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The subject of blast-furnace operations, so far as they appertain directly to the production of pig iron, does not appear to have been the subject of any noticeable amount of literature. For this reason, particularly, as well as for the fact that the writer has had considerable practical experience in this as well as other branches of the steel industry, the subject of this thesis, it is hoped, will prove of some value to students who desire information on this branch of what is probably the largest industry in the world. In view of the fact that the writer's experience has dealt largely with steel plants making not only pig iron but steel products which originate therewith, the operations to be detailed here will be those of blast furnaces as a part of a large steel plant rather than those of an individual plant making nothing but pig iron for sale. Closely related to blast furnace operations in a modern steel plant are the operations of coke ovens and coal washeries. For that reason reference will be made to these other two features as well as to blast-furnace operations. It would not be amiss and should prove of some value to describe first briefly the operations of a blast furnace from the practical rather than the accounting standpoint.

A blast furnace may be a unit producing as much as 800 tons of pig iron a day or it may be a unit producing not more than 100 tons a day. The latter is the average tonnage produced in the old style furnace which may still be charged by a hydraulic elevator; the former is the product of a unit operated entirely by electricity and designed to meet the ever-increasing demands for steel products all over the world. A particularly interesting feature of blast-furnace operations is that they cannot be so thoroughly controlled by mechanical means as, say, a rail mill or a plate mill. Production may be affected by humidity in the air blown into the furnaces. It may be affected by the quality of the materials used, resulting in serious accidents at times. For example, a particularly bad quality of coke can cause what is termed a "scaffolding," which has resulted to the writer's personal knowledge in an explosion blowing off the entire top of the blast

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furnace. It is here that the accountant will see the urgent necessity for reserves for relining and renewals. Of course, the necessity for relining arises from ordinary operations as well as from extraordinary conditions.

The ore may be received by boat or by rail, depending upon the geographical location of the plant, and it will be stored in piles and later placed in bins in order to facilitate the handling when necessary to charge the furnace. The ores will be stored first in piles according to the metallic contents, as it is upon the metallic contents of the iron as well as upon other chemical analyses that the "charge" is based and upon which the price is fixed. Thus it will be seen that ores from different sources may be dumped in the same piles if they are very closely related in the matter of chemical analyses.

Coke at the present time is produced at a number of the larger steel mills as it has been found that it is much more convenient to obtain control of a coal supply and produce coke than it is to depend entirely upon coke produced by others at points remote from the furnaces. Besides, coke is such a very important factor in the production of pig iron that the commercial value of the iron may be adversely affected by a poor quality of coke. Not only must the coke be volatile to a definite degree but the structure of the coke must be such that it can support the ore and limestone and other items constituting what is called the "stock." For convenience in handling, the coke is stored in bins when necessary to be used in the furnace. In some plants, coal is still being used to a great extent for fuel, but this is due largely to the fact that in those cases in which it is used the quality of iron being produced is required to be of a special grade.

Limestone and other fluxes are stored in piles and conveniently situated for handling. Some steel plants have their own limestone deposits, and when this is the case there arises a situation analogous to that when a company produces its own coke, that is, the cost factor enters into the accounting end of the problem to a greater degree than is the case when purchases of these materials are made outside. Limestone is used for fluxing, i.e., for removing the undesirable elements in the ore, hence the importance that a company have its own supply of known quality. With a poor quality of stone, the impurities are not properly eliminated, and there may be produced a poor quality of iron, fit perhaps

only to be remelted or used in the foundry for a very inferior quality of castings.

At intervals, say of four or five hours, the furnace is tapped and the iron disposed of in various ways. It may be sent to the Bessemer or open-hearth plants to be made into ingots; it may be sent to the foundry to be used for castings, or it may be cast into pig iron for storing for future use or for sale. In order to determine the disposition of each "tap," a sample of the iron in its molten state is taken immediately after the metal has begun running from the furnace and an analysis is made in time to determine its proper disposition. An excess of phosphorus or sulphur may make the iron useless for one class of steel production, while the presence of the same degree of these elements may render the iron useful for other purposes.

It may be of interest to state here that a very careful record is usually kept of the production of each "tap" and its disposition. One of the principal reasons for such a record is that in case of a defective product in the rail mill or some other branch of the business, the blame can be traced to where it belongs. It is, of course, well known to the readers of this article that every rail laid down has upon it a heat number, which is given to the ingots either at the Bessemer plant or the open-hearth plant. By this means it is possible in case of accidents upon the railroads resulting from defective rails to trace back to the original furnace production and determine whether the fault was due to defective materials or an accident due to local trouble on the railroad track.

Assuming that it is intended to store the iron for future use or to sell it, the metal is cast into pigs. Under the old style the pigs were cast on the blast furnace floor into sand molds, but the more modern method is to send the iron to what is called a pig-casting machine situated away from the blast furnace, where the iron can be cast into pigs much more readily and with less interference with the operations of the blast furnace.

In view of the fact that the accounting for blast-furnace operations involves recording expenditures for the maintenance of ladles, it should be stated here that two classes of ladles are used at the blast furnace: one kind for the iron itself and another kind for the slag or what is sometimes called "cinders." The disposition of the slag depends largely upon whether the company finds its profitable to put this slag to commercial use or merely

to dump it on the large slag dumps situated near the property of the steel plants. For a number of years blast-furnace slag has been used for a variety of purposes, one of the principal uses being the manufacture of a fireproof cloth, which is supposed to be as effective as asbestos, but as this is an expensive and involved operation, the steel companies themselves do not seem to have engaged in this industry but have disposed of the slag and left it to others to convert it.

With the operation of the blast furnace itself, we have also to consider the expense of operating the blowing engines which supply the blast to the furnaces. In the more modern plants facilities have been installed to supply to the engines for fuel the gases which are created in the blast furnace. This is a feature which should be considered in the accounts when preparing costs of production.

Coke ovens usually operate in a steel plant for the direct benefit of the blast furnaces, although other departments also use coke. For this reason, the cost of coal, labor handling the coal and other expenses incidental to the production of coke form a vital part of the accounts for blast furnaces. This is particularly important in view of the fact that the by-product retort is now used largely and the by-products, such as coal tar and sulphate of ammonia, form an important credit to the operating expenses of the coke ovens.

It will be seen from the foregoing that accounting for blast-furnace operations is largely a cost proposition and the recording of the consumption and production is necessarily subordinated to the main object, that is, cost finding.

The accounting for blast-furnace operations may be divided into four principal divisions, namely:

Blast furnace,
Blowing-engine house,
Casting machine,
Ladle house.

Blast Furnace

Materials—A distribution book is necessary to record the amount of ore, lime, coal, coke and other materials consumed. This information is obtained chiefly from the superintendent's reports of materials ordered to be charged into each "mix." In view of the fact that the value of the mixture is dependent upon

accurate weights the superintendent's reports are usually accepted for cost purposes. It develops, however, upon taking physical inventories of the items of coke, coal, etc., that shortages will be disclosed as between such actual weights and the book inventories. In the case of coke this is due largely to that part of the material which escapes as dust or loses value otherwise. In the case of ore itself, it is difficult to check the inventory, except by measurement, until the piles have been considerably reduced. Therefore, in order to provide against excessive shortages at the end of any period, it is desirable to add a percentage to the weights reported used, such percentages being based upon experience over a number of periods.

Under a good cost man it is possible to maintain a good check on materials reported used, owing to the fact that under efficient operating conditions at a blast furnace there is a general average of consumption of coke and limestone to each unit of iron produced. In the writer's experience at a modern plant, this worked out to about a pound of coke to a pound of iron and about 1,100 pounds of limestone to 2,240 pounds of iron. The prices to be used will be, of course, actual cost. In the case of ore, this will cover the cost of the ore to the plant plus any freight paid thereon, plus handling charges which can be definitely apportioned to the material. When the company operates vessels, the cost of the ore will be charged with the cost of the operation of such vessels. Limestone cost will be calculated the same way. In case the company produces its own limestone, cost is somewhat more complicated, but all expenses applicable to this material should be charged thereto.

