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Second Interregional Symposium
on the Iron and Steel Industry

Moscow, USSR, 19 September – 9 October 1968

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POSSIBILITIES OF DEVELOPING AN IRON AND STEEL INDUSTRY WITH OTHER THAN FULLY INTEGRATED PLANTS [1/]

by

R. Tietig, Jr.,
United States of America

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by

Rudolph Tietig, Jr.,
Oakland, California

SUMMARY

A fully integrated plant is defined as one that has blast furnaces, coke ovens, steelmaking furnaces, and rolling and finishing facilities. It also could have a direct reduction or metallizing plant for iron ore or concentrates in place of the blast furnaces and coke ovens, and under special circumstances, electric smelting furnaces. In contrast, a semi-integrated plant starts with steelmaking furnaces, and a non-integrated plant has only rolling and/or finishing facilities.

* This is a summary of a paper issued under the same title as ID/WG.14/13.

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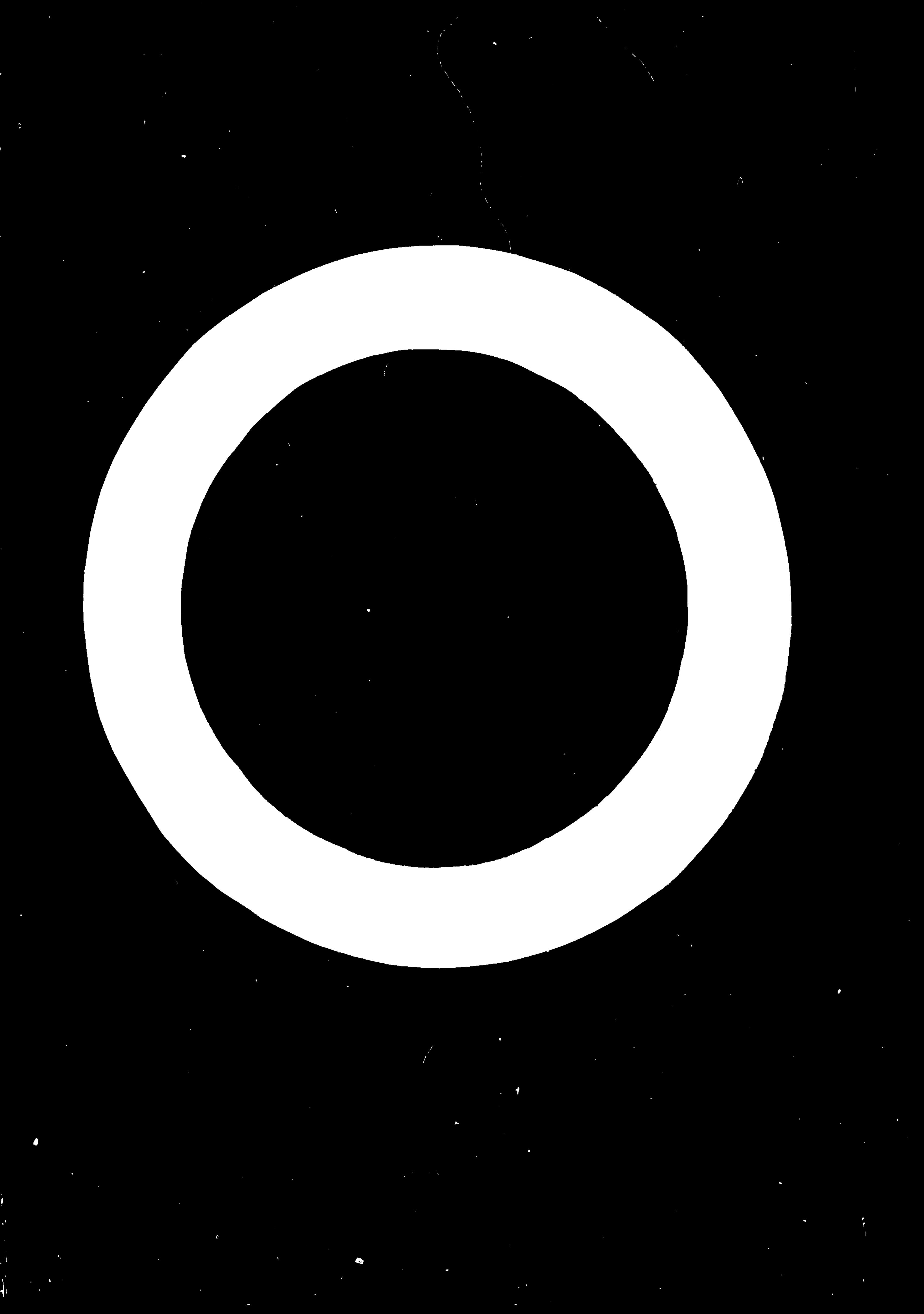


An efficient, present-day integrated plant with blast furnaces should have an initial capacity of at least 2,000,000 MT of raw steel per year. Capital costs are high, and the plant must be supported by an adequate market to permit near capacity operations. Steps of incremental expansion would be in the order of magnitude of 1,000,000 of raw steel capacity MT per year. Because of the large fixed capital charges, such plants are not, economically feasible unless they maintain a high level of production. For example, with 75 per cent of a new plant financed by loans at a low interest rate of 6.0%, there would be a loss even when the production level of the plant is at 90 per cent of capacity.

