

(No Model.)

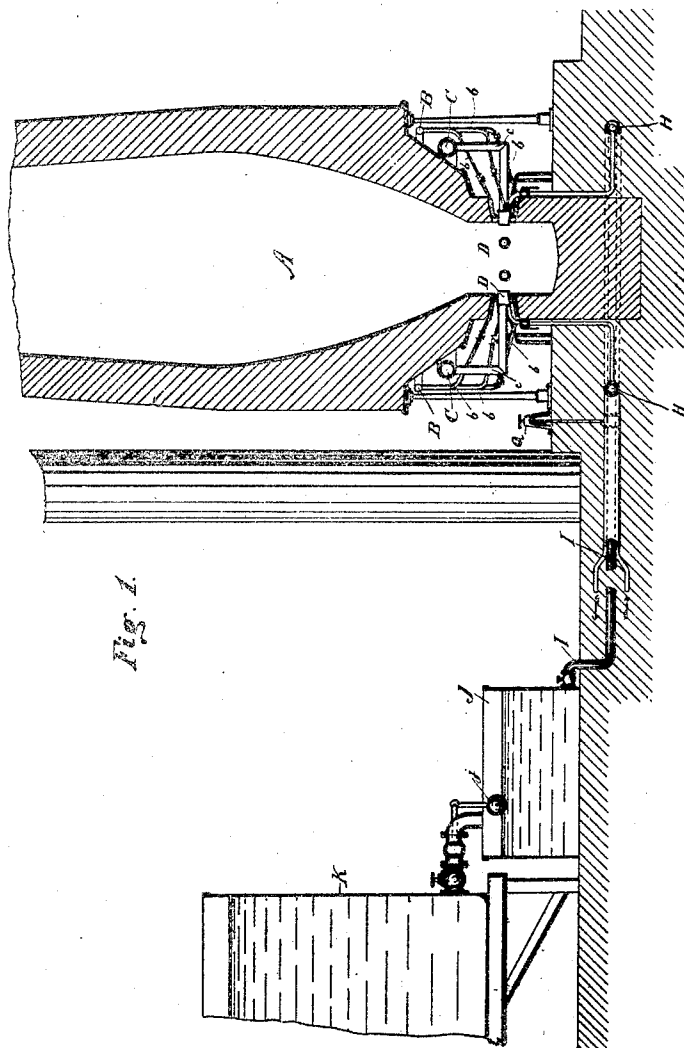
2 Sheets—Sheet 1.

F. C. WEBER.

PROCESS OF SMELTING ORES BY MEANS OF PETROLEUM

No. 325,293.

Patented Sept. 1 1885.



WITNESSES:

as Pare
E. A. Hubbard.

INVENTOR

INVENTOR
Frederick C. Weber.

BY

Banning & Banning

ATTORNEY

(No Model.)

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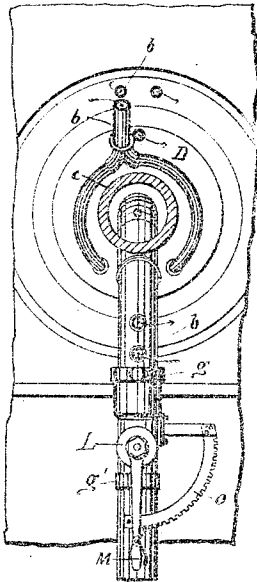


Fig. 3.

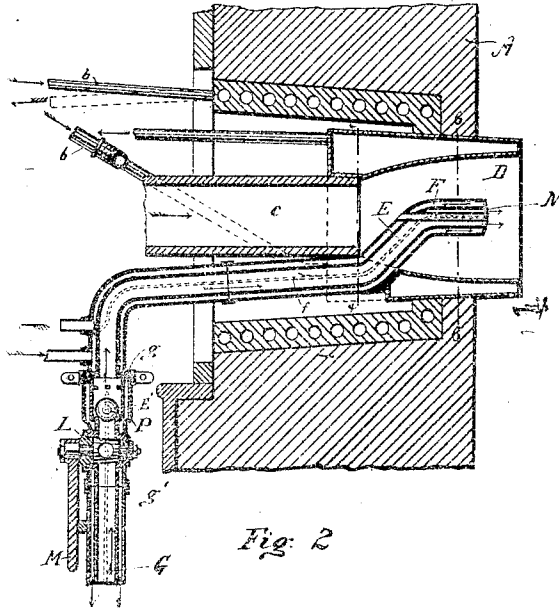


Fig. 2

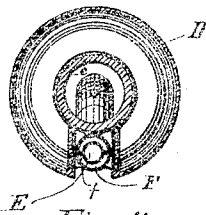


Fig. 4.

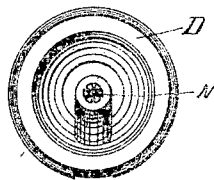


Fig. 5

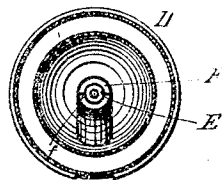


Fig. 6

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UNITED STATES PATENT OFFICE.

FREDERICK C. WEBER, OF CHICAGO, ILLINOIS.

PROCESS OF SMELTING ORE BY MEANS OF PETROLEUM.

SPECIFICATION forming part of Letters Patent No. 325,293, dated September 1, 1885.

Application filed May 2, 1885. (No model.)

To all whom it may concern:

Be it known that I, FREDERICK C. WEBER, a citizen of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented a certain new and useful Process for Smelting Ores by Means of Petroleum, of which the following is a specification.

The object of my invention is to reduce iron, lead, copper, and other ores by gases and heat produced from the combustion of a mixture of petroleum or hydrocarbon, and coke, charcoal, or coal, as described in my application of June 23, 1884. In doing this I feed the petroleum with the hot blast in such manner and in such proportion as to form the required reduction-flame, with excess of air sufficient to secure the combustion of and fully to utilize the fuel fed with the ore-charges.

In the accompanying drawings I have shown one form of apparatus with which my process can be carried into effect, and such process will be described in connection with said apparatus as applied to the smelting of iron ore; but it must be understood that many variations of the form of apparatus for introducing the petroleum or carbo-hydrates may be made without affecting the process proper or departing from the spirit of my invention. The apparatus herein shown consists of sundry additions to the mechanism now in use in blast furnaces, and such apparatus may be readily applied to such furnaces.

In the accompanying drawings, Figure 1 is a central vertical section of a blast-furnace and of my apparatus for applying petroleum thereto, this figure being designed to show the relative positions of my apparatus to the furnace. Fig. 2 is a central vertical section of a part of the furnace, taken through one of the tuyeres with its blast-pipe and through one of my petroleum-burners with its supply-pipe. Fig. 3 is a rear elevation of one of these petroleum-supply pipes, with its stop-cock, and mechanism for operating the latter. Fig. 4 is an enlarged view in vertical section, taken through one of the tuyeres and through the petroleum-burner and its supply-pipe. Fig. 5 is a rear elevation, partly in section, of one of

my burners and its supply-pipe; and Fig. 6 is 50 a section taken on line 6 6 of Fig. 2.

In carrying my process into effect it is necessary that the petroleum or hydrocarbons be introduced with the blast in certain defined relative proportions, and for this purpose I 55 provide the mechanism shown in the accompanying drawings. This mechanism consists, essentially, of a reservoir or other suitable provisions for containing the petroleum-supply, service-pipes having devices whereby the 60 flow of petroleum may be regulated, and devices for properly connecting the supply-pipes with the blast-pipe or tuyere.

A represents a section of the smelting-furnace, this furnace being supplied with a main 65 water-pipe, B, having branches *b b*, a blast-pipe, C, having branch pipes *c c*, and tuyeres D. The tuyere may have an opening in its rear wall through which the end of the burner is inserted.

The burner consists of a pipe, E, surrounded 70 by a water-jacket, F, and may be held either upon said burner or upon the tuyere. The burner E is provided at its end with suitable orifices through which the petroleum is admitted to the blast-furnace. I prefer to make the 75 water-jacket F in two horizontal compartments, which may be formed by casting a dividing-rib, *f*, so as to bridge the space between the inner wall of the water-jacket F and the outer 80 wall of the burner. This water-jacket F surrounds the burner to the point where the latter is connected with the feed-pipe G. I prefer to connect this feed-pipe with a circular underground main, I, also underground. The 85 main I leads from a feed-tank, J, the level of the petroleum in which is maintained by a float, *j*. The supply-tank J is connected with a storage-tank, K, which latter contains the petroleum-supply. 90

I have contemplated locating the storage and feed tanks at such distance from the furnace that all danger of explosion of the petroleum is avoided. The service and supply pipes should also be surrounded with water-jackets where there is danger from fire. The 95 petroleum is held at a level above the point where the burner enters the tuyere, and is

caused to flow through the orifices of the burner by its own weight or by the suction induced by the blast. This level is maintained by the use of a float, *f*, which is so arranged as to operate a valve in the pipe leading from the storage to the feed tank, and is such that the head of the liquid shall overcome the pressure in the furnace. The operation of this float will be readily understood from an inspection of the drawings.

The supply-pipe *G* and burner *E* are connected by a coupling, *g*. Below this coupling, pipe *G* is provided with a stop-cock, *I*, which may be an ordinary plug-valve with an aperture of any suitable form. The plug of this stop-cock is provided with a lever, *M*, which is made to swing in front of an arc-dial, *O*, the latter being marked with a graduated scale. By means of this lever and arc-dial the amount of hydrocarbons admitted through the burner may be accurately regulated or determined. A ball-valve, *P*, is placed within the pipe just above the stop-cock, and as the head of oil allows the petroleum to flow up to a stated pressure in the furnace, this ball-valve automatically checks all flow in excess of this pressure.

The part which I have denominated the "burner" (marked *E* in the drawings) consists of a pipe which is cylindrical in form up to the point where it enters the tuyere. At this point the form of pipe changes from the cylindrical to the oval. The burner terminates in a mouth or orifice, *N*. The castings which form the walls of the mouth or orifices of the burner may be cored out, and through these chambers thus formed the water flows from the lower to the upper compartment, thus cooling the burner and the walls of the orifices. It is evident that the shape or form of the burner and its orifices may be considerably varied without affecting the results sought to be accomplished by them. All that is necessary to be observed in the construction of these burners, as well as of the surrounding water-jackets, is that the construction be such as to permit a regular flow and avoid the possibility of melting.

I have described but one burner; but it will of course be understood that each tuyere has its burner, and each burner receives its petroleum supply from the circular main *H* through pipes similar to pipes *G*.

By means of the above apparatus a predetermined quantity of petroleum may be applied to the hot blast in each of the tuyeres. The petroleum thus admitted to mingle with the blast is converted into a gaseous form as soon as it enters the tuyere, and its combustion is simultaneous with its volatilization. The amount of solid carbon necessary to be used in the practical operation of a furnace where petroleum is used as the principal fuel will vary with the character of the ores operated upon and the petroleum used; but in all cases such an amount of solid carbon should be retained as will carburize the reduced iron,

maintain the permeability of the descending charge to the ascending gases, and reduce the carbonic acid in the reduction-flame to carbonous oxide. The sum of the carbonous oxide in the ascending furnace-gases constitutes the principal reducing element in the smelting operations.

In operation the furnace is prepared and charged with the ore, the fluxes, and a limited quantity of solid carbon in the usual way. An important point to consider while blowing in is, that at the point of substitution of one-half of petroleum, in using a hot blast of usual temperature, the heat of the hearth is too high unless regulated. This can be readily obviated by gradually lowering the temperature of the blast, and again increasing it as the substitution of more than half progresses, thus maintaining a fairly uniform degree of heat throughout the hearth during the blowing in. When the furnace is prepared and the charges are being put in, the quantity of solid fuel may be gradually reduced and petroleum admitted to take its place. The petroleum is admitted, as before stated, in regulated quantities, and is forced by its own weight or drawn by the hot blast into the tuyere, in which it is converted into gas, in which form it enters the furnace. The substitution of petroleum or hydrocarbon for solid carbon may be carried forward until only such quantity of solid carbon is retained as will carburize the reduced iron and maintain the permeability of the descending mass, &c.

In order to maintain a uniform flow of petroleum through the stop-cock *I*, the retardation of the flow of the liquid, caused by the friction in the service-pipes, should be compensated for by making the service-pipes of increased diameter according to their length.

The fuel and reducing agents now in common use to perform the usual operations of blast furnaces are coke, coal, and charcoal. These are burned and utilized in such a way that carbonic acid is principally formed before the tuyeres. This carbonic acid is promptly reduced to carbonous oxide by coming in contact with incandescent carbon, and then, while ascending through the charges, performs the required operations of reductions, forming slags, &c., by decompositions, recombinations, heating, &c., as desired. About one half the carbon of the coke furnace passes through the hearth, principally as carbonic acid. The other half is utilized for adding the molecule of free carbon required to reduce carbonic acid to carbonous oxide, and the heat produced by the combustion of the solid fuel plus the artificial temperature of the blast performs the operations within the hearth. The intensity and quantity of the heat in the body of the furnace, and which performs the operations there, is that of the temperature of the carbonous oxide plus that of the blast not previously consumed in the hearth, and also of the chemical reactions which obtain between the materials of the charges.

In substituting petroleum or hydrocarbons for solid fuel in blast-furnace operations it must be done in such a way as to simulate the mode of use of solid fuel, so as to comply with existing conditions and perform the required operations in present manner as nearly as possible.

Crude petroleum is a compound body of varying composition, being a mixture of hydrocarbons in varying proportions of admixture, forming a thin liquid. To prevent explosion within the furnace it is fed only in regulated quantities relatively with the blast, and this also insures the formation of the combustion-products from the burning hydrocarbons, which are indispensable to success in the substitution of the liquid for the solid fuel. To feed the petroleum in regulated quantities relative with the blast, the arrangements for the blast must be as perfect as possible, so that a steady and regular stream of blast will continually enter the furnace with the petroleum.

In a furnace using it principally as fuel the petroleum should be burned so as to get an excess of carbonous oxide before the tuyeres in the reduction-flames, and in such proportions to the carbonic acid in the flames as practice will demonstrate to be most advantageous with a given ore and crude petroleum or hydrocarbon mixture. The amount of petroleum fed into the furnace with the blast should be short of the point where sooting occurs. The limit of being able to substitute petroleum for solid fuel is also short of that point where the proportions of carbonous oxide, carbonic acid, and water in the reduction-flames are such that, owing to the greater affinity of oxygen for hydrogen over that for carbon, the amount of oxygen in the blast is insufficient for complete combustion of the petroleum to gases, for then free carbon is deposited as soot. This deficiency of blast would also cause the formation of carburized hydrogens, which are undesirable in the furnace operations. In practice there will be a slight excess of blast over the limit of the production of the carbonous-oxide point, and this slight excess is compensated for by solid fuel.

Solid or free carbon must be fed with the charges in such relative proportions to the carbonic acid formed before the tuyeres that this carbonic acid shall be reduced to carbonous oxide by the addition of one molecule of free carbon, and enough additional coke or free carbon should be fed in with the charges as will carburize the reduced iron. The limit of retaining solid fuel in the blast-furnace using petroleum principally as fuel is governed by two factors: First, if all the carbon of the petroleum is burned to carbonic acid there must be enough free carbon to reduce it to carbonous oxide by the addition of one molecule of free carbon and enough to carburize the reduced iron; and, second, if all the carbon of the petroleum is burned to carbonic acid, the temperature is so high, unless controlled in the way above suggested, that it

will soon destroy the furnace-lining in the hearth. From these factors the chemist in charge will readily determine the proportions of the various materials required in the blast-furnace operations for any required mixture.

The practical utilization of crude petroleum will be nearer the first-mentioned limit of not sooting for making pig-iron, for then all waste gases can be used in heating the blast. The permeability of the descending charges must and will be maintained by volatilizing and burning the solid fuel fed with the charges of ore and fluxes. It is not necessary or desirable in practice that these proportions be theoretically perfect so long as there is a slight excess of carbon fed with the charges, for the slight excess of air over that required to form perfect reduction-flames works well, for the ore charges and fluxes and free carbon being fed in alternate layers the required chemical reactions are perfect.

A petroleum containing eighty-four per cent. of carbon, ten per cent. of hydrogen, and six per cent. impurities can be so burned in a blast-furnace that seventy-five per cent. of the carbon will be burned to carbonous oxide and twenty-five per cent. to carbonic acid, the hydrogen being burned to water. The carbon forming the principal reducing element, the hydrogen is considered as a heating element only. Inasmuch as no two petroleum are alike, the relatively-formed proportions of carbonous oxide and carbonic acid will vary in each case. By mixing naphtha or other light hydrocarbons and heavier petroleum together, a petroleum can be formed of constant composition, and thereby, with given ores and fluxes, constant results can be obtained. The varying composition of the petroleum is provided for by adding free carbon, as described above. The chemist and laborers in charge will readily adapt themselves to the methods required, understanding the principles involved.

The furnace-gases of a petroleum blast-furnace using petroleum and coke or charcoal in combination, as above, will be almost the same above the boshes as those of an ordinary furnace, being slightly increased in volume. In the hearth, however, there is more of a difference, for, as in the coke-furnace one-half of the carbon is burned or used in converting the carbonic acid to carbonous oxide, that much never gets below the boshes, while in using crude petroleum, about three-fourths of the carbon will pass through the hearth, and the difference in equivalence between the carbon and hydrogen will necessitate an increased volume of blast. The ratios of the volumes of gases in different parts of the two classes of furnaces will differ as above. The volume or amount of blast necessary to carry on the furnace operations of a petroleum blast-furnace will be figured about as follows: Take, for example, one hundred pounds of the last-mentioned petroleum, and 5.805 pounds of air to burn one pound of carbon to carbonous oxide,

and 11.61 pounds of air to burn one pound of carbon to carbonic acid, and 34.78 pounds of air to burn one pound of hydrogen to water.

The result is, mathematically stated, $63 \times 5.805 = 365.715$; $21 \times 11.61 = 277.03$; $10 \times 34.78 = 347.08$ —equals 993.545, making a total of 990.5 pounds of air to burn the petroleum to the above-indicated mixture of gases. These gases are increased in volume above the boshes by just so much as the carbon fed with the ore-charges will increase the volume of the carbonic acid by reducing it to carbonous oxide, and this reaction doubles the volume of the carbonic acid so reduced. Allowance must of course be made for varying conditions of the air in making the calculations.

In calculating the relative diameters required of the hearth and body of a petroleum blast-furnace, the volume of the gases passing from one to the other and the changes in their composition as affecting their volumes must be a governing factor. In a coke-furnace the carbonic acid of the hearth is promptly converted to carbonous oxide at and above the boshes, this reaction doubling the volume of the carbonic acid, as above stated, and about one-half of the carbon goes through the hearth. For this reason the furnace is enlarged at the belly above the hearth; otherwise the tension of the gases would prevent the descent of the charges and choke up the furnace. In a petroleum-furnace using petroleum principally, about three-fourths of all the fuel passes through the hearth, and three-fourths of the carbon is carbonous oxide, so that the increase in volume is so much less. This will necessitate an increased diameter for the hearth and a more obtuse angle for the boshes. The benefits arising from this, will be that the wear of the lining of the furnace-walls will be far less, and it will also afford a larger space within the hearth for the reduction-flames. The furnace-lining can be further preserved by reducing the temperature of the blast, for, inasmuch as a coke-furnace works best with a hot-blast, and consequently a hot hearth, it does so because that determines a hot body, and so hot ore, upon which the reducing-gases act most promptly; but as in a petroleum-furnace the heat rendered latent is far less, the body is still hotter, even though the temperature of the blast is lowered, which in turn lowers the temperature of the hearth.

The burning of the carbon within the coke-furnace hearth to carbonic acid determines and performs the operations of the hearth, and the degree and intensity of the heat in this space is that of burning carbon to carbonic acid plus the temperature of the blast modified by the pressure, losses by radiation, &c. As a comparison of the heat produced by the different methods of using solid and liquid fuels in combination or solid fuel alone, that degree of heat produced by burning carbon to carbonic acid in air will furnish a fair unit, as almost all the carbon of a coke-furnace burned before the tuyeres is burned to

carbonic acid before its reduction to carbonous oxide, that degree of heat being, according to Scheerer, 2,458° centigrade.

When using petroleum, as described above, the degree of heat before the tuyeres will be about that of the sum of the various gases or compounds formed by the burning of the elements forming these compounds. These compounds will be the gases (carbonous oxide, carbonic acid, and water) formed by burning the hydrocarbons to a reduction-flame. Having a petroleum containing eighty-four per cent. carbon, ten per cent. hydrogen, and six per cent. impurities, which, burning seventy-five per cent. of the carbon to carbonous oxide, twenty-five per cent. to carbonic acid, and the hydrogen to water, the sum or degree of heat produced will be that of these elements so burning. Taking, for example, one hundred pounds of such a petroleum, we would have for so burning, twenty-one pounds of carbon for carbonic acid, sixty-three pounds for carbonous oxide, and ten pounds of hydrogen for water, and the impurities modifying the result in a measure. Accepting that hydrogen is capable of producing an even four times as much heat as an equal weight of carbon, and accepting that carbon burning to carbonous oxide is capable of producing a heat of 1,310° centigrade, we would have the following result, mathematically: $2,458 \times 21 = 51,618$; $1,310 \times 63 = 82,530$; $2,458 \times 4 \times 10 = 98,320$, making a total of 232,468 units, which, being divided by 94, gives 2,558° centigrade. This calculation gives 100° centigrade more for the petroleum-furnace, resulting from the combustion of the fuel in the hearth. This is modified, however, being lower, because hydrogen requires more air for combustion than carbon, and so imparts more heat to the increased volume of the nitrogen of the blast. It is plain that as the heat as here calculated is only an approximation, every advantage can be taken of raising and lowering the temperature and pressure of the blast to attain the required results in the furnace operations.

The blast will be heated with the waste gases of the petroleum-furnace just in the same manner as from a coke or charcoal furnace. The same plant as now used for a furnace using coke or charcoal may be used to utilize petroleum with simply the addition of proper tanks and attachments as required by the altered conditions. The furnace-gases of a petroleum blast-furnace will vary in composition and in volume from a coke-furnace in that they will contain more nitrogen and water; but this will be immaterial when taking into consideration that but a fraction of the sum of the fuel can be replaced, and that coke and charcoal also contain hydrogen and water, while petroleum contains practically no water as such. The hydrogen products of combustion being water are practically neutral in the chemical reactions of reduction of the furnace, (acting as desulphurizers and dephosphorizers,) and consequently are consid-

ered more as a heating element and as affecting the required capacity of the furnace and size of the tuyeres, burners, and blow-pipes.

The temperature of the petroleum-furnace above the hearth will be higher than in a coke-furnace, because the amount of heat rendered latent by converting the full amount of carbonic acid to carbonous oxide of the solid fuel of the coke-furnace is greater, the amount rendered latent being just the difference between burning carbon to carbonic acid or carbonous oxide.

There is a marked difference in the temperature of the two classes of furnaces, which obtains only at the zones where the reduction to carbonous oxide takes place, being highest in the petroleum-furnace. Above these zones it rapidly diminishes in the petroleum-furnace, and approaches nearer to that of a coke-furnace, because the ascending gases are continually parting with their heat to the descending charges, and of losses by radiation. The petroleum-furnace will have the advantage of a more even gradation of heat from the bottom to the top of the furnace, and will be increased especially with benefit in the zones of carbonization and reduction. The ultimate amounts of heat obtained from like amounts of carbon are precisely alike, whether obtained from coke, charcoal, or petroleum. The heat is calculated and utilized from these various sources as carbonous oxide at and above the point of its reduction to carbonous oxide within the furnace. The carbon is almost completely converted to carbonous oxide in both classes of furnaces at about the same points within the furnaces, differing only in the manner.

The slags to be formed will have to be altered to suit the changed conditions. The temperature of the body of the furnace being higher, the slags must be rendered more basic and difficult of fusion. Then the fact that the petroleum contains no ash will have to enter, or rather not enter, into the calculation for making the mixture to produce the desired slags. The petroleum-blast-furnace process will proceed more regularly and rapidly, because there will be less slag and slag-forming material to mechanically interfere with the action of the reducing-gases on the ore, and the liquid fuel being fully under control the amount of fuel required per ton of iron produced will more nearly correspond with that called for theoretically. The ten per cent. (or more) of hydrogen of the petroleum producing about four times as much heat as its weight of carbon, will do about four times the work of heating by heating the ore-charges, melting slags and reduced iron, keeping crucible hot, &c., and leave the carbonous oxide formed from the carbon of the petroleum and the free carbon fed with the charges to perform their proper work of reducing iron oxide to metal.

In comparing the relative value of coke or charcoal and petroleum for blast-furnace operations, their relative compositions govern

the proposition. Solid fuel contains from five to fifteen per cent. of ash, six to ten per cent. of hygroscopic water and moisture, and one to twelve per cent of combined hydrogen and oxygen. Then the ash of the solid fuel must be fluxed and melted and the moisture volatilized, so that from ten to twenty per cent. of the value of the solid fuel is consumed in getting rid of the contained impurities. Consequently only from sixty to eighty per cent., by weight, of the solid fuel is utilized in the furnace economy. Petroleum contains as impurities only a little dirt and water, with some sulphur. The water and dirt, settling to the bottom of the storage-tanks, are mostly removed, and do not go through the furnace at all, so that petroleum may be considered as being practically a pure fuel. As a very liberal general estimate, a coke-furnace now requiring one and one-half ton of coke to make one ton of pig-iron would require about one-third ton of coke and about three-fourths ton of petroleum.

