Our invention relates to methods of open hearth furnace operation and to furnace structure particularly adapted to be used when employing such methods. More particularly our invention relates to methods and means for controlling the combustion of fuel in open hearth furnaces to the end of most effectively imparting the heat energy of the fuel to the charge.

Among the advantages sought is the production of a flame which will effectively sweep over the charge, blanketing or covering it in a manner to most effectively convey energy to the charge rather than to the walls and roof of the furnace. Another object is the utilization of fuels which have offered certain difficulties. Another purpose is to secure a varying input of heat energy with changing heat demands or needs of the charge or furnace without impairing the effective movement of the flame over the hearth.

The realization of these ends and of other advantages of the invention, as well as the modes and principles of operation, will be apparent after setting forth a particular embodiment thereof. Accordingly we shall first briefly describe the structure which may be advantageously used and then shall set forth a particular example of the inventive method as applied to the carrying out of the basic open hearth process.

Referring to the drawings:

Fig. 1 is a longitudinal section of an end and a portion of the furnace proper of an open hearth structure, taken on line 1-1 of Fig. 2;

Fig. 2 is a transverse, longitudinal section of the same portion of the furnace, taken on the line 2-2 of Fig. 1;

Fig. 3 is a cross section taken through an intermediate portion of the furnace along the line 4-4 of Fig. 1;

Fig. 4 is a cross section taken on the line 4-4 of Fig. 1, near the end of the furnace; and

Fig. 5 is an enlarged longitudinal section of the gas and oil burner structure.

Most of the structure of the furnace shown does not depart from that which is well known in the art. Accordingly this description of structure will be largely confined to that which relates directly to the inventive matter. The structure of the hearth 11, walls 12, roof 13, and supporting means 14 is old in the art and needs no description. The structure which is of main interest for this invention is that which concerns the introduction of fuel and air and the directioning of these agencies and of the flame produced by burning the fuel. The structure involved is disposed at each end of the furnace, and since the two ends are essentially identical, the description of one end will suffice for both.

Air uptakes 15 communicate at their upper ends with chamber 16 and at their lower ends with slag pocket 17. Slag pocket 17 communicates with a regenerator in the usual way. Uptake 18 is also an air uptake, communicating at its upper end with chamber 16 through space 20. This uptake communicates at its lower end with slag pocket 21 which latter communicates with a regenerator.

Gas is introduced into the furnace through burner 22. This burner is supported in the end wall and in block 23 located between uptakes 15. This burner is downwardly inclined toward the hearth 11 and somewhat laterally toward the charging side 24 of the furnace.

Burner 22 comprises tubular member 25, through which the gas may pass, having a water jacketed portion 26, for that portion which is within the furnace. Near the discharge end of the burner, tubular member 25 tapers in diameter and then expands, giving the restricted portion 27; this contracting expanding structure being adapted to prevent too great diverging of the issuing stream of gas. Burner 22 receives its gas from pipe 22'.

Liquid fuel pipe 28 is disposed centrally of member 25, being adapted to be connected at its outer end to a source of liquid fuel and its inner a discharge end terminates within tubular member 25, a moderate distance from the discharge end thereof.

Let us now proceed to the description of the operation of a representative heat as carried out according to the basic process and involving "melting down" of a charge of ore scrap and limestone followed by "purifying" or "refining".

Limestone is first charged on the hearth of the furnace. The amount of this material will be approximately equal to 10% of the complete charge of metal, that is to say, of metal contained in the ore, the scrap, and the hot metal. Upon the limestone is next charged tofo ore in an amount to furnish 7% of the metal of the complete metal charge. Scrap, containing about 0.20% carbon is next charged. This metal will be used in amount about equal to 35% of the total charge.

This charge is now "melted down". To effect this operation a mixture of coke oven gas and blast furnace gas is burned in the furnace chamber. This mixture consists of these two gases in such relative amounts as to give the mixture a
thermal value of about 300 B. t. u. per cubic ft. This thermal value may be secured by using nearly equal amounts of coke oven and blast furnace gases.

5. The gas mixture is fed through pipe 22 into burner 21. Sufficient pressure is employed to cause it to enter the furnace with considerable velocity. Very effective results have been obtained by using a pressure at the discharge opening of 10 in. of the burner, of about one and one-quarter pounds above atmosphere, this opening having a diameter of 5/16 in. Under these conditions the gas issues from the burner with a velocity of 278 linear feet per second.