The capacity of the other type of integrated plant with direct reduction facilities for iron ore or possibly electric smelting furnaces would be much smaller, possibly as low as 100,000 MT of raw steel per year. However, such a plant with direct reduction facilities must have a source of iron ore or concentrates averaging 65 per cent iron or more and have available a reducing agent of high heat value and low sulfur content; this agent may be coal, oil, or natural gas. This type of plant should be located near a supply of labour and potential steel consumers.

Based on 1965 imports, there are six countries that might justify fully integrated plants having blast furnaces; these countries together with their 1965 imports of steel are as follows:

East Germany	2,063,100 MT
Federal Republic of Germany	5,660,800 MT
France	3,892,900 MT
Netherlands	2,528,900 MT
Spain	2,014,100 MT
United States	9,301,000 MT

Japan, with its remarkable industrial growth, should also be added. All these countries have established iron and steel industries.

Regarding small integrated plants based on direct reduction processes, only five countries fulfil the necessary requirements of having a high grade iron ore, an adequate reductant, and a suitable location. They are China (Mainland), Mexico, South Africa, Union of Soviet Socialist Republics, and the east and west coasts of the United States. Again, each of these countries has a developed steel industry. Therefore it is concluded that there is no country without an established steel industry that should consider a fully integrated steel plant either large or small.

However, there are several countries where there is a possibility of establishing a steel industry with semi-integrated or non-integrated plants. Because of the relationship between product mix and the capacities of steel-making processes, continuous casting, and rolling mills, only countries having imports of 200,000 MT per year and not having a large-scale steel industry should be considered. Using the United Nations figures for 1965, there are only 11 countries known to be in the above category; they are:

Hong Kong	Indonesia
Iran	Israel
Lebanon	Malaysia
Nigeria	Pakistan
Peru	Saudi Arabia
Thailand	

In all of these countries, there is a market for light sections, bars, and wire rod that could support an electric furnace, continuous casting, and a bar and rod mill complex. However, these countries could not support a semi-integrated plant making such other steel products as sheet, plate, and pipe, because capacities of the necessary rolling mills are too great.

Initially, the plant might ship about 72,000 MT of products per year and have a capacity of about 93,000 MT of products. Such a plant could be expanded in incremental steps of about 110,000 MT of raw steel capacity per year to about 279,000 MT of products per year which is about the capacity of a modern bar and rod mill.

Facilities for the first step would consist of a 34-MT electric furnace, a three-strand continuous casting machine, a merchant bar and rod mill, and bar finishing facilities. The mill would be adequate for plant expansion.

Ultimately, the plant would consist of three 34-MT furnaces, two 3-strand continuous casting machines for billets, the initial bar and rod mill, and additional finishing facilities. Product mix would consist of:

Structural Shapes	3 x 3 in. Max. Angles
Carbon bars	3 in. Max. diameter
Reinforcing Bars	1-1/2 in. Max. diameter
Wire Rods	7/32 in. Min. diameter

The basic raw material for this plant would be reduced iron ore (94% Fe) as sized lumps or pellets suitable for continuous charging into an electric furnace. This material is not yet available in large quantities on the world market; however, there are in advanced stages of planning projects to produce such a material in quantities of 1,000,000 MT or more per year. It would be priced below that of imported No. 1 Heavy Melting Scrap, which is estimated to have an average delivered cost of at least $42.50 per MT in the 11 countries listed as having a potential for a semi-integrated plant.

When reduced iron ore lumps or pellets are charged in the electric furnace by the new continuous charging technique, they could comprise as much as 70% of the charge, and heat times might be reduced by as much as 40% compared with the conventional all-scrap charge. A similar advantage is not possible if the material is used in a cold-charge open hearth or in the cupola of a cupola L-D steelmaking combination. It is for the above reasons that reduced iron ore and electric furnaces are recommended. These reasons are probably the most important factor in the success of a semi-integrated plant. The direct production costs for each of the three incremental steps by which the plant might be established and expanded are estimated to be as follows:

Step I -	$93.29 per MT of Product
Step II -	$88.85 per MT of Product
Step III -	$87.79 per MT of Product

These costs do not include selling and administrative expense (estimated to be $6.00 per ton of product) and fixed charges.

The fixed charges would be based on the following estimated total capital expenditures that would have been made for the initial stage and two expansion steps:

Step I -	$38,300,000
Step II -	$42,200,000
Step III -	$60,400,000

The Step II and III figures include all previous expenditures.

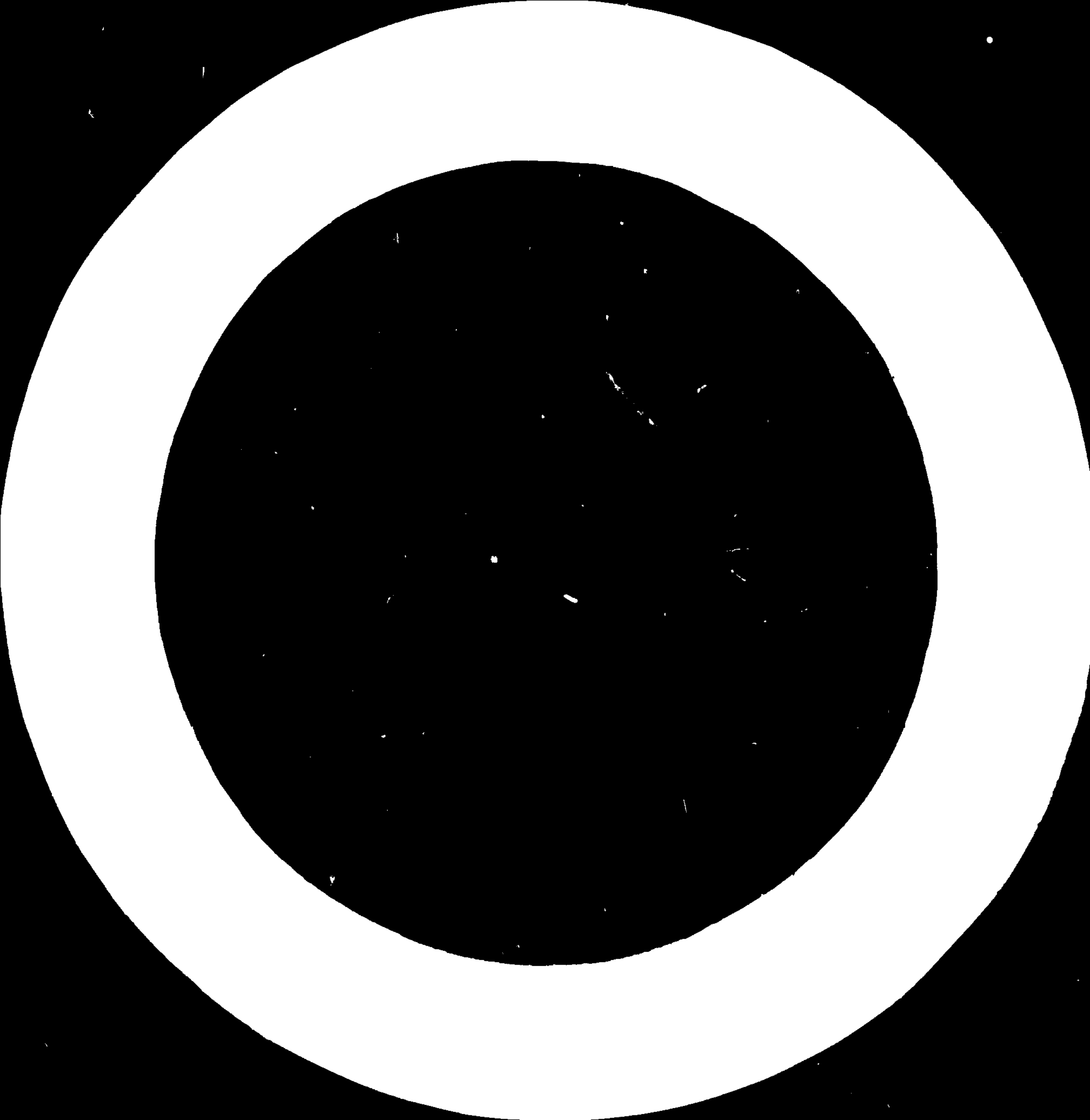
Assuming 4.0% for depreciation and a loan of 60% of the required investment capital at a low rate of 6.0% interest, the total cost of product including direct production costs, selling, and administrative expense would be as follows for various levels of production:

Step I at 72,000 MT per year	$139.72 per MT Product
Step I at capacity (92,900 MT per year)	$130.62 per MT Product
Step II at 144,000 MT per year	$117.12 per MT Product
Step II at capacity (185,800 MT per year)	$112.12 per MT Product
Step III at 216,000 MT per year	$116.04 per MT Product
Step III at capacity (278,000 MT per year)	$110.26 per MT Product

These costs should be compared with the delivered prices presently being paid for similar products by each of the countries being considered to determine the economic feasibility of a semi-integrated plant for bar products and wire rods.

Besides the semi-integrated plant, some consideration should be given to the potential for non-integrated plants. If the products are to be small shapes, bars, and wire rod rolled on a mill similar to that of the semi-integrated plant, the economic advantages are less for the non-integrated plant than if steelmaking facilities are included. Assuming the price for re-rolling billets to be the same as in the United States, (currently $98.08 per MT) plus $15.00 per MT average shipping charges, $6.00 per MT for selling and administrative expense, and fixed charges on a lower capital investment of $27,000,000 production costs would be higher than for the semi-integrated plant. For the six levels of production previously shown, the weighted average for the non-integrated plant would be $130.48 per MT compared with $117.56 per MT for the semi-integrated plant, or $12.92 per MT more.

However, there are certain other situations where a non-integrated plant might be feasible. For example, Iran and Saudi Arabia each had imports of more than 100,000 MT of tubular products in 1965. Some of these products could be made on an electric-weld pipe mill by importing wide, hot-rolled skelp as coils, although the economics of this operation has not been explored in this paper. Another possibility that requires further investigation is that several of the 11 countries each imported more than 100,000 MT of sheet in 1965. This might indicate a potential for a sheet galvanizing installation. Generally, however, the non-integrated plant does not seem to have the possibilities of a semi-integrated plant, particularly if it is based on the new developments in which a reduced or metallized iron ore is fed continuously into an electric furnace. Therefore, it is concluded that there are several countries in which a steel industry might be developed that does not involve a fully integrated plant.



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DEFINITIONS

In order to discuss adequately the subject of this paper, some definitions are necessary. They pertain to the use of the words "integrated," "semi-integrated," and "non-integrated" in connection with both a steel plant and a steel company.

The American Iron and Steel Institute (AISI) terms a fully integrated plant as one that has blast furnaces, coke ovens, steelmaking furnaces, and rolling and finishing facilities. However, to this list should be added a plant that has direct reduction, sometimes called metallizing facilities, for iron ore treatment instead of blast furnaces and coke ovens. In this latter type of plant, the reduced or metallized product which is not molten should be suitable for charging into steelmaking furnaces or into cupolas for the production of iron equivalent to blast furnace metal. It should also be noted that there is a third type of integrated plant in which iron ore is reduced to molten pig iron by electric smelting with or without some pre-reduction. Such a plant has a limited application, requires an extremely low price for power, and is not considered in this paper.

The next definition is that of a semi-integrated plant which is termed by the AISI as one that has only steelmaking furnaces and rolling and finishing facilities. There is also the non-integrated plant which has only rolling and finishing facilities.

Finally there is what may be termed an integrated steel company. Such a company may have plants in all three of the above categories, and in addition, has or controls iron ore, coking coal, and possibly limestone properties.

As is indicated by its title, this paper discusses primarily the semi-integrated and non-integrated plants. However, some attention is also given to the fully integrated plant, particularly with respect to the burdens that full integration impose in developing an iron and steel industry.

BURDENS OF INTEGRATION

The usual burdens of an integrated plant are first the enormous capital expenditure involved, second the size of the market necessary to support such an operation, and third the problems of incremental growth. For an integrated company there are the additional burdens of securing and developing sources of ore, coal, and limestone.

By present day standards, a fully integrated well balanced plant with blast furnaces should have a capacity of at least 4,000,000 NT* of liquid steel per year. A typical flow diagram for such a plant is shown in Figure 1. In this connection, it should be noted that the most modern fully integrated Japanese plants such as Yawata's Sakai Works and Nippon Kokan's Fukuyama Works are based on incremental expansion programs in steps of about 2,000,000 NT of raw steel per year, and that both are in the second expansion phase.

The capital cost for a 4,000,000 NT per year plant built in the United States today might be as high as $1,600** million, but if built in Japan, it might cost only about one-half that amount. The major facilities in the plant covered by Figure 1 are as follows:

Coke Plant	- Two Batteries of 77 ovens each
Sinter Plant	- One Strand, 12 ft wide
Blast Furnaces	- Three - 32 ft diameter hearths
L-D Plant	- Three - 175 NT furnaces
Continuous Casting Slabs	- Three - Single/Double Strand Machines
Continuous Casting-Blooms	- One - Six Strand for 10 by 10-in. blooms with furnace and billet mill

* Both Net Tons (NT) and Metric Tons (MT) are used in this paper as indicated.

** All costs and prices in this paper are in $US

Plate Mill	- One - 2 Stand 160-in. Mill
Slabbing Mill	- One - 45-in., Universal Mill with Soaking Pits
Hot Strip Mill	- One - Semi-Continuous, 80-in. Mill with 8 Stands
Continuous Pickling	- Two - 80-in. Lines
Cold Reduction Mill	- One - 80-in., 5-Stand Tandem Mill
Annealing Facilities	- Single and Multiple Stack Furnaces
Temper Mill	- Three - 80-in. Single Stand Mills
Galvanizing Lines	- Three - 72-in. Lines
Sheet Finishing and Shipping	- Cutup Lines, Slitters, etc.
Merchant Bar Mill	- 18 Stand 12-in. Mill

The average production cost of such a plant in the United States would be about $95.00 per NT of product. To this must be added depreciation, interest, and taxes. For details of production costs see Appendix A.

Of these added costs, those resulting from the required capital investment are the most important. Assuming that 75% of the required capital is borrowed at a low rate of 6.0% and that 5.0% is used for depreciation, the two items add $50.45 per ton of product at capacity operations. With a 75% product yield from liquid steel, this amounts to $152,000,000 per year. This is a fixed amount and represents the burden that must be carried by a project of the magnitude described regardless of the rate at which the plant might operate.

The average price realized from the product mix shown in Figure 1 is about $149 per NT in the United States. Thus, operating at capacity, the profit before taxes would be only $3.55 per ton of product. At 90% capacity, there would be a loss of $2.40 per NT of product, assuming production costs before fixed charges remain the same as at the 100% capacity level. However, if there is a drop in production to only 75% of capacity, production costs will increase, and the loss will be somewhat greater. These considerations clearly indicate the necessity of having a market that absorbs capacity output of a fully integrated plant based on blast furnaces.

It might be asked why a plant with an annual capacity of 4,000,000 tons of raw steel should be built. The basic reason is the high capacity of the modern blast furnace. In the plant used as an example, daily output would average about 3,400 tons of hot metal per furnace per day, which is actually less than that of the most recently built furnaces. Therefore, one blast furnace will support a raw steelmaking capacity of about 1,333,000 NT per year. This, then, is the minimal incremental figure on which the project must be planned.

This amount of steel is not even adequate to support the operation of a much smaller hot strip mill than the one used in the example. A moderate sized mill, such as the new seven-stand 56-inch semi-continuous hot strip mill of Republic Steel at Warren, Ohio, has an estimated capacity of 1,740,000 NT of coils per year; therefore, it needs over 2,100,000 NT of raw steel per year for capacity operation.

On the other hand, a single blast furnace of recent design is far too large for a modern merchant bar mill of the type used in the example. Such mills consume a maximum of about 420,000 NT of raw steel per year.

Intermediate to these two mills is the plate mill. It could consume up to about 1,000,000 NT of raw steel per year when producing 720,000 NT of plate. However, there is a problem to find a market for 720,000 NT of plate per year. It should be noted that in 1966 only 10 steelmaking countries are reported to have exceeded this output of plate.

The other type of fully integrated plant does not have the aforementioned problems. In it, iron ore is metallized, and then used directly for the production of steel or as a cupola charge for the production of molten pig iron. For example, its capacity can be much less, possibly as small as 100,000 tons of raw steel. Hence, the steelmaking units of the plant could be geared to a small market, although there may be some problems with the economic operation of rolling mills. In addition, incremental units for the expansion of such a plant could be much less than for the integrated plant with blast furnaces.

There are additional considerations for the plant using the metallized ore route. In the first place, if the plant is to be considered integrated, the reduction facilities must be a part of it, and conditions must be favorable for the operation of such facilities. High-grade iron ore or concentrate averaging at least 65% iron must be available as well as a suitable reducing agent. This agent could be coal, natural gas, or oil, but it must have a high heating value and low sulfur content. Sources of ore and reductants should be in locations where transportation costs to the site of the plant are not excessive. In this connection, it should be recognized that the site of the plant should be near a supply of labor and potential steel consumers. Furthermore, the cost of the reduced material should be competitive with the delivered price of steel scrap as adjusted to reflect the better physical and chemical properties of the reduced mineral raw materials.

All of these conditions seldom exist in one place as evidenced by the fact that, aside from three notable exceptions in Mexico and one in the western United

States, the only known commercial integrated steel plants in operation or planned that include a direct reduction process for iron ore are in Sweden, Spain, New Zealand, and South Korea. None of these plants are of sufficient magnitude to indicate a trend. However, the three plants in Mexico show what can happen when the previously stated favorable conditions exist. In these cases, iron ore runs about 67% Fe, and there is an abundant supply of natural gas. All three plants are located near a supply of labor and potential customers in Monterrey, Vera Cruz, and Puebla (near Mexico City).

In the western United States, an integrated steel plant using a direct reduction process is under construction at Portland, Oregon. The iron ore concentrate to be supplied to this operation will contain at least 71% Fe, natural gas is available, and probably the most favorable item is the current high price of scrap in Portland. Recent prices (April 1, 1968) for electric furnace scrap in that area are $6.00 to $8.00 per NT higher than similar grades in the major steel producing centers of the United States.

Based on the foregoing discussion of large integrated plants having blast furnaces and small integrated plants using a direct reduction process for iron ore, the following conclusions relate to the subject of this paper:

First, the commercial success of a new fully integrated steel plant having blast furnaces is doubtful if the potential market for that plant cannot support a raw steel production of at least 1,815,000 MT (2,000,000 NT) per year.

Second, an integrated plant with direct reduction or metallizing facilities for iron ore must have a source of high grade (65% Fe or more) iron ore or concentrates and a readily available reducing agent at a location close to a market for its products.

Both of these conditions have been examined with respect to the world steel situation. Table 1 has been prepared using data from the United Nations publication "Statistics of World Trade in Steel - 1965" and the "Annual Statistical Report - 1966" of the American Iron and Steel Institute.

This table lists all countries whose annual imports of steel products were in excess of 1,815,000 MT in 1965, the amount of those imports, and the approximate output of those countries in steel products (assumed to be 75% of the raw steel production for that year). It should be noted throughout this paper that no market projections are used. Markets are based on historical data, generally the 1965 and 1966 figures. This is a conservative approach; however, many projections of steel consumption have been exaggerated in the past.

TABLE 1

COUNTRIES SHOWING A POTENTIAL FOR LARGE INTEGRATED PLANTS

Country	Imports of Rolled Steel MT-1965	Approximate Production of Rolled Steel MT-1965
East Germany	2,063,100	3,544,000
Fed. Rep. of Germany	5,660,800	33,546,000
France	3,892,900	17,856,000
Netherlands	2,528,900	2,865,000
Spain	2,014,100	3,203,000
United States	9,301,000	108,802,000

All of these countries already have developed iron and steel industry. But at present they are probably the only individual countries, that have a domestic market that would justify the construction of a new, fully integrated plant with blast furnaces. A single exception is Japan with its remarkable overall industrial growth. But it should also be noted that other exceptions could be brought about through the grouping of countries into common markets or free trade areas.

Capacity is not a major consideration for an integrated plant with direct reduction facilities for iron ore. As has been pointed out, the essential factors are the availability of suitable raw materials at or near a potential market area. Table 2 has been prepared using data from a number of sources. It lists the countries suitable for such a steelmaking facility including areas known to have iron ore or concentrate that are adequate for the production of a metallized material and can be used in an electric arc furnace or a cupola as a replacement for scrap. Table 2 also notes the availability of a suitable reductant and a nearby market.

TABLE 2

COUNTRIES SHOWING A POTENTIAL FOR SMALL INTEGRATED PLANTS

Country-Area	Ore and Concentrate % Fe	Available Reductant and Type	Available Market and Plant Site
Australia	64+	Yes	No
Brazil	67+	No	No
Canada, Eastern Ontario	64+	No	No
Chile	64+	Yes	No
China (Mainland)	64+	Yes	Yes
India	63+	No	Yes
Liberia	67+	No	No
Mauritania	65+	No	No
Mexico	65+	Yes	Yes
Peru	66+	No	No
South Africa	65+	Yes	Yes

Country-Area	Ore and Concentrate % Fe	Available Reductant and Type	Available Market and Plant Site
Sweden	66+	No	No
Venezuela	64+	Yes	No
USSR	64+	Yes	Yes
United States-East Penn.	65+	Yes	Yes
United States-Lake Superior	64+	No	No
United States-Pacific Coast	65+	Yes	Yes

It can be seen from this table that the only countries and areas that fulfill the conditions for an integrated plant with direct reduction facilities are China (Mainland), Mexico, South Africa, USSR, and the east and west coasts of the United States. Except for Mexico and possibly the west coast of the United States, all of these are primarily committed to fully integrated plants having blast furnaces. It does not seem likely that the second type of integration will make general headway although there may be some exceptions.

SEMI-INTEGRATED PLANTS

Potential Areas

An examination of world trade data on steel for 1965, as tabulated by the United Nations, indicates that there are a number of countries that could become steel producers in spite of the problems associated with setting up an integrated plant. These countries fall into two general categories: those whose situation is compatible with building one or more semi-integrated plants, and those where only non-integrated plants could be justified.

Countries that might justify a semi-integrated plant should have annual imports of at least 200,000 MT of steel products per year. The basis for this figure requires an understanding of product mix of imports, the type of rolling mills that can be justified, the relationship of the steelmaking operations with the mills, and the impact of continuous casting.

Table 3 indicates imports and product mix for each country having imports in excess of 200,000 MT in 1965, and whose imports are greater than the country's steel production. The reason for this latter limitation is that there are a number of countries whose imports exceed 200,000 MT per year but also have several times that quantity in domestic steel production. Such countries already have an established steel industry and are not pertinent to the subject of this paper.

Among the countries listed on Table 3 are some that (1) are presently installing steelmaking facilities, or (2) are located near major steel producers. Consequently, they are not likely to invest in a relatively small steel

TABLE 3
IMPORTS OF SEMI-FINISHED & FINISHED STEEL PRODUCTS
BY TYPE AND COUNTRY - 1965
(In Thousands of Metric Tons)

Country	Ingots and Semis	Railway Track Material	Heavy & Light Sections	Wire Rods	Strip	Plates	Sheets	Steel Tubes & Fittings	Wire	Tinplate	Tires & Axles	Total
Finland	65.3	1.1	106.2	17.1	24.0	76.6	216.1	75.0	14.3	10.2	1.9	645.5
Greece	113.4	11.4	136.8	32.2	62.4	41.3	76.2	20.2	6.9	27.5	0.3	528.0
Hong Kong	8.6	2.0	197.1	12.8	3.4	58.3	80.0	22.5	11.8	13.7	3.6	413.8
Indonesia		4.4	112.7	1.5	8.1	10.5	41.1	20.6	24.1	5.8	1.2	230.0
Iran	1.6	0.6	212.8	1.2	6.7	26.8	92.3	185.4	11.5	13.0	0.8	558.6
Israel	73.6	6.5	60.5	31.9	7.9	46.5	50.6	7.3	10.7	15.5	1.0	313.0
Lebanon	8.7		117.0	1.1	9.6	11.6	16.2	8.2	4.4	3.9	0.1	204.6
Malaysia	0.1	10.3	89.0	4.6	5.4	24.2	55.0	32.1	8.4	18.4	0.7	248.2
New Zealand	0.6	10.7	164.2	36.8	12.0	49.0	123.8	47.5	23.8	23.7	1.7	493.8
Nigeria		6.7	53.2	22.4	1.5	7.1	47.9	89.9	1.7	7.6	0.4	243.9
Norway	75.0	44.9	168.9	42.0	62.2	274.8	122.1	38.0	11.2	18.0	1.7	858.8
Pakistan	180.1	32.4	143.5	17.3	21.0	28.5	136.9	44.4	20.4	29.2	5.1	658.8
Peru	5.4	7.2	75.6	10.2	10.3	34.3	42.2	30.0	3.8	18.9	1.6	239.5
Philippines	104.5	3.8	77.6	8.1	12.8	42.2	176.6	29.2	37.3	37.6	0.3	530.9
Saudi Arabia		4.1	78.3	0.7	0.1	5.6	7.0	143.9	0.3	3.9		243.9
Switzerland	192.6	51.2	386.9	79.0	124.5	214.3	219.9	124.8	18.7	30.7	7.8	1,443.4
Thailand	6.7	27.1	105.9	3.1	15.3	21.8	99.4	17.4	42.9	13.7		353.3

producing unit. Those in the first category are New Zealand and the Philippines, and in the second category are Finland, Greece, Norway and Switzerland. This leaves eleven countries that probably could have justified a semi-integrated steel plant in 1965. These countries are:

Hong Kong	Indonesia
Iran	Israel
Lebanon	Malaysia
Nigeria	Pakistan
Peru	Saudi Arabia
Thailand	

In addition to these eleven countries, Algeria, Cuba, East Africa, Iraq, Kuwait, Lybia, Morocco, and the Republic of Vietnam might be also considered.

It can be seen from Table 3 that heavy and light sections, which include bars plus wire rods that can also be rolled on bar mills, generally form the largest class of products. Generally, sheets are next in importance, followed by plate. In some countries, particularly those where oil is produced, tubular products are important. Where there is considerable shipbuilding, plates rank first or second.

If produced in a semi-integrated plant, sheet, plate, and tubular products require an investment that would be difficult to justify using the 1964 import figures or even much larger figures. There are certain exceptions as will be noted in the discussion of non-integrated plants.

Facilities

Based on the various product mix data in Table 3, semi-integrated plants should be designed for the production of light sections, bars, and wire rod. Using data from this table, it appears that an average of about 36% of total imports fall into this category. A minimum import figure of 200,000 MT per year results in a figure of 72,000 MT of these products. With continuous casting, the 72,000 tons of product would require about 85,000 tons of raw steel per year and there is a reasonable balance betw steelmaking, continuous casting, and rolling with adequate provisions for expansion. As will be discussed later, it has been assumed that steelmaking will be in electric arc furnaces. The balance and provision for expansion are shown in Table 4 which is based on the following assumptions.

Heat time, tap to tap	- 2.5 hr
Number of electric furnaces	- 1
Furnace operating turns per week	- 15

Average cycle time, continuous casting	- 1.25 hr
Average rolling mill production rate	- 35 MT/hr
Yield, raw steel to cast billets	- 95.0%
Yield, cast billets to rolled product	- 88.9%

TABLE 4

SEMI-INTEGRATED PLANT BALANCE AND EXPANSION

Facility	Capacity MT/Yr	Production MT/Yr	8 Hr Oper Turns - No Per Wk	Utili %
	Step I			
1 - 34 MT Electric Arc Furnace	110,000	85,000	15	78.0
1 - 3 Strand, Cont Billet Casting Machine	245,000	81,000	15	33.0
1 - Semi-Continuous Bar and Rod Mill	290,000	72,000	5	25.0
	Step II			
2 - 34 MT Electric Arc Furnaces	220,000	170,000	15	78.0
1 - 3 Strand Cont Billet Casting Machine	245,000	162,000	15	66.0
1 - Semi-Continuous Bar and Rod Mill	290,000	144,000	10	50.0
	Step III			
3 - 34 MT Electric Arc Furnaces	330,000	255,000	15	78.0
2 - 3 Strand Cont Billet Casting Machines	490,000	243,000	15	50.0
1 - Semi-Continuous Bar and Rod Mill	290,000	216,000	15	75.0

A description of the facilities listed in the table is found in Appendix B.

As to the product mix, a typical example for Step I would be as follows:

Structural Shapes	- 3 x 3 in. max. angles
Carbon Bars	- 3 in. max. diameter
Reinforcing Bars	- 1 1/2 in. max. diameter
Wire Rods	- 7/32 in. min. diameter

It is important to note from Table 4 that the limiting facilities are the electric furnace. Furthermore, the percent utilization is an average figure; hence, there are allowances for peaks in demand that cannot be avoided in any steel plant. In addition, after the initial investment in Step I the plant capacity can be doubled in Step II by merely adding one electric furnace, and in going from Step II to Step III, only one more electric furnace and one more continuous casting machine are required. This avoids a condition that could be disastrous to a steel company where too perfect a plant balance at some stage requires a major expenditure for almost all facilities.

Raw Materials

In the past, semi-integrated steel plants have been based largely on steel scrap as the principal raw material. Using data from a paper on scrap by Dr. W. D. Pugh, of the English Steel Corp. presented in October 1967, at the Seventh Latin America Iron and Steel Congress, the following significant conclusions relative to the subject of this paper can be deduced:

- Europe should not be regarded as a source of scrap. In 1965, imports to the various European countries amounted to 5, 578, 900 MT and exports 5, 567, 200 MT. By far the majority of imports were by Italy and the principal exporters were Belgium, Luxembourg, France, West Germany, and the Netherlands.

- As an importer Japan was second only to Italy, which imported 4,592,200 MT of scrap in 1965. Japan imported 3,406,000 MT, primarily from the United States, plus significant quantities from India and Australia.

- The largest exporter of scrap in 1965 was the United States with a total of 5,171,000 MT, of which 2,340,000 MT went to Japan, 925,700 to Canada, 762,300 to Mexico, and 706,000 to Italy.

- Trade between other parts of the world possibly amounted to 200,000 MT of scrap in 1965.

These conclusions mean that the only potential source of scrap to the semi-integrated plants being discussed is the United States and only then in the event that Japanese demand falls off. however, this is a distinct possibility as blast furnace capacity in Japan is increasing.

The price of scrap in the United States is far from stable. As an example, the following is the average annual price per MT for No. 1 Heavy Melting Scrap at Philadelphia, a principal Atlantic port for shipping scrap, from 1960 through 1966:

Year		Price per MT
1960		$35.06
1961		38.07
1962		27.64
1963		25.37
1964		30.81
1965		33.06
1966		29.69
	Average	$31.32

Although a considerable amount of scrap is shipped from Pacific and Gulf ports, no comparable figures are available. For a definition of No. 1 Heavy Melting Scrap and its impurities see Appendix C.

To the above average cost should be added shipping costs which are shown in Table 5 These costs or rates are for 30,000 MT lots and do not include loading and unloading charges that average $1.50 or more per MT.

TABLE 5

SCRAP SHIPPING COSTS PER METRIC TON

Destination	From United States Atlantic Ports	From United States Pacific Ports	From United States Gulf Ports
Hong Kong	$ -	$ 13.00	$ -
Indonesia	-	18.00	-
Iran	11.00	-	-
Israel	11.00	-	-
Lebanon	11.00	-	-
Malaysia	-	18.00	-
Nigeria	12.50	-	14.50
Pakistan	11.00	-	-
Peru	8.50	9.50	7.00
Saudi Arabia	11.00	-	-
Thailand	-	18.00	-

Therefore, it is evident that the delivered price of scrap to the several countries where there may be a potential for a semi-integrated plant can be as high as $50.82 per MT and as low as $39.82. During periods when the price of scrap is high in the United States, the above figures could be $6.75 per MT more, and when the market is weak, $5.95 less. Hence, for any single country there is a possible variation of $12.70 per MT in the price of scrap. Thus, the price of scrap that an importing country must pay to the exporting country is extremely unstable unless long-term contracts can be negotiated.

In contrast with this, the cost of blast furnace metal, indicated in Appendix A as $37.06 per MT, will remain relatively constant over long periods of time since both ore and coal prices do not fluctuate widely. It would obviously be to the advantage of a developing country to base its planning for a semi-integrated plant on an iron bearing raw material suitable for steelmaking that is available from a reliable source at a relatively constant price.

There are, at the present time, a number of projects in advanced stages of planning that will be sources of such a material. These projects involve the production of reduced or metallized ore on a large scale, possibly 1,000,000 MT or more per year. Their locations are being carefully selected so that high-grade iron ore or concentrates and reductants will be available at the lowest possible cost. The delivered cost of this type of material to consumers in most locations is expected to be in the range of $35 per MT. The long-range availability of such iron bearing materials at a stable price is a most important favorable factor with respect to the feasibility of a semi-integrated plant for a developing nation.

Chemically, the reduced or metallized ore should analyze approximately as follows:

Total Iron	- 93% to 95%
Metallic Iron	- 87% to 89%
Ferrous Oxide	- 4% to 7%
Phosphorus	- 0.05% max.
Sulfur	- 0.02% max.
Gangue	- 4% to 8%
Contaminents (Cu, Sn, Ni, Cr, Mo, Sb, As, etc.)	- 0.10% max.

Physically, such metallized ore or concentrates can be in the form of a lump material or pellets ranging from 6 to 15 mm in size. The bulk density of pellets produced from a lump ore of about 85 lb per cu ft will be about 125 lb per cu ft.

The only uncertainty about this material is the degree to which under certain circumstances it might reoxidize particularly during ocean shipments. This problem and its solution is presently the subject of a massive investigation.

Because of its size and high iron content, this type of material is ideal for an electric furnace operation that utilizes the new practice of continuously feeding reduced material directly into a pool of molten metal in the area of the arc. Such a practice, which is not feasible with a 100% scrap, can reduce heat times by up to 40% compared with an all scrap charge. In addition, power, electrode, and refractory consumption will be less.

Similar advantages are not possible if this type of reduced material is used as part of the cold charge in a semi-integrated plant with open hearth furnaces. If used in a cupola to produce hot metal in a semi-integrated plant with L-D type basic oxygen furnaces, the reduced material actually is at a disadvantage. This is shown by the following figures that compare a 100% scrap charge in a cupola with charges comprising 50% and 100% reduced material.

Charge	100% scrap	50% scrap 50% reduced ore	100% reduced ore
Hot Metal - MT per hour	31.45	29.75	28.22
Coke-lb per MT hot metal	490	521	551

The open hearth and the cupola-L-D combination are the only feasible methods besides the electric arc furnace by which steel can be produced in a semi-integrated plant at the present time. For the above reasons, the electric furnace has been selected as the steelmaking unit. In addition there are other advantages in using electric furnaces for a steel plant of the type being considered.

(1) Steel temperature is more easily controlled in the electric furnace than in either the open-hearth or the L-D furnace, and accurate temperature control is essential for continuous casting.

(2) The cycle time of an electric furnace is more compatible with that of a continuous casting machine than either of the two other

steelmaking facilities. One machine is required for two electric furnaces, whereas two machines are required for one L-D furnace and three or four open hearths are required for one casting machine.

(3) Electