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Moscow, USSR, 19 September - 9 October 1968

D-8

IRON-MAKING PLANT OF CHIBA WORKS - ITS
CONSTRUCTION AND RATIONALIZATION[1]

by

T. Nagai,
Japan

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SUMMARY

The Iron-Making Plant of Chiba Works of Kawasaki Steel Corporation has in operation five blast furnaces with a total annual pig iron production reaching about 4.5 million metric tons.

The construction of Chiba Works was started off in 1951 with the reclamation of a shallow sea coast of Tokyo Bay, with a view to building nation's first post-war integrated steelworks from the ground up. With the desire of making the plant the most up-to-date, the erection of blast furnaces was carried out using as many advanced techniques as then available.

In March 1965, No.5 blast furnace, the largest in the world at that time, was blown in. It is not an exaggeration to say that all the new technologies were incorporated in these furnaces so as to meet an increasing trend in the industry for building bigger blast furnaces.

* This is a summary of a paper issued under the same title as ID/WG.14/4.

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Pig iron output showed a large increase each year due to a series of the installation of remodelling of blast furnaces. In 1961 a total output exceeded a 1.3 million tons level, and reached 4.2 million tons in 1966. The increase in output of pig iron is attributed to not only the construction of new blast furnaces but also to the construction and rationalization of various auxiliary equipment as follows.

1. Ore preparation

The fundamental principle underlying our pig iron making operations is that strengthening of ore preparation is essential for better and higher efficiency of blast furnaces operations.

1.1. Application of ore blending system

Under the peculiar raw materials conditions Japan must seek its iron ore supply to so many foreign resources that brands of ore imported amount to a large number, with resulting wide variations of chemical and physical properties.

In order to obtain good blast furnace burden of uniform quality from these ores of different properties, an introduction of ore blending facilities was planned together with the blast furnace construction project, and in 1953 the ore blending was employed by us for the first time in Japan.

1.2. Improvement of sizing

In order to uprate blast furnace productivity and to lower fuel ratio, a complete exclusion of fine, a reduction in size range of charged ore, and a lowering of grain size are required.

A sizing method taken at Chiba Works in earlier days was such that ore unloaded from a ship was passed through crusher and screen at the time of unloading so that only sized ore was piled at the ore yard. Later, however, with a view to strengthening the sizing operation, a secondary crushing and screening equipment was installed in 1961, thereby establishing a two-stage sizing system as is used today. Top size of ore has been gradually lowered to 30 mm.

1.3. Agglomeration of fine ore

During the earlier stage of the construction of Chiba Works, majority of imported ore available to our company was such sticky ore as Dungun, Goa and Larap,

and that their fine included so much of extra fine that they were not suitable for sintering. Motivated by such circumstances, we took interest in the pelletizing process which was yet then at an experimental stage in the United States as a low-grade ore treatment method, and introduced it for treating fine ore in our hands.

Meanwhile, simultaneously with the construction of No.3 pelletizing plant, the construction of sintering plant was also planned with the various reasons.

The construction of another sintering plant was based on the expected benefit of maintaining both equipment, thereby using their respective features so as to supply burden most suitable for blast furnace requirement.

In May 1962, No.1 sintering equipment (3000 t/d) entered into operation, to be followed by the start of No.2 sintering equipment in 1965.

In order to improve blast furnace productivity, a further increase in the proportion of treated ore is essential. At present, we are planning the installation of a third sintering plant (6000 t/d) which is scheduled to start operation in 1970.

2. Blast furnace operations

Our rationalization effort was directed not only to the raw materials processing as stated above, but also to the blast furnaces themselves in order to realize greater productivity and lower cost.

2.1. High temperature blast operation

One of the most effective means of reducing the fuel cost for blast furnaces is to raise the temperature of hot blast. For attaining this objective, however, it will be essential to install due equipment capable of supplying hot blast of much higher temperature as well as to be assured of constant and excellent raw material conditions that can ward off "hangings" and other troubles that usually occur as the temperature of hot blast in the tuyere part is raised. We have already related on the various improvements made on the raw material conditions. Turning to the equipment aspects, we have made a series of improvements and reinforcements on the hot stoves, blast pipe and other parts, in consequence of which the average blast temperature for all the blast furnaces at Chiba has reached 1000°C, while the average temperature of hot blast for No.5 blast furnace alone has marked the high of 1200°C.

This is to say that hot blast temperature has been raised by an average of 250°C during the past seven years.

2.2. Injection of heavy oil and heavy oil-coal slurry

In Japan, the prices of coal (domestic), heavy oil, and coke are in the ratio of 1 : 1.3 : 1.6. If the coke could be substituted with coal, heavy oil, and other fuels, it would be possible to reduce the cost of pig iron. The practice of heavy oil injection was first applied to No.4 blast furnace, and was gradually extended to other blast furnaces. This method was found useful in saving the use of the costly coke.

In 1965, we began to study the possibility of injecting the coal instead of heavy oil, with a view to making a greater use of domestic coal. Though one of our earlier ideas was the injection of coal itself into the tuyere, we later developed and eventually adopted the method of injecting it mixed with heavy oil in the form of slurry as this made it easier to control the volume of injection.

2.3. High top pressure operation

If a maximum productivity is to be attained with a limited inner volume of blast furnace, it is necessary to supply the blast furnace with as great a volume of hot blast as possible.

The high top pressure operation can widely increase the volume of hot blast by raising the furnace-top gas pressure, thereby increasing blast furnace productivity, while preventing various troubles which are otherwise apt to occur as the flow rate of furnace gas increases.

In 1964, No.2 blast furnace was remodelled into a high top pressure blast furnace capable of maximum furnace-top pressure of 1.0 kg/cm^2, with its two bell system unaltered. Then in 1965, the new No.5 blast furnace was completed as a 3-bell, high top pressure blast furnace, with a maximum top pressure of 1.1 kg/cm^2.

The high pressure operation brought about an increased pig iron output, recording a pig iron production rate of 2.0 t/m^3/d.

As already mentioned, the technical improvements on raw materials processing and the blast furnace operations have stepped up the blast furnace efficiency and reduced the unit consumption rate of fuels, greatly contributing to the lowering of the cost of pig iron.

As stated above, Chiba Works has so far been grappling with the rationalization problems by adopting every possible latest technique. And yet the rigorous international economic environment as we find it today is pressing us for further drastic rationalization. For instance, the ever-expanding capacity of blast furnaces seems dwarfing the existing plant space more and more every year.

Aside from our perennial concern as to how to deal most economically with an ever-mounting volume of raw materials and products to be moved about within a limited space, we are addressing ourselves continuously, aiming at the goal of higher productivity and lower cost.

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We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

1. PRESENT STATE OF IRON-MAKING PLANT

The Iron-Making Plant of Chiba Works of Kawasaki Steel Corporation has in operation five blast furnaces with a total annual pig iron production reaching about 4.5 million metric tons. Main specifications of the blast furnaces, their auxiliary equipment and ore preparation facilities are tabulated in the attached Table 1, with a schematic layout of Chiba Works including these equipment and facilities shown in the attached Figure 1.

2. CONSTRUCTION OF BLAST FURNACES

The construction of Chiba Works was started off in 1951 with the reclamation of a shallow sea coast of Tokyo Bay, with a view to building a nation's first postwar integrated steelworks from the ground up. With the desire of making the plant the most up-to-date, the erection of No.1 blast furnace was carried out using as many advanced techniques as then available. Some of the features of No.1 blast furnace are:

1) The furnace structure was made to be of free standing type, which was the first of its kind in Japan.

2) Unlike the conventional type, cooling boxes were installed high up to the upper part of the shaft so as to minimize heat expansion of the shaft. Also, for a longer service life of the furnace refractories, cooling boxes were so designed as to reinforce the refractories.

A new blast furnace of our own design with these features well incorporating advanced techniques of the USA and Germany was elected in June 1953.

Elsewhere, various new ideas were employed for the layout of cast house, mud gun, and hot stoves. For the stabilized performance of the furnace, the use of instruments was emphasized so as to promote a centralized control system.

No.1 blast furnace showed a very smooth operation thereafter, and achieved a 1000 t/d production in 1960, drawing a wide attention of the industry. During the following two years and a half until the blowing-in of No.2 blast furnace, various new techniques were further matured and a fundamental concept of No.2 blast furnace was worked out.

