practice in a small foundry, where it is not possible to secure the economies easily attained in large shops equipped with a number of furnaces, and not subject to delays, wide variations in output, etc. The figures here given are intended to represent conservative estimates of cost, that will not often be exceeded, rather than the much lower figures that can be attained when the process is being run under more nearly ideal conditions.

Costs of steel per gross ton in a 15-ton basic open-hearth furnace, burning producer gas and making 15 heats per week, or 225 gross tons.

RAW MATERIAL, assuming a conversion loss of 5 per cent., and using 40 per cent. pig, 30 per cent. purchased scrap, and 30 per cent. shop scrap.

Fifteen tons÷.95=15.79 tons, of which .135 will be ferros, leaving 15.655 tons, of which

6.262 tons will be pig,
4.6925 tons will be purchased scrap,
4.6925 tons will be shop scrap.

6.262	tons basic pig at $15.00,	= $94.00
4.6925	tons purchased scrap at $10.00	= 46.93
4.6925	tons shop scrap at $14.00,	= 65.70
.075	tons ferromanganese at $50.00	= 3.75
.06	tons ferrosilicon at $75.00,	= 4.50
		$214.88 or for 15 tons $14.33 per ton

LABOR PER WEEK

2 melters at $150 per month,	= $69.23
2 second helpers at $2.50 per day,	= 35.00
2 ladle men at $3.00 per day,	= 36.00
2 gas makers at $2.50 per day,	= 35.00
4 common laborers at $2.00 per day,	= 48.00
	$223.23

Production per week 15×15=225 tons. $\frac{223.23}{225}$=$.99 per ton

SUMMARY	Per ton steel tapped
Raw material	$14.33
Labor	.99
Coal, 700 lb. at $3.00	.94
Yard labor	.15
Repairs and maintenance	.75
Supplies and miscellaneous	.75
Management 50 per cent. of labor	.47
	$18.38

Interest and depreciation, 15 per cent. on $65,000=$9750 per year. At 225 tons per week, 48 weeks per year, we produce 10,800 tons of steel. This item then amounts to about $.90 per ton, bringing our total cost to $19.28 per gross ton.

Estimating 60 per cent. good castings, 40 per cent. scrap, we have $\frac{19.28}{.60}$=$32.13 per ton of good castings, less credit for .40 ton scrap at $14 per ton = $5.60, or $26.53 per gross ton of good castings.

W. M. Carr gives in his book, "The manufacture of open-hearth steel castings," the following figures on the cost of installation of open-hearth plants, on which the above estimate is based.

ITEM	Cost of installation per ton of steel
Basic furnace	$1200
Gas producers, etc	600
Power, machinery, cranes, etc	2300
	$4100

On this basic, a 15-ton furnace will cost $61,500, not including buildings.

Costs of steel per gross ton in a 15-ton acid open-hearth furnace, burning producer gas and making 16 heats per week or 240 tons.

RAW MATERIAL, assuming a conversion loss of 4 per cent., and using 20 per cent. pig, 30 per cent. shop scrap and 50 per cent. purchased scrap.

Fifteen tons÷.96=15.63, of which .22 tons will be ferros, leaving 15.41 tons, of which

3.08 tons will be pig,
4.63 tons will be shop scrap,
7.70 tons will be purchased scrap.

3.08 tons low phosphorus pig at $22.00	$67.76
4.63 tons shop scrap at $13.00	60.19
7.70 tons low phosphorus scrap at $14.00	107.80
.09 tons ferrosilicon at $75.00	6.75
.13 tons ferromanganese at $50.00	6.50
	$249.00 or $16.60 per ton

LABOR

$223.23÷240=.93 per ton

SUMMARY	Per ton steel tapped
Raw material	$16.60
Labor	.93
Coal	.94
Yard labor	.15
Repairs and maintenance	.60
Supplies and miscellaneous	.60
Management 50 per cent. of labor	.47
	$20.29

Interest and depreciation, 15 per cent. on $60,000=$9000 per year. At 240 tons per week, 48 weeks per year, we produce 11,520 tons of steel. This item then amounts to $.78 per ton, bringing our total cost to $21.07 per ton of steel in ladle.

