会 议 报 告

第三届中日钢铁学术会议

THE THIRD CHINA—JAPAN SYMPOSIUM
ON
SCIENCE AND TECHNOLOGY
OF
IRON AND STEEL

中 国 · 洛 阳

1985.4.26～29

中 国 金 属 学 会

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STUDIES ON A BLAST FURNACE SIMULATOR AND HIGH TEMPERATURE PROPERTIES OF BURDENS

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SYNOPSIS

As a result of dissections of more than ten commercial blast furnaces in Japan, it has been recognized that a proper control of cohesive layers is indispensable for an optimum operation of furnace and much attention must be paid to the high temperature properties of burden.

In the authers' laboratory, the processes of swelling, softening, cohesion, slag-metal separation and final melt-down of burden materials were visually observed during heating-up reduction by using a small scale test apparatus equipped with an X-ray transmission device. And it was confirmed that the beginning temperatures of these phenomena differ very much owing to the history of reactions at lower temperatures even for the same sample.

In order to evaluate these properties in a blast furnace, it is desirable to test under continuously varied temperature and gas composition in accordance with the descent of burden through the furnace. But these profiles of temperature and gas composition in the furnace are affected by the reactions of burden materials and vice versa. Therefore, a blast furnace simulator, which is able to modify the experimental conditions according to in situ obtained data of reactions, seems to be a suitable equipment for this purpose.

The authers consequently designed and set up a blast furnace simulator by combining above mentioned test apparatus and micro computers. An outline of the simulator is reported and some results obtained are discussed as compared with conventional tests.

I. INTRODUCTION

It is no exaggeration to say that the remarkable progresses in ironmaking technologies in Japan during the past decade owe very much to the dissection investigations of the commercial blast furnaces. Since 1968 more than ten furnaces were blown down in usual operating states and dissected after quenched. One of the most important results of these investigations was the determination of the cohesive ore layers which existed regularly with the charging sequences but whose locations and shapes of distributions were varied corresponding to the operating conditions of each furnace.

A rough sketch of a vertical section of quenched Hirohata No.1 B.F.$^{1)}$ is shown in Fig.1. The burden in the furnace descended while maintaining its layer-by-layer structure and the cohesive ore layers were distributed in a sharp invert V-shape from the upper part of the shaft down closely to the tuyeres. Isothermal lines estimated by tempil pellets or graphitization of coke are also depicted in this figure. The profile of the cohesive layer zone corresponded very well to these isothermal lines and also with the observed distribution of reduction degree of ores in the lumpy zone. This situation was common to all dissected furnaces, although the shape of the profile may be different with each other.

Based on these results, it has been concluded that the gas rising through the coke bed of the dripping zone flows then horizontally into the lumpy zone by way of the coke slits formed between the cohesive layers, because the cohesive layers seem to be almost impermeable. In other words, the cohesive layers are regarded as a kind of louver boards which control the gas flow distribution within the furnace. And it is considered that a considerale portion of the total pressure drop between the bottom and top of the furnace is generated when the gas passes through the cohesive zone.

Therefore, such a cohesive zone as that of Hirohata No.1 B.F., which is widely spread from the upper part of the shaft down to a level close to the tuyeres, has a large total area of coke slits and is advantageous for the permeability of the furnace, that is, an operation with high productivity. The fuel rate of such a furnace, however, may be rather high, because the relative volume of the lumpy zone becomes smaller, resulting in lower η_{CO}. The cohesive layers in a furnace operated with lower fuel rate are distributed in the lower part of the furnace as determined by the dissections of Kukioka No.4 B.F.$^{1)}$ or Nagoya No.1 B.F.$^{2)}$

If a stable operation with low fuel rate and yet with high productivity is aimed, it is necessary to form a cohesive zone of good permeability distributed in the lower part of the furnace. The permeability of the cohesive zone depends not only on the total area of the coke slits but also on the length of each slit. Therefore, it is preferable that the temperatures of melting down and the softening of ore layers are kept considerably high and the difference between them is as small as possible. In order to fulfil these requirements, the properties of burden materials must be suitable for these purposes besides the operating technologies of the furnace. Under these circumstances, the high temperature properties of burden ores, that is, the properties during the heating-up reduction till melt-down, have come to be of major importance.