In 1958, No.2 blast furnace with its size larger than No.1 went into operation. The furnace was of our own design almost in every respect. Despite the similarity of its layout and the structure with No.1 blast furnace, a wide range of rationalization was realized in the new materials feeding facilities and the skip charging system; namely,

1) Inner volume was enlarged to 1172 m^3.

2) For skip bridge control system, Logit method using semi-conductor was employed.

3) Frames for supporting the furnace body were made of Rahmen (rigid) structure, unlike the case of No.1 blast furnace where Rahmen structure was used for the lower part, and truss structure for the upper part.

4) For the structure of hearth bottom, carbon refractories totalling 60 tons were used.

The operation of No.2 blast furnace doubled the pig iron production of Chiba Works. Parallel with the expansion of the output, raw materials handling facilities were also reinforced with major equipment relative to the No.1 main wharf almost completed, and No.2 pelletizing plant started operation a little later, contributing much to an increase in pig iron output.

By the time when the start-up operation of No.2 blast furnace was finished, the construction of No.3 blast furnace had been started.

The construction of No.3 blast furnace called for a re-examination of the layout of the entire plant as a result of an increase in the total annual ingot production target of the plant from the earlier one million tons to 2.5-3.5 million tons, and it was at this stage that the locations of No.3, 4 and 5 blast furnaces were decided conclusively.

No.3 blast furnace, though of free standing type as Nos.1 and 2, had a 1689 m^3 inner volume, the largest in Japan at that time. The features of this furnace were as follows:

1) Skip bridge control room was positioned of the same floor as work floor, thereby saving construction costs and improving work efficiency.

2) Tilting trough system was employed, thereby improving the layout of cast house and uprating work efficiency near the furnace.

3) For all the valves for controlling hot stoves, Japanese-made equipment was used.

4) Under the so-called block-type engineering method, a number of plates were welded together to form furnace shell except where the shell makes joints with top ring and tuyere frame. This engineering method was made possible by the marked improvement then of welding techniques. This technique found its use in the construction of other blast furnaces subsequently built at Chiba Works.

The foundation work for No.4 blast furnace was started together with that for No.3 blast furnace, and it was completed at the time of the blowing-in of No.3 blast furnace. No.4 blast furnace, the sister furnace to No.3 blast furnace, had its type and inner volume entirely the same with the latter, except some improvements made in minor portions.

Simultaneously with the blowing-in of No.4 blast furnace, No.3 pelletizing plant went into operation. This plant was able to continue a high efficiency operation under the then favourable raw materials supply condition.

The No.1 blast furnace which was blown down a week before the blowing-in of No.4 blast furnace recorded an 8 years and 2 months of operation with a total pig iron production of 2.41 million tons, which was an astonishing record for the technology at that time.

The remodelled No.1 blast furnace had larger hearth and furnace diameter than the original, with a 913 m^3 inner volume. A feature of this remodelling was the use of air-cooling method incorporated for the hearth bottom as the first of its kind in Japan.

In August 1964, the remodelling of No.2 blast furnace was completed in 81 days, due mainly to the advantage of PERT method which was first employed in Japan for this kind of work. No.2 blast furnace marked a record pig iron production of 2.75 million tons for the 6 years and 3 months period. Major points of the remodelling at this time were as follows:

1) High top pressure operation was used.
2) Hopper scale was employed in lieu of larry car.
3) A 2-tap hole system and a 2-cast house set-up were used.
4) Raw materials feeding was computerized for automatic controlling.

With the above remodelling, the capacity of No.2 blast furnace increased to 2000 t/d, despite a little decrease in its inner volume to 1156 m^3. The improved capacity is due mainly to a skillful introduction of technical developments such as pre-treatment of iron ore and high top pressure.

Prior to the blowing-in of No.2 blast furnace, the third ore crushing and screening equipment was completed in February 1964. This contributed to a further improvement of sizing as an important supporting factor for the blast furnace operations.

Successively to the remodelling of No.2 blast furnace, No.5 blast furnace, the largest in the world at that time, was blown in. It is not an exaggeration to say that all the new technologies were incorporated in this furnace so as to meet an increasing trend in the industry for building bigger blast furnaces. The features of No.5 blast furnace are as follows:

1) With its inner volume of 2142 m^3, the world's largest class, the furnace can produce pig iron at a rate of 4000 t/d.

2) Mantle was supported with brackets from 6 columns.

3) High top pressure (max. 1.1 kg/cm^2) operations can be made. A 3-bell system of John-Mohr type was employed.

4) By the use of hot stoves of external combustion type, blast temperature can be raised to 1200°C.

5) Belt conveyor system was employed for the charging of furnace burden.

6) Computer is employed for sequential control of charging system.

Simultaneously with the blowing-in of No.5 blast furnace, No.2 sinter plant was installed and raw materials unloading facilities were reinforced. Because of this, the capacity of No.5 blast furnace was widely increased to attain 4250 t/d production in March 1967.

No.4 blast furnace which had been blown-in in August 1961 was blown down in September 1965, and resumed its operation after 113 days of the remodelling work. In this remodelling, a 2-tap hole system was employed and also a 2-cast house system was used for the production increase.

In October 1967, No.3 blast furnace was blown down and remodelled in 77 days. In this case, a 2-tap hole system was also used, together with new techniques such as the high top pressure operation, charging control by computer, high-temperature water cooling, oil-pressured type mud gun and others. A total pig iron output of No.3 and 4 blast furnaces up to the stage of the blowing down were 5.21 and 3.15 million tons, respectively.

As outlined above, pig iron output showed a large increase each year due to a series of the installation of remodelling of blast furnaces. In 1961, a total annual output exceeded a 1.3 million tons level, and reached 4.2 million tons in 1966. The trend of this pig iron output is shown in Fig.2 The increase in output of pig iron is attributed to not only the construction of new blast furnaces but also to the construction and rationalization of various auxiliary equipment as mentioned earlier. The detail on the rationalization will be described in a later chapter.

3. IMPROVEMENT OF PIG IRON MAKING TECHNIQUES

3.1 Ore preparation

The fundamental principle underlying our pig iron-making operations is that strengthening of ore preparation is essential for a better and higher efficiency of blast furnace operations.

3.1.1 Application of ore blending system

Under the peculiar raw materials conditions Japan must seek its iron ore supply to so many foreign resources that brands of ore imported amount to a large number, with resulting wide variations of chemical and physical properties.

In order to obtain good blast furnace burden of uniform quality from these ores of different properties, an introduction of ore blending facilities was planned together with the blast furnace construction project, and in 1953 the ore blending technique was employed by us for the first time in Japan.

Blending facilities at Chiba Works were expanded along with the increase in ore requirement, with a 70% (4500 t/d) of sintering materials and a 25% (4500 t/d) of blast furnace burden being blended today.

Under the blending method at Chiba Works, various brands of ore are piled by the stacker on the ore yard layer by layer and then are fed by the reclaimer. One example of components of blended ore for sintering is shown in Table 2.

Effects of the ore blending are as follows:

1) It can avoid the turbulance of furnace conditions due to frequent changes in ore burden when using many types of ore.

2) Number of bunkers at the blast furnace can be reduced.

3) Undesirable variations of physical and chemical properties of charged ore can be reduced.

4) By reducing number of brands of ore, a weighing time before charging is shortened, with weighing accuracy raised and charging capacity increased.

3.1.2 Improvement of sizing

In order to uprate blast furnace productivity and to lower fuel ratio, it is necessary to improve permeability within the furnace and to increase a rate of ore reduction per unit hour. To this end, a complete exclusion of fine, a reduction in size range of charged ore, and a lowering of grain size are required. In other words, emphasis should be placed upon minimizing grain size, with efforts for lowering top size so as to reduce average grain size. Also, fine ore which generates from the above processing must be thoroughly removed.

A sizing method taken at Chiba Works in earlier days was such that ore unloaded from a ship was passed through crusher and screen at the time of unloading so that only sized ore was piled at the ore yard. Later, however, with a view to strengthening the sizing operation, a secondary crushing and screening equipment was installed in 1961, thereby establishing a two-stage sizing system as is used today. Therefore, unloaded ore is passed through the first sizing to be stored at the ore yard. These ores are again sized when being sent to the ore bin or the blending ore yard from the yard. Fig. 3 shows a flowsheet of a series of the above sizing processes. Top size of ore has been gradually lowered in line with the above-mentioned principle and the trend of the lowering top size and the proportion of 10-30 mm ore in sized ore are shown in Fig. 4. As is evident from the Figure, -10 mm and +30 mm size ore have been widely reduced during the past several years.

In Fig. 5, correlation between top size and pig iron production is shown, taking No.3 and 4 blast furnaces for example. It is noticeable that a lowering of top size from 40 mm to 35 mm then to 30 mm is contributable to a wide range of production increase of both furnaces. Even when the results of both furnaces are combined, a lowering of top size from 40 mm to 35 mm resulted in a 6-9% increase in output, and that of from 40 mm to 30 mm brought about an 8-12% production rise.

3.1.3 Agglomeration of fine ore

Along with the improvement, as described in the foregoing, of ore sizing for the purpose of uprating blast furnace productivity, an amount of fine ore generation has increased. In view of an increasing rate of high-grade ore inclusion in such fine ore generation, and a rising trend of fine ore collection at ore mines, a need for fine ore treatment is increasing.

During the earlier stage of the construction of Chiba Works, majority of imported ore available to our company was such sticky ore as Dungun, Goa and Larap, and that their fine included so much of extra fine that they were not suitable for sintering. Motivated by such circumstances, we took interest in the pelletizing process which was yet then at an experimental stage in the United States as a low-grade ore treatment method, and introduced it for treating fine ore in our hands. The pelletizing method was entirely new to Japan and after some deliberate study and research, we were able to enter into a commercial production rated at 400 t/d in March 1955. Keeping pace with the erection of blast furnaces in the following years, No. 2 and 3 pelletizing plants were installed one after another in such a large-scale as are existing today. The features of pellet can be summarized as follows:

1) Fine ore of -44 micron, 80% which is not suitable for sintering can be made into pellet. Sticky ore is more suitable for pellet.

2) Average grain size is small (15 mm) and a range of grain size is narrow.

3) Pellet has an excellent reducibility and a higher bulk density than sinter.

4) Slag generation is little because of high-grade of pellet.

5) Dust generated from open hearth furnaces and L-D converters and also sludge can be treated into pellet.

Meanwhile, simultaneous with the construction of No.3 pelletizing plant, the construction of sintering plant was also planned with the following reasons:

1) Mass production system is more suitable to sinter than to pellet.

2) Techniques for manufacturing self-fluxing sinter having excellent characteristics for blast furnace burden material were developed.

3) Our sintering technique was markedly improved as compared with the earlier stage of the Chiba Works construction.

The construction of another sintering plant was based on the expected benefit of maintaining both equipment, thereby using their respective features so as to supply burden most suitable for blast furnace requirement.

In May 1962, No.1 sintering equipment (3000 t/d) entered into operation, to be followed by the start of No.2 sintering equipment in 1965, simultaneously with the blowing-in of No.5 blast furnace. As a result, a total output of sinter rose to 6000 t/d.

Since the earlier stage of sintering operation, the Iron-Making Plant had been making a concentrated effort for developing high basicity sinter, and finally succeeded in the making of a high basicity (1.8-2.2) self-fluxing sinter. Main reasons for the making of the self-fluxing sinter were as follows:

1) The use of self-fluxing sinter can reduce the volume of lime otherwise to be added separately to the blast furnace burden, thereby saving heat energy requirement necessary for limestone decomposition.

2) Carbon Solution loss can be reduced.

3) It can prevent the generation of fayalite ($2FeO\ SiO_2$) and help forming calcium ferrite ($n\ CaO\ Fe_2O_3$).

As explained above, Chiba Works, because of its advantage of having both sintering and pelletizing plants, can treat fine ore, fully utilizing the features of both equipment.

For instance, undersize generated from the sizing process can be made into high basicity self-fluxing sinter, and sticky ore which is not suitable for sinter can be made into pellet. In order to improve blast furnace productivity, a further increase in the proportion of treated ore is essential.

Table 3 indicates a chronological development of our fine ore treating equipment. At present we are planning the installation of a third sintering plant (6000 t/d) which is scheduled to start operation in 1970.

As shown in Table 3, the construction of pelletizing plants was completed in 1961, as scheduled, establishing a 4000 t/d pellet production system. As a result, a rate of pellet in a total burden rose to 20-25%. Meanwhile, a 6000 t/d sinter production system was also established with the start in 1965 of No.2 sintering equipment, raising a rate of sinter in total burden to 30-35%. Thus, a total daily production of agglomerated ore at Chiba Works amounts to 10,000 t/d, occupying some 55% of a total burden requirement.

Figure 6 shows the trends at Chiba Works of the ratio of agglomerated ore, pig iron output per cubic metre of blast furnace inner volume per day, and coke rate. As is evident in the Figure, coke rate lowered under the effect of the increase in pellet proportion, but went up again reflecting a temporary shortage of treated ore resultant from the blowing-in of No.3 blast furnace in 1960. Thereafter, however, it lowered steadily to show a marked decline in 1962 reflecting the effect of ore agglomeration and sizing which were largely improved by that time.

Since then, pig iron output per cubic meter of blast furnace inner volume per day has been showing a noticeable increase, with some momentum for further rise. This is considered to be attributable also to the effect of the high top pressure operation.

In 1970, when No.3 sinter plant is scheduled for completion, the ratio of agglomerated ore in a total burden is expected to be about 80% with a resultant further rise in blast furnace productivity.

3.2 Blast furnace operations

Our rationalization effort was directed not only to the raw materials processing as stated above, but also to the blast furnace themselves in order to realize greater productivity and lower cost.

3.2.1 High temperature blast operation

One of the most effective means of reducing the fuel cost for blast furnaces is to raise the temperature of hot blast. It is generally held that, for each 100°C of rise in the blast temperature, coke may be economized by 20-25 kg/t-pig. For attaining this objective, however, it will be essential to install due equipment capable of supplying hot blast of much higher temperature as well as to be assured of constant and excellent raw material conditions that can ward off "hangings" and other troubles that usually occur as the temperature of hot blast in the tuyere part is raised. We have already related on the various improvements made on the raw material conditions. Turning to the equipment aspects, we have made a series of improvements and reinforcements of the hot stoves, blast pipe and other parts, in consequence of which the average blast temperature for all the blast furnaces at Chiba has reached 1000°C, while the average temperature of hot blast for No.5 blast furnace alone has marked the high of 1200°C. This is to say that the hot blast temperature has been raised by an average of 250°C during the past seven years, as graphically presented in Fig. 7.

Worthy of special note is No.5 blast furnace, where the large-type high-powered hot stoves (external combustion type) were installed. The said stoves are not only fired with blast furnace gas, but are also equipped with a special apparatus for mixed combustion of both the coke-oven gas the heavy oil, and are capable of supplying hot blast of 1200°C at the rate of up to 4000 m^3/min. Fig. 8 shows the section through the hot stoves for No.5 blast furnace.

3.2.2 Injection of heavy oil and heavy oil-coal slurry

In Japan, the prices of coal (domestic), heavy oil, and coke are in the ratio of 1:1.3:1.6. If the coke could be substituted with coal, heavy oil, and other fuels, it would be possible to reduce the cost of pig iron. The practice of heavy oil injection was first applied to No.4 blast furnace (hearth diameter: 8.8 metres), and was gradually extended to other blast furnaces. This method was found useful in saving the use of the costly coke.

In 1965, we began to study the possibility of injecting the coal instead of heavy oil, with a view to making a greater use of domestic coal. Though one of our earlier ideas was the injection of coal itself into the tuyere, we later developed and eventually adopted the method of injecting it mixed with heavy oil in the form of slurry, as this made it easier to control the volume of injection. Fig. 9 gives the flowsheet of the slurry injection process. The said equipment was adopted for use with No.1 blast furnace (hearth diameter, 7.2 metres; pig iron capacity, 1500 t/d). It has since been improved upon in various ways and has been functioning satisfactorily. This method contributes to the saving of coke as the slurry of 30% coal is injected at the rate of 60-70 kg/t-pig. Fig. 10 shows the operation result obtained from the test of slurry injection, and tells us that the substitution ratio of the coal comes to about 1.0, roughly corresponding in effect to heavy oil.

3.2.3 High top pressure operation

If a maximum productivity is to be attained with a limited inner volume of blast furnace, it is necessary to supply the blast furnace with as great a volume of hot blast as possible. But in this case it must be remembered that a drastic increase in the volume of the hot blast will lower the air permeability within the blast furnace and tend to deter a smooth furnace performance. In contrast, however, the high top pressure operation can widely increase the volume of hot blast by raising the furnace-top gas pressure, thereby increasing blast furnace productivity, while preventing various troubles which are otherwise apt to occur as the flow rate of furnace gas increases.