There is consumed, in addition to the raw materials mentioned previously, scrap of various kinds, consisting of off-grade iron, runner scrap and ladle scrap. At this point develops the question at what price this scrap should be charged to the furnace. In the case mentioned the most practical arrangement at the time seemed to be to charge the blast furnace with its own scrap at a fixed figure. This figure was also used as a credit for scrap when compiling the cost of production. There may have been weaknesses in this method, but the quantity used is never considerable and the probable ultimate cost was not much affected. The blast furnace will also use roll scale from the rolling mills. The scale is usually charged to the blast furnace by the rolling

mills at the figure quoted in the trade journals for such scrap and the same price is used in charging the furnace.

In the record of ore used it is necessary to show the metallic contents as well as the quantities. The object of this is to check up the theoretical yield of the ore with the actual production. Owing to the fact that the ores are purchased on the basis of the iron content, there will, of course, always be a slight difference due to the fact that a part of the iron goes into the flues or is carried away in the slag. Unless the slag is run through the furnace again, which is very rarely done, this iron is entirely lost. The flue dust can be charged back into the furnaces.

Labor—The labor charged against the furnace will be subdivided briefly into the following:

Superintendence,
Stocking,
Charging,
Blowing,
Casting (tapping).

This information will be obtained from the pay-rolls in the usual way. In view of the fact that the costs are subject to close scrutiny and that any variation is the subject of inquiry, it is necessary that the sub-divisions previously referred to should be carefully maintained.

Supplies and Repair Labor and Materials—These items will be obtained on requisition and will be reported by the stores department at the end of each accounting period. Some of these supplies are so expensive that when certain parts such as tuyeres, blocks or cooling plates are changed, the fact is usually recorded in the daily blast-furnace report to the management. Usually the necessity for changing the foregoing items arises from normal operations, but when a furnace is operating erratically and certain sections become overheated or otherwise abnormal, the expense of frequently replacing these parts is considerable.

General—The overhead expenses will consist principally of steam, water, power, handling, laboratory, and the reserve for relining and renewals. Steam and power can be calculated accurately. Handling will be a pro-rata share of the expenses not charged directly to materials. Laboratory expenses can be calculated if the furnace has its own staff. The fund for relining

and renewals will cover stacks, gas flues and gas pipes, hearth and bosh metal work, stoves and hoists. There will be a credit under certain conditions for any steam and gas supplied by the furnaces to the blowing-engine houses.

The relining and replacement fund is reserved on the basis of a certain amount per ton of iron produced based entirely upon the experience with a particular unit.

Production—The production records should indicate grades of iron produced and also its disposition, in order that the department receiving it may be properly charged. Credit should be given for ladle scrap, consisting of the ladle skulls or shells and the ordinary scrap. Production should also be given credit for runner scrap and off-grade iron produced. As stated previously, the values at which they are credited are nominal and as all of the scrap produced is usually charged back into the furnace, the net operating result should not be seriously affected. Of course, where there are a number of blast furnaces and the scrap is stocked for their future use or for the use of other departments, it is important that a record be kept of the amount produced, as far as practicable, from each furnace in order that due credit may be given the unit responsible for its production.

Credit should also be given for flue dust produced. At one time flue dust was thrown away, as being of no commercial value, but for a number of years past it has been stored and charged back into the furnaces or the iron contained in it has been recovered by other means. An average of iron content in the flue dust will suggest a fair value therefor, and the amount should be properly recorded in order that the results may reflect the true cost of the iron as far as possible.

Statistical Data—Apart from the actual expenses of operations found in all periodical compilations of costs, certain statistical data should be incorporated in any report on blast-furnace practice. The following are such items of information:

Number of days operating,
Disposition of product:
  Foundry,
  Pig iron for stock,
  Open-hearth department, etc.,
Number of tuyeres changed,
Actual production—tons,
Theoretical production—tons.

