Jan. 11, 1927. 1,614,295

A. E. GRUNERT ET AL

FURNACE CONSTRUCTION

Filed Nov. 24, 1923 2 Sheets-Sheet 1

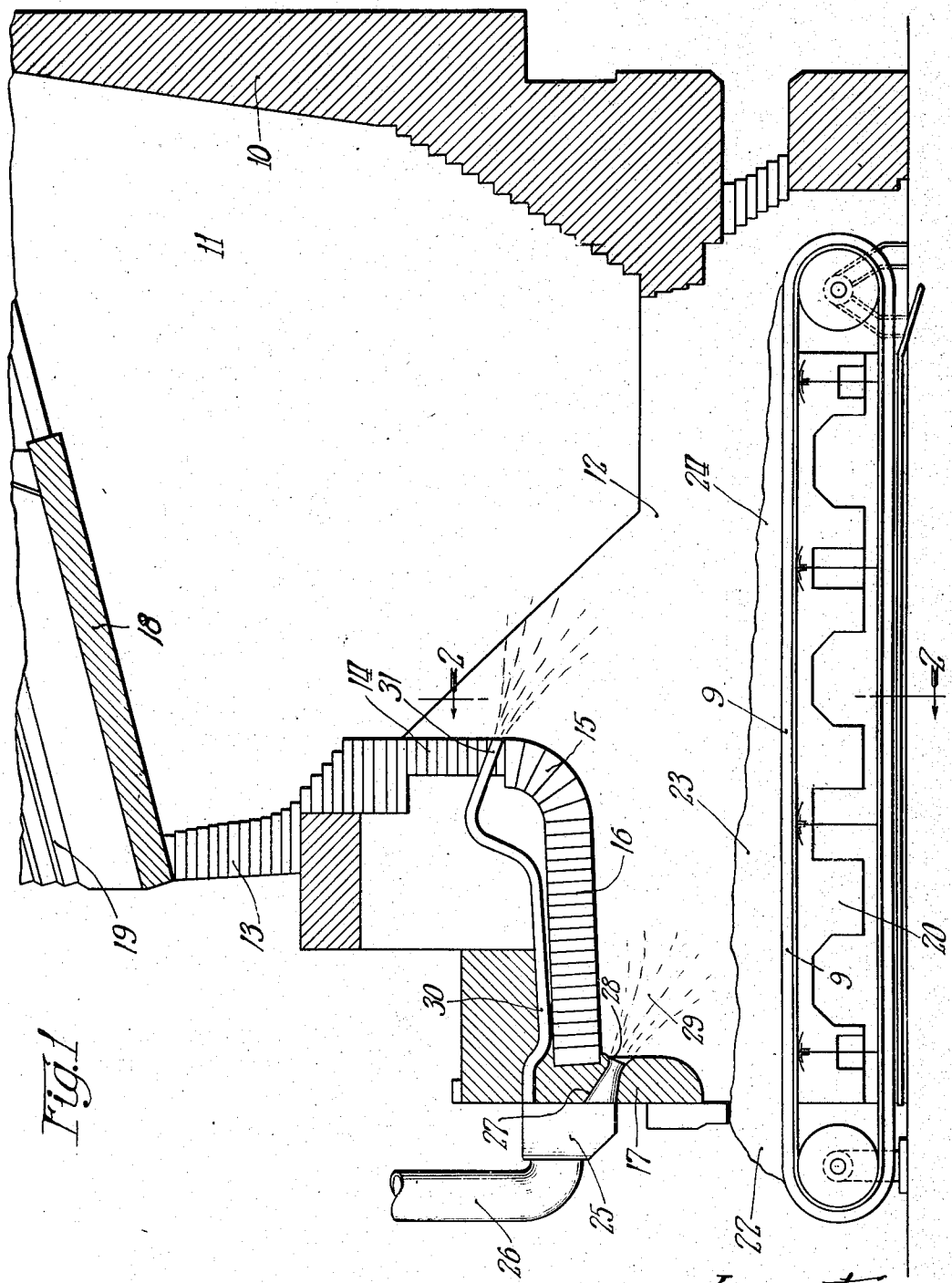


Fig. 1

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Fig. 2