In 1964, No.2 blast furnace (hearth diameter: 7.5 metres) was remodelled into a high top pressure blast furnace capable of maximum furnace-top pressure of 1.0 kg/cm^2, with its two-bell system unaltered. Then in 1965, the new No.5 blast furnace was completed as a three-bell, high top pressure blast furnace, with a maximum top pressure of 1.10 kg/cm^2. The high pressure operation brought about an increased pig iron output, recording a pig iron production rate of 2.0 t/m^3/d.

Nevertheless, however, there still remain a number of equipment problems to be solved if the present high top pressure operation is to be carried far into the future. One of the big problems is the abrasion of the bells as it affects the maintenance of the charging gear at the furnace top. In an attempt to solve this, a device has been developed for making the gas seal of the bells last longer than before, and a reasonably good effect is expected from this measure for the time being.

Likewise, No.3 blast furnace will be remodelled in autumn 1968 for a high top pressure operation. Fig. 11 shows the correlation between the pig iron production rate and the furnace top pressure of No.5 blast furnace. Fig. 11 gives only the results obtained during the start-up period of the furnace. At present, the production rate of pig iron stands at 2.0-2.2 t/m^3/d under the top pressure of 0.7-0.9 kg/cm^2.

4. REDUCTION OF COST

As already mentioned, the technical improvements on raw materials processing and the blast furnace operations have stepped up the blast furnace efficiency and reduced the unit consumption rate of fuels, greatly contributing to the lowering of the cost of pig iron. These relations were already illustrated in Fig. 6. Coupled with the reduced prices of imported iron ores, our continuous rationalization efforts have proved effective in reducing the cost of pig iron.

As No.3 Sinter plant at Chiba will come into operation in the near future, the cost of pig iron will further be brought down because the increased use of agglomerated ore will increase the blast furnace productivity, and to reduce the coke rate.

5. CONCLUSION

As stated above, Chiba Works has so far been grappling with the rationalization problems by adopting every possible latest technique. And yet the rigorous international economic environment as we find it today is pressing us for further drastic rationalization. For instance, the ever-expanding capacity of blast furnaces seems dwarfing the existing plant space more and more every year.

Aside from our perennial concern as to how to deal most economically with an ever-mounting volume of raw materials and products to be moved about within a limited space, we are addressing ourselves continuously to the following outstanding tasks, aiming at the goal of higher productivity and lower cost:-

a) Expansion of port facilities.

b) Rationalization of handling of raw materials.

c) Reinforcement of raw material processing facilities.

d) Reinforcement of auxiliary equipment of blast furnaces.

e) Development of new operation techniques.

f) Construction of blast furnaces with larger capacity.

Table 1. Outline of iron-making equipment

(A) Blast furnace section

		1BF	2BF	3BF	4BF	5BF
Capacity	(t/d)	1,500	1,800	2,700	2,600	3,900
Inner volume	(m^3)	913	1,156	1,686	1,663	2,142
Heath dia.	(m)	7.2	7.5	8.8	8.8	10.0
Tuyere Nos.		14	16	18	20	24
Tap hole Nos.		1	2	2	2	2
Hot stove:						
type		cowper	cowper	cowper	cowper	koppers
numbers		5	3	3	3	4
heating surface	(m^2)	12,170 (2) 11,990 (3)	23,640	25,600	25,600	39,680
Gas cleaning:						
1st		dust catcher	"	"	"	"
2nd		spray washer	"	"	"	"
3rd		elec. precip.	"	"	"	"
Blower:	(m^3/min. xkg/cm^2)	1,650 x 1.4	2,350 x 2.6	2,800 x 2.4	2,800 x 2.4	3,900 x 3.0

(B) Ore preparation section

Sintering plant	D L type 80 m^2 x 2	capacity 6,000 t/d
Pelletizing plant	shaft furnace type	
	(150 t/d x 4)	ceasing
	250 " x 6 400 " x 6 1,000 " x 1	capacity 4,500 t/d
Blending yard	48,000 m^2	
Ore yard	103,000 m^2	

Table 2. Components of a blending ore for sintering

Brand	Wet weight (t)
Korea:	
Yangyang	1,995
Mulgum	504
India:	
India	1,008
Sandur	1,007
Bailadila	1,499
Kiriburu	2,990
Brazil:	
Rio Doce	1,015
Australia:	
Mt. Coldsworthy	3,998
Chile:	
Santa Barbara	3,033
Santa Fe	1,994
South Africa:	
Asoman	2,196
USA:	
Eagle Mt.	4,021
Iron sand	998
L D slag conc.	628
B F dust	3,026
India mangan ore	986
Others	1,003
(total)	(32,078)

Table 3. Development of fine ore agglomeration equipment

Year	Item			Capacity (t/d)
1954	No.1 pelletizing plant	construction	4 furnaces	800
1958	No.2 pelletizing plant	"	6 furnaces	1,200
1961	No.3 pelletizing plant	"	6 furnaces	2,300
1962	No.1 sintering plant	"		3,000
1965	No.2 sintering plant	"		3,000
"	No.1 pelletizing plant	enlargement		800 - 900
1966	"	replace to 1,000 t/d Fce.		900 - 1,000
1970	No.3 sintering plant	at planning		6,200

