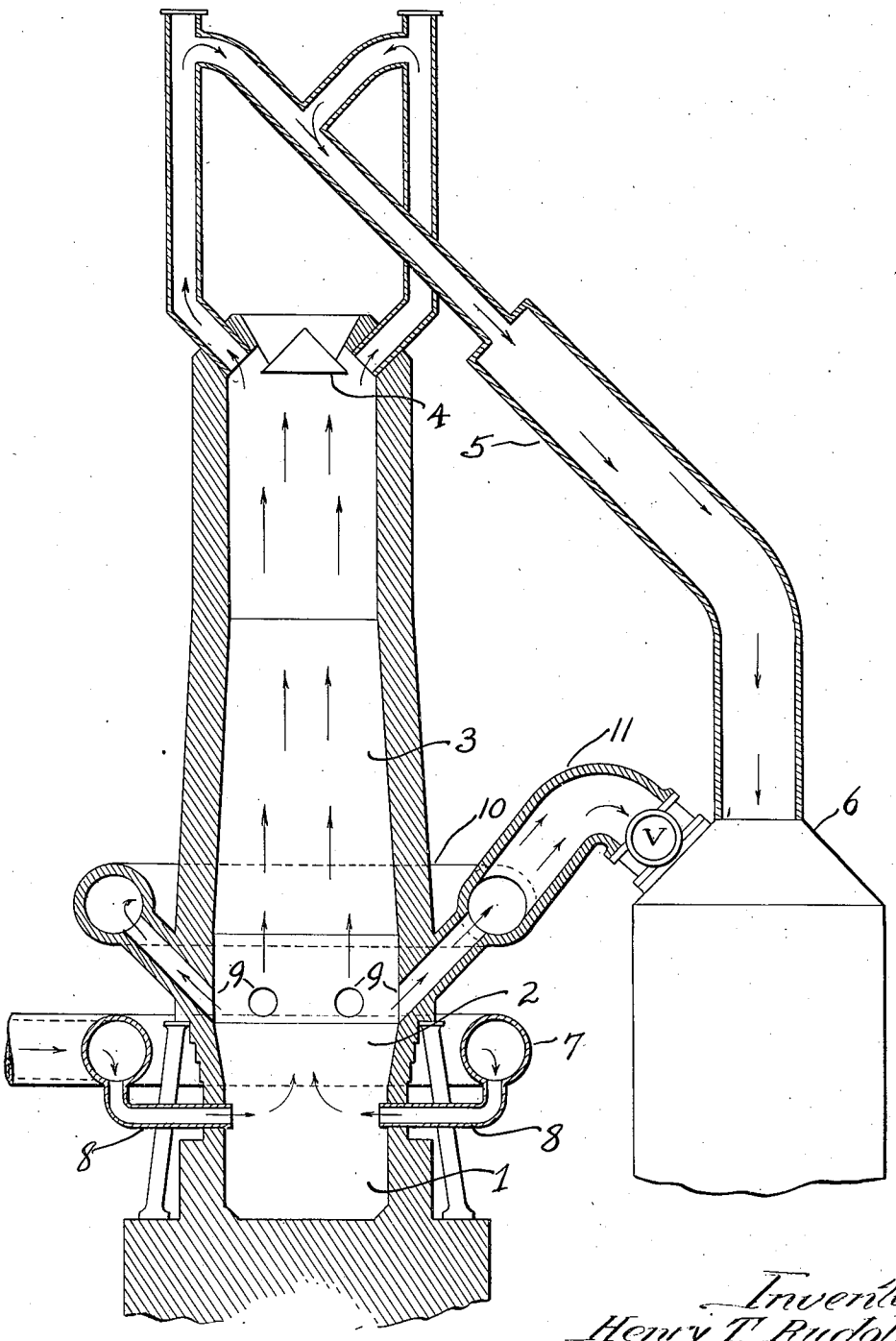
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METHOD FOR OPERATING BLAST FURNACES

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METHOD FOR OPERATING BLAST FURNACES

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1 Claim. (Cl. 75—41)

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This invention relates to improvements in blast furnaces and method of operating the same. The iron blast furnace is an apparatus of considerable antiquity. It is used for the purpose of reducing iron ore, which is usually in the form of the oxides Fe_2O_3 or Fe_3O_4, to iron by causing the oxygen of the ore to combine with carbon monoxide (CO) formed by the combustion of carbon-containing fuel, usually coke.

