

July 9, 1940.

H. K. WORK

2,207,309

CONTROLLING BESSEMER CONVERTER

Filed March 22, 1939

2 Sheets-Sheet 1

Fig. 1.

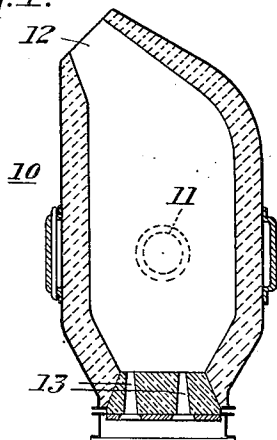


Fig. 2.

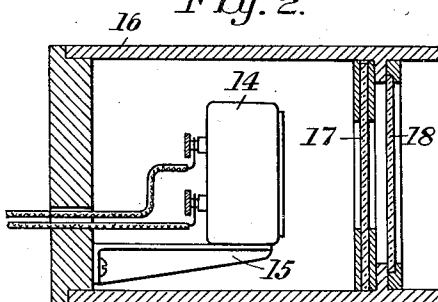


Fig. 3.

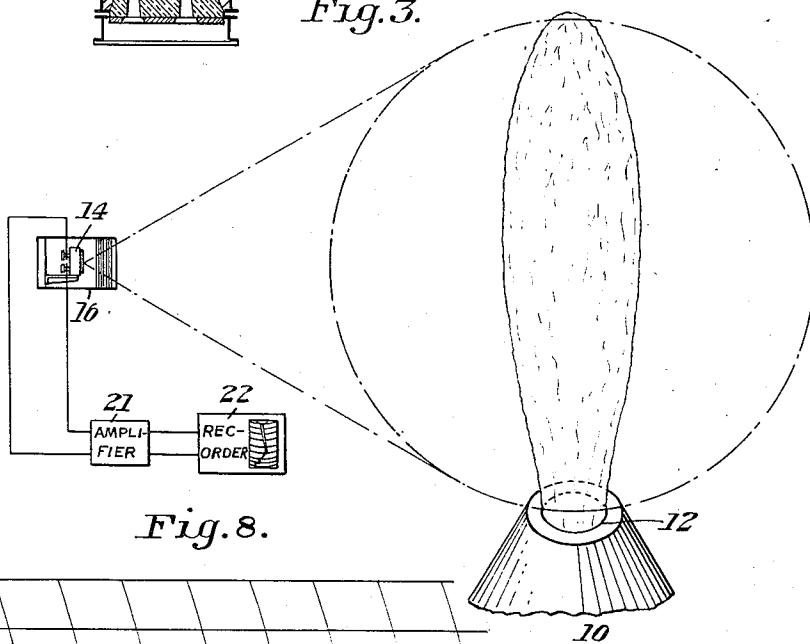
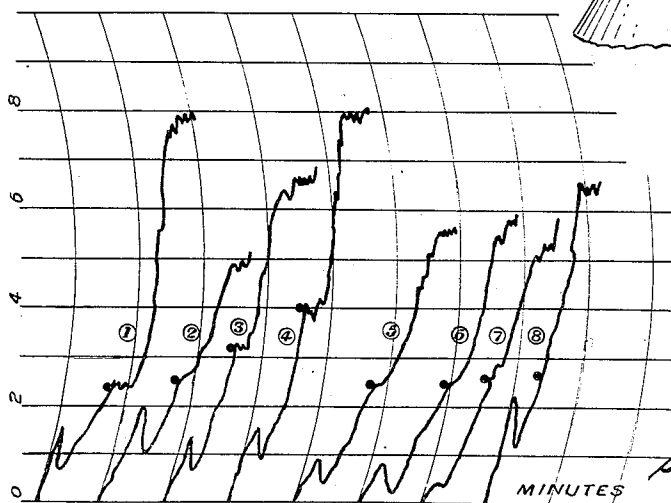


Fig. 8.



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2 Sheets-Sheet 2

Fig. 4.

