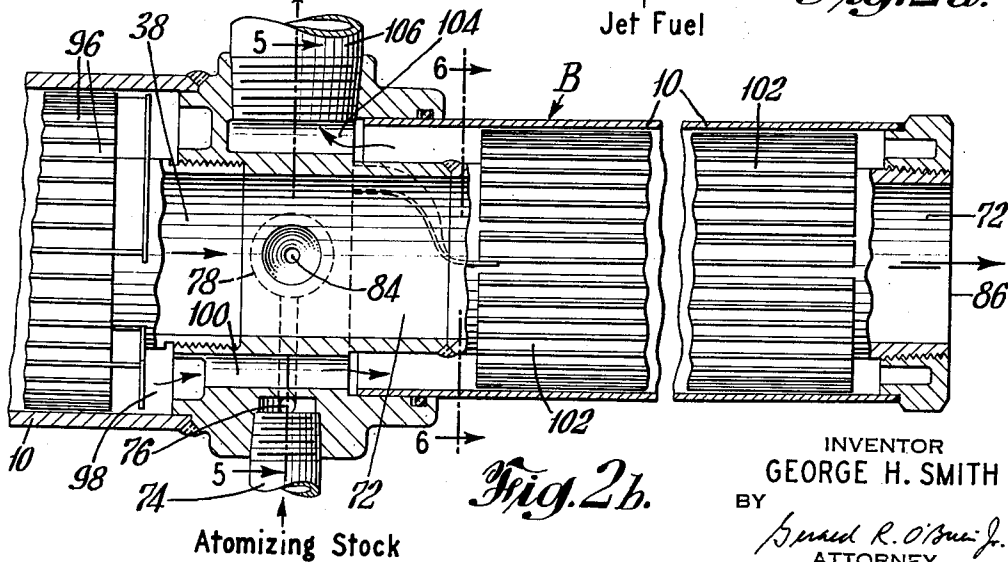
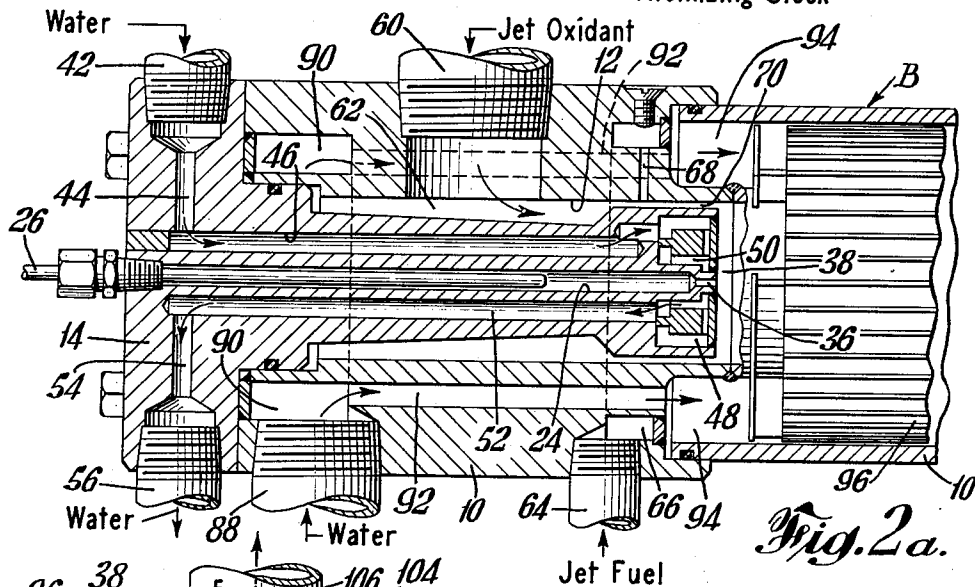
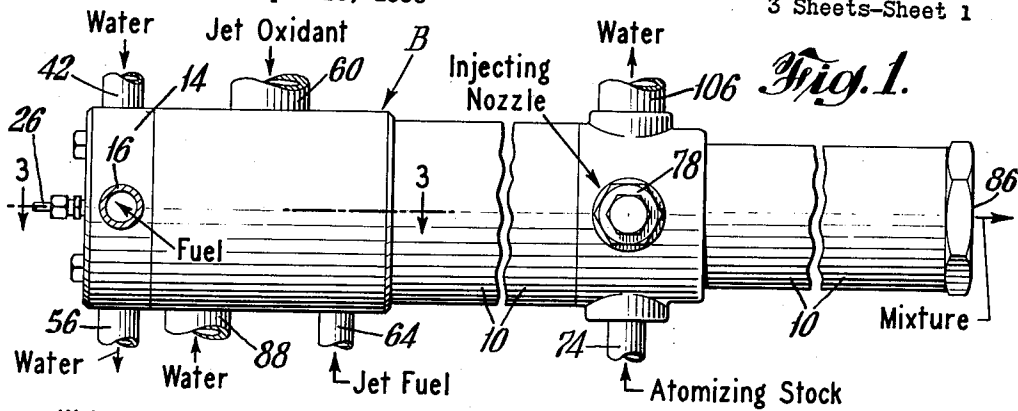
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3,091,446

METHOD FOR THE HEATING OF INDUSTRIAL FURNACES

Original Filed Sept. 18, 1956

3 Sheets-Sheet 1



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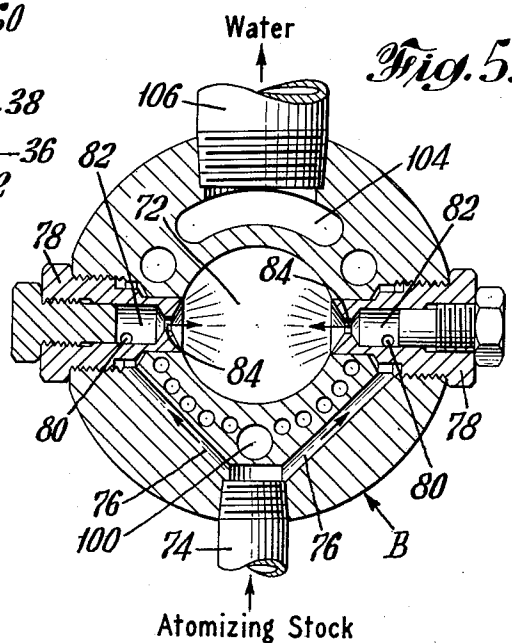
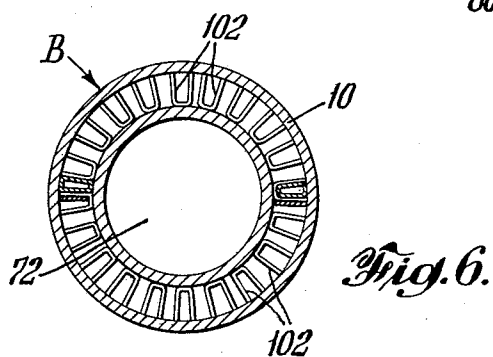
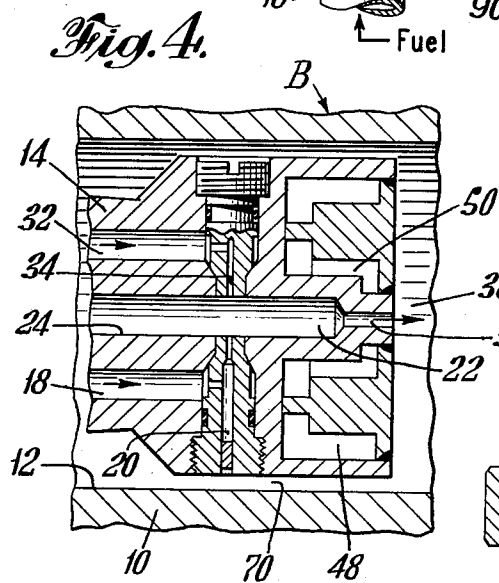
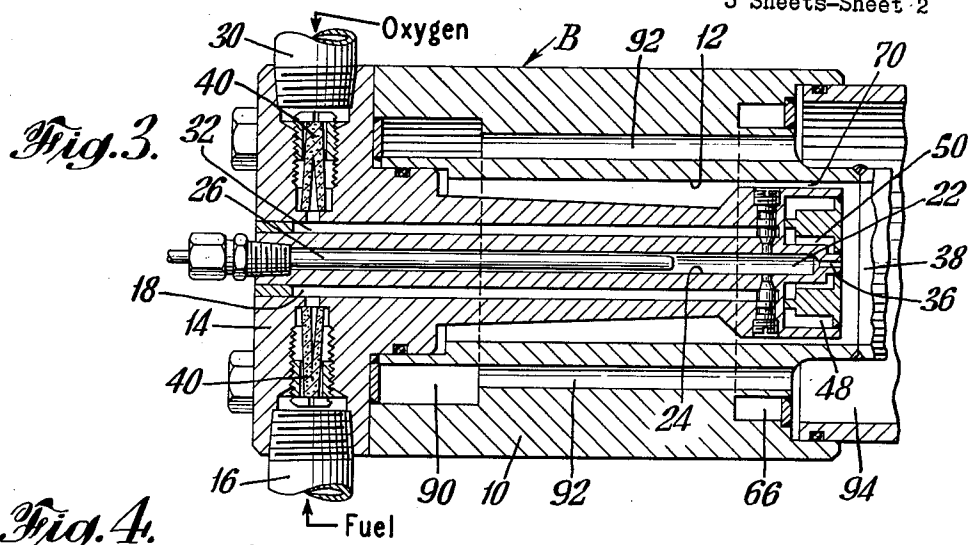
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METHOD FOR THE HEATING OF INDUSTRIAL FURNACES

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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

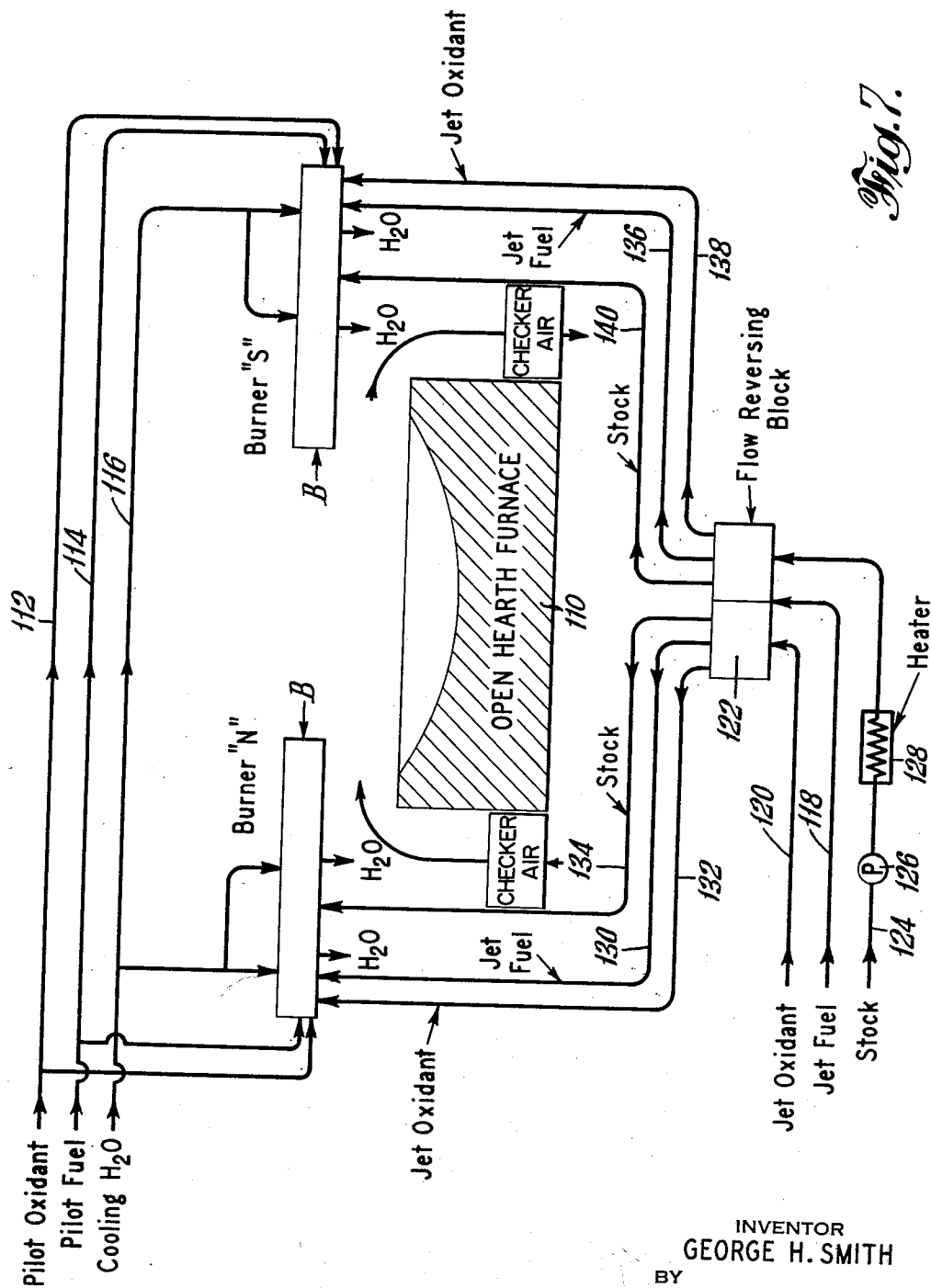


Fig. 7.

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3,091,446

METHOD FOR THE HEATING OF INDUSTRIAL FURNACES

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Continuation of application Ser. No. 61,619, Oct. 10, 1960, which is a continuation of application Ser. No. 610,553, Sept. 18, 1956. This application Feb. 19, 1962, Ser. No. 176,480

6 Claims. (Cl. 263—52)

The present invention relates to the heating of industrial furnaces, such as open hearth furnaces and the like.

Annually over one hundred million tons of steel, or about 85% of the nation's production, is made in open hearth furnaces. The primary fuel for these furnaces comprises about two billion gallons of oil while some employ fuel gas and by-product tar. To fire liquid fuels satisfactorily in the open hearth furnace requires breaking up the liquid into minute droplets by some means of atomization at high velocity.

Generally, liquid fuel is atomized into the open hearth furnace by a hot gas under pressure. Since steam is readily available, it is most commonly employed and supplied at 150–200 p.s.i.g. pressure and preferably superheated. Other compressed gases such as air, natural gas, coke oven and blast furnace gas, have been tried with relative degrees of success.

In ordinary prior atomization practice, about 3 to 5 lbs. of steam are used per gallon of oil atomized and fired, depending on the type flame desired, and perhaps as much as twice this amount of steam is used per gallon of tar or pitch fuel. This means that a furnace firing 600 g.p.h. of oil will require 1800 to 3000 lbs. of steam per hour. Although there are some practical advantages for steam atomization, there are very significant thermal disadvantages inherent to the use of steam, particularly in decreasing the maximum flame temperature and subsequent thermal radiation to the bath or melt. These disadvantages are primarily attributed to: (1) absorption of sensible heat by the steam, and (2) heat of chemically dissociating part of the steam at high temperature. In the prior steam atomization method, energy is supplied to the fuel stock at a temperature of steam-atomized oil in the range of about 250–300° F. The low final temperature of steam-atomized oil is of cardinal importance and should be expected with any compressed gas system where pipe-line specifications limit the practical operating temperatures to less than 1000° F. At these relatively low temperatures adiabatic expansion of the compressed gas within the burner imparts a cooling effect while doing work on the oil. A useful means for evaluating the effect of adiabatic expansion is readily obtained from Mollier diagrams for various gases. For example, the Mollier chart for steam shows that for steam to expand adiabatically from an initial pressure of 175 p.s.i.g. to atmospheric pressure at only 300° F., the steam must be at an initial temperature of 915° F. Steam at this temperature (915° F.) and 175 p.s.i.g. pressure is deemed impractical for open hearth furnace use.

The temperature and physical character of the open hearth flame and final performance will depend largely on the condition of oil leaving the burner, particularly

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as to: (1) degree of atomization, (2) oil temperature, (3) chemical composition of oil and inerts, and (4) velocity and momentum. With consideration of the oil temperature and the chemistry of final combustion, calculations indicate that 4 lbs. of steam (150 p.s.i.g. and 600° F.) per gallon of oil atomized may decrease the theoretical flame temperature by about 275° F. as compared with the flame temperature produced if no steam diluent were required for atomization. Also, the corresponding useful heat available to the bath, i.e., the quantity of heat available above a "critical temperature" of 2800° F., may be decreased by as much as 8,000 B.t.u. per gallon of fuel.

In any high temperature combustion process, such as the open hearth furnace, it is very worthwhile to introduce the concept of "mean critical temperature level" or simply the "critical temperature." This temperature level is ascertained as the lowest temperature at which the process could function theoretically and is very useful in analyzing the thermal aspects of high temperature systems. The critical temperature for open hearth steel-making depends on several factors such as the melting points of iron and slag, depth of bath and furnace geometry and, as such, is usually taken at about 2800° F. Full consideration of this high temperature datum level is beneficial since maximum thermal efficiency will depend on generating the maximum amount of heat per unit of fuel fired at temperatures in excess of the critical value of 2800° F. This represents a thermal "driving force" for the system, and any heat produced at temperatures below the critical cannot be used by the furnace directly. This heat (at less than 2800° F.) comprises most of the heat of the open hearth furnace and should be considered as waste heat except insofar as it can be recovered partially by regeneration or in waste heat boilers.

It is therefore the object of the present invention to provide a method for treating fluid hydrocarbon fuels, including pitches, tars and fuel oils in order to produce a flame which is a much more efficient heat radiator than are flames from conventional processes employing such fuels atomized with steam or other compressed gases.

Another object of the invention is to provide a method wherein fluid hydrocarbons, such as fuel oils, pitches and tars, are finely atomized and introduced into an industrial furnace and burned therein.

A further object of the invention is to provide such a method effecting a higher preheat to the fuel during atomization and injection into the burning zone within the furnace so that the rate of burning therein will be correspondingly greater, resulting in a higher temperature and a higher volumetric heat release.

A still further object of the invention, in its application to steel making furnaces, such as the popular open-hearth type, is the provision of the desired momentum required for bath agitation which can be imparted to the flames without the undesirable thermal dilution, with steam for example, which would have the effect of lowering the flame temperature and radiation.

Other aims and advantages of the invention will be apparent from the following description and appended claims.

In accordance with the method of the present inven-

tion, a fluid fuel and oxidant are mixed and burned in a combustion zone and hot products of combustion are discharged into a treating zone into which a stream of fluid or fluidized combustible stock material, such as liquid fuels, gaseous fuels and fluidized solid fuels, is injected. The hot products of combustion enter the treating zone at high temperatures and of the order of sonic velocities (for example, approximately 3000 f.p.s. for stoichiometric $\text{CH}_4\text{--O}_2$ mixtures) to accomplish preheating and fine atomization of the fluid stock there injected. The preheating and atomization of the fluid stock, which is then discharged into an industrial furnace and burned with an oxidant therein, increases the heat transfer efficiency of the subsequent combustion reaction. It is believed that, upon entering the industrial furnace, the fine degree of atomization greatly increases the speed of combustion as well as the efficiency of heat transfer within the furnace. In addition, the fine degree of atomization is believed to promote some desirable pyrolysis of the fuel stock in the furnace to produce gaseous products which are very easily combusted within the furnace. Accordingly, the entire combustion process within the industrial furnace is accelerated and highest temperatures are achieved. Thus, the preheating and atomizing process of the invention serve to increase the efficiency of heat transfer from the flame to the mass within the furnace to be heated, i.e. the bath or charge, for an open hearth furnace.

All the various modes of heat flow are present in the open hearth system, including conduction, convection transfer in liquids and between gases and liquid or solid surfaces, and radiation from solids, liquids and gases. However, since it is generally agreed that when the bath is flat, as much as 80-85% of the heat transferred to the bath is by thermal radiation, only this mechanism of heat flow will be discussed. The mathematical relationship of radiant heat emitted with temperature is shown by the following modification of the Stefan-Boltzmann Law:

$$(1) \quad H = ek(T_f^4 - T_c^4)$$

In which:

H =Heat radiated from a unit region or target area of the flame at temperature T_f to the bath at temperature T_c =B.t.u./hr. $\times$ ft.²

e =Emissivity ≤ 1.0

k =Boltzmann constant 17.3×10^{-10} B.t.u./hr. $\times$ ft.² $\times$ ($^\circ$ F. abs.)⁴

T_f, T_c =Absolute temperature ($^\circ$ F.+460) of flame and the critical temperature, respectively.

$(T_f - T_c)$ =Thermal "driving force" for heat flow from flame to melt.

The above equation shows two important criteria which must be considered to obtain maximum thermal efficiency in the open hearth furnace: (1) maximum flame temperature T_f above the critical temperature T_c , and (2) a maximum emissivity e . As an example of how this relationship may show the effect on radiation heat transfer when increasing the flame temperature, let us assume a steam atomized fuel flame at 3400° F. and a jet atomized fuel flame at 3500° F. and with the following calculation:

- Theoretical flame temperature T_{fs} of steam-atomized oil=3400° F.+460=3860° F. abs.
- Theoretical flame temperature T_{fj} of jet-atomized oil=3500° F.+460=3960° F. abs.
- Critical temperature T_c =2800° F.+460=3260° F. abs.
- Emissivity for all cases=1.0
- Relative heat radiated with steam flame= H_s
- Relative heat radiated with jet flame= H_j

Then from Equation 1:

$$(2) \quad \frac{H_j}{H_s} = \frac{ek(T_{fj}^4 - T_c^4)}{ek(T_{fs}^4 - T_c^4)}$$

And substituting the above assumed numerical values, then:

$$\frac{H_j}{H_s} = \frac{(3960)^4 - (3260)^4}{(3860)^4 - (3260)^4} = 1.22$$

From the above, it is shown that an increase in the theoretical flame temperature from merely 3400 to 3500° F. (3% increase) results in about a 22% increase in the high temperature heat transferred by radiation.

In effecting the jet atomization of fluid stock with high velocity hot combustion products in accordance with the invention, the stock may reach practical atomization temperatures as high as 1200-1300° F. (average about 900° F.). This compares with steam atomized stock temperatures of probably less than 300° F. The effect on thermal radiation intensity can be seen by a consideration of the effects of increases in theoretical flame temperature, discussed hereinabove.

Further, whereas it was pointed out above that the decrease in flame temperature for a given example was about 275° F. for steam atomization, and that the quantity of heat available above a "critical temperature" of 2800° F. may be decreased by as much as 8000 B.t.u. per gallon of fuel, it has been found that for equivalent weights of hot jet combustion products per gallon of fuel, the theoretical flame temperature is decreased only about 60° F. and the quantity of heat available above a "critical temperature" of 2800° F. is decreased only about 400 B.t.u. per gallon of fuel.

It can therefore be seen that any atomizing diluent (steam of high velocity hot combustion products) detracts from the flame intensity, but that atomization by hot gaseous products is far superior to atomization with strongly diluting steam.

In the drawings:

FIG. 1 is a longitudinal view of the jet atomizing burner of the invention;

FIGS. 2a and 2b are partial longitudinal sectional views of the burner of FIG. 1;

FIG. 3 is a partial sectional view of the burner taken along the line 3-3 of FIG. 1;

FIG. 4 is a partial sectional view showing the details of construction of the pilot burner of FIG. 3;

FIG. 5 is a cross-sectional view of the burner taken along the line 5-5 of FIG. 2b;

FIG. 6 is a cross-sectional view of the burner taken along the line 6-6 of FIG. 2b; and

FIG. 7 is a schematic view of an open hearth furnace with two burners mounted at opposite ends for alternate operations, and shows fluid supply conduits for the system.

Referring specifically to the apparatus embodiment of the drawing, burner B is provided having an elongated outer casing 10 containing cylindrical longitudinal passage 12 passing therethrough. A pilot burner 14 is mounted in longitudinal boring 12 at the rear end of casing 10.