In making the various grades of pig-iron, similar methods as now employed will apply. The quality of the iron from a petroleum-furnace will be most excellent, as the higher temperature of the zone of carbonization will favor full carbonization. Then the reduced iron, because of falling through a mixture of gases in which there is a larger quantity of the reducing-gas, carbonous oxide, it will not lose its carbon; and, further, as the slags will be more basic with the iron more fully carburized, a smaller amount of silica will be reduced to contaminate the iron with silicon. As petroleum contains scarcely a trace of phosphorus, this element will be present in less quantity in the iron. The sulphur will be far less because of the large quantity of hydrogen present in the furnace-gases. This will tend to form sulphureted hydrogen, which will go off with the waste gases, as will also the phosphorus. The data contained in the above will furnish the formulae for determining the relative dimensions of a furnace and its parts, the size of the tuyeres required and their burners, the amount of blast-power and blast, and the required mixtures for conducting smelting operations.

In blowing in a petroleum blast-furnace the same precautions of properly preparing the furnace must be taken as with a coke-furnace. The charging can begin either wholly with solid fuel, the petroleum flow not being turned on until the furnace is fully under way, and the petroleum gradually substituted until the practical limit is reached; or the petroleum may be used in part at once and the limit of its most advantageous substitution gradually reached. That this can be done is seen from the fact that in either case all the carbon from the petroleum is burned to carbonic acid until about one-half is substituted, and goes through the furnace the same as that from the ordinary combustion so long as there is oxygen in excess in the blast. After that it goes through

in part as carbonous oxide, and the solid carbon is of course diminished in proportion.

In thus using hydrocarbons the proportions of the charge will vary according to the character of the petroleum, the kind of ore used, and other special circumstances, as explained above; but as an example for an iron ore charge having a fifty-five per cent. ore with silicious gangue I give the following: two hundred parts of iron ore, one hundred and twenty parts petroleum, forty parts coke, and fifty parts limestone. A fraction of the solid fuel is also replaced in smelting by crude petroleum or other hydrocarbons for the purpose of desulphurizing and dephosphorizing the ores. This does not apply to smelting pure sulphurets, like iron pyrites, but only to such ores as are charged for smelting in blast-furnaces, in which sulphur and phosphorus are present as impurities up to a few per cent. This is accomplished by using one-half or less of hydrocarbons, and burning the hydrocarbon to carbonic acid and water, these gases being formed and introduced with the blast, and forming a fractional portion of the furnace-gases, and the smelting, desulphurizing, and dephosphorizing being performed during this one operation of smelting. The effective agent performing the desulphurizing and dephosphorizing is the water of the burned hydrocarbons, this water acting either as superheated steam or as nascent hydrogen formed, owing to its decomposition, by incandescent carbon. This desulphurizing and dephosphorizing obtains when substituting crude petroleum in any proportion whatever for solid fuel.

The reasons for these reactions is the varying chemical affinities of the elements, the explanation being about as follows: Pure hydrogen gas will promptly reduce iron oxides, the oxides being heated; but it will not do so if there is present in the hydrogen gas any of the carbon oxides. Carbonous oxide will reduce oxides of iron promptly in presence of hydrogen gas or water-vapor, the oxides being heated. Carbonous oxide will also reduce iron oxide in presence of carbonic acid if the carbonous oxide is in excess. Water-vapor as superheated steam, or decomposed, having formed nascent hydrogen, will decompose compounds of sulphur or phosphorus, forming sulphureted and phosphoreted hydrogens, respectively, in the presence of carbon oxides. Now, these conditions are present while partially substituting hydrocarbons for solid fuel with the blast and burning the hydrocarbons to carbonic acid and water. All hydrocarbons can be so burned, whether solid, liquid, or gaseous. They can be burned to carbonic acid, water, and carbonous oxide, or to carbonic acid and water, but can in no case whatever be burned to carbonous oxide and water, because of the difference in the affinity between the carbon and oxygen, and the carbon and hydrogen, and the hydrogen and oxygen. For this reason, complete substitution of petroleum or hydrocarbons for solid fuel is a practical impos-

sibility, and this because the ever-present carbonic acid is an oxidizing agent, and so retards all reduction.

When smelting with the object of making better iron, less than half of liquid fuel should be used and enough free carbon additional be fed with the ore-charges to utilize the carbonic acid as carbonous oxide, the carbonic acid taking part in these operations the same as if formed from solid fuel within the hearth of the furnace. The temperature of the blast must also be regulated to suit the requirements of each individual case, according to the amount of hydrocarbon substituted, so as to avoid wasting the furnace-lining. In thus using hydrocarbons the proportions of the charge will vary according to the character of the petroleum, the kind of ore used, and other special circumstances, as explained above; but as an example for an iron-ore charge, having a fifty-five per cent. ore with silicious gangue, I give the following: Two hundred parts of iron ore, one hundred and twenty parts coke, twenty-five parts petroleum, fifty parts limestone.

It has long been known that superheated steam would desulphurize and dephosphorize iron ores, and also dephosphorize molten iron in the Bessemer converter, but owing to difficulties experienced in introducing the steam into the converter, or with the blast, it has been only a partial success. Introducing steam directly into an iron blast-furnace in this way causes large losses of heat, and so seriously interferes by retarding operations that it has been abandoned. Recently, also, I am informed, iron ores have been subjected to the action of superheated steam in reverberatory furnaces, and then smelting the so-treated ores. This necessitates two operations, and has the further disadvantage of again introducing the same impurities by means of the solid fuel and fluxes now used in smelting, which, during the one operation, while forming steam from the crude petroleum or hydrocarbons by their burning, are expelled not only from the ores but from both the fluxes and solid fuel. In utilizing crude petroleum as last above described, it is burned to a mixture of water and carbonic acid with such excess of blast as will utilize the solid fuel fed with the ore. The water formed during this combustion does not cause a loss of heat, but, on the contrary, is a source of heat and aids the furnace operations by so much. The proportion of hydrocarbons and solid fuel to be used, while using principally solid fuel, will vary with the character of the ores, fluxes, and solid fuel of each case.

I do not consider that ten per cent. or less of solid fuel can be used practically in my process, because of the affinities of the different elements: hence the proportions will always be more than ten per cent. of solid to less than ninety per cent. of liquid fuel. Pig-iron contains from five to eight per cent. of carbon, which is calculated as coming from

solid fuel, and this alone calls for over ten per cent. of solid fuel.

As above shown, I am aware that experiments have been made to reduce iron and other ores by means of a flame of petroleum or hydrocarbon vapor; also that a small percentage of carbon has been mixed with iron ore and the charge reduced by means of petroleum; but in these instances the amount of solid fuel has not been sufficient to perform the reducing operations of the blast-furnace process; nor do I claim the mere use of petroleum as a fuel for the smelting of ore, but only when used in connection with solid or free carbon and in such relative proportions that the burning of the two will furnish the required reducing-gases. I also disclaim the use of steam as an aid in the combustion of the petroleum, and my process is also limited to the complete burning of the petroleum, so as to produce a mixture of carbonic and carbonous oxides, vapor of water, and other gases, and so as to utilize these gases by the addition or use of the proper amount of solid or free carbon to furnish the true reducing-gases required in the smelting of ores; and I now disclaim all processes operating in different ways or on different principles from those here stated.

I also wish it understood that I do not contemplate or intend to cover the use of gas strictly as a fuel, but only petroleum or liquid hydrocarbons when mixed with solid fuel in such a way that the liquid fuel will be volatilized and burned simultaneously, and not first converted into a gas to be afterward used as

a fuel; and I also disclaim the use of wood as a solid fuel.

I do not now claim the apparatus shown for carrying out my process, the same being the subject-matter of an application filed by me January 19, 1885.

I claim—

1. The process of smelting ore, which consists in charging the furnace with one hundred parts of ore, proper fluxes, and from sixteen to forty parts of free carbon, and injecting from sixty-five to forty parts of crude petroleum with air, and regulating the amount of air to produce a non-oxidizing flame, the proportions of free carbon and petroleum varying relatively within said limits as required by the varying compositions of the petroleum or other circumstances, substantially as described.

2. The process of smelting iron ore, which consists in charging the furnace with one hundred parts of ore, proper fluxes, and from fifteen to sixty parts of free carbon, and reducing the mass by a flame produced by the burning of crude petroleum or liquid hydrocarbons injected with sufficient air to produce a non-oxidizing flame, the amount of the liquid fuel being determined and regulated by the varying composition of the ore, solid and liquid fuel, or other circumstances, substantially as described.

FREDERICK C. WEBER.

Witnesses:

EPHRAIM BANNING,
THOMAS A. BANNING.