Air enters chamber 16 from uptakes 15 and 19, passing upwardly to each side of burner 22 but not directly from beneath such burner. The air flow within chamber 16 because of the downward inclination of roof 30 is also given a direction similarly inclined downward over the hearth. This flow of air in cooperation with the downward inclined movement of gas cooperates in producing a flame which sweeps directly over and blankets the charge. It should be noted that a direct wind of air beneath the burner opening is avoided and therefore the sole action of the air flow is to aid the downward movement of the gas over the hearth and there is nothing in the flow of air to deflect the gas stream or the resulting flame upwardly.

The introduction of the gas in this manner, that is through a restricted opening, and under considerable pressure, produces a rapidly moving jet of gas at the burner mouth. This jet of a mixture of blast and coke oven gases gives a flame of relatively low luminosity which passes over and in direct contact with the charge on the hearth. This is continued until the scrap is melted or until a substantial part thereof is melted and the remainder is in a softened or mushy condition.

Basic pig, in the molten condition is now poured into the furnace in amount substantially 55% of the total metal charge, and the refining or purifying operation instituted. The gas mixture which is now passed through the furnace is changed in composition by increasing the percentage of blast furnace gas so as to give a mixture having approximately 180 B. t. u. To give this thermal value of the mixture about three and one half volumes of blast furnace gas is used to one volume of coke oven gas. During this refining stage fuel oil is forced into the gas stream of burner 22 from the discharge opening of pipe 28. The fuel oil issues from the burner 22 as a "solid" jet and burns in such manner as to give increased luminosity to the gas flame over a large part of the hearth. The oil is used in amounts between 4 and 10 gallons per ton of steel produced.

By the expression "melting down" it will be apparent that complete "melting" is not necessarily meant; it merely refers to the preheating which is effected prior to the charging of "hot metal". By "refining" or "purifying" is meant that portion of the operation during which desulfurizing occurs.

Now let us scrutinize the more significant aspects of the process. The flame character is a point upon which we desire to lay great stress. A primary object of the invention is to bring the stream of burning gases into effective engagement with the charge. This is accomplished by introducing a downwardly inclined jet of gas, moving with considerable speed, whereby a flame of relatively shallowness is produced which passes rapidly over the hearth, closely blanketing it. Such a flame may well be characterized as a directed flame. The moving stream of burning gases to a considerable degree maintains its path in close engagement with the charge, adequately covering it.

Several conditions contribute to this effect. In the first place, the gas is introduced as a downwardly inclined jet, that is as a stream of small cross sectional dimension. The pressure of gas in the burner is substantially above atmospheric. These factors insure that the gas mixture is moving with a high velocity as it issues from the burner. Furthermore, the presence of a substantial percentage of blast furnace gas renders the mixture of considerably greater density than it would otherwise be, which results in virtually keeping the gas stream in a greater momentum and therefore enables it to more effectively maintain its path of movement. Then also the gas mixture because of its relatively low thermal value means that a considerable volume of gas must be introduced, which together with the rapid movement of the gas stream, serves to cause the flame to cover a large portion of the charge.

Evidently the injection of gas in the form of a jet is an important feature of our process. If the required amount of fuel were to be introduced through the ordinary blast, the speed of gas movement would be greatly reduced and the directive character of the flame and its covering capacity would be greatly lessened. In consequence of not using the port, however, the gas is not regenerated. This leads to a condition which offers difficulties. We have found that during the refining or purifying stage the directed flame, sweeping directly over the hearth, and made up of the burning coke oven and blast furnace gases, results in an excessive foaming or frothing of the slag. Not long after charging the molten blast furnace pig, and using a burning stream of coke oven and blast furnace gases, the slag appears to become excessively charged with gas and a frothiness ensues which causes the slag layer to virtually become a heat insulating blanket to the bath beneath. Consequently the furnace efficiency immediately becomes greatly reduced.

This inimical condition can be overcome by increasing the radiative power of the flame. The unaltered mixture of coke and blast furnace gases gives a flame of relatively low luminosity. If the radiative power of the flame is increased, as by increasing its luminosity, the excessive foaming or frothing is overcome. In the specific example of our process given above, we get this increased luminosity by burning a relatively limited amount of oil during the refining stage.

Again referring to the illustrative example of my process, it is to be especially noted how the fuel oil is introduced as we have found this particular result to be especially efficacious. A "solid" stream of jet fuel oil is introduced into the furnace. Oil is forced from pipe 28 into the gas jet of burner 22 and issues as a solid jet into the furnace within the stream of gas. The air moves forwardly in an enveloping relation to the gas. Under these conditions a relatively early mixing of air and gas takes place and therefore by a relatively early combustion of the gas is secured. With the oil on the other hand, the combustion is relatively delayed. As the oil is in the form of a substantially "solid" jet its burning will necessarily be slower than would be the case with a gas or an atomized liquid. Furthermore, the gas which envelops the jet as it
the reduced demands of the operation.

Introducing the oil in this manner insures a luminous, highly radiative condition of the flame, over a very large portion of the hearth. This condition results in a much more effective inhibition of the excessive foaming of the slag. Moreover it permits of a substantial economy in the quantity of oil used.

Obviously other means may be used to increase the luminosity of the flame or its radiative power to control foaming of the slag. In practice we have found the most effective means, however, to be the use of a liquid fuel of same sort.

Now reverting to the melting down operation, as exemplified in the illustrative process above outlined. Excellent results have been obtained by using a directed flame of a burning mixture of blast furnace and coke oven gas, in such relative amounts as to give a thermal value of about 300 B. t. u. This flame is of low luminosity but it very effectively heats the charge and applied, as it is, in the form of a directed flame, the melting period is very substantially reduced.

During the melting down the use of a relatively non-luminous flame seems to be particularly effective. This kind of flame passing over the solid constituents of the charge seems to have a "cutting" effect and rapidly softens or melts the scrap. Obviously, however, under some conditions it may be advisable to alter the flame more or less luminous during the entire melting down or during certain portions thereof.

Another feature of our invention of decided importance is that which relates to using a gas mixture for the refining stage of lower thermal value than that employed for the melting down.

In the example given, the thermal value of the gas mixture of about 300 B. t. u., employed during the melting down, is lowered to about 180 B. t. u. for the refining stage. During the refining stage, there is a considerably lessened need for energy input from introduced fuels. Accordingly the thermal value introduced is lessened to conform to the reduced demands of the operation. This we accomplish by lessening the thermal value of the gas. So far as the mere introduction of heat and energy by means of fuel concerned, it would be physically possible to reduce the flow of gas into the furnace without changing the composition of the mixture. To do this, however, would mean to lose one of the primary functions of our invention, namely the directive, charge covering flame. We attain the lessened energy input without losing these desired flame properties by altering the composition of the gas mixture to obtain a gas mixture of lower thermal value and thereby get a reduced input without greatly changing the volume of gas introduced. Thus the velocity of the gas jet is maintained at a sufficient velocity so that the flame does not lose its directive and covering characteristics. In the illustrative process we accomplish this end by increasing the proportion of blast furnace gas in the mixture.

A further effect of the increase of the proportion of blast furnace gas in the mixture is to increase the density of the mixture which condition also contributes to the capacity of the flame to maintain its path in close blanketing engagement with the charge.

This increase of density acts in two ways in producing this effect. The greater density gives a greater momentum to the moving gas stream and the greater weight tends to keep the flame down upon the bath.

Of course it is not new with us to burn gas in an open furnace hearth from a burner. It is old, for example, to burn coke oven gas with atomized luminous, high-temperature blast. But these prior practices do not contain the significant features of our invention. Our primary object is to obtain a directed flame of marked covering capacity. These we secure by the introduction of considerable volumes of gas of relatively low thermal value under substantial pressure through a restricted opening.

This aspect of our invention is so important that it may be wise to dwell upon it somewhat further. To obtain a flame which will maintain its path across the hearth in close proximity to the charge, and which will also cover a large portion thereof, and which will have the conditions important. Among these, as has already been pointed out, are speed of the gas stream and the volume of gas introduced. It would be physically possible to get great speed with a small volume of gas. If the volume input is too small, however, the covering power is lost; consequently there must be a considerable volume of gas. It is possible to get both adequate volume and speed of gas. Yet in obtaining both of these conditions a further factor must be considered. Under practical conditions there are very definite limits to the permissible input of heat energy. An important feature of our invention therefore is to select a sufficiently low thermal value of gas so that it is possible to obtain such velocity and volume of the gas as to produce directioning and covering power of flame and still keep within the thermal requirements of the furnace.