Following is a form of cost sheet intended to give effect to the results of operations for any accounting period:

(Condensed form)

COST OF PRODUCING PIG IRON AT FURNACE NO. ——. MONTH OF ——, 192—.

	Gross tons	Price	Amounts	Material per ton Pounds	Per cent.	Cost per ton
Metallic mixture:						
Ores						
Mill cinder and roll scale						
Scrap						
Gross metallic mixture						
Deduct, scrap produced						
Net metallic mixture						
Fuel and fluxes:						
Coal						
Coke						
Limestone						
Total fuel and fluxes						
Total materials charged						
Labor						
Materials and supplies for repairs, etc.						
Casting machine cost (as annexed)						
Water, power, steam, etc.						
Total cost above net material						
Grand total cost						

STATISTICS

Iron produced—by grades
" " —by disposition
Days in operation
Average product per diem
Cost by grades
Actual production—tons
Theoretical " — "
Loss — "

BLOWING-ENGINE HOUSE

From this department the furnace receives all the air required for operations. A separate cost should be kept for this department as in some cases the engines are also operating upon other units in the plant, in which case a division of such cost should be made in order properly to charge the departments benefitting thereby. As stated previously the blowing-engine house receives gas produced by the blast furnace and for this reason a charge should be made to the blowing-engine house in order that other departments may not receive the benefit of this item.

Record should be kept of all labor by occupations. Repair labor and material should be recorded properly and charged to this department periodically. Overhead expenses are usually light and not difficult of allocation. The entire cost of this depart-

ment should be apportioned to the departments upon a basis determined by a qualified technical expert.

Pig Casting

If pig iron is being cast by various methods, such as sand casting at the furnace or in a modern pig-casting machine, different costs should be kept in order that this expense may be exhibited eventually as a part of the blast-furnace operations. The main divisions are direct labor, labor on repairs and maintenance, lubricants, tools and supplies. The information for this cost exhibit will be obtained in the same manner as for the other departments of the plant.

Ladle House

Separate cost should be kept for hot-metal ladles as distinct from cinder or slag ladles. The principal subdivisions of expense will be direct labor, labor repairs and maintenance, repair materials, tools, refractories, etc. The items herein will be obtained from payrolls, stores requisitions, etc., in the way that this information is obtained for other departments of the plant. This department is an important adjunct of the blast-furnace operations, and it has always been deemed necessary to the management to know to what extent this expense enters into the cost of production.

General

As stated, this subject is considered on the assumption that the blast furnaces are a part of a complete steel plant. Fundamentally the treatment of the matter would differ only slightly in the case of a plant devoted entirely to the production of pig iron for sale.

The general books would contain appropriate asset, liability and nominal accounts and would control a works ledger. The works ledger would contain all operating debits and credits.

The payrolls should be compiled from daily time-cards, wherever practicable, supplemented by personal checks by an employee of the time department.

All supplies other than raw materials should be withdrawn only upon approved requisitions. It has also been found practicable to issue certain items of raw materials such as fire clay and coal, on signed authorizations. In the case of ore, coke, limestone, etc., the superintendent's order for a certain "charge"

is deemed sufficient authority for and a good check on the issuance of these materials.

Credits to cost of coke production for such by-products as coal tar and sulphate of ammonia are made (but the practice may vary) at market values. The reason for this in the case cited was the fact that the by-products were sold f. o. b. the plant and contracts were in force covering all production for a term of years, thus eliminating the question of selling expenses.

Coal Washeries and Coke Ovens

The coal washery is an adjunct of the coke ovens and the cost of producing coke should include the expenses of both divisions. In addition to the data showing quantities of coke produced, a memorandum should show the actual production as compared with the theoretical yield. The total weight of the coal less the ash and certain minor properties contained therein should approximate the weight of the coke. The gases given off, which are made into coal tar and sulphate of ammonia, account for most of the difference between the weight of coal charged and coke produced.