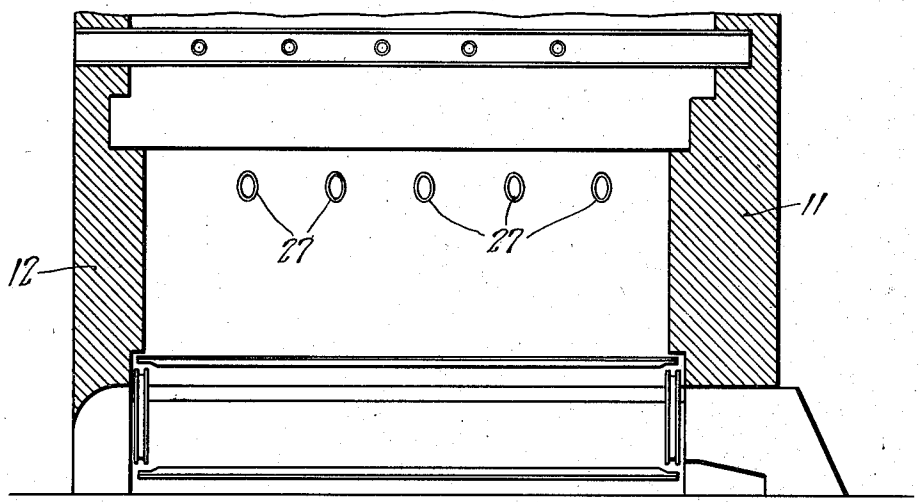


Fig. 3

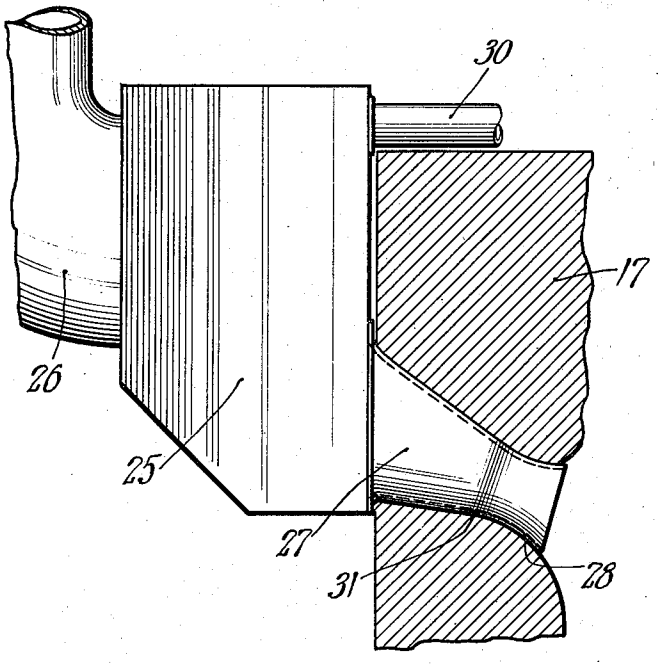
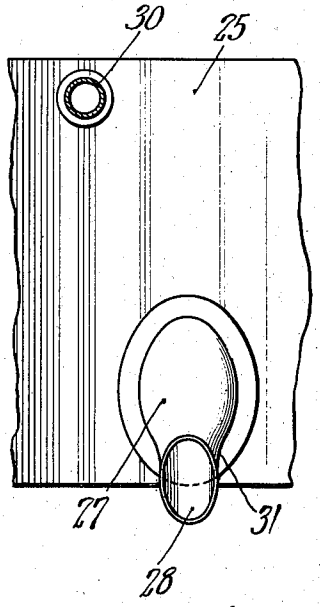


Fig. 4



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UNITED STATES PATENT OFFICE.

ARTHUR E. GRUNERT AND ALEX D. BAILEY, OF CHICAGO, ILLINOIS.

FURNACE CONSTRUCTION.

Application filed November 24, 1923. Serial No. 676,744.

Our invention relates to furnace construction and more particularly to means for improving the combustion in a furnace.

It is a purpose of the invention to provide means for injecting air under pressure above the fuel bed so as to provide for a sufficient supply of oxygen to cause more perfect combustion than is obtained otherwise at the point in the furnace where the combustible gases are distilled off so as to cause a thorough and continuous mixture of air and said gases so as to complete the combustion of same earlier and substantially completely, also consume substantially completely the unburned particles of free carbon or coal, thus increasing the efficiency of combustion of the fuel and substantially preventing the formation of smoke.

It has been found that where the natural draft is depended upon for mixing air over the fire with the volatile combustible gases driven off by the heat from the fuel bed that no matter how the openings are arranged nor how many openings are provided there will not be a uniform mixture of air and combustible gases throughout the furnace but the air will tend to travel more along the walls of the furnace than toward the center thereof where the volatile combustible gases are banked and there will be a region in which there will be an insufficient supply of oxygen to cause the proper combustion to take place. This uneven stratification not only takes place longitudinally with the fuel bed but also tends to unevenness in mixture in a transverse direction. Due, therefore, to the tendency of gas streams toward parallel flow, a condition exists resulting in a delay in the combustion, and incomplete combustion with resulting smoke. This condition is what is ordinarily referred to as "long flaming" or "delayed" combustion, and the degree of prevalence tends in general to increase with the proportion of volatile constituents of the fuel. This flaming is partially reducing and causes an increase in the slagging and fouling of the heating surfaces. This is true even where a forced draft is provided such as in the case of mechanical stokers where air under pressure is blown through the fuel bed. These volatile gases are of the same kind as are driven off from coal in a gas retort where illuminating gas is formed from the destructive distillation of coal. The gases are colorless and do not of themselves either constitute nor form smoke. It is only when these gases are burned in an incomplete manner as, for example, chilled while burning or ignited in the presence of insufficient air, or the air is not sufficiently mixed with or distributed throughout the gases, that the phenomenon of formation of smoke occurs. Formation of smoke results from a breaking up of the hydrocarbon gas. It appears that the hydrogen part of the gas will dissociate from the carbon and will combine with oxygen more readily than the carbon, leaving the carbon in the form of a fine amorphous powder suspended in the gas and termed smoke. The dissociation of the hydrogen may be carried on at a temperature below the ignition temperature of the said carbon with oxygen with which it may be in contact.

By applying the air under pressure above the bed of burning fuel and injecting it at a sufficient velocity so that a stream of air will be projected into the furnace a sufficient distance to reach that portion of the furnace where a large amount of distillation of gases occurs, which portion but little air reaches, due to natural draft, thus bringing about an intimate mixture of oxygen with the partially burned combustible gases at a point much earlier than would ordinarily occur, and as a result practically all these gases are burned and a much greater efficiency is obtained from the furnace than where the draft is blown through the fuel bed or the natural draft is depended upon through openings in the sides or front of the furnace. Proper combustion of the large amounts of combustible gases which are released from bituminous coals such as we find in the Chicago region, presents a very difficult problem. The difficulty is not so much in getting sufficient air into the furnace, for that is easy enough. Merely forming an opening in the walls of the fire-box will, by natural draft, admit any required amount of air. But that will not do.

If the air is admitted in large quantities it will tend naturally to cool the walls of the fire-box with which it is in contact. It will also cool the boiler and instead of securing the desired effect it merely decreases the efficiency of the furnace and of the boiler. But the large volumes of combustible gas require correspondingly large vol-

umes of air to complete the reaction of combustion. This is the first condition which must be fulfilled for complete and satisfactory chemical union between the oxygen of the air and the hydrogen carbon sulfur, etc., of the combustible gases.