The pilot burner 14, shown in detail in FIGS. 3 and 4 of the drawings, is provided with radial fuel inlet conduit 16 at the lower end and communicates with longitudinal fuel conduit 18 which passes fuel to the forward end of the pilot burner to radial fuel metering port 20 which discharges the fuel into chamber 22 at the forward end of the pilot burner. Chamber 22 is formed by axial boring 24 into which thermocouple 26 is inserted. Radial oxygen inlet conduit 30 is positioned in the upper end of pilot burner 14 and communicates with longitudinal oxygen passage 32 which passes oxygen to the forward end of the burner and discharges it through communicating radial metering passage 34 to chamber 22. The fuel and oxidant are mixed and burned in chamber 22 and the resultant flame is discharged from pilot burner 14 through

discharge passage 36, to the main combustion zone or chamber 38 of the burner. Filters 40 are provided in both the fuel and oxidant inlet conduits 16 and 30, respectively, to filter the gases entering the pilot burner.

The pilot burner 14 is water cooled to prevent overheating, cooling water entering inlet conduit 42 communicating with radial passage 44 at the rear of the pilot burner and passing successively to longitudinal cooling passage 46, annular cooling passages 48 and 50 at the forward end of the burner, and through longitudinal passage 52 and radial passage 54 to outlet conduit 56.

Jet fuel and oxidant are supplied to the combustion stage or chamber 38 of burner B for mixing and ignition by the pilot flame discharging from the passage 36. Jet oxidant, such as high purity (95-100%) oxygen, low purity (45%) oxygen, or air enters the burner casing 10 through radial conduit 60 and passes through annular space 62, formed between the walls of longitudinal passage 12 and outside of pilot burner 14, to the primary combustion zone or chamber 38 where it is mixed and burned with the jet fuel. It is to be understood that dimensions of passages must be modified, as is well known to the art, when changing the selection of oxidant employed in order to insure flame stability.

Concurrently therewith, fluid jet fuel enters burner casing 10 through radial inlet conduit 64 and passes through annular distributing passage 66 to a plurality of radial metering ports 68 through which it is discharged into a shallow annular mixing passage 70, through which an annular stream of jet oxidant passes transversely from annular passage 62 to combustion zone 38.

Mixing of the jet fuel and jet oxidant streams is accomplished in the shallow annular chamber 70 and an intimate mixture is attained by the time the mixture passes into combustion zone or chamber 38 in the region of the pilot flame. Combustion is there initiated from combustion zone or chamber 38 to the treating zone or chamber 72 where the fluid stock to be preheated and atomized is injected. The velocity of the oxidant and fuel mixture passing through annular chamber 70 should be high enough so that the flame cannot flash-back into this chamber at any point. This velocity has been found to be satisfactory at 300 to 500 feet per second, or higher. The danger arising from too low a velocity is that flash-backs or other oscillatory conditions cause pressure fluctuations resulting in rough or interrupted fuel and oxidant flow, which conditions are associated with rough and erratic burning in the combustion chamber.

The velocity of the hot combustion products passing from the combustion zone is preferably greater than a Mach number of 0.5 and can be considerably higher. The high velocity promotes the mixing and improves atomization of the second stage fluid stock without requiring complex nozzles for injection of such stock. With the use of high velocity mixing the preheating, atomization and acceleration of the second stage fluid stock is accomplished most rapidly.

As employed herein, the term "Mach number" refers to the ratio of the linear gas velocity of the mixture to the velocity of sound in the same mixture for the given temperature and gas composition.

The fluid fuel atomizing stock to be treated is introduced into the burner through radial conduit 74 from which it passes through a plurality of borings 76 to spray nozzles 78. The atomizing stock preferably enters spray nozzles through borings 80 which communicate with internal chambers 82 of the nozzle at an angle tangent to the internal face of the chamber. In this manner, the entering atomizing stock stream is caused to swirl around the internal walls of chamber 82 and pass from chamber 82, through port 84 of the treating zone 72, as a fine spray of atomizing stock.

The hot products of combustion passing at high temperature at or near sonic velocity from the combustion

chamber contact the atomizing stock sprayed from nozzles 78 and carry the stock down the length of the treating zone 72 and discharge it from the open end 86 of the burner as a preheated, atomized accelerated stream of stock.

Cooling water is circulated through the outer casing 10 of burner B to prevent overheating. Water enters the rear end of casing 10 through radial water conduit 88 and passes through annular distributing passage 90 to longitudinal cooling passages 92 and in turn, to annular passage 94 supplying a plurality of cooling compartments 96 surrounding the combustion zone 38. Cooling water passes through these cooling compartments 96 is discharged through annular cooling passage 98 to longitudinal cooling passage 100, which communicates with plurality of radially-positioned cooling ducts 102 (similar to radial cooling ducts 96 surrounding combustion zone 38). Cooling water is then returned through another series of opposite-positioned cooling ducts 102 to longitudinal passages 104, from which it passes from the burner casing 10 through outlet conduit 106.

As shown in FIG. 7 of the drawing, two atomizing burners embodying the invention are positioned at opposite ends of an open hearth furnace and operated alternately, for periods of time well known in the art, to heat the furnace and pass the products of combustion through alternate checker systems which, on the reversal of burners, serve to preheat the incoming air. Burners B are positioned so as to discharge an atomized stream over the length of open hearth furnace 110 and are supplied with various process fluids through parallel distributing lines. The pilot burner is supplied with pilot oxidant and fuel, such as oxygen and propane, respectively, through lines 112 and 114, respectively, and cooling water is supplied to both burners through line 116. The flow of these fluids to both burners is continuous and occurs regardless of whether the burner is then operating to atomize stock. Jet fuel and oxidant are supplied to the burners through lines 118 and 120, respectively, passing to flow reversal block 122 which times the period during which flow of these fluids is maintained to one of the two burners. Atomizing stock is similarly supplied to the reversal block through conduit 124, and a pump 126 and heater 128 are provided in atomizing stock conduit 124. During that portion of the cycle when the north burner ("N") shown in FIG. 7 is to be operated, jet fuel, jet oxidant and atomizing stock are passed through flow reversal block 122 and lines 130, 132 and 134, respectively, to that burner. During the other portion of the cycle, flow reversal block 122 operates to pass these fluids through lines 136, 138 and 140, respectively to the south burner ("S"), positioned at the opposite end of the open hearth furnace 110. In this manner, a continuous cycle is established and periodic and alternating operation of the two burners is provided in accordance with established open hearth furnace procedure.

A wide variety of fuel oils, pitches and tars have been atomized into an open hearth furnace in accordance with the invention and an improvement in heat transfer efficiency to the bath over efficiencies obtained for conventional steam atomization was attained in every case.

It is, of course, to be understood that the fuel and oxidant employed in the pilot burner, as well as the fuel and oxidant employed in the jet combustion stage, may consist of any suitable fuel and oxidant which forms a combustible mixture. The fuel and oxidant are preferably supplied to the jet combustion stage in such proportions as to form a substantially stoichiometric mixture. This has been found desirable for maximum stability of the first stage flame. Moderate excess of oxidant could be consumed in the second or treating zone without altering the efficiency of the overall process.

In a series of three tests, an air jet atomizing burner of the type shown in the embodiment of the drawings was

7 installed at one end of an open hearth furnace and a conventional steam injection burner was installed at the opposite end. The burners were operated cyclically as described hereinabove. Table I below sets forth comparative data for operation of these tests.

TABLE I

Furnace and Test	Type Burner	Oxidant		Fuel		Max. Flame Radiation Intensity B.t.u./hr./sq. ft. $\times 10^4$	Maximum Checker Temp. ° F.
		Purity, percent	Flow, c.f.h.	Type	Flow, g.p.h.		
A-1	Steam	45	12,400 undershot O ₂	Oil	455	32.7	1,770
A-1	Jet	45	12,400 jet	Oil	455	39.6	1,500
A-2	Steam	95	6,500 undershot O ₂	Pitch	350	38.6	1,650
A-2	Jet	Air (20)	45,600 jet	Pitch	350	44.6	1,450
B-3	Steam			Oil	500	35.5	2,200
B-3	Jet	Air (20)	35,000 jet	Oil	500	39.0	1,925

In each of the comparisons in Table I above, it is to be noted that the maximum flame radiation intensity is substantially greater for jet burner atomization than for corresponding steam atomization. In addition, lower maximum checker temperature values for jet burner atomization indicate a more efficient transfer of thermal energy to the open hearth bath with less heat loss to the outlet checkers.

The following table sets forth production data for 121 jet atomizing burner heats made in a 200-ton fired open hearth furnace and comparative data for 166 steam atomizing burner heats made in the same furnace immediately prior to the jet atomizing burner heats.

TABLE II

Production Data Comparing Steam and Jet Atomization in a 200-Ton Open Hearth Furnace—65 Percent Hot Metal Practice

	Steam Atomization	Jet Atomization (Air)
Total number of consecutive heats	166	121
Total product, net ingot tons	33,515	24,581
Average heat size, tons	202	203
Average heat time, charge-tap, hrs.	10.48	9.43
Average production rate, charge-tap, tons/hr.	19.26	21.54
Average heat time, tap-tap, hrs.	11.77	11.06
Average production rate, tap-tap, tons/hr.	17.16	18.37
Fuel consumption, gal. oil/ton	20.7	19.05
Oxidant consumption, cu. ft./ton		1,400
Natural gas consumption, cu. ft./ton	109	140
Steam consumption, lb./ton	3.07	2.82
B.t.u./ton of ingots ($\times 10^6$)		

¹ Entire shop average production with steam atomization equaled 16.75 tons per hour.

The following Table III sets forth data for test at four flow rates of an air jet atomizing burner employing natural gas as the jet fuel.

TABLE III

Air Flow, c.f.h.	Natural Gas Flow, c.f.h.	Exit Temp., ° F.	Exit Velocity, f.p.s.	Burner Thrust, lb.	Chamber Pressure, p.s.i.g.
35,000	4,120	1,110	1,840	73	50
30,000	3,530	1,000	1,570	58	38
25,000	2,940	900	1,390	43	30
20,000	2,360	810	1,210	31	22

In these tests water was employed as the fluid stock to simulate operation using No. 6 fuel oil and to permit measurement of burner thrust and chamber pressure. The temperature and velocity were corrected for oil and calculated from a heat balance. Calculations were based on 425 gallons per hour of oil with a 1.5 inch inside diameter atomizing burner.