During the melting down stage we employ a gas having considerably less thermal value than coke oven gas but because of the volume and velocity with which it is introduced a flame is secured which more adequately passes down and across the charge than could be the case with the use of a gas like coke oven gas. During the refining stage, likewise we maintain a covering flame directly in contact with the charge by still further lowering the thermal value of the gas. By our method of introducing oil or other luminosity producing material we are enabled to make this relatively non-luminous flame, and one which is much lower in thermal value than coke oven gas, radiatively effective to adequately heat the charge.

Briefly stated, by injecting gas of sufficiently low thermal value in a rapidly moving jet we obtain a comparatively shallow flame, moving with considerable speed over and in close proximity to the charge, and effectively covering it. When such flame is rendered highly radiative by the use of liquid fuel or other radiation increasing medium, as above illustrated, a luminous "blanketing" flame is produced, which because of its close proximity to the hearth, is in the most advantageous position to convey heat thereto.

A further object of using a gas of relatively low thermal value is in the more effective heating of the air regenerators. Clearly the greater volume of gas involved in using a low thermal value gas, over using a high thermal value gas, serves much more effectively and safely for conveying the heat to the checker work.

In the practices of the prior art, where gas of low thermal value is used, the aim has commonly been to increase the thermal value by increasing...
the sensible heat, which in practice means by regeneration. Regeneration, however necessitates the use of gas ports of substantial sized openings. These ports require a large amount of water cooling with consequent loss of large amounts of heat. Moreover, effective directioning of the flame cannot be obtained. These disadvantages we avoid. The water cooling of the burners used is very little. Consequently what is lost by not regenerating the gas is more than made up in the greater amount of heat given to the regenerated air.

By thus proceeding we obtain a much more effective conveyance of heat to the charge than has heretofore been possible, resulting in marked saving of fuel and in a great reduction in the time of operation.

Obviously we do not wish to be limited to specific thermal values for gases employed during the melting down and refining operations. As is evident from what has already been said, to obtain adequate volume and velocity of the gas jet it is needful to avoid having the thermal value too great. In the example, given a gas mixture of about 300 B. t. u. for the melting down and about 180 B. t. u. for the refining have served the purpose. In practice, the thermal value probably should not exceed 450 B. t. u. during the melting down nor 200 to 250 B. t. u. during the greater portion of the refining stage.

As to the use of oil or other liquid fuel to give luminosity during the refining operation we have found that in the neighborhood of six gallons per ton of steel to be produced is a desirable amount to use. In practice, probably one should not go below an amount between 4 and 5 gallons nor for the most economical results should one exceed 10 gallons.

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

1. In an open hearth steel process, the steps of melting down by burning a gas injected into the furnace with sufficient velocity and density to give a flame sweeping directly over the charge, and refining by burning a gas of composition changed to lower the thermal value and to increase the density thereby to maintain the charge sweeping character of the flame.

2. In the refining stage of an open hearth steel process, the step of injecting a relatively low luminosity giving gas to furnish the principal amount of added heat, and simultaneously injecting a solid stream of liquid fuel.

3. In the operation of an open hearth furnace, the steps of injecting a stream of gas having relatively low luminosity giving properties, and simultaneously injecting a solid stream of liquid fuel.

4. In an open hearth steel process, the steps of introducing a stream of gas into the furnace chamber and introducing a solid jet of liquid fuel within the stream of gas.

5. In an open hearth steel process, the steps of introducing at one end of the furnace a jet of gas, introducing a solid jet of liquid fuel within the stream of gas, and introducing air in an enveloping relation to the stream of gas.

6. In an open hearth furnace operation, the steps of introducing gas, in the form of a jet, with sufficient velocity to produce and maintain a direction of the flame over and in proximity to the charge, and in sufficient volume to give a flame of desired covering capacity, and regulating the composition of the gas to conform to the needs of the operation and yet to maintain the speed and volume of the gas to give the desired flame direction and covering power.

7. In an open hearth furnace operation, the steps of introducing gas, in the form of a jet, with sufficient velocity and volume to produce and maintain a direction of the flame over and in proximity to the charge, and to cover a large portion thereof, changing the composition of the gas to alter the thermal value thereof and thereby to change the energy input of the furnace without unduly changing the velocity and volume of the gas that enters the furnace.

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