II. HIGH TEMPERATURE PROPERTIES OF IRON ORES

For the purpose of clarifying the changes in the properties of iron ore burdens descending through a blast furnace, the authors intended to continuously observe the behaviors of ores throughout the course of heating-up reduction till melt-down by using an X-ray transmission device. In these experiments the rate of iron oxide reduction and carbon solution loss were also in situ calculated from the flow rates of CO and CO_2 at the inlet and outlet, and the relationship between these reactions and the changes of properties were investigated.

2.1 Experimental apparatus and procedures

The schematic diagrams of the apparatus and the system of measurements are shown in Fig.2 and Fig.3. The alumina reaction tube (42 mmI.D. x 1000 mmL) was set in a vertical furnace heated with six SiC heating elements and controlled by a SCR voltage regulator. For the sake of X-ray transmission, two 50 mm x 40 mm holes were bored through the wall of the furnace. The reaction tube was fitted with water cooled, O-ring sealed end caps, and the gas inlet pipe was inserted through the bottom end cap. The graphite crucible shown in Fig.4 was of 34 mm in O.D., 23 mm in I.D. and 72 mm in depth, and had 72 holes of 0.8 mmϕ at the bottom so as to make the gas flow uniform. The crucible was screwed to the upper end of the holder which was connected to the gas inlet pipe.

In order to apply a load to the ore samples in the crucible, a hollow graphite rod was placed upon a coke plate (20 mm x 10 mm x 8 mm) which was held between the rod and the samples. The load was adjusted with steel balls. The expansion or shrinkage of the samples were detected by the displacement of a silica rod (3 mmϕ x 700 mmL) which was inserted through the hollow part of the graphite rod and connected to an electrical dial gauge.

The reducing gas was prepared by mixing each component gas whose flow rate was precisely controlled by the respective thermal mass flow controller. CO and CO_2 contents of the outlet gas were analyzed with the respective infrared gas analyzers, and the total flow rate of the outlet gas was measured before purging. The pressure drop between the inlet and outlet of the reaction tube was measured with a pressure transducer. These measured values were recorded with a pen recorder and at the same time put in a micro computer, and the rates of reactions were in situ calculated.

The X-ray observation system is shown in the lower part of Fig.3. The X-ray transmission images, which were intensified by an image intensifier, were taken by a TV camera, displayed and recorded together with the marks of time and temperature. Filming with a 16 mm cine camera was also available at any time. In case of precise examinations of the image were required, a photograph with X-ray film was taken directly.

The crucible assembly is shown in Fig.4. Six pieces of ore sample were set in the crucible in three layers, supported by two graphite side plates. Coke fragments were filled below the samples. After setting the above-mentioned coke plate upon the samples, the crucible assembly was set in the reaction tube in such a manner that the X-ray beam would irradiate at right angles to the side plate. Then the loading rod was lowered onto the coke plate and a load was applied with steel balls. After checking up the gas leakage, the samples were kept at 200°C in N_2 gas flow for a while. Then CO was added at a specified flow rate and the heating-up was started.

The composition and the flow rate of the reducing gas were fixed at N_2:CO = 70:30 and 2000 Ncm^3/min, respectively, throughout this series of experiments. The load applied was 0.5 kg/cm^2. The temperature was raised linearly with time at a heating rate of 5, 10 or 15°C/min.

The ores used in these studies were a self-fluxed pellet and a sinter of such chemical compositions as shown in Table 1. Their basicities were almost equal. As the samples for the experiment, pellets of 11.5 mm in dia. were selected and sinters were ground to spheres of the same size.

Table 1. Chemical compositions of ores

	T.Fe	FeO	SiO_2	CaO	Al_2O_3	MgO	C/S
Pellet	60.7	0.35	4.0	5.4	1.88	1.4	1.35
Sinter	59.9	9.81	4.76	6.89	2.09	0.61	1.45