The next consideration is that it is not sufficient merely to supply the proper amounts to form the right proportions, but the proper amounts must first be provided and then they must be mixed so thoroughly that each particle of combustible material has, in sufficiently close relation thereto, the proper amount of oxygen to permit of chemical union. This is difficult to attained because of the peculiar but well-known tendency of the gases in the furnace to flow in parallel streams and to diffuse only very slowly into each other. The more rapid the passage of the gases through the furnace, the less time and tendency is there for them to diffuse and intermingle.

The best way known to the prior art to secure the desired diffusion and intermingling was to provide a long fire-box giving the gases a maximum of time to intermingle and burn before they struck the boiler tubes.

The next consideration is that such intermingling alone is not sufficient. The gases, after they are intermingled, must be ignited continuously and not chilled, otherwise the chemical reaction is retarded or prevented from being completed.

We secure the desired effect of completing the chemical reaction of burning of the gases by fulfilling the above recited and other incidental requirements by our method of combustion.

We introduce the proper amount of air by proportioning the air introduced over the fire to the amount passing through the fuel bed. Next, we deliver the air into the gases to be burned at the point where they are formed, i. e., immediately above the incandescent fuel bed. Next, we deliver the air in jets of such size and velocity as to produce a violent turbulence and mixing of the air and fuel gases. This turbulent mixing of the fuel gases and air stirs them thoroughly into each other. This is done in a region where ignition is maintained first, by the incandescent fuel bed and, second, by the hot walls of the arch and adjacent furnace walls. The turbulence and mixing of the gases is comparable to stirring of two reagents together to secure completion of a chemical reaction.

In the form of the invention shown in the drawings the air blast means is shown as being applied to a furnace having what is known as a flat arch in which the air under pressure is injected under the arch and well above the bed of fuel. It has also been found to be desirable in some cases to inject air under pressure into the furnace at the front wall thereof rearwardly of said flat arch and this is also shown in the form of the invention illustrated. It is of course to be understood that while a flat arch is shown, the device could be applied as well to a furnace having any form of arch desired.

Preferably, the air is injected over the bed of fuel through nozzles which are arranged in spaced relation so as to properly distribute the air among the distilled off gases and these nozzles are preferably so constructed as to obtain a high velocity from the nozzle to thus inject the air as far as possible into the furnace. The desired object of high velocity injection nozzles is penetration of the zone of incomplete combustion before agitation takes place.

Other objects and advantages of the invention will appear as the description of the accompanying drawings proceeds. However, we desire to have it distinctly understood that we do not intend to limit ourselves to the exact details shown or described but that we intend to include as part of our invention all such obvious changes and modifications of parts as would occur to a person skilled in this art and as would fall within the scope of the claims.

In the drawings:

Fig. 1 is a vertical, longitudinal, sectional view of a furnace showing our improvements applied thereto;

Fig. 2 is a transverse, sectional view taken on the line 2—2 of Fig. 1;

Fig. 3 is a fragmentary enlarged vertical sectional view showing one of the nozzles; and

Fig. 4 is a fragmentary face view, partly in section, showing the compressed air means, the refractory material through which the nozzles extend being omitted for purposes of clearness.

Referring in detail to the drawings, in Figs. 1 and 2 is shown a furnace comprising a rear wall portion 10, a side wall portion 11 and partitions 12 between adjoining furnace portions. Only one furnace portion is shown in the drawings as the furnace portions are, of course, duplicates. The furnace is also provided with a front wall 13 which comprises a substantially vertically extending portion 14 extending to the curved rear end portion 15 of the flat arch 16 which extends from the forwardly projected portion 17 of the front wall of the furnace to the portion 14 thereof. The furnace is also provided with a baffle wall 18 below the tubes 19, the boiler shown being a well known form of water tube boiler and the furnace construction referred to above being a well known type of furnace construction. The function of arch 16 is primarily to hold and reflect heat upon the entering fuel for the purpose of igniting the same. The space

under the arch is the chief region where the combustible gases are driven off, and it is here that combustion of the gases should take place in order to secure the most effective use of the space and of the fuel. By introducing the proper amount of air into the bank of gases and securing turbulence in this hot chamber, the reaction of combustion is carried out quickly and completely with resulting increase of efficiency and the elimination of smoke formation.

The furnace is shown as being provided with a mechanical stoker having a chain grate 9 which may be provided with forced draft means 20 blowing through the grate and through the bed of fuel thereon. The bed of fuel is indicated by the numeral 21 in the drawings and, as is well known, the fuel 22 at the end of the stoker, where the same enters the furnace, is not yet ignited while that intermediate the length of the stoker at the region indicated by the numeral 23, is coking and is giving off a large amount of hydro-carbon gas or what is known as volatile matter which is highly combustible and renders a very hot flame provided the proper amount of air or oxygen is mixed with the same to obtain the full heat value thereof and a condition of ignition is maintained. After the fuel has been thoroughly coked the same is made up largely of carbon and contains but very little of volatile matter, this condition existing in the region indicated by the numeral 24. The amount of air supplied through the grate at this point is generally in practice more than sufficient for burning the coked fuel.

However, in the region above the portion 23 of the fuel bed where coking occurs and where the volatile matter is being driven off it has been found to be very difficult to supply the proper amount and distribution of air even where forced draft is provided through the fuel bed as the fuel, of course, offers considerable resistance to the air blast and the ability of the force of the air to cause thorough mixing of the oxygen with the gases is lost because the chemical reaction known as combustion taking place due to a flow of air through an incandescent fuel bed is in the presence of an excess of carbon, hydrogen and sulphur, wherefore it is highly improbable that sufficient oxygen to complete the combustion could be forced through the fuel bed itself in the zone 23 where the e conditions prevail.

This is true because of the volatile contents of the fuel. The oxygen of the air tends to combine at once with the incandescent carbon of the fuel bed to form carbon dioxide and to give off heat. The heat in turn drives off volatile gases. Hence the faster that heat is liberated the faster will the coal be coked by driving off volatile constituents. Since the fuel bed is fairly thick at this point, the carbon dioxide in passing through the incandescent mass of fuel tends to be reduced, at least in part, to carbon monoxide. Both of these effects result in the formation of large amounts of combustible gases in the coking region of the furnace. Also, in supplying air through draft openings in the walls of the furnace above the fuel bed where the natural draft of the furnace is depended upon for mixing the air with the volatile matter, it has been found that most of the air follows the walls of the furnace toward the smoke stack following the path of least resistance and the shortest path. This causes a condition where the air is arranged in substantially one stratum while the volatile matter is in another stratum and the same are not properly mixed to obtain the best combustion. It is a well known phenomenon that in a flowing fluid there is a tendency for the particles to move in so called stream lines, that is to say, in smooth curves, and the tendency of these particles is, furthermore, to move in generally parallel lines.

Diffusion which includes a lateral movement requires time for its accomplishment. Where the lateral distance that must be traveled is appreciable, and the velocity fairly high, it can be seen that the gases may pass out of the fire-box before diffusion can occur. It is because of this fact that the prior art has provided long or deep fire-boxes in an attempt to provide a length of path great enough to secure the desired lateral travel of the gases to secure diffusion or intermingling.

This invention also applies to the prevention of smoke, inasmuch as smoke is a distilling out of minute carbon particles in a reducing medium which condition is prevalent to a varying degree in zone 23. The air injection as described above supplies the necessary oxygen for consuming this smoke dust and carbon particles which together are known as smoke, which in itself improves combustion efficiency when air in proper amounts is supplied.

We have provided means whereby the air is injected into the furnace in such a manner as to reach the portion of the furnace above the fuel bed at the coking portion 23 thereof, the air entering in the proper volume and at such a velocity that the same penetrate the bank of combustible gases and mixes thoroughly with them. While it has been found to be particularly advantageous to use this arrangement with the nozzles supplying the air under an arch, yet considerable advantage results in any case where the air is supplied under pressure at a high enough velocity and in proper volume to cause the same to mix thoroughly with the combustible gases immediately

above the fuel bed to complete the reaction of combustion.

The means for supplying the air under pressure in the manner referred to above, shown in the drawings, comprises an air pressure box 25 which extends along the front of the furnace and to which air under pressure is supplied by means of the supply pipe 26. A plurality of nozzles 27 is connected with said air pressure box 25 and said nozzles, as will be clear from Figs. 1 and 3, preferably extend at an oblique angle downwardly from a point above the fuel bed toward said fuel bed so as to throw a stream of air from the same downwardly toward the upper surface of the fuel bed where the gases are being distilled off, said nozzles being directed so as to project a stream of air into the region immediately above the coking portion of the fuel bed. The nozzles gradually diminish in diameter to a point intermediate the length thereof indicated by the numeral 31, and then again increase to provide a gradually flaring mouth 28, as will be clear from Figs. 1 and 3, thus causing the air to pass from the same at a high velocity and projecting the air deep into the furnace, as will be clear from Fig. 1, the stream of air from the nozzle 27 being indicated by the numeral 29. The nozzles 27 are distributed at substantially spaced distances along the front wall of the furnace, as will be clear from Fig. 2. In the case where a flat arch is used it will be noted that the nozzles are placed very near the bottom face of said arch. The location of the injection nozzles may be varied from the position shown as it may be under certain conditions advisable to locate them in other relations to the arch and furnace walls than that shown.

It has sometimes been found to also be desirable to inject air at a somewhat higher point into the furnace, particularly where a furnace of the type shown in the drawings is used, so as to supply additional air to the distilled off gases after the same have risen a considerable distance above the fuel bed. This means comprises a pipe or duct 30 leading from the compressed air supply box 25 which is provided with a nozzle 31 which is directed at an oblique angle downwardly into the furnace, as clearly shown in Fig. 1, said nozzle 31 passing through the straight wall portion 14 of the furnace above the flat arch 16 and a slight distance above the curved portion 15 connecting the flat arch with the straight wall portion 14.

The pressure used need not be extremely high, it being merely necessary to use sufficient pressure to obtain the desired velocity at the discharge end of the nozzle so that the air will be injected into the furnace a sufficient distance so as to reach the space immediately above the bed of fuel in the region where the volatile matter is distilled off.

While a coal burning furnace having a grate is shown in the drawings, it is evident that air under pressure may be applied to the combustion chamber of the furnace to obtain a more uniform supply of oxygen therein when other fuels such as gas, oil or powdered coal are used. The air may be supplied at room temperature or a higher temperature if desired.

Having thus described our invention, what we desire to claim and secure by United States Letters Patent is:

1. The process of burning fuel in a closed furnace which consists in moving the fuel in a bed along a definite path through the furnace, igniting the entering fuel, creating a flow of air through the ignited fuel to support combustion of the fuel in the bed, driving off the volatile combustible constituents of the fuel by heat in the first part of the path to coke the fuel, introducing air in sufficient amount above the fire to support substantially complete combustion of the volatile combustible constituents, by projecting said air into the region of formation of the volatile combustible constituents and with sufficient velocity to stir the air and combustible constituents together thoroughly, and maintaining said stirred air and combustible constituents at the temperature of ignition until the reaction of combustion is substantially completed.

2. In combination, a furnace equipped with an arch, means for maintaining a travelling fuel bed in the furnace, means for admitting air through the fuel bed, means for projecting a stream of high velocity air into the furnace above the fuel bed forwardly and diagonally downward toward the fuel bed, and below the arch into the combustible gases rising from the fuel bed.

In witness whereof, we hereunto subscribe our names this 31st day of October A. D., 1923.

ARTHUR E. GRUNERT.
ALEX D. BAILEY.