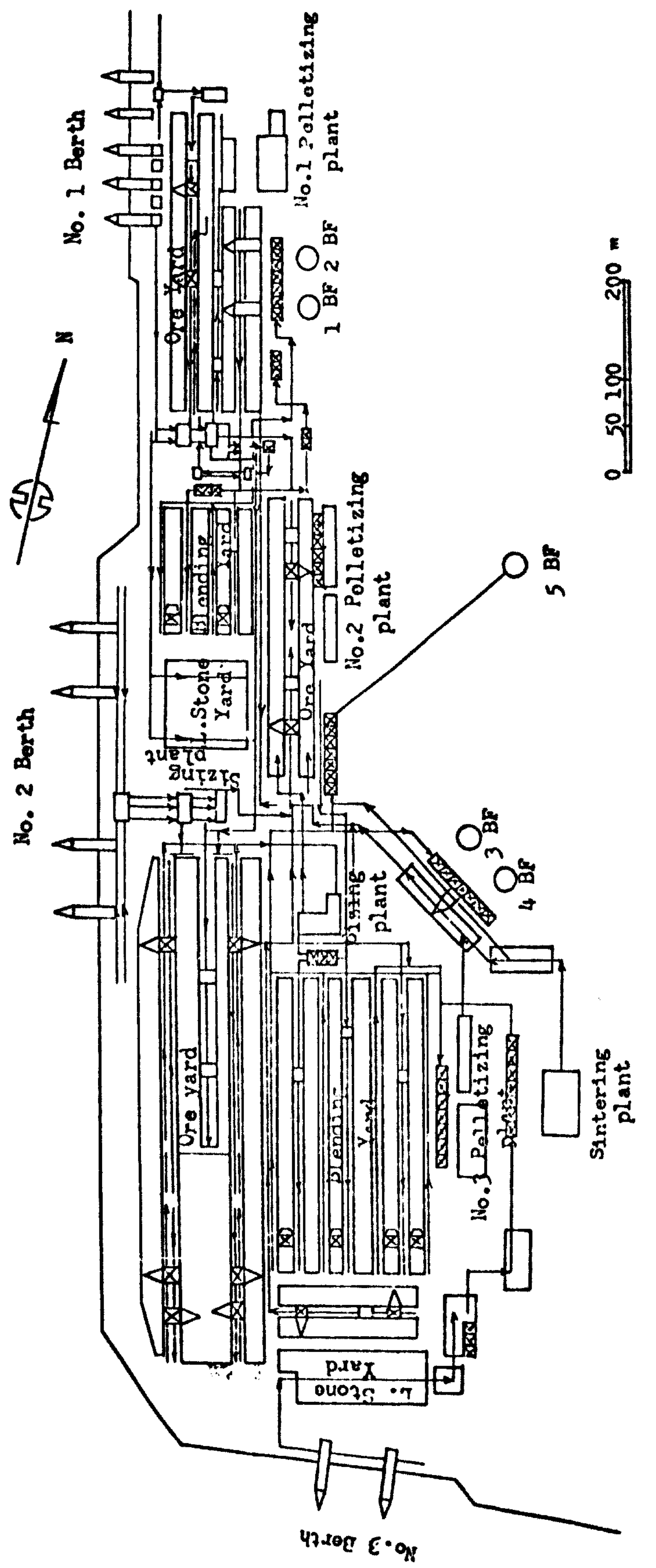


Figure 1

Ironmaking layout of Chiba Works

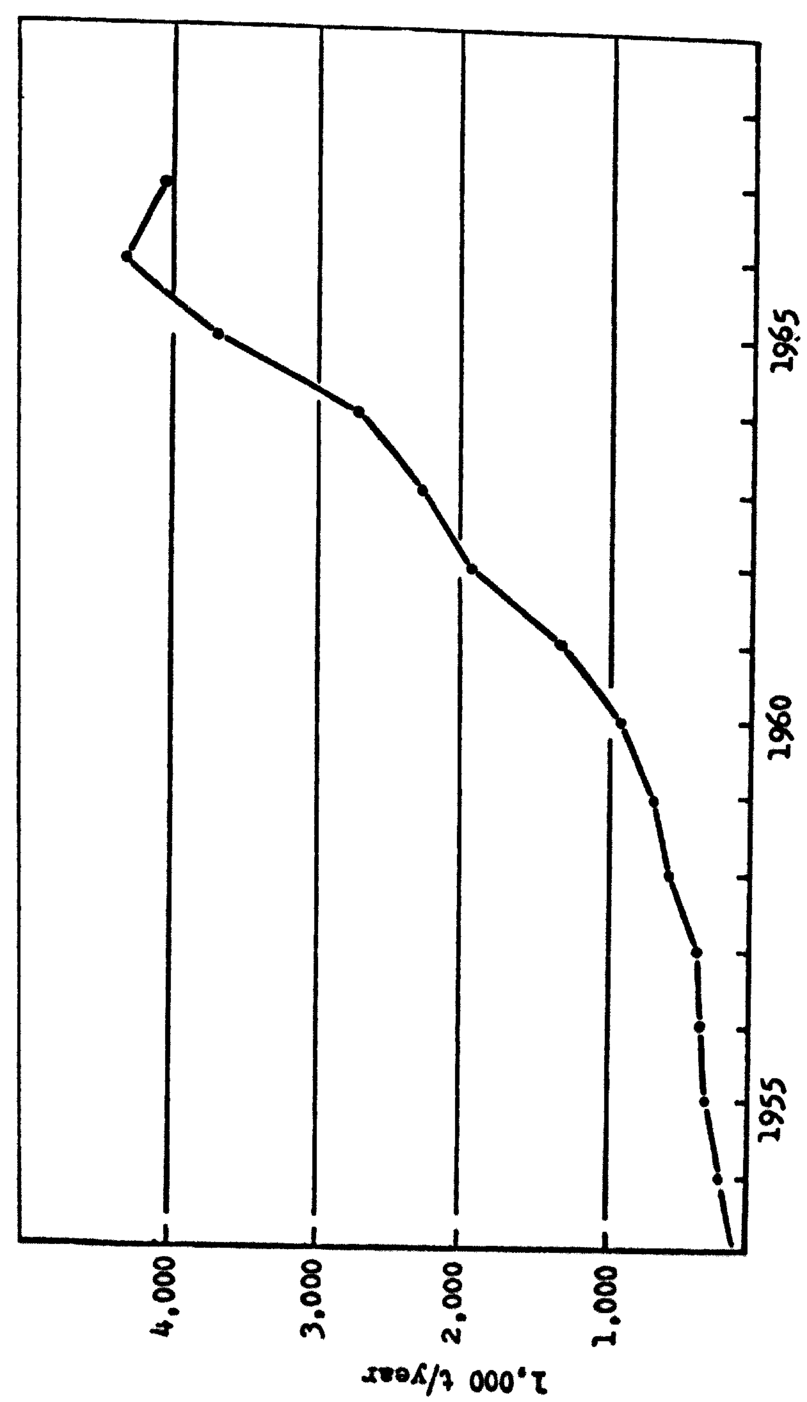


Figure 2

Trend of pig iron production

Figure 3

Flowsheet of ore sizing

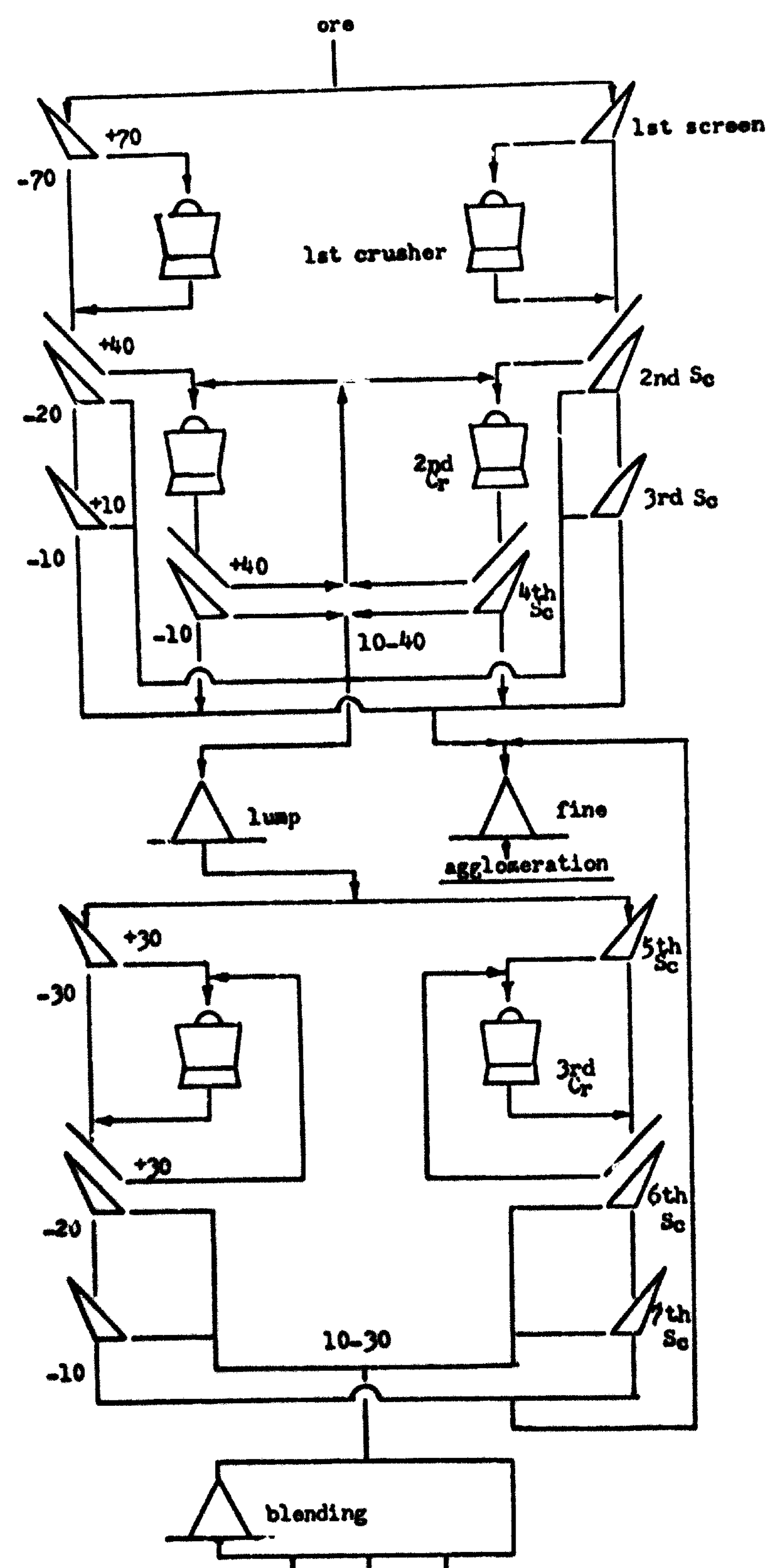


Figure 4

Trend of the 10-30 mm proportion in sized ore