As the demands for pig iron have increased, the effort of those skilled in the art has been to devise blast furnaces of greater productive capacity. Generally speaking, this has been done by increasing the size of the furnace and particularly by enlarging the hearth area. As a result of these efforts, blast furnaces have been built in this country having hearths of 26 feet in diameter and, as is well known, to build such furnaces involves tremendous expense. So far as I know, increasing the hearth area is the only practicable method heretofore suggested and followed for the purpose of increasing the production of pig iron.

I propose to increase the production of pig iron in existing furnaces, or to provide new furnaces of greatly increased capacity, without increasing the hearth area. In connection with such structural changes as I propose, I have developed a new method of operating blast furnaces so as to increase greatly their production of pig iron in a unit of time.

My invention involves the application of a new thought to the operation of blast furnaces which, stated broadly, is the speeding up of the rate of fuel combustion without increasing the volume of gas that passes upwardly through the voids in the burden in the stack.

According to my invention, more oxygen is supplied for combustion by increasing the air blast volume, thereby generating an increased gas volume. But the increased part of the gas volume is removed from the furnace before it can enter the stack, so that the volume of gas passing upwardly through the burden remains substantially constant.

Thus, according to my method, the rate of fuel combustion is increased, which means that the bulk of fuel is more rapidly removed with the result that the rate of descent of the burden in the stack is accelerated while the volume of gas passing upwardly through the stack is limited to substantially the same volume as when the furnace is normally operating at maximum capacity.

As is well known to those skilled in the art, a

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blast furnace is blown on a wind volume which is, generally, speaking, determined experimentally. Such factors are taken into consideration as the character of the fuel and the nature of the burden with respect to the size of the particles and the void areas. The wind volume is fixed at that point where the gas will pass freely upwardly through the burden without such resistance as will create a back pressure sufficient to impede the descent of the burden or cause it to hang in the stack. There are, of course, other factors which are taken into consideration in determining the wind volume but so far as my process is concerned they need not be considered here. On the wind volume so determined, the production of pig iron in a unit of time will be the maximum for a particular furnace, all other factors remaining constant.

If it be attempted to increase the wind volume beyond the point so experimentally determined, the operation of the furnace will be seriously impaired. The gas volume will either not pass freely through the burden, thus creating a back pressure which will impede its descent, or the blast will be so strong as to blow much of the ore out of the furnace in the form of dust, thereby upsetting the carefully calculated proportion of fuel to ore, causing the furnace to become too hot as well as reducing the pig iron production.

By my improvement, a given blast furnace can be operated on a wind volume in excess, by so much as may be desired, of the volume which has been experimentally determined for maximum pig iron production in that furnace without interfering with the movement of the burden and without increasing the dust loss. This I accomplish by withdrawing the excess gas volume created by the increased blast so that substantially the same volume of gas passes through the burden as when the furnace is normally operating at its maximum production.

For many years it was believed that a blast furnace would operate most efficiently when the CO/CO_2 ratio of the top gas is 2:1. However, this belief is no longer tenable. Ratios as low as 1.4:1 have been obtained, and it is now believed on good authority that the ratio may be reduced to as low as 1:1. Generally speaking, a blast furnace is most efficient thermally and chemically when the CO_2 in the top gas is highest. But it must be borne in mind that the higher the CO_2 content of the gas, the lower will be its calorific value. Pig iron may be produced economically when the CO/CO_2 ratio of the top gas is as low as 1:1, but how to obtain such a ratio has

not heretofore been known. By my process such a ratio may be obtained, as well as any other desired ratio within practical limits, and this without affecting the calorific value of the gas.