The rate of reduction and carbon solution loss were calculated from the mass balances of oxygen and carbon of the in- and outlet gases. The difference in the mass flow rate of oxygen between outlet and inlet gases equals to the rate of oxygen removal from the iron oxide, that is;

$$\Delta[O] = \frac{16}{22414}\{v_o(x_{CO,o}+2x_{CO_2,o}) - v_i(x_{CO,i}+2x_{CO_2,i})\} \qquad (1)$$

where $\Delta[O]$ is the rate of oxygen removal in g/min, v is the gas flow rate in Ncm^3/min, x is mole fraction and the subscripts i and o designate the inlet and outlet, respectively. Because N_2 is inert to the reaction, the flow rate of the outlet gas, v_o, is expressed by $v_o=(x_{N_2,i}/x_{N_2,o})v_i$. Substitution of this relation in Eq.(1) gives

$$RDR = \frac{7.138\times10^{-2}\, v_i\{x_{N_2,i}(x_{CO,o}+2x_{CO_2,o}) - x_{N_2,o}(x_{CO,i}+2x_{CO_2,i})\}}{x_{N_2,o}\cdot[O]_0} \qquad (2)$$

where RDR is the reduction rate in %/min, $[O]_0$ is the mass of reducible oxygen in the original ore in g. The rate of carbon solution loss is similarly calculated from the mass balance of carbon,

$$RCS = 5.354 \times 10^{-4} v_i (x_{N_2,i} - x_{N_2,o})/x_{N_2,o} \qquad (3)$$

where RCS is the rate of carbon solution loss in g/min. The reduction degree, TDR, and the total mass of carbon solution loss, TCS, at a certain time were calculated by summing up RDR or RCS from the beginning.

2.2 Results and discussions

2.2.1 X-ray observations

Photo.1 and Fig.5 show the X-ray images and diagrams of shrinkage and pressure drop of the bed of pellets and sinters in the course of heating-up reduction at a rate of 10°C/min. The swelling of samples was observed in the initial stage, but then it turned to the shrinkage as the production and aggregation of the metallic iron proceeded. An abrupt shrinkage of the bed started at 1065°C in the sinters and at 1090°C in the pellets, suggesting the appearance of molten substances within the samples.

The flow-out of primary slag was observed above 1120°C particularly on the surface of the sinters like as sweating. Considering that the outer boundary of the cohesive layers were reported to be about 1100°C and that the burdens of commercial furnaces were usually rich in sinters, the beginning of the cohesion in the furnace would be due to this phenomenon. As for the pellets, the flow-out of primary slag was hardly observed below 1300°C, although the shrinkage accompanied by flattening of samples proceeded more rapidly than the sinters. At 1324°C, however, the separation of slag and metal suddenly occurred and the violent reduction of molten slag began at the same time, resulting in the abrupt pressure drop increase, shown as P_1 in Fig.5. In case of sinters, the slag-metal separation did not occur until 1420°C and the pressure drop increase, P_1, was smaller than that of pellets because of the much less remaining FeO.

This difference in the behaviors of slag-metal separation between the pellets and sinters would be explained as follows. The pellets were reduced topochemically and the reduced iron shell became less permeable with rise in temperature as proved by the remarkable retardation in reduction between 1250 and 1300°C. This is the reason why the flow-out of primary slag was hardly observed below 1300°C. But when the temperature reached the melting point of the slag which had been formed within the core, it was squeezed out suddenly and the violent reduction occurred. In case of sinters, the reduction did not proceed topochemically, and moreover, their large pores kept the slag from flowing out suddenly.

The metal finally melted down at 1416°C in the pellets and at 1435°C in the sinters. At the moment of melt-down another sharp peak of pressure drop, P_2 in Fig.5, was observed, indicating the reduction of FeO included in the metal.

2.2.2 Influence of heating rate

Figs.6 and 7 show the reduction degree of pellets and sinters against temperature in the course of reduction at various heating rate. At 5°C/min both samples are almost completely reduced by the gas-solid reaction and the amount of smelting reduction is very little. As the heating rate is set larger, the amount of smelting reduction increases, which is less in the sinters at the same heating rate. In the upper left of Figs.6 and 7 the reduction curves at high temperatures are enlarged. The rate of smelting reduction is almost independent of the heating rate and determined by the amount of slag separated. Summerizing these results, it is obvious that the reducibilty of sinters is superior to that of pellets at high temperatures and this feature is more prominent at larger heating rate due to the less retardation of reduction in the sinter. These situations are caused by the differences in the reduction mechanism and the structure between them, as described above.

Figs.8 and 9 show the temperatures and reduction degrees at which the changes in properties began against heating rate. The larger the heating rate, the higher the temperature of maximum expansion. The reduction degree at that moment is, however, about 30% regardless of heating rate, suggesting that the average mineral composition is wustite.

The temperature of primary slag flow-out is about 1120°C at every heating rate in the sinters. It seems to be determined by the melting point of the original bonding slag, because it is almost independent of the heating rate and reduction degree as shown in Figs.8 and 9. In case of the pellets in which the gangues have not yet been perfectly slagged, the flow-out temperature is dependent on the melting point of slag just formed during the reduction.

The temperature of slag-metal separation is much affected by the heating rate. The higher the heating rate, the lower the temperture and the reduction degree. This situation corresponds to the reduction degree of cohesive layers in the blast furnace. The melt-down temperature of metal is almost independent of the heating rate. Therefore, at a larger heating rate the temperature gap between the metal melt-down and slag-metal separation becomes larger, resulting in a longer duration of operation with large pressure drop due to the smelting reduction. In the operation of the blast furnace many efforts are made to promote the reduction before slag-metal separation by improving the operating technology and the properties of burdens.

2.3 Conclusions

The relationships between the behaviors of burdens and the reactions were examined by observing the pellets and sinters with X-ray in the course of heating-up reduction at various heating rates. The results obtained are summerized as follows.

i) The temperature of primary slag flow-out in the sinters is about 1120°C regardless of the heating rate and it corresponds to the beginning of cohesion in the blast furnace.

ii) The larger the heating rate, the lower the temperature of slag-metal separation and the reduction degree at that moment. Therefore, the amount of smelting reduction becomes larger.

iii) The tendency of ii) is more remarkable in the pellets than in the sinters. This situation seems to be caused by the differences in the reduction mechanism and the structure between them.

iv) The melt-down temperature of metal is almost independent of the heating rate.

v) The abrupt increase of pressure drop occurs at the beginning of the smelting reduction accompanied by the slag-metal separation and the large pressure drop continues until the metal melts down.

III. BLAST FURNACE SIMULATOR

The importance of the high temperature properties of burdens have been widely recognized among the researchers and engineers of ironmaking and the test apparatus are set up at many loboratories. The standerdization of this test has been discussed at the 54-th Committee (Ironmaking), the Japan Society for the Promotion of Science (JSPS). The details of the experimental conditions, however, are difficult to be normalized, because the high temperature properties are much affected by the history of the reactions at lower temperatures as described in the preceding section.

For the sake of evaluating the properties in the furnace, it may be preferable to test under a simulated conditions to which the burdens are subjected during the descent through the furnace. A blast furnace simulator so-called BORIS-furnace was developed at IRSID(3) to simulate the behaviors in the lumpy zone. Okamoto et. al.(4) recently developed a "Blast furnace Inner-reaction Simulator" (BIS) by adding a high temperature reactor to the BORIS-furnace. These two might not be correctly called simulators with respect to the heating up of the burdens, as the temperature distributions of the lumpy zone were set beforehand. Aiming the simultaneous simulations of temperature and gas composition, the authers set up a hybrid simulator based on the experimentation and mathematical model by combining the above mentioned test apparatus and micro computers.

The computers in situ calculate the rates of reactions with the input data from the reactor, solve the equations of mass and heat balances and then set the new experimental conditions at the next stage. The simulation is thus carried out by repeating these sequences from the conditions of the top down to the melting zone of the furnace. The test apparatus acts as a differential reactor which offers the data of reaction.

3.1 Design of simulator

In this simulator, the blast furnace is regarded as a cylindrical moving bed reactor in which a gas phase and a solid phase consisting of a mixture of ore and coke flow one-dimensionally and countercurrently. The reactions except the reduction of iron oxide with CO and the carbon solution loss are not considered for simplicity. Therefore, the elements exchanged by the reactions between both phases are oxygen and carbon.

The equations of mass transfer of each component element in a stationary state at Z are expressed by Eqs.(4a) and (4b) in terms of mass fluxes;

$$dI_i/dZ = R_{s,i} \qquad (4a) \qquad\qquad dJ_i/dZ = R_{g,i} \qquad (4b)$$

where I and J are the mass fluxes of the solid and gas phases in $\mathrm{kmol/m^2s}$, Z is the distance from the top of furnace in m, R is the rate of reaction in $\mathrm{kmol/m^3s}$ and the subscripts i, s, and g designate species of element, solid phase and gas phase, respectively.

If the furnace is devided into stages as shown in Fig.(10) and the reaction rates and moving velocities are assumed to be invariable within each stage, the mass balances of oxygen and carbon in n-th stage (the stage from Z_{n-1} to Z_n) will be simply expressed by Eqs.(5) and (6) in terms of the rates of reduction and carbon solution loss and the mass fluxes of gas;

$$J_O^n - J_O^{n-1} = -R_{s,O}^n \times \Delta Z \qquad (5) \qquad\qquad J_C^n - J_C^{n-1} = -R_{s,C}^n \times \Delta Z \qquad (6)$$

In case of the simulation experiment, $R_{s,i}^n$ is calculated by J_i^{n-1} from the analyses of outlet gas and J_i^n from the given inlet gas as shown in Eqs. (5) and (6). In order to make a step to (n+1)-th stage, J_i^{n+1} must be determined by predicting $R_{s,i}^{n+1}$ from the experimental data obtained up to the present stage. This prediction has a major importance in this simulation and will be discussed later. The gas composition to be supplied to the (n+1)-th stage is calculated as follows;

$$\%CO = 100 \times (2J_C^{n+1} - J_O^{n+1})/(J_C^{n+1} + J_N^{n+1}) \qquad (7)$$
$$\%CO_2 = 100 \times (J_O^{n+1} - J_C^{n+1})/(J_C^{n+1} + J_N^{n+1}) \qquad (8)$$

The gas composition from the top of furnace down to the melt-down zone can be simulated by repeating the changes of CO and CO_2 flow rates in accordance with Eqs.(7) and (8).

The heat balances will be similarly presented by Eqs.(9) and (10) in terms of heat content fluxes of the gas and solid phases, if the heat of reactions are entirely given to the solid phase;

$$d(W_gT_g)/dZ = h_pA_p(T_g - T_s) \qquad (9)$$
$$d(W_sT_s)/dZ = h_pA_p(T_g - T_s) + Q \qquad (10)$$

where h_p is the heat transfer coefficient in $\mathrm{kcal/m^2s\ K}$, A_p is the specific surface area of solid phase in $\mathrm{m^2/m^3}$ calculated from the particle sizes of ore and coke, and $Q(=-\Sigma\Delta H_iR_{s,i})$ is the rate of heat generation by reaction in $\mathrm{kcal/m^3s}$. Assuming that the values of physical constants are invariable within a certain stage, T_s and T_g at the lower end of the stage can be integrated as functions of the temperatures at the upper end and the reaction rates. The temperatures of the next stage are thus predicted by using the predicted reaction rates in the next stage. This predicted temperature is put in the temperature regulator.

The initial conditions in these simulation studies are determined in the following manner. The top gas composition is calculated after Rist's model$^{5)}$, by setting such operating conditions as blast temperature and so on. The composition of the hot metal is fixed at 5%-C without any other component, for simplicity. Ore-by-coke ratio is obtained from the slope of the operating line and the weight of the coke plate is determined accordingly. The solid temperature at the furnace top is fixed at 200°C due to the convenience of the experiment. The top gas temperature is calculated by the heat balance equation using the assumed distributions of temperature and reduction degree between the top and the thermal reserve zone.

3.2 Experimentals

The test apparatus was the same as described in Section II except the crucible assembly. The entire crucible assembly was made of alumina so as to prevent CO_2 from reacting besides the coke plate.

The experiments were carried out by using two micro computers with 16 and 8-bit CPU, respectively. The flow diagram of measurement and control system is shown in Fig.11. The 8-bit computer took charge of the accumulation of data and the control of temperature and gas flow rate, while the 16-bit one the calculation of initial conditions and reaction rates and the prediction of conditions at next stage.

The predicted temperature of the next stage was put in the temperature controller at every minute, and the gas flow rates of CO and CO_2 were changed at every 5 minutes by applying the corresponding voltages to the mass flow controllers(MFC). The flow rate of N_2 was kept constant throughout an experiment by applying a constant voltage to MFC. The total flow rate was about 2000 Ncm^3/min, which had been verified to be adequate for a differential reactor.

The most important and still difficult problems in successful performance of experiment were the accuracy and constancy of MFC's and the infrared gas analyzers. For instance, in order to detect RDR during the stages corresponding to the chemical reserve zone, which was less than 0.1 %/min, the accuracy of the measurement and control must be of the order of 0.01 %/min and it corresponded to the flow rate of 1 - 0.5 Ncm^3/min. Though many efforts and improvements were made in the procedures and maintainances, this problems still remain.

3.3 Results and discussions

In order to predict the reaction rates at the next stage, it is considered to apply such a theoretical model as the unreacted core model. In this case, the parameters in the equation must be checked momentally with the experimental data, and it seems to be unpractical because of longer calculation time.

The prediction method applied at first was a extrapolation of recent data of reaction rates by use of a quadratic equation. This method was less accurate in prediction and apt to give overshooting values at the moments of abrupt changes in reaction rates.

A linear regression equation composed of the reduction degree, temperature of solid and gas composition $\nu (= \%CO/(\%CO+\%CO_2))$ was applied afterwards. Eq.(11) is the equation for the reduction rate;

$$R^{n+1} = a + b\,[TDR]^n + c\,T_s^n + d\,\nu^n \qquad (11)$$

The coefficients a, b, c, and d were calculated by the multiple regression among the observed data in the latest 10 stages. Fig.12 shows the comparison between predicted and observed RDR. The regression method seems to be almost satisfactory for the purpose.

A simulation result with a sinter is shown in Fig.13. The average heating rate up to 800°C was as large as 15°C/min then fell down to 0.5°C/min around 1000°C and the thermal reserve zone appeared. The reduction rate reached a peak of 0.8 - 1.0 %/min around 800°C then decreased to 0.05 %/min around 950°C, that is 6 m below the stock line(S.L.), and this situation continued down to 13 - 14 m below S.L., indicating a long chemical reserve zone. As the temperature rose, though slowly, the reduction rate increased again accompanied by the carbon solution loss and reached a second peak of FeO to Fe around 1200°C, 17 m below S.L. The smelting reduction began about 19 m below S.L.

The effect of coke rate in the simulation of lumpy zone is shown in Fig.(14). In case of A, CO_2 content had a minimum at 6 m below S.L. and then increased again. This situation seems to be unreal. The carbon solution loss reaction has an effect of increasing CO_2 content in the next stage according to Eq.(8), while the reduction promote the increase of %CO according to Eq.(7). Therefore, if the carbon solution loss begins before the reduction proceeds to a certain extent, the former will be accelerated and the latter suppressed more and more. Curve-C is a contrary to A and B seems to be reasonable. These examples suggest that the latitudes for the initial conditions are considerably narrow for the simulator to be carried out successfully. In such unsuccessful cases as A and C, the actual distributions of temperature and reduction degree up to 1000°C differ very much from the assumed ones. Therefore it is necessary to develop new programs with which the initial conditions are so modified as to adjust the reduction up to 1000°C during a run.

The tests of high temperature properties of burdens under programmed conditions are reported by Yamaoka et al.[6] The authors also carried out two tests under the same heating pattern for the sake of examining the

the effect of the simulation on gas composition as compared to a programmed one. The heating rates were at 10 °C/min [200 - 800°C], 2 °C/min [800 - 1200°C] and 5 °C/min [1200°C - melt-down] after the tentative recommendation of JSPS. The initial gas composition was $n_{CO} = 0.46$ in both tests, but it was changed stepwise to 100% CO between 750°C and 1200°C in the programmed test. The sample used in these tests was a self-fluxed pellet.

The results of these tests are shown in Fig.15. In the simulated test, CO content increased between 600 and 900°C by the effect of reduction and the reduction degree became higher than that of the programmed test in this region. Above 1000°C the change of gas composition was slowed down and almost in line with the wustite-iron equilibrium by the effect of carbon solution loss reaction. The reduction degree was much lower than that of the programmed test between 900 and 1200°C and the amount of smelting reduction was considerably large. The shrinkage and pressure drop of the bed reflected these behaviors of reduction.

The pattern of reduction, however, resembled that of the simultaneous simulation of both gas composition and temperature and those measured by vertical probes in the commercial blast furnaces. Considering these facts, this test method may be the second best for the evaluation of burdens in the blast furnace,though problems exist in the setting of heating pattern.

3.4 Conclusion

A blast furnace simulator, which can simultaneously simulate the temperature and gas composition from the top to the melting zone of the blast furnace, was designed and set up. The concept of design, system, procedure and some results of simulation are described. For its successful performance, there still remain the problems of the accuracy and constancy of instruments and the setting of initial conditions. As for the latter, new programs must be developed, which in situ revise the conditions so as to bring about the actual reduction degree at 1000°C to the assumed one, figuratively speaking, like the adjustment of orbit of an artificial satellite. A test method, in which the gas composition is simulated and the heating rate is programmed, seems to be the second best for the purpose of evaluating the properties of burdens in the blast furnace.

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