The following Table IV sets forth further data of comparative tests of an air jet atomizing burner embodying the invention and a standard steam injecting burner installed in an open hearth furnace in the manner described hereinabove.

TABLE IV

Burner-type atomizer	Steam	Steam	Jet	Jet
Bore diameter-inches	0.824	0.824	2.037	2.067
Fuel-type	Oil	Oil	Oil	Oil
Fuel rate, g.p.h. (main fuel)	420	500	500	600
Jet fuel rate, c.f.h.			3000	3500
Jet fuel pressure, p.s.i.g.			28	28
Jet oxidant-type			Air	Air
Jet oxidant rate, c.f.h.			30,000	35,000
Steam flow for atomization, lb./hr.	2,200	2,600		
Temperature of atomized oil, ° F.	250	250	900	900
Thermal radiation:				
No. 1 door, mv.	85	88	97.5	99.5
No. 2 door, mv.	83	85	84	87
No. 3 door, mv.	65	70	67	68.5
No. 4 door, mv.	62	66.5	62.5	64
No. 5 door, mv.	61.5	64	61.5	63.3

¹ Estimated on the basis of heat balances.

The thermal radiation data of Table IV indicate the more desirable concentration of higher thermal radiation intensity at the inlet end of the open hearth furnace obtained with the jet atomization of the invention than for the conventional steam atomization.

This application is a continuation of my copending application Serial No. 61,619 filed October 10, 1960, which is a continuation of my copending application Serial No. 610,553 filed September 18, 1956, which, in turn, is a continuation-in-part of my copending application Serial No. 516,879 filed June 21, 1955, all now abandoned.

What is claimed is:

1. The method of heating an industrial furnace with a main fluid hydrocarbon fuel stock and furnace air comprising forming a substantially stoichiometric mixture of fluid fuel and oxidant; burning said mixture in a combustion zone; during the operation, continuously discharging the hot products of said combustion as a stream at a velocity greater than 0.5 Mach number into a treating zone into which a stream of fluid hydrocarbon fuel stock is injected continuously during operation; preheating and atomizing said stream of fluid hydrocarbon fuel stock in said treating zone; during the operation, continuously discharging the resultant preheated and atomized stream into said industrial furnace; and there burning said resultant streams with air provided externally of the combustion and treating zones.

2. The method of heating an industrial furnace by the combustion of fluid hydrocarbon fuel stock and furnace air comprising forming at a constant and at a near sonic velocity a substantially stoichiometric mixture of fluid fuel and oxidant; burning said mixture in a combustion zone; discharging the hot products of said combustion as a stream at a velocity greater than 0.5 Mach number into a treating zone into which a stream of fluid hydrocarbon fuel stock is injected continuously during operation; preheating and atomizing said stream of fluid hydrocarbon fuel stock in said treating zone; during the operation, continuously discharging the resultant preheated and atomized stream into said industrial furnace; and there burning

ing said resultant stream in air provided externally of the combustion and treating zones.

3. The method of heating an open hearth furnace with fluid hydrocarbon fuel stock as the primary fuel and checker air as the primary oxidant comprising forming a substantially stoichiometric mixture of secondary fluid fuel and secondary oxidant; burning said mixture in a combustion zone; during the operation, continuously discharging the hot products of combustion at a constant velocity greater than 0.5 Mach number into a treating zone into which a stream of primary fuel is injected continuously during operation; preheating and atomizing said stream of primary fluid fuel in said treating zone; discharging the resultant preheated and atomized stream along with said hot products of combustion into said open hearth furnace; and there burning said resultant stream above the open hearth furnace bath with checker air provided externally of the combustion and treating zones to provide a flame of high radiation intensity capable of transferring energy to said bath at high efficiency.

4. The method in accordance with claim 3, wherein said secondary oxidant is air.

5. The method in accordance with claim 3, wherein such heating of the bath is effected alternately from opposite ends of said bath and checker air is provided from alternately operating checkers at opposite ends of the bath.

6. The method of heating an open hearth furnace with liquid hydrocarbon fuel stock as the primary fuel and checker air as the primary oxidant, which comprises forming a substantially stoichiometric mixture of secondary fluid fuel and secondary oxidant; burning said mixture in a combustion zone; during the operation, continuously discharging the hot products of combustion from said combustion zone at a constant velocity greater than 0.5 Mach number into an elongated treating zone; simultaneously continuously injecting a stream of liquid hydrocarbon fuel stock transversely into said elongated treating zone; utilizing the heat and velocity of said discharged hot products of combustion for preheating and atomizing said transversely injected liquid hydrocarbon fuel stock and carrying the same down the length of said treating zone; directing the resultant preheated and atomized liquid hydrocarbon fuel stock along with said hot products of combustion continuously at high constant velocity into said open hearth furnace; there burning said resultant stream above the open hearth furnace bath with checker air provided externally of the combustion and treating zones to provide a flame of high radiation intensity and capable of transferring thermal energy to said bath at high efficiency.

No references cited.