As is well known, the blast furnace gas is used to heat the air blast for the furnace, to operate the blowing engines and, in an integrated plant, for many other purposes. Generally, the apparatus used has been designed to be operated on fuel of fairly definite heat value and it is important not to greatly reduce that value. By my process the production of pig iron in a unit of time may be greatly increased without sacrificing any of the heat value of the gas.

As heretofore stated, I propose to increase the wind volume to accelerate fuel combustion and thereby produce an increased gas volume, but the increase in gas, or substantially all the increased gas volume, is withdrawn from the furnace so that approximately the same volume of gas passes upwardly through the burden. The CO/CO_2 ratio of the top gas in my process is thereby reduced and hence its calorific value is decreased. However, I may mix with the top gas the withdrawn excess gas volume, or any desired part of it, which has a high calorific value, thereby producing a gas mixture of substantially the same heat value as that of the top gas which is produced in the normal operation of the furnace.

But instead of mixing the two gas volumes as just described, I may use each volume separately. The top gas may be used for low temperature combustion whereas the withdrawn gas may be used for higher temperature combustion. The choice will be made with reference to the nature of the apparatus at a particular plant and the desire of the operator in respect to the heat value of the gas.

My invention may best be explained and more readily understood by reference to an ordinary blast furnace operated to produce the maximum quantity of pig iron in a given time. For example, a blast furnace operating on a wind volume of 60,000 C. F. M. (cubic feet per minute) of air at normal temperature and pressure will produce a top gas volume of about 84,000 C. F. M. at normal temperature and pressure and will produce a certain number of tons of pig iron in a unit of time. This top gas contains, roughly, about 40% carbon gases and about 60% nitrogen. There will also be a small percentage of hydrogen due to moisture in the air and the burden, but this may be disregarded for my purposes.

The carbon gases in the top gas comprise, on the average, about 26.6% CO and about 13.3% CO_2, so that the CO/CO_2 ratio is about 2:1. The volumes, in my example, are substantially 22,400 C. F. M. of CO and 11,200 C. F. M. of CO_2. The bosh gas contains roughly about 40% CO, or a volume of 33,600 C. F. M. Hence, it is plain that only about one-third of the available CO is used in the reduction process and becomes CO_2 by union with the oxygen of the ore.

The 11,200 C. F. M. of CO thus used will reduce a certain quantity of ore in a given time. If we can lower the CO/CO_2 ratio to 1:1, thus utilizing an additional 5600 C. F. M. of CO. or a total of 1.5 times as much CO, we should be able to reduce an additional percentage of ore in the same time by the same proportion, provided we can make the burden travel 1.5 times as fast.

The rate of the down travel of the burden can be increased by removing the bulk of the coke more rapidly, so that the ore can settle faster, whereby more oxygen of the ore is available for union with the CO to produce CO_2 in increased quantity. In the example given, I propose to speed up the rate of coke combustion 1.5 times. It is known that combustion proceeds roughly as the rate of application of the oxygen of the air to the carbon of the coke. Generally speaking, it takes about 75 cubic feet of air at 62° F. and 30 inches of mercury to burn one pound of carbon. But this air volume is subject to variation on account of changes in the temperature and humidity of the air and in barometric pressure. The air volume will also vary in accordance with the carbon content of the fuel. In my process it is desired to increase the rate of down travel of the burden 1.5 times and this can be accomplished by speeding up the combustion of the fuel to 1.5 times the normal rate. This means that 1.5 times as much oxygen will be supplied in the same time period which, in turn, means that the wind volume must be increased 1.5 times. Thus, in my example of a furnace operating on a blast of 60,000 C. F. M., the blast must be increased to 90,000 C. F. M. in order to increase the combustion rate 1.5 times. Thus, the bulk of the coke is more rapidly removed and it follows that the burden will descend more rapidly in the stack, providing that it is not prevented from so doing by the increase in gas volume which is produced by the increased air blast.

Such an increase in blast volume would be unthinkable if it were not for the improvements I propose in the construction and operation of the furnace. If, in my example furnace, in which, when operating at capacity, 84,000 C. F. M. of gas passes upwardly through the burden, the gas volume is increased to 126,000 C. F. M., it will readily be understood that the back pressure created will be so great as to cause the burden to hang in the stack. However, I provide means for removing this increased part of the gas volume from the furnace before it can enter the stack, thus maintaining the volume of gas that passes upwardly substantially constant. This I accomplish by the means and method now to be described.

To make my explanation clear, I have appended hereto a drawing showing a blast furnace with my improvements applied. This drawing is only illustrative and is entirely diagrammatic, no attempt being made to show any particular proportion of parts or precise location of elements.

The single figure of the drawing is a vertical section of a blast furnace comprising the conventional elements, hearth 1, bosh 2 and stack 3. At the top I show only the large bell 4. From the top, the gas passes through the downcomer 5 into any form of cleaning apparatus 6. The usual bustle pipe is marked 7 and from this the air blast passes through the tuyères 8, which are of the usual or desired number and of typical construction. Thus far, the parts of the furnace described may be of any well known construction, size and shape.

My improvement, structurally, resides in the provision of gas escape openings or exhaust ports 9, of which a plurality are provided, and which are located at or about the bosh line. The exhaust ports 9 all communicate with a collector pipe or manifold 10 which may surround the furnace in the same manner as the bustle pipe 7. An exhaust pipe 11 leads from the collector

pipe 10 to the cleaning apparatus 6. This latter feature will be incorporated whenever it is desired to mix the withdrawn excess volume of gas with the top gas emanating from the furnace in the usual manner. However, where it is desired to use the gas volumes separately, the exhaust pipe 11 may lead to any other form of cleaning and processing apparatus so that the excess gas of high calorific value may be used separately from the ordinary top gas.

At any convenient place in the pipe 11, I place a valve V which may be either automatically or manually controlled so as to regulate the escape of gas from the bosh through the ports 9. The mechanism for operating the valve may be any of the known ratio control devices, or the valve may be of the pressure responsive type which will open only when the gas pressure in the bosh reaches a predetermined point. Thus, the valve V is used for the purpose of controlling and regulating the quantity of gas in the bosh which will be permitted to escape and thus preventing it from passing upwardly through the stack. By this arrangement the volume of gas passing upwardly through the burden may be maintained substantially the same as the gas volume that passes through the stack in the normal operation of the furnace. In the example heretofore given of a furnace normally operating on a wind of 60,000 C. F. M. and the blast is increased to 90,000 C. F. M., the gas volume is increased from about 84,000 C. F. M. to 126,000 C. F. M. This increase of approximately 42,000 C. F. M. in the gas volume may substantially all be withdrawn through the exhaust ports 9 and this result will be accomplished by a proper regulation of the valve V.

It will, of course, be understood that once a blast furnace is equipped with my improvements it need not be continuously operated in accordance with my process. That is to say, it may be desirable at times to operate the furnace in the normal manner so as to produce only the tonnage of pig iron corresponding to its rated capacity. At such times the valve V may be permanently closed and thus none of the gas volume withdrawn prior to its entry into the stack. In such cases, of course, the wind volume is reduced to its normal figure.

I have shown and described the exhaust ports or outlets 9 as located at or about the bosh line. This is the preferred location of said ports because at this point the gas pressure is lowest per unit cross-sectional area of the furnace. Moreover, at this point dust and fine particles have completed melting or have agglomerated so that there is little or no danger that the increase in gas pressure will cause any increase at all in the dust loss.