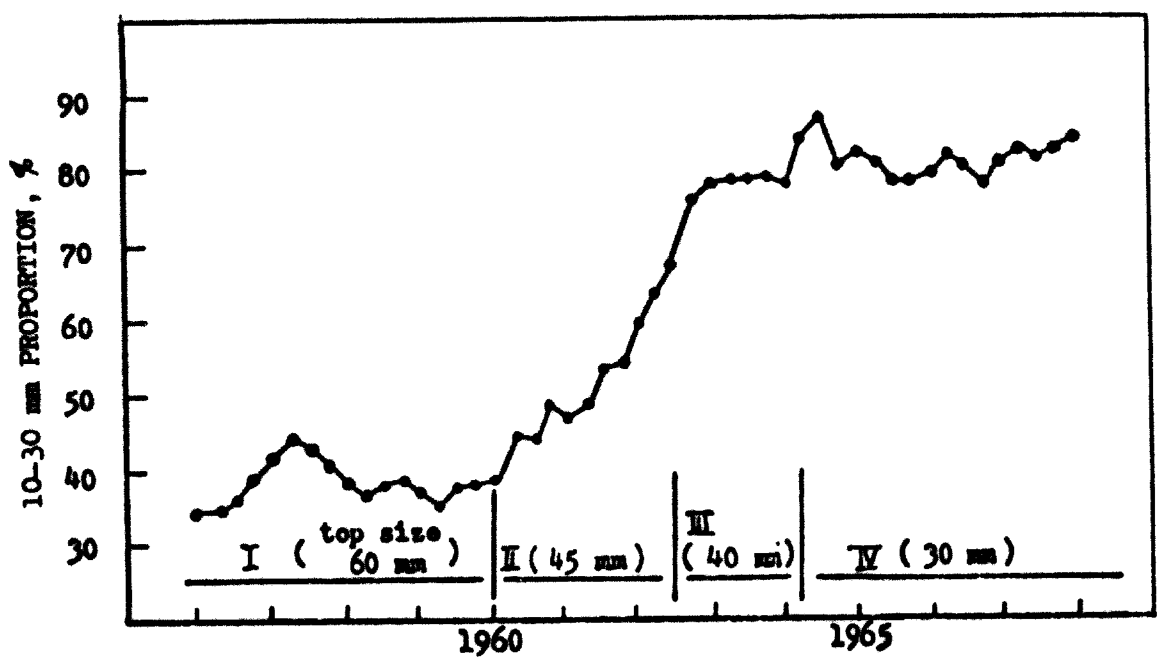


Figure 5

Correlation between ore top size and pig iron production

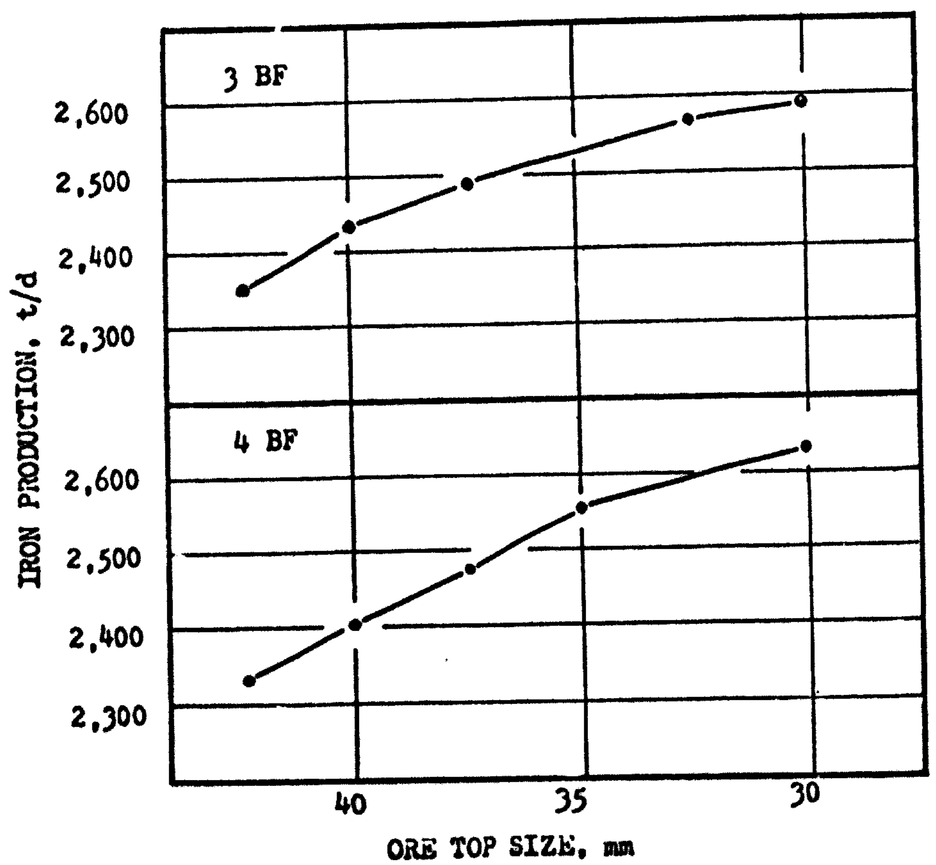


Figure 6

Effect of fine ore agglomeration upon coke rate and pig iron production

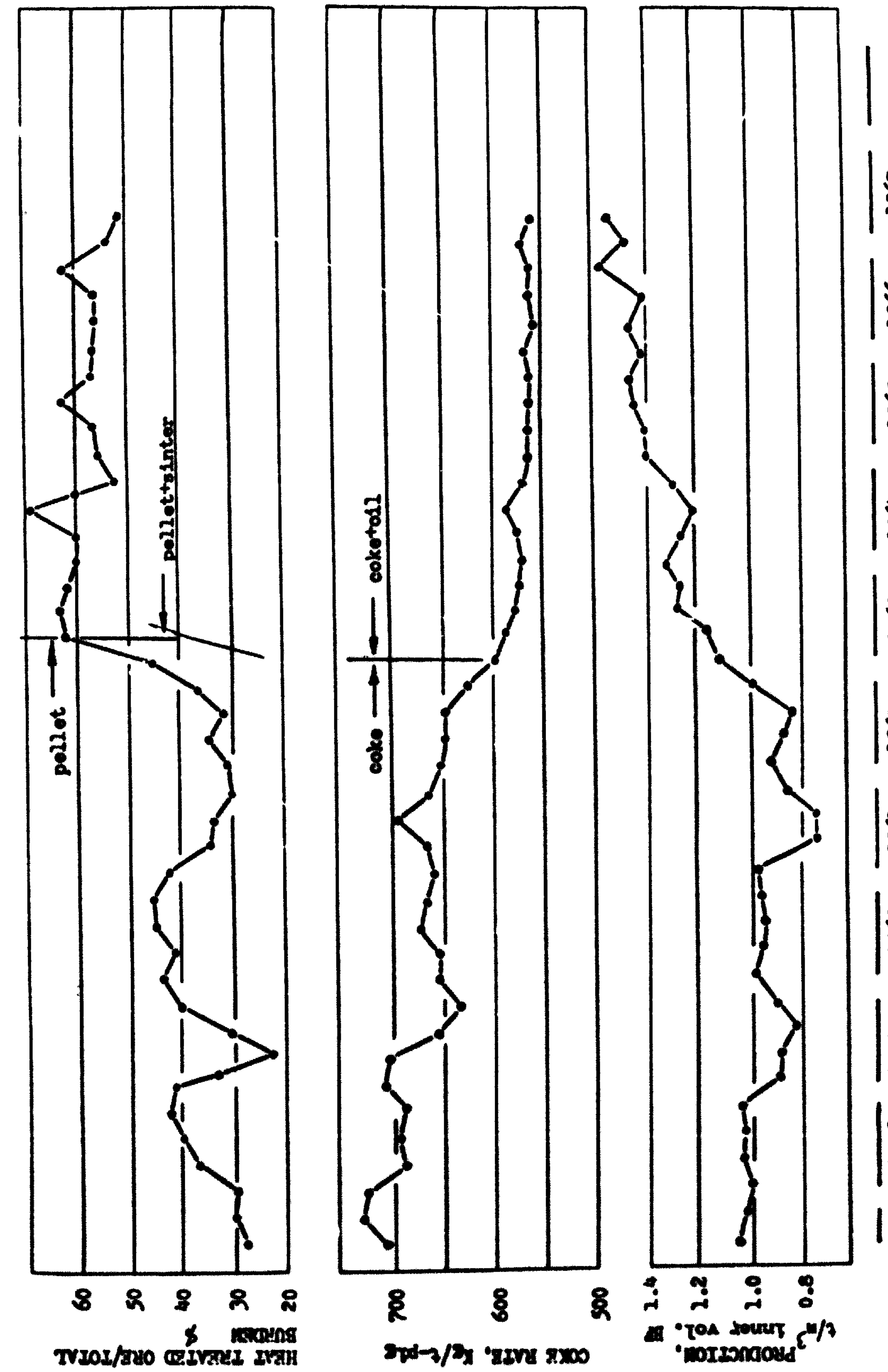


Figure 7