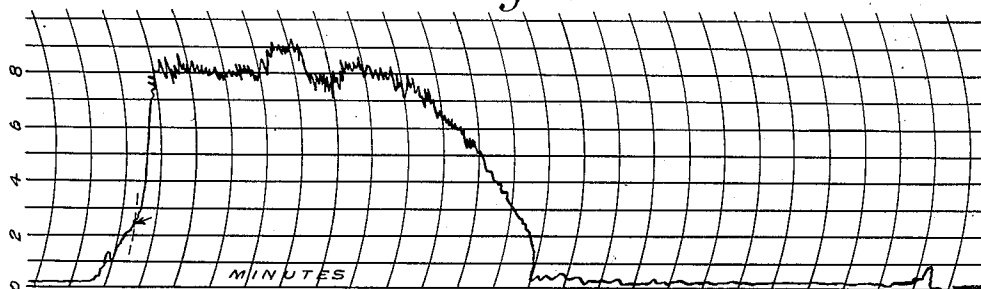


Fig. 5.

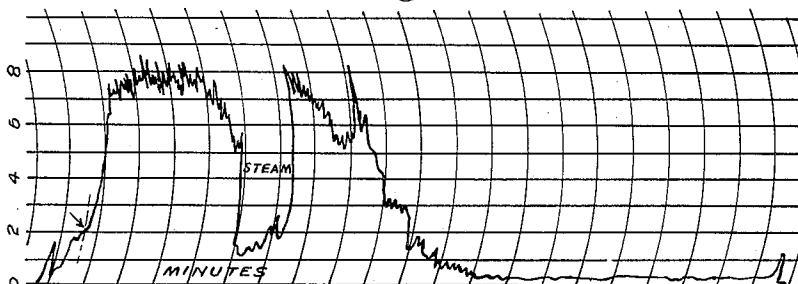


Fig. 6.

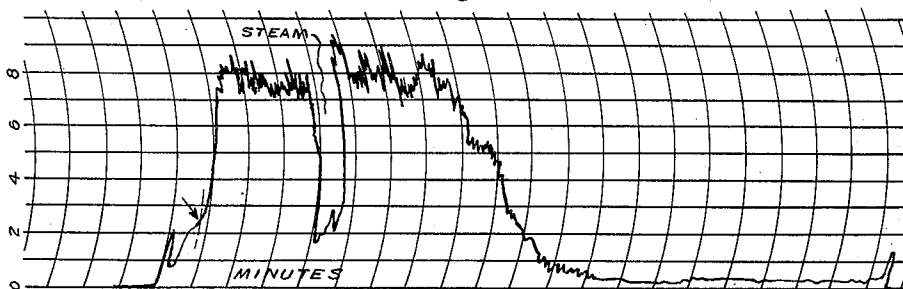
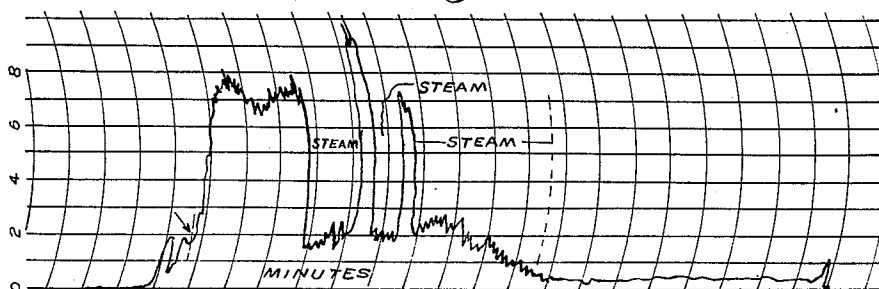


Fig. 7.



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CONTROLLING BESSEMER CONVERTERS

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Application March 22, 1939, Serial No. 263,575

13 Claims. (Cl. 75-60)

This invention relates broadly to the manufacture of steel by the Bessemer process and, in particular, to a method for controlling the blow. By "controlling the blow" I mean the choice of the initial condition of the charge, e. g., the temperature, the amount of scrap used, etc., as well as variation in the blast through the converter.

Although the manufacture of steel by the Bessemer process has been carried on since 1857, and is in fact the oldest of our present methods of making steel in quantity, the measure of metallurgical control which it has been possible to exercise over this process, previous to the invention herein to be set forth, was no greater eighty years later than at the time of Bessemer's invention. The two main problems of the process—first, when to stop the blow for a desired composition of the steel, and second, how to obtain uniform chemical and physical properties for a series of blows—have, previous to this invention, been capable of determination by no more accurate means than the observation and experience of the blower. In these respects the Bessemer process has been outdistanced by the open hearth and electric furnace processes, the products of which are subject to quite accurate control, both with respect to physical as well as chemical properties.

The short time in which a blow is completed and the rapidity with which the reactions change as the end point approaches, are factors which greatly complicate the problem of Bessemer blow control.

Despite numerous efforts, it remains a fact that the success of the Bessemer process, i. e., the extent to which the finished product conforms to the desired standards of physical characteristics and chemical composition, depends almost entirely upon the skill and experience of the operator controlling the blow, which enable him to determine, from the character of the conversion as indicated by the appearance or sound of the flame issuing from the mouth of the converter or the nature of the sparks emitted, the stage of the reactions occurring therein. Such method of control is highly uncertain, at best, and is known to produce an excessive number of "off" heats, i. e., batches which do not conform as closely as desired to the standards for physical characteristics and chemical composition. The operator's visual reaction to the appearance of the flame is not quantitative and the only standard of comparison is that afforded by his recollection of the behavior of previous heats. In any event, the nature of the process, i. e., the relatively short

time required for its completion, practically precludes any check of physical characteristics or analysis of chemical composition which might serve as a guide in controlling the blow.

I have invented a method and apparatus whereby the Bessemer process for making steel may be more accurately controlled and the number of "off" heats greatly reduced. Broadly stated, the invention consists in substituting for the visual effect of the converter flame on the operator's eye an index of the progress of the blow which is more reliable and not subject to human fallibility. In a preferred practice of the invention, I make a photometric determination of the radiant-energy emitted by the converter flame at various stages during the blow, and thereafter control the blow as may be required to produce steel of the desired characteristics and composition, basing the mode of control on similar determinations of previous blows.

The apparatus which I find satisfactory for performing the method just outlined includes a light-sensitive cell so positioned as to be subject to the radiations from the converter flame, an amplifying system for multiplying the output of the light-sensitive cell, and a suitable form of indicating device which may conveniently be a graphic recorder of known construction. I may also employ suitable filters between the photo-sensitive cell and the converter flame either to protect the cell from excessive radiation or to restrict the radiations reaching the cell to frequencies in a predetermined band or bands. The apparatus mentioned will be described in greater detail herebelow together with the procedure which I have found most satisfactory for practicing the method of my invention. A typical arrangement of the apparatus is shown somewhat diagrammatically in the accompanying drawings but this showing is to be considered as purely illustrative since other apparatus and arrangements thereof may be employed for the same purpose. In the drawings:

Fig. 1 is a vertical central section, largely diagrammatic, through a Bessemer converter in blowing position, the plane of section being perpendicular to the tilting axis of the converter;

Fig. 2 is a central vertical longitudinal section through a photocell housing;

Fig. 3 is a diagrammatic view illustrating the location of the photocell housing relative to the converter and also shows the approximate position of the flame during blowing;

Fig. 4 is a curve showing the variation of radi-

ant-energy emitted by the converter flame through the entire length of a typical blow;

Figs. 5 through 7 are similar curves for blows involving slightly different procedures; and

- 5 Fig. 8 is a set of curves illustrating the radiant-energy emission during the last minute of several different blows.

Referring now in detail to the drawings, a typical form of Bessemer converter is shown largely diagrammatically at 10. Such converters are mounted for tilting on trunnions 11 and are provided with a spout 12 through which they are charged and emptied. Tuyères 13 in the bottom of the converter permit the introduction of air under pressure to carry out the Bessemer conversion process. As indicated, the converter proper comprises a shell of steel plate lined with refractory brick.

A photocell 14 of any suitable type is mounted on a bracket 15 within a housing 16. The housing is provided with means for removably receiving and supporting filters 17 and 18.

The photocell unit is so disposed, as indicated diagrammatically in Fig. 3, that it is subject to the radiation emanating from substantially the entire converter flame. The photocell 14 is connected to an amplifier 21 whereby its output is multiplied sufficiently to actuate an indicating device shown at 22. This device may be of any desired type but I prefer to utilize a graphic recorder capable of producing a permanent record of the variation of radiant-energy emission during the course of a blow.

By the aid of the apparatus illustrated in Fig. 3, I am able to obtain a record such as that just mentioned, a typical example of which is illustrated in Fig. 4. On this curve, the abscissae are units of time, e. g., minutes, while the ordinates represent the current in milliamperes traversing the recorder 22. The output of the photocell bears a substantially linear relation to the intensity of radiation impinging thereon.

I have found that for a given set of initial conditions, viz., the temperature of the iron in the converter, the condition of the bottom (i. e., the number of tuyères blanked off and the size of the tuyères remaining open), and the state of the converter lining, the amount of radiant-energy emitted by the converter flame at successive periods of time during the blow follows a well defined pattern and it also appears that changes in the amount of radiant-energy emitted during the blow are related to the progress of the chemical reactions in the converter closely enough to permit an accurate determination of the latter by measuring the amount of radiant-energy emitted. The progress of the chemical reactions, furthermore, may be regulated by appropriately controlling the blow. I am thus able to cause the radiant energy-time curve for any blow to conform substantially to that of a previous blow which resulted in steel of the desired characteristics and composition, and to control any given blow appropriately to produce the desired product on the basis of experience with previous blows, even though the blow in question does not exactly duplicate any previous blow. If the initial conditions are maintained reasonably constant and the blowing of successive heats is controlled in such a manner as to produce radiant energy-time graphs of similar or identical shape and amplitude, the steel from such blows will be found to possess quite uniform chemical and physical characteristics. Even where the initial conditions of a series of blows are not uniform it is

possible, by using the graph of the radiant energy against time, which is drawn by the recording meter during the progress of the blow, as a guide whereby to control the blowing, to produce steel of a substantially greater degree of uniformity than heretofore.

From the standpoint of actual operating practice, the invention requires only the production of curves such as that shown in Fig. 4 for a considerable number of blows or heats and picking therefrom to serve as master curves for the guidance of the operator in subsequent blows, those curves produced by blows which resulted in steel conforming most closely to the predetermined standards of physical characteristics and chemical composition. Preferably master curves are made for each converter to be controlled. The curves produced by one converter are used to control the subsequent blows of that converter only.

The character of the blast may be varied by changing the volume or pressure, by steaming (i. e., blowing steam through the tuyères with the air), or by side blowing (i. e., by tilting the converter so that the blast passes through only a portion of the heat). It may also be desirable to control the temperature of the iron, if necessary, by throwing cooling agents such as scrap or the like in the converter. The initial conditions, i. e., the temperature of the iron and the state of the converter lining, are maintained as near to the optimum as practical.

The results of these various means of control, as indicated in a curve such as that of Fig. 4, are as follows: an increase in pressure is followed by a rise in the curve, and a decrease by a fall; steaming is usually followed by a sudden drop very similar to that caused by a sudden reduction of pressure.

Figs. 5 through 7 are curves of three successive blows made in accordance with the invention. These curves will serve to illustrate the effects of the various control means. (It should be noted that time runs from right to left along the abscissae, each division of which represents one minute.) The flame produced by the burning out of the silicon in the earlier portion of the blow causes only a small indication on the recorder. The point at which all three curves shown leave their nearly zero value and begin to climb is approximately the point at which the carbon flame begins. All three blows were begun at a reduced pressure, to avoid overheating. In the blows represented by Figs. 5 and 6, after the carbon began to burn, and the curves had reached the ordinate 1.5, or thereabouts, the blast pressure was suddenly increased to its full value, and all three curves jumped to values around 7 or 8. The curve in Fig. 7 represents a blow that was steamed in the early stages. On shutting off the steam, the curve rose to a value between 6 and 7. The practice employed in turning down these blows was as follows: The drop of the curve at the end of each blow was watched for the knee or bend indicated in each curve by a vertical line and arrow. This knee has been found to indicate the point beyond which further carbon elimination is accompanied by a greatly increased oxidation of the iron itself. Beyond this point the rate of carbon elimination appears to be much slower than for previous periods, while the rate of oxidation of iron appears to increase rapidly. The blowing was then allowed to proceed for an additional period (listed for each blow in the tabulation

given herebelow) which had been found experimentally to produce the carbon content desired without producing an unduly large amount of FeO. For the particular grade of steel being made, this period was approximately 20 seconds, though individual blows were not all held exactly the desired time, as will be seen. The vessel was finally turned down at the point indicated on each curve by the small peak at the left end.

The results of a series of nine Bessemer blows, all of the same grade of steel, fully controlled by the method and apparatus of my invention, are summarized in the following tabulation:

Blow	C	Mn	After blow (sec.)	Percent rejects etch test	Percent rejects surface
A.....	.10	.77	26	5.8	1.67
B.....	.11	.78	19	3.7	1.66
C.....	.11	.76	20	0.0	4.34
D.....	.10	.69	15	5.2	10.40
E.....	.09	.75	21	1.8	1.03
F.....	.11	.85	19	3.7	3.40
G.....	.10	.72	22	0.0	0.00
H.....	.11	.81	19	0.0	0.00
I.....	.11	.88	20	0.9	1.22
Average..... percent.....				2.3	3.0
Average of blows made without photocell control..... percent.....				9.7	5.0

The carbon contents of the nine blows so controlled is seen to fall within a two point range, between .09% and .11%, which would be remarkably consistent even for open hearth practice. The manganese contents vary between the two extremes of .69% and .88%; omitting these two extremes the variation is only between .72% and .85%. These figures are far more consistent than the average of ordinary practice where a variation in manganese content of .30% between successive blows is not uncommon for this grade.

Figs. 5 through 7 illustrate the effect of steaming which produces a sudden drop in the curves, quite similar to those in Figs. 5 and 6.

Fig. 8 illustrates interesting phenomena which further show the range of usefulness of the photocell control. The curves plotted represent the last minute of the blow of eight different low carbon Bessemer blows, designated 1 to 8, inclusive. The black circles mark the point on each curve where the vessel started to turn down; the abrupt peaks at the bottom mark the end of the blow—the point at which the blast was shut off. It will be noted that the point of turn down corresponds to a more or less well-marked break in the shape of the curve, in general. It has been observed that, other conditions being the same, the higher the sulphur content of the steel, the lower the position of this break. It also appears that the period of time between the first sign of this break and the end of the blow—that is, the distance along the horizontal axis between the commencement of the break or bend and the tip of the concluding peak of the curve—is inversely proportional to the efficiency of the manganese addition, or, it would seem, directly proportional to the FeO content of the steel.

It should be explained that the manganese contents mentioned in the above table are not those of the steel at the end of the blow, but the final analysis obtained by adding ferromanganese to the practically manganese-free, blown metal after it is poured from the converter into the ladle. It might be expected that the problem of obtaining the desired manganese content in

the steel would be simple, as the blown metal contains an inconsiderable amount of this element and the theoretically required amount is added by throwing in an amount of ferromanganese which may be calculated accurately from the weight of the blow, the analysis of the ferromanganese, and the final analysis desired. The problem is, however, complicated by the presence in the blown metal of a considerable and previously uncontrolled amount of FeO, resulting from the oxidation of the iron by the air of the blast. It has been discovered that the greater amount of this FeO is formed after the blow has progressed beyond the point indicated by the "knee" or break in the radiant energy-time curve, as mentioned above. This FeO readily oxidizes the added Mn to MnO, a non-metallic, so that the amount of manganese actually alloying with the steel is always less than the total amount added. Since the amount of FeO in any given blow was neither known nor subject to any but the crudest degree of control, prior to the invention, the "manganese efficiency" or relative amount of manganese added which would alloy with the steel could never be known with any degree of precision, and consequently the proper amount of ferromanganese to be added could be calculated only to a rough degree of approximation. With the aid of the invention, however, the blowing period after the "knee" of the curve has been reached is readily controlled, thus controlling the amount of FeO in the steel and hence the manganese efficiency. It is now possible, therefore, by the use of the invention, to obtain the desired manganese contents in Bessemer steel with much greater consistency than heretofore.

It is sometimes desirable to interpose one or more filters such as shown at 17 and 18 between the converter and the photocell for the purpose of excluding the radiant-energy of certain wavelengths or frequencies and admitting that of other wavelength or frequency regions. This is done because the energy distribution over the frequency spectrum is not uniform, and it has been discovered that, under certain conditions, the graph of radiant-energy of a restricted portion of the spectrum of the blow lends itself more readily to control purposes than that of the entire spectrum. For example, under unfavorable conditions the use of a red filter cuts out certain superficial variations in the radiant-energy time-graph which, without such a filter, tend to obscure the significant trend of the reactions. The use of a green filter, on the other hand, is sometimes desirable near the end point of a blow, as the graph of the radiant-energy transmitted through such a filter plotted against time exhibits a less precipitous slope than the graph obtained with no filter. I find that the use of a filter which cuts off all radiations but the infrared rays is desirable for certain reasons. These rays are more penetrating than the visible rays and thus are less affected by smoke or vapors in the air. It is unnecessary, furthermore, to make correction for daylight when using infrared radiation.

It may also be desirable under certain conditions that one of the filters, e. g., that shown at 17, serve as a protection against excessive radiation which might injure the photocell. I also contemplate using more than one indicator, each having a different filter, as certain frequencies or colors are more suitable than others for indicating the progress of various stages of the

blow. Steaming affects radiations of certain frequencies but not green rays. The green radiations seem to be of steadier intensity and more uniform throughout the blow.

It will be appreciated from the foregoing that the invention makes it possible to produce steel by the Bessemer process having characteristics and composition which vary much less between heats than under the prior practice whereby the operator relied solely on his visual reaction to the character of the converter flame. With the aid of the invention, a relatively inexpert blower is able to equal the results obtained heretofore by the best blowers. Not only is it possible to obtain a greater degree of uniformity between heats but also to approach more closely the increasingly exacting standards now being insisted upon by steel users as to the characteristics and compositions of many special purpose steels. The invention thus overcomes the historic disadvantage of the Bessemer process and enables it to compete with newer methods such as the open hearth and electric furnace wherein very accurate control of the progress of the chemical reactions involved in steel making may be obtained.

Etch test and surface inspection results show that the steel from blows controlled by the invention is both sounder and of better surface quality than the average of that made without this control. Etch tests are made by cutting out a cross-sectional slice from the billet and heating this section in sulphuric acid. The acid dissolves non-metallics and thus renders visible cracks, laps, and blow-holes caused by their presence. From the above tabulation it is seen that three of the nine blows had no rejections whatever when so tested; the highest percentage of rejects, in blow A, was only 5.8% by weight, which is considerably lower than the 9.7% average for this grade of steel when made without the invention. The average rejection for the nine blows controlled by my invention was only 2.3%, or less than one-fourth the average for blows made without this control. Surface rejections are made for cracks, slivers, seams, or other visible defects which will harm the quality of the finished product. The average rejections for the nine blows above mentioned was 3.0%, or a little over half that of blows made without the control afforded by my invention.

This method of control is also advantageous in that its use makes possible the accurate determination of the end point of the blow even when the flame characteristics visible to the human eye are obscured by fumes, gases, and other effects of alloying elements which are sometimes added in the converter.

It will be understood that it is not essential to make a continuous record of the radiant-energy emitted, in order to obtain the benefits of the invention. It is possible that instantaneous observations at intervals will be sufficient to indicate to the operator the necessity for changing the course of the blow. For purposes of ready comparison, however, the use of a recording instrument has obvious advantages.

From the foregoing description and explanation, it will be apparent that the operations treated herein are those characteristic of the acid Bessemer process. The invention is not limited thereto, however, but is also applicable, with equally satisfactory results, to the control of converters operated according to the basic Bessemer process.

Although I have illustrated and described herein but a preferred practice and embodiment of the invention, it will be understood that changes in the procedure or arrangement of apparatus may be resorted to without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. In a method of so controlling a Bessemer converter as to produce steel having desired characteristics and composition, the steps including measuring the radiant-energy emitted by the converter flame from time to time during the blow of a heat, and varying the character of the blast to produce a time-energy curve conforming substantially to that of a previously observed heat which produced steel having said characteristics and composition.

2. In a method of so controlling a Bessemer converter as to produce steel having desired characteristics and composition, the steps including measuring and recording the radiant-energy emitted by the converter flame from time to time during the blow of a heat resulting in steel having said characteristics and composition, and so varying the character of the blast applied to subsequent heats as to reproduce substantially the time-energy curve of said first-mentioned blow.

3. In a method of so controlling a Bessemer converter as to produce from a heat of iron therein, steel having characteristics and composition similar to that of a previous heat, the step of varying the character of the blast applied to the first-mentioned heat in such manner that the radiant-energy emitted by the converter flame from time to time during the blow conforms substantially to a record of the radiant-energy emitted during the blow of said previous heat at corresponding times.

4. In a method of controlling a Bessemer converter, the steps including making a photometric determination of the intensity of the flame produced by the blast, and controlling the character of the blast applied to the converter in accordance with the result of said determination.

5. In a method of controlling a Bessemer converter, the steps including photometrically determining the amount of radiant-energy emitted by the converter flame, and controlling the character of the blast supplied to the converter in accordance therewith.

6. In a method of controlling a Bessemer converter, the steps including photometrically determining the amount of radiant-energy emitted by the converter flame, and varying the character of the blast upon a departure of said amount from a predetermined norm.

7. In a method of determining the progress of a blow in a Bessemer converter, the steps including measuring the radiant-energy emitted by the converter flame during the blow, and comparing the result of such measurement with the record of radiant-energy emission by a previous blow.

8. A method of making steel in a Bessemer converter which includes measuring the radiant-energy emitted by the converter flame during the blow of a heat resulting in steel of the desired physical and chemical properties and so regulating the blowing of subsequent heats that variations in the rate at which radiant-energy is emitted by the flames thereof substantially con-

form to the pattern afforded by said measurement.

9. A method of controlling a Bessemer converter which includes measuring the radiant-energy emitted by the flame thereof and so controlling the blast that variations in the emission of radiant-energy by the flame substantially conform to the variations recorded during the blow of a previous heat which produced steel having the desired physical and chemical properties.

10. In a method of controlling a Bessemer converter, the steps including photometrically determining the amount of radiant-energy emitted by the converter flame in a predetermined frequency band, and controlling the character of the blast supplied to the converter in accordance therewith.

11. In a method of controlling a Bessemer converter, the steps including photometrically determining the amount of radiant-energy emitted by the converter flame, controlling the

character of the blast supplied to the converter in accordance therewith, and restricting the photometric determination to different frequency bands during different portions of a blow.

12. In a method of controlling the blowing of a Bessemer converter, the steps including recording on a graph the instantaneous variations in the radiant energy from the converter flame as the blow proceeds, continuing the blow until a knee appears in the graph, and terminating the blow substantially at the end of a predetermined period after the appearance of the knee.

13. In a method of controlling the blowing of a Bessemer converter, the steps including recording on a graph the instantaneous variations in the radiant energy from the converter flame as the blow proceeds, continuing the blow until a well-marked break in the graph appears toward the end of the blow, and then turning the converter down and terminating the blow.

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