Estimating 60 per cent. good castings, 40 per cent. scrap, we have $\frac{21.07}{.60}$=$35.12 per ton of good castings, less credit for .40 tons scrap at $13.00 per ton=$5.20, or $29.92 per gross ton of good castings.

W. M. Carr (*loc. cit.*) gives cost of installation of acid open-hearth plants, not including buildings, as follows:

ITEM	Cost of installation per ton of steel
Acid furnace	$1000
Gas producers, etc	600
Power, machinery, cranes, etc	2300
	$3900 or for a 15 ton furnace, $58,500

Costs of steel per gross ton in a 3-ton bottom-blown Bessemer vessel, making 15 heats per day or 45 tons.

RAW MATERIAL, assuming a melting and conversion loss of 12 per cent., and using 60 per cent. pig, 30 per cent. shop scrap, 10 per cent. purchased scrap.

Three tons÷.88=3.41 tons, of which .05 tons will be ferros, leaving 3.36 tons, of which

2.016 tons will be pig,
1.008 tons will be shop scrap,
0.336 tons will be purchased scrap.

2.016 tons low phosphorus pig at $22.00	$44.35
1.008 tons shop scrap at $13.00	13.10
0.336 tons low phosphorus scrap at $14.00	4.70
0.024 tons ferrosilicon at $75.00	1.80
0.026 tons ferromanganese at $50.00	1.30
	$65.25 or $21.75 per ton

LABOR	Per day
Charging cupola and yard, 4 men at $2.00 per day	$8.00
1 cupola tender at $3.00 per day	3.00
1 cupola tender helper at $2.00 per day	2.00
4 vessel men at $2.50 per day	10.00
1 blower at $5.00 per day	5.00
	$28.00 or $.62 per ton

SUMMARY	Per ton of steel in ladle
Raw material	$21.75
Labor	.62
Fuel, $\frac{1}{6}$ ton coke at $5.00	1.00
Repairs and maintenance	.40
Supplies and miscellaneous	.25
Power	.20
Management 50 per cent. of labor	.31
	$24.53

Interest and depreciation, 15 per cent. on $35,000=$5250 per year. At 300 days per year, 45 tons per day, we produce 13,500 tons of steel. This item then amounts to $.39 per ton, bringing our total cost to $24.92 per gross ton of steel in ladle.

Estimating 60 per cent. good castings, we have $\frac{24.92}{.60}$=$41.53 per ton of castings, less credit for scrap, .40 tons at $13.00=$5.20, giving us $36.33 per gross ton of good castings.

Costs of steel per gross ton in two 2-ton side-blown Bessemer vessels, making 10 heats per day, or 20 tons.

RAW MATERIAL, assuming a melting and conversion loss of 16 per cent., and using 50 per cent. pig, 30 per cent. shop scrap and 20 per cent. purchased scrap.

Two tons÷.84=2.38 tons, of which .034 tons will be ferros, leaving 2.346 tons, of which

1.173 tons will be pig,
.7038 tons will be shop scrap,
.4692 tons will be purchased scrap.

1.173 tons low phosphorus pig at $22.00	$25.81
.7038 tons shop scrap at $13.00	9.15
.4692 tons low phosphorus scrap at $14.00	6.57
.016 tons ferrosilicon at $75.00	1.20
.018 tons ferro manganese at $50.00	.90
	$43.63 or $21.82 per ton

Labor	Per day
Charging cupola and yard, three men at $2.00 per day	$6.00
1 cupola tender at $3.00 per day	3.00
1 cupola tender helper at $2.00 per day	2.00
2 vessel men at $2.50 per day	5.00
1 blower at $5.00 per day	5.00
	$21.00 or $1.05 per ton

Summary	Per ton of steel in ladle
Raw material	$21.82
Labor	1.05
Fuel 1/5 ton coke at $5.00	1.00
Repairs and maintenance	.50
Supplies and miscellaneous	.25
Power	.25
Management 50 per cent. of labor	.53
	$25.40

Interest and depreciation, 15 per cent. on 25,000=$3750 per year. At 300 days per year, 20 tons per day, we shall produce 6000 tons of steel. This item then amounts to $.63 per ton of steel, bringing our total cost to $26.03 per gross ton of steel in the ladle.