Trend of blast temperature

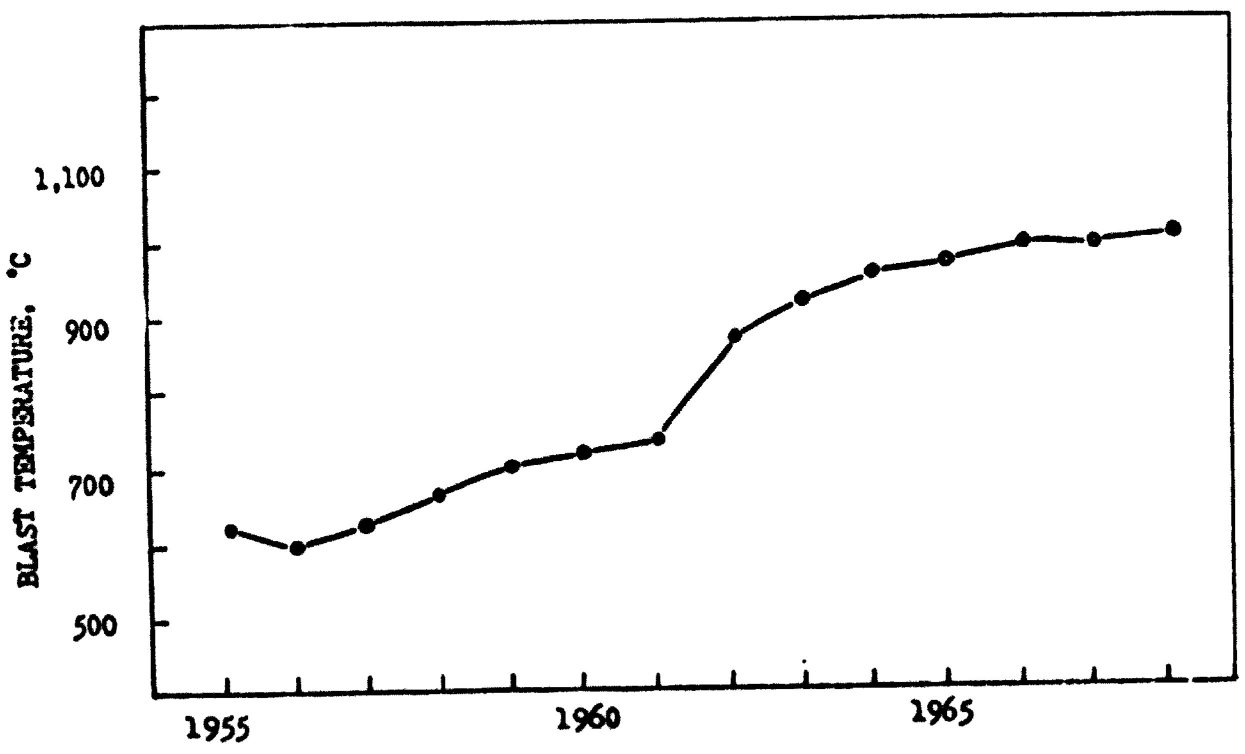


Figure 8

Section through hot stove

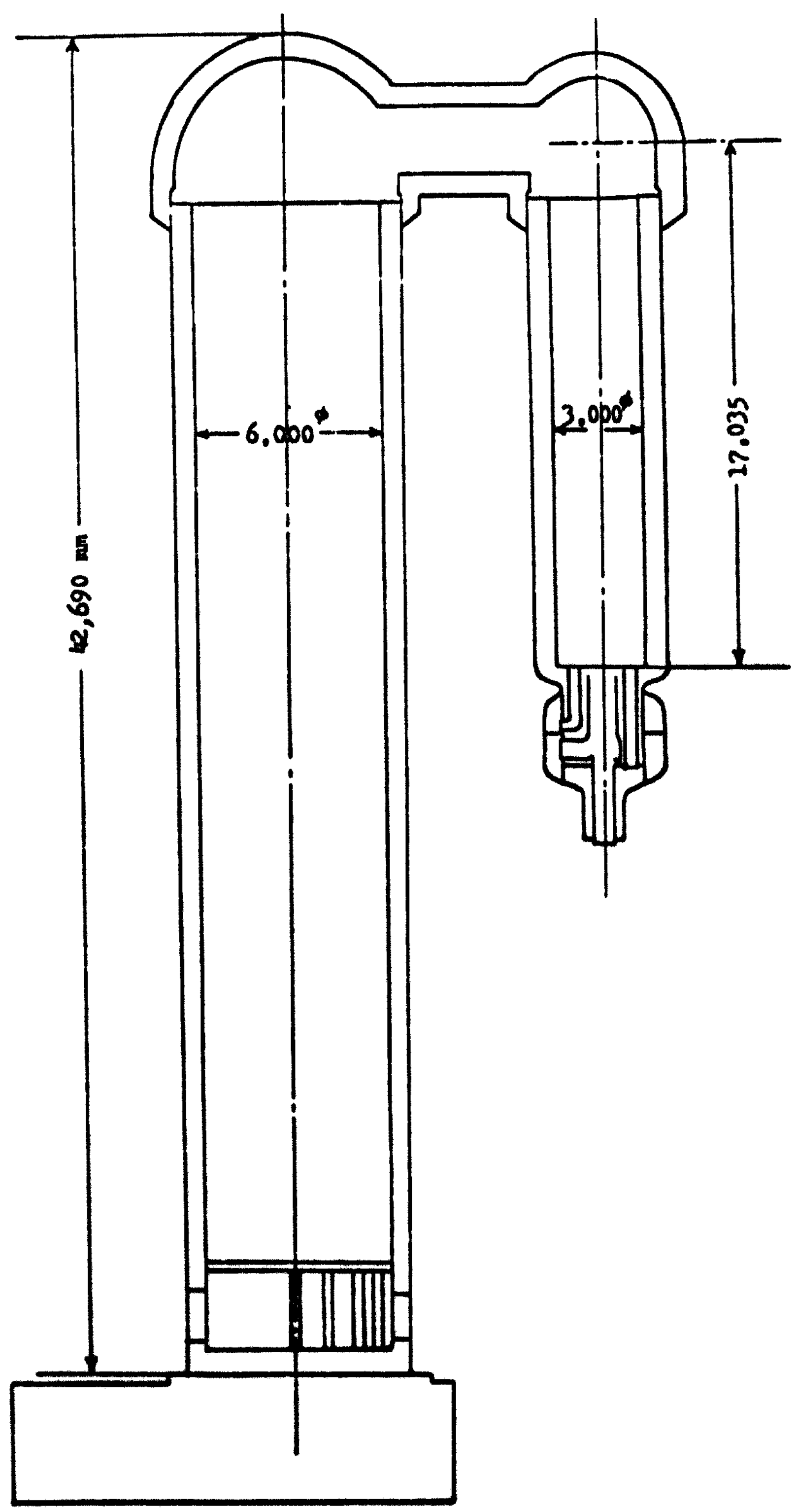


Figure 9

Flowsheet of slurry injection

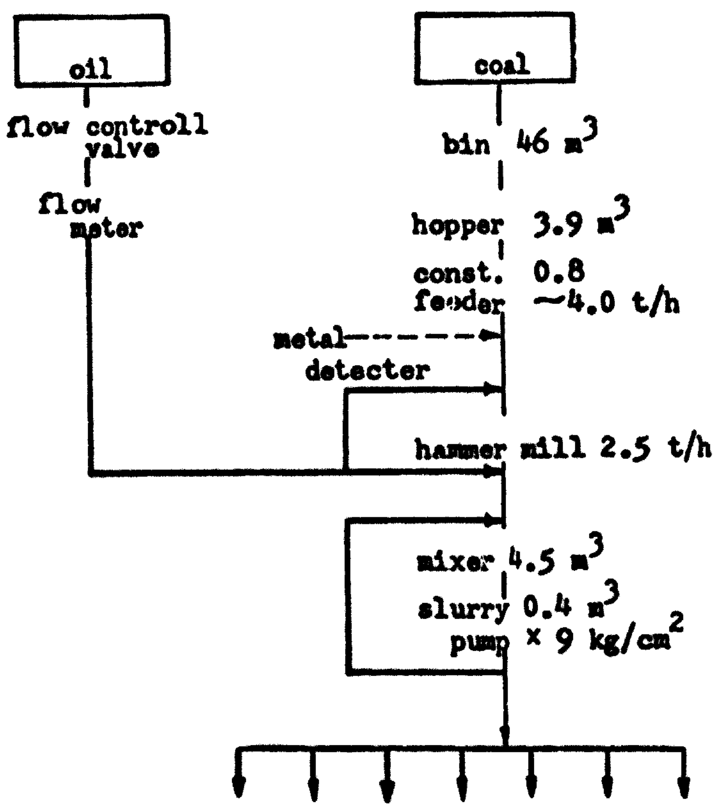


Figure 10

Correlation between coke rate and slurry concentration

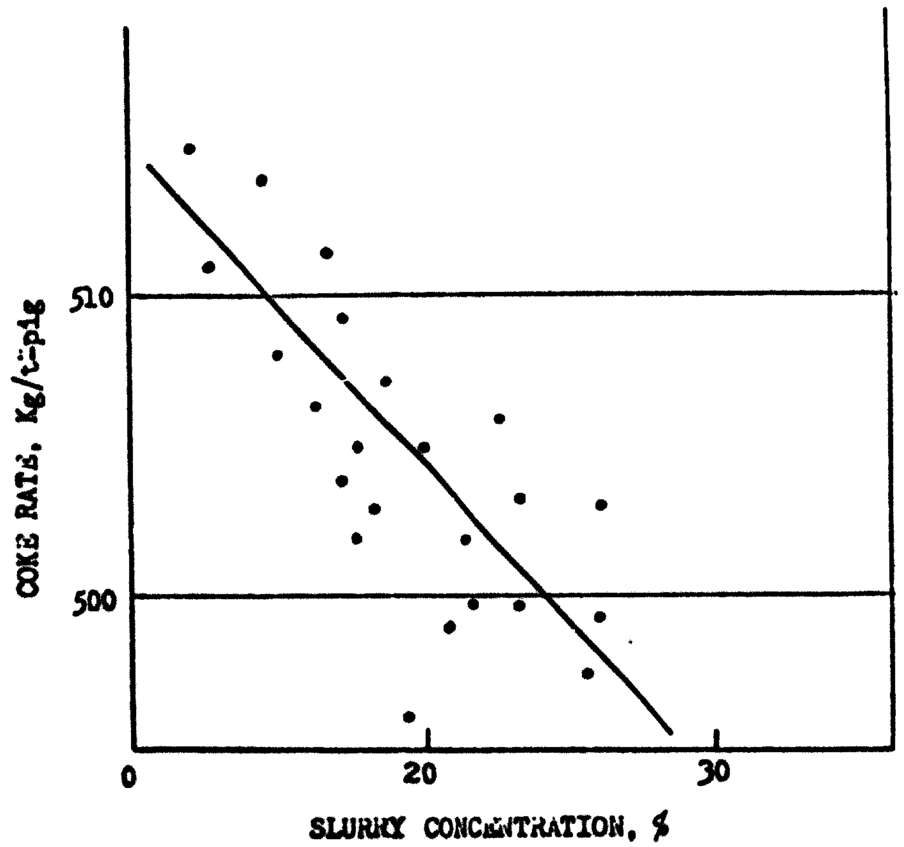


Figure 11

Correlation between top pressure and iron production

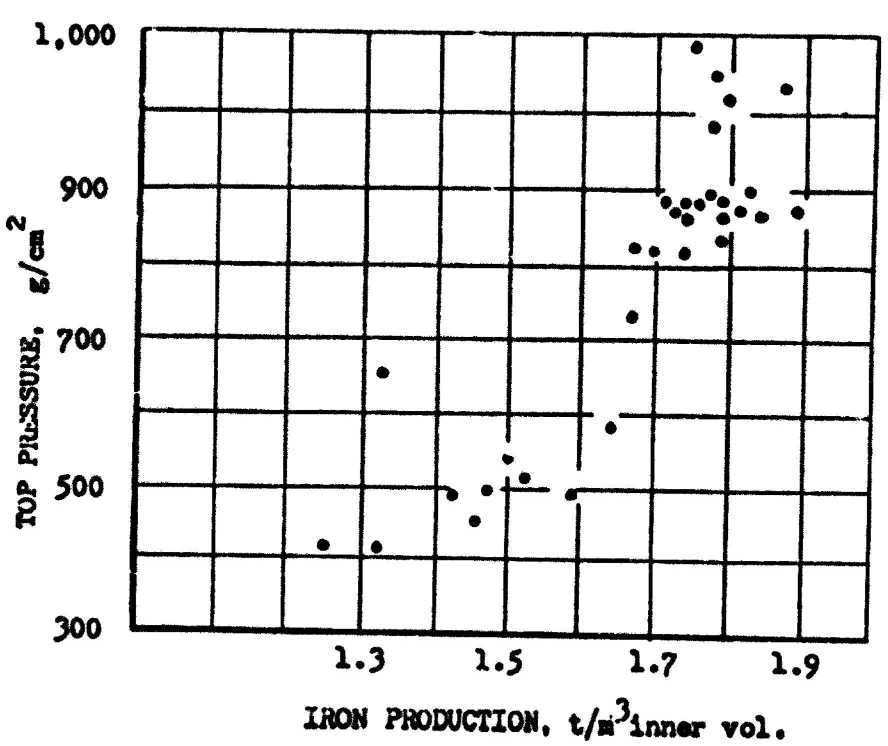
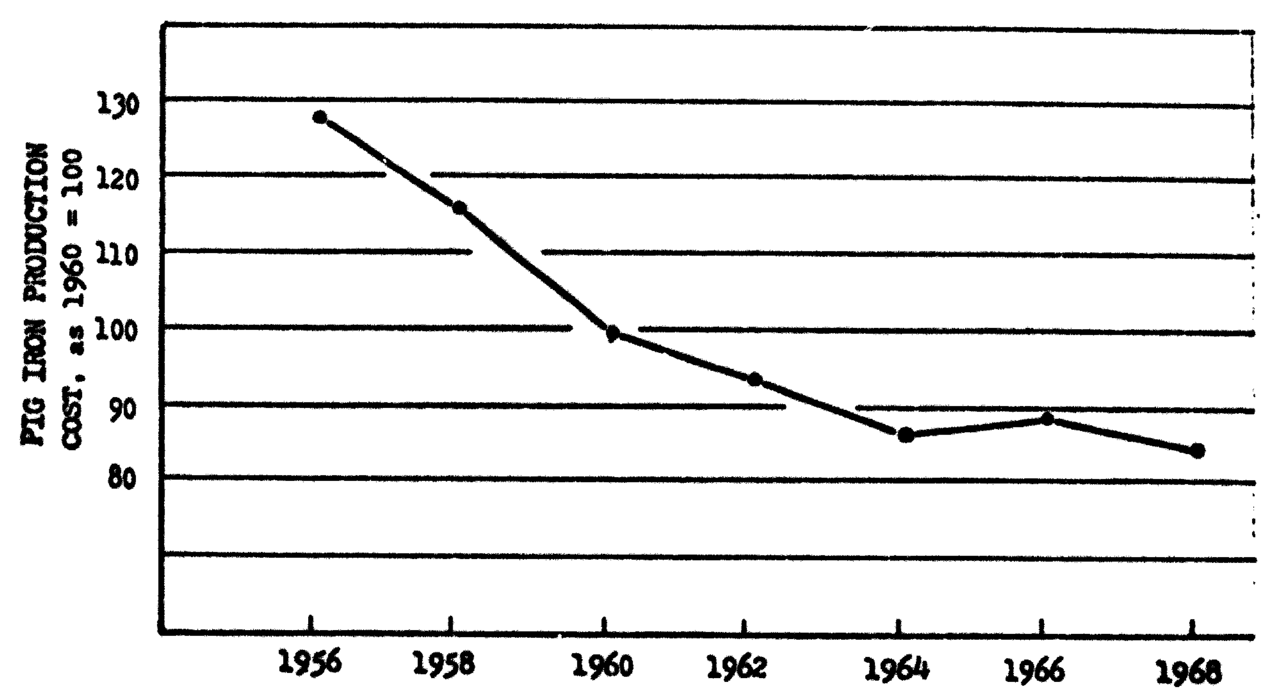


Figure 12

Trend of pig iron production cost



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