From the foregoing description of the construction of a blast furnace embodying my improvements and of operation thereof, I believe that my invention will be clear to those skilled in the art. Obviously, my structural improvements and new method may be applied to, and used in connection with, existing furnaces. It is likewise clear that new furnaces may be built embodying my improvements from the start and that such furnaces may be made very much smaller and yet have the same capacity as the large furnaces now in use. Thus, there results a considerable saving in building and maintenance expense.

Because of the fact that in my furnace operated in accordance with my method the rate of down travel of the burden is increased whereas the rate of up travel of the gas volume remains substantially constant, it follows that the gas volume will in a given time pass through a correspondingly greater burden volume. Hence, more of the CO in the gas will unite with the oxygen of the ore, resulting in greater reduction in the given time period. Inasmuch as a higher percentage of the CO is thus converted into CO_2, it follows that the CO/CO_2 ratio of the top gas is correspondingly reduced which, of course, is accompanied by a reduction in the heat value of that gas. For example, when the furnace is operating normally and the CO/CO_2 ratio is on the average approximately 2:1, the calorific value of the gas is substantially 87 B. t. u. per cubic foot. When the ratio is reduced to 1:1, the calorific value of the gas falls to approximately 65.4 B. t. u. per cubic foot. This may be a serious loss of heat value in a given plant where the stoves for the air blast and the blowing engines and auxiliary equipment are designed to operate on a gas having a higher heating value.

However, by my process there need be no resulting loss in heating value of the gas. This is because the withdrawn excess gas volume taken from the bosh may be mixed with the top gas, as heretofore described. The gas volume thus withdrawn contains nearly 40% CO and, therefore, has a calorific value of approximately 130.05 B. t. u. per cubic foot. Thus, in the example furnace operation heretofore described, the normal gas volume is 84,000 C. F. M. Under my process whereby the CO/CO_2 ratio has been reduced to 1:1, the heating value of that volume of gas is 65.4 B. t. u. per cubic foot. The increased gas volume of 42,000 C. F. M. withdrawn from the bosh has a heating value of 130.05 B. t. u. per cubic foot. If we mix these two volumes, we shall then get a total of 126,000 C. F. M. of gas having a calorific value of approximately 87 B. t. u. per cubic foot, which is the same heating value of the top gas the furnace had when it was operating normally and when the CO/CO_2 ratio is 2:1.

Thus, in accordance with the foregoing, it will be seen that by my process the production of pig iron in a given unit of time may be very greatly increased without any corresponding reduction in the heating value of the gas. It will be understood, however, that I do not contemplate that always and in every case the entire excess volume of gas withdrawn from the bosh shall be mixed with the top gas. There may be cases where the reduction in heating value of the top gas is not of sufficient consequence to require the mixing of the two gas volumes and where the separate use of the bosh gas may be in itself of considerable value.

In the example I have given, I have more or less arbitrarily elected to reduce the CO/CO_2 ratio from 2:1 to 1:1. This, of course, is not always necessary nor may it be desirable always to make such a great reduction in the ratio and such a correspondingly great increase in the air blast volume. What I propose to do in any case is to determine the CO/CO_2 ratio of the top gas when the furnace is operating at its rated maximum capacity, and then to reduce that ratio to any desirable point limiting myself perhaps to the ratio of 1:1, which is now on good authority believed to be attainable in an economic ore reduction process. However, it will be seen that if we start off with a normal ratio of 2:1, it may

be desired to reduce this only to, say, 1.5:1. In such a case, instead of using only 33⅓% of the available CO in the reduction process, we shall use approximately 40% of the CO. This means an increase of 20% and, hence, in that case the air blast volume would be increased by 20%.

An important result of the use of my improved blast furnace and method of operation is that the temperature gradient of the furnace will be very much steeper. In the ordinary blast furnace in normal operation, the temperature gradient is estimated to be from about 3300° F. to about 400° F. whereas in my process the gradient will be from a higher point, say, 3600° F. down to 100° F. This means that more of the heat of the gas volume is given up in the exchange in the reduction process with the result that the various sections of the burden will reach the different zones of the furnace at more nearly the proper temperature. It is also possible that because in my process the gas emerges at the top at a so much lower temperature and pressure, more gas may pass upwardly through the stack than in the normal operation of the furnace.

I am aware of the fact that it has heretofore been proposed to speed up the rate of coke combustion in a blast furnace by oxygen enrichment of the blast, that is to say, by adding pure oxygen to the air blast. Doubtlessly, this will have the effect of speeding up combustion which, as heretofore stated, proceeds roughly as the rate of application of oxygen to the carbon in the fuel. However, such oxygen enrichment of the blast is not practicable, for the reason that there results a serious unbalance of the components of the gas generated. It will be quite apparent that the percentage of nitrogen in the gas generated by such an oxygen enriched air blast will be very much reduced and this will seriously impair the operation of the furnace. It is well known that the function of nitrogen in the gas is that of a heat-transferring agent and, obviously, where the nitrogen content is seriously reduced, the heat exchange in the furnace is impaired and the ratio of direct and indirect reduction will be altered so as to cause a much higher percentage of direct reduction. This, of course, will radically and adversely affect the efficiency of the furnace.

I am also aware of the fact that blast furnaces have at times been operated on what is called slack wind. That is to say, whenever it has been desired to operate a furnace at less than its maximum capacity, the wind volume has been reduced. After such reduction, and when it was desired to restore the operation to normal maximum capacity, the wind volume has been increased. My process is, of course, readily distinguished from this slack wind operation because I increase the air blast volume above that which is normally used when the furnace is operating at its maximum capacity.

Whenever throughout this specification, and in the appended claims, I use the expression "increasing the production of pig iron" or "increasing the capacity" of the furnace, it is to be understood that I mean an increase over and above the rated maximum capacity of the furance. For example, if the capacity of a blast furnace to produce its maximum tonnage of pig iron is defined as that condition under which the furnace burns 60 pounds of coke per 24 hours per cubic foot of volume of the furnace measured from the center line of the tuyères to the stock line, then it is that capacity which I increase. In the example given, a furnace operated in accordance with my process would burn 90 pounds of coke per 24 hours per cubic foot of volume of the furnace measured as above stated. By my process a blast furnace which, when operating at its capacity, produces approximately 1000 tons of pig iron per 24 hours may be operated so as to have a capacity of approximately 1500 tons per 24 hours.

It will be understood that the figures given throughout this specification for ratios, volumes and percentages are not intended to be exact but are fair approximations of average figures. Nor are these figures constant because, as is well known to the blast furnace engineer, they vary from furnace to furnace and even in the same furnace from time to time. There are, of course, many other factors that affect the operation of a blast furnace and its production of pig iron but these I have not thought it necessary to mention herein because they will affect a blast furnace operated by my process in the same way and proportionately.

On more recently built blast furnaces, there usually is a good deal more wind volume available than is normally used and in such cases sufficient excess capacity may be found so that the blowers can be used in my process without change. On older furnaces it may be necessary to incorporate new blowers having sufficient capacity for my purposes. So far as the tuyères are concerned, it will probably be necessary to increase their cross-sectional area to meet the higher wind volume while maintaining the pressure substantially constant. These things can readily be taken care of by the skilled blast furnace operator who desires to use the new process herein described.

I claim as my invention:

The method of operating a blast furnace to increase the production of pig iron which comprises increasing the air blast volume to speed up the rate of fuel combustion and thereby increase the rate of down travel of the burden, and controlling the gas volume entering the burden to maintain the rate of up travel of the gas substantially constant.

HENRY T. RUDOLF.

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