Estimating 60 per cent. good castings, we have $\frac{26.03}{.60}=\$43.38$ per ton of castings, less credit for scrap, .40 tons at $13 =$5.20, or $38.18 per gross ton of good castings.

Costs of steel per gross ton in a 5-ton electric furnace, melting cold scrap, working double turn and making 15 heats per week.

Raw Material	
.60 ton high phosphorus scrap at $10.00	$6.00
.40 ton shop scrap at $14.00	5.60
	$11.60 per ton

Labor	Per week
2 melters at $150 per month	$69.23
2 helpers at $4.00 per day	48.00
2 helpers at $2.50 per day	35.00
	$152.23 or for 75 tons $2.03 per ton

Summary	Per ton of steel in ladle
Raw material	$11.60
Labor	2.03
Power, 900 kw.-hr. at .015	13.50
Electrodes	1.50
Repairs and maintenance	1.00
Supplies and miscellaneous	0.75
Yard handling	0.25
Management 50 per cent. of labor	1.02
	$31.65

Interest and depreciation, 15 per cent. on $30,000=$4500 per year. At 75 tons per week, 48 weeks per year, we produce 3600 tons of steel. This item then amounts to $1.25 per ton, bringing our total cost to $32.90 per gross ton of steel in the ladle.

Estimating 60 per cent. good castings, we have $\frac{32.90}{.60}=\$54.83$ per ton of good castings, less credit for scrap, .40 ton at $14.00 per ton or $5.60, giving us $49.23 per gross ton of good castings.

Costs of steel per gross ton in a 5-ton electric furnace, refining molten Bessemer or open-hearth metal, and making 55 heats per week or 275 tons.

Labor	Per week
2 melters at $150 per month	$69.23
2 helpers at $4.00 per day	56.00
	$125.23 or for 275 tons, $.46 per ton

Summary	Per ton of steel in ladle
Labor	$ .46
Power, 300 kw.-hr. at .015	4.50
Electrodes	.35
Repairs and maintenance	.25
Supplies and miscellaneous	.50
Management 50 per cent. of labor	.23
	6.29

Interest and depreciation, $4500 per year. At 275 tons per week, 48 weeks per year, we produce 13,200 tons of steel. This item then amounts to $.34 per ton, bringing our cost to $6.63 per ton. This is to be added to the cost of open-hearth or Bessemer metal in the ladle.

In the case of Bessemer metal, the credit for shop scrap, and also the value of scrap charged to the vessel, should be taken on a basis of about $14.00 per ton of scrap, because low phosphorus steel will be made in the electric furnace.

Costs of steel per gross ton in a 20-pot crucible steel plant, using coal holes and making 2 heats per day. Pots containing 100 lb. of steel each, bringing our output to 4000 lb. of steel per day. Pots will average 3 heats each.

RAW MATERIAL

59 lb. low phosphorus boiler plate punchings at $13.00	$.3424
1 lb. washed metal at $25.00	.0112
40 lb. shop scrap at $13.00	.2321
½ lb. ferromanganse at $50.00	.0112
½ lb. ferrosilicon at $75.00	.0167
	$.6136 or $.006136 per lb.

LABOR

	Per day
1 melter at $5.00 per day	$5.00
1 pot puller at $3.75 per day	3.75
1 helper at $2.75 per day	2.75
1 helper at $2.00 per day	2.00
	$13.50 or $.003375 per lb.

POTS

1 pot worth $2.00 makes 300 lb. of steel. Pots, therefore, amount to .006666 per pound of steel.

SUMMARY

	Per pound of steel
Raw material	$.006136
Labor	.003375
Pots	.006666
Repairs and maintenance	.001000
Management 50 per cent. of labor	.01678
	$.018855 or $42.24 per ton

	Per ton of steel
Items above	$42.24
Fuel, 4 tons hard coal at $4.00	16.00
Supplies and miscellaneous	1.00
Power	.60
	$59.84 per ton of steel in pot

Interest and depreciation, 15 per cent. or $5000, amounts to $750 per year. At 4000 lb. of steel per day, 300 days per year, we shall produce 536 tons per year. This item therefore amounts to about $1.40 per ton, bringing our total cost to $61.24 per gross ton of steel in the pots.

Estimating 60 per cent. of good castings, we have $\frac{61.24}{.60} = \$102.07$ per ton of good castings, less credit for scrap, .40 ton at $13.00 per ton, $5.20, bringing our total cost to $96.87 per gross ton of good castings.

Costs of steel per gross ton in a 30 pot regenerative crucible furnace, burning producer gas, and making 6 heats per 24 hours. Production 18,000 lb. per day. Pots will average 3½ heats each.

LABOR

	Per week
2 melters at $5.00 per day	$60.00
4 pot pullers at $3.75 per day	90.00
2 helpers at $2.75 per day	33.00
2 gas men at $2.50 per day	35.00
2 gas men at $2.00 per day	28.00
	$246.00 or for 108,000 lb. of steel, $.002277 per lb.

POTS

1 pot worth $2.00 makes 350 lb. of steel. Pots, therefore, amount to $.005714 per pound.

SUMMARY

	Per pound of steel
Raw material (as before)	$.006136
Labor	.002277
Pots	.005714
Management 50 per cent. of labor	.001139
	$.015266 per pound or $34.20 per ton

	Per ton of steel
Items above	$34.20
Repairs and maintenance	1.00
Fuel, 1500 lb. gas coal at $3.00 per ton	2.00
Supplies and miscellaneous	.75
Power	.20
	$38.15

Interest and depreciation, 15 per cent. on $30,000, amounts to $4500 per year. At 18,000 lb. per day, 300 days per year, we shall produce 2410 tons of steel. This item therefore amounts to about \$1.87 per ton, bringing our total cost to \$40.02 per gross ton of steel in pots.

Estimating 60 per cent. of good castings, we have $\frac{40.02}{.60} = \$66.70$ per gross ton of good castings, less credit for scrap, .40 ton at \$13.00 per ton, \$5.20, bringing our total cost to \$61.50 per gross ton of good castings.

SUMMARY

	Per ton molten steel	Per ton good castings
Basic open hearth	\$19.28	\$26.53
Acid open hearth	21.07	29.92
Bottom-blown Bessemer	24.92	36.33
Basic open hearth and electric	25.91	....
Side-blown Bessemer	26.03	38.18
Electric—cold scrap	32.90	49.23
Crucible—30-pot gas furnace	40.02	61.50
Crucible—coal holes	61.24	96.87

Thus we see that the cost of the steel will run from about 1.2 cents to about 4.3 cents per pound of good castings. As casting prices range from about $3\frac{1}{2}$ cents on large tonnages of simple work to 12 or 15 cents for what is generally considered average light work, it will be seen that the costly crucible process can be used only for the latter class of material, and that on the cheaper grades of castings generally produced in bulk, it is impossible to figure a profit with Bessemer or electric furnaces. The open-hearth foundries producing in bulk can shade the price the small amounts necessary to attract purchasers of heavy tonnages, and live.

A 6. Tonnage.—The yearly tonnage to be produced affects rather the size and number of the furnaces to be installed than the choice of a process, as a little consideration of the foregoing discussion will show.

Production per week for the different processes is about as follows:

3-ton bottom-blown Bessemer	90–120 heats,	270–360 tons (single turn)
15-ton open-hearth furnace	15– 18 heats,	225–270 tons (double turn)
Two 2-ton side-blown Bessemer	72 heats,	144 tons (single turn)
One 5-ton electric furnace, melting and refining	15 heats,	75 tons (double turn)
One 5-ton electric furnace, refining only	55 heats,	275 tons (double turn)
30-pot gas crucible furnace	36 heats,	48.2 tons (double turn)
20-pot coal hole crucible furnace	12 heats,	10.7 tons (single turn)

The crucible process, of course, can be used only for high-priced castings, and no possible increase of production can bring the costs down so that with this process we can compete with the others on tonnage work. In the case of the open-hearth furnace, tonnage determines only size and number of furnaces. Though an increase of tonnage would somewhat reduce the cost of Bessemer metal, the small vessels can never be brought in direct competition with open-hearth foundries, as the cost of steel does not decrease with the tonnage produced in the same proportion as in open-hearth shops. The Bessemer foundries therefore compete with crucible shops and with the best of the acid open-hearth steel makers.

The position of the electric furnace is as yet indeterminate. As a melter and refiner in small units, it is at a disadvantage compared to Bessemer shops, yet can compete with them. To run large units, melting and refining cold stock, considerably decreases the cost of the metal, but leads to a state of affairs in which, owing to the bulk of steel to be handled per heat, the production of small castings is far from easy; and the production of tonnage work is not economical since the cost of the metal is much higher than that of open-hearth steel, and the margin of profit on this cheap work too small to permit of successful competition. By refining basic open-hearth metal, the electric furnace can be brought into competition with Bessemer shops, and therefore, as an adjunct of a steel foundry handling heavy work, can do effective service in allowing the shop to get into the small casting or specialty field. Habit is compelling, however, and the tonnage shop trying to handle the small casting business frequently fails because the management will not pay the minute attention to detail necessary to success in this field.

To refine open-hearth metal in a large electric furnace and produce heavy castings is not economical, since the steel still costs some 4 or 5 dollars per ton more than open-hearth metal, and the position of a large electric furnace refining open-hearth metal and producing heavy castings of a grade of steel too good for the market is thus a poor one strategically.

In electric-furnace installations, therefore, the indications seem to point to the advantage of using the largest units that can be employed and still pour small castings; taking advantage of the comparatively large size to reduce costs of metal as much as possible, and selling in a specialty or jobbing market to obtain good prices for the output.

B. Raw Material and Fuel most Available.—In the older iron-making centers raw material for any of the processes is readily available, and hence is a secondary consideration in the choice of a process. Fuels may not be readily obtainable at a price to allow of the use of a process in a particular locality, especially where competing shops are already intrenched. This is especially the case with the electric furnace, whose fuel is electric power which it uses most uneconomically as compared with many of the other processes, in places where power must be generated from coal. The raw materials and fuels used in the processes are as follows:

Process	Fuel	Raw material
Crucible	Anthracite coal or coke Producer gas (soft coal) Natural gas Oil	Puddled iron. Charcoal iron. Open-hearth scrap. Washed metal (or charcoal).
Bessemer	Coke (in the cupola) Power to drive blowing engines and compressors obtained from coal, gas, oil, water, etc.	Low phosphorus pig. Low phosphorus scrap.
Electric	Electric power, obtained from coal, natural gas, blast-furnace gas, coke-oven gas, oil, water.	(Basic pig), and High phosphorus scrap, or Bessemer or open-hearth metal, or (Low phosphorus pig), and Low phosphorus scrap.
Basic open hearth	Producer gas Natural gas Oil (Coke-oven gas), etc	Basic pig. High phosphorus scrap.
Acid open hearth	As above	Low phosphorus pig. Low phosphorus scrap.

It is apparent that only in exceptional cases will the fuel and raw material available be the chief determining factor in the choice of a steel-making process. So many fuels can be used for each process that only in comparatively rare cases will only one be available, and even then this fuel will almost always be capable of use for several processes.

Electric power is frequently available at comparatively low figures in districts where mineral fuels are costly, as for instance on the Pacific coast of the United States and Canada. In such cases the

disadvantage under which the electric furnace labors in more favored districts may be entirely eliminated, and conditions point conclusively to the necessity of adopting this process to the exclusion of any other, on considerations of fuel alone. When it is remembered that for Bessemer practice the only fuel needed is the comparatively small amount of coke or coal used to melt pig iron in the cupola, or oil to melt it in a separate furnace or in the vessel, it will be seen that the mineral fuel must be very expensive and power very cheap, for this to be the case. The open-hearth furnace is so easily handled with oil, a very concentrated fuel, that it is rare for electric-furnace steel to be cheaper than open-hearth.

Again, where pig iron is extremely costly and scrap abundant and cheap, pig-iron consuming processes are at a disadvantage. This generally affects only the Bessemer process, leaving the choice among the other three open.

Even here, however, the problem can frequently be rendered soluble with the Bessemer process by melting almost all scrap in the cupola, and obtaining the silicon necessary for the process from small amounts of ferrosilicon melted with the charge in the cupola, or melted separately and added before charging the mixture into the vessel. In this way, by paying freight on the silicon necessary for producing heat in the vessel, in very condensed form, the Bessemer process may be made applicable in the face of great scarcity of pig iron.

At least one process exists for adding carbon to steel scrap in the open-hearth furnace in the form of coke or some such substance, and thereby greatly reducing the amount of pig iron needed in the pig and scrap process. Thus, on our Pacific coast, advantage is taken of abundant oil fuel and cheap scrap to conduct the manufacture of open-hearth steel quite cheaply. With cheap oil and electric power and abundant scrap, the coast should in a very few years make itself independent of the East in steel castings.

C. Capital Available.—This is a question, of course, of first cost of plant, and is too often the cause of disaster with companies started with insufficient knowledge of the conditions to be faced. The processes, in order of their first cost of installation, the cheapest first, are as follows:

1. Crucible—coal holes.
2. Side-blown Bessemer.
3. Electric—(not counting power-house).
4. Crucible—gas furnace.

5. Bottom-blown Bessemer—(including engines, boilers, etc.).
6. Open hearth.

From the point of view of the installation costs per ton of steel, however, as the figures already given show, this order is quite different. For convenience, the processes are again tabulated below, in order of installation cost per ton, as estimated above.

Process	Interest and depreciation per ton
Electric furnace, refining hot metal	$ .34
Bottom-blown Bessemer	.39
Side-blown Bessemer	.63
Acid open-hearth	.78
Basic open-hearth	.90
Electric furnace, melting cold scrap	1.25
Crucible, coal holes	1.40
Crucible, gas furnace	1.87

While there is much to be said in favor of starting a specialty or jobbing business on a small scale, especially when the men in charge are not thoroughly familiar with the work to be handled, it is easy to overdo this and start with so little capital that before the difficulties are all understood and overcome the management finds itself embarassed from lack of funds. Thus if we mean to run a gas crucible steel furnace of 30 pots, and start our business with four or five coal holes, it is necessary to figure on a largely increased cost of metal at the start, and we may find it takes very much longer than we had expected to accumulate the earnings counted on to build the larger plant. As a general rule, however, the safest plan is to start with the same process we intend to use ultimately, since each process has its peculiarities that must be mastered, and the experience gained with the small plant is useful with the larger one.

D. Competition.—A very few words must dispose of this heading, since it is too much a matter of plain business sense to need exposition.

Frequently, in a field already covered by tonnage foundries a good deal of business in small jobbing work can be picked up. To start a small plant to take care of such business is frequently profitable, since the work is generally high priced. It must be remembered, however, that it is "turned down" by the tonnage foundries because it is hard to make, hence it will not be plain sailing to turn out the castings. Moreover, the field will seldom be a large one and therefore the business can be handled only with a small tonnage equipment.

It is almost unnecessary to point out, after what has preceded, that to enter into competition with a firm well intrenched in a particular line, with a more expensive process than the competitor is using, is almost always suicidal, since extra prices are not commonly paid for superior steel, if the established firm makes good sound castings. The new concern will get chiefly the "cats and dogs" turned down by the older shop, on which it is difficult to make a profit; and to try to get business by price concession is fatal, since the other fellow with his cheaper process can stand more than the newcomer in that line. Should one find that his shop has inadvertently got into such a situation, there are generally but three things to do—take the scrapings of the business, which if the controlling shop in the field carries on a tonnage business will often support a small concern; get some good specialties; or shut up shop.

E. Labor Available.—In districts where steel making is new, it is as easy to train men to one steel-making method as to another. Experienced men must be imported to start operations, but generally will not stay. The management must count, therefore, on training the local labor as rapidly as possible.

In the older steel-making districts, labor will frequently be available that understands one or two processes, but not the others. This is especially true of the electric furnace and of special designs of old types, as for instance the Krupp type of crucible furnace; trained labor for either is hard to get. Should the case for two processes be otherwise about even, a lack of men that understand one of them should at once put that process or special design of furnace out of the running. At times the difficulty of obtaining men to handle a process unfamiliar to the labor of the locality will even be found to convert a supposed superiority of a special design of furnace into a decided inferiority from the point of view of economical production of steel.

F. Intermittent or Steady Operation.—If the furnace can be kept going steadily, with no shut downs, any process may be used. Regenerative gas-fired furnaces (open hearth and crucible) cannot be shut down and started up again without great expense, and must be kept constantly hot. They are, therefore, best suited to double-turn operation at their maximum capacity. Operated single turn, the cost of steel will be greatly increased—and short shut downs will be costly, both because the furnace must be kept hot, and because to keep an expensive furnace idle runs rapidly into money.

The Bessemer converter is well suited to intermittent operation, and lends itself readily to very considerable fluctuations in the daily tonnage produced. The side-blown equipment being cheaper than the bottom-blown is less affected by shut downs.

Oil or coal burning crucible furnaces can be operated intermittently as easily as continuously, and their installation cost is so low that shut downs are relatively inexpensive.

Electric furnaces can be operated intermittently, but had far better be kept constantly hot, since the power consumed in heating them up is considerable, and the wear and tear on the furnace due to heating and cooling is severe. That shut downs of large (and hence costly) electric furnaces greatly increase the cost of metal, goes without saying.

SUMMARY

Process	Quality	Flexibility	Suitability for small work	Cost of steel	Tonnage	Cost of installation	Cost of installation per ton
	1 best	1 most flexible	1 most suitable	1 lowest	1 highest	1 lowest	1 lowest
Crucible	2	1	1	6	5	1	6
Electric	1	2	2	5	4	3	5
Acid open-hearth	3	4	5	2	1	5	3
Basic open-hearth	4	4	6	1	1	5	4
Side blown Bessemer	6	3	3	4	3	2	2
Bottom blown Bessemer	5	3	4	3	2	4	1

Note.—Electric furnace refining basic open-hearth steel stands between No. 3 and No. 4 in cost of steel.

Note.—Gas-fired crucible furnace stands between 3 and 4 in cost of installation.

Note.—Electric furnace refining hot metal stands No. 1 in cost of installation per ton.

CHAPTER III

THE CRUCIBLE PROCESS

The crucible process is the oldest of the steel-making methods now extensively used, and like practically all our modern processes is "indirect"; that is, steel is produced from some other product derived from the iron ore.

In very early times, both steel and iron were produced directly from the ore in open forges. These consisted essentially of an open basin or hearth in which very pure iron ore was heated in contact with a large excess of charcoal, the fires being blown with bellows or other primitive means of producing blast. Part of the ore was reduced by solid carbon, according to the usual formula,

$$FeO + C = Fe + CO,$$

while a considerable amount of the FeO combined with the silica, lime, etc., of the gangue of the ore to form a fluid or pasty slag. The metal obtained from these forges was in the form of a coagulated mass of small particles, much like a puddled "ball," and was hammered to squeeze out the slag contained in the interstices, cut into pieces, heated to welding and rehammered, until a fairly pure and uniform bar was obtained. If the metal absorbed much carbon from the charcoal a steel of varying degree of hardness was obtained. As a rule, however, soft, carbonless iron was the product desired, and in order to convert this into steel it was heated in a bed of charcoal out of contact with the air until it was cemented or case hardened to the center.

Later, the soft iron used for cementation was produced from the new product, pig or cast iron, by melting a bar of pig iron with a charcoal fire in an open hearth, and allowing the slowly melting iron to trickle down through the air blast used. By the oxidizing action of the blast, the carbon, silicon, manganese, sulphur and phosphorus of the pig were eliminated and nearly pure iron was obtained in a sponge of coagulated particles and slag, which was worked up as before. By this method also either iron or steel could be obtained, but iron was the usual product. This is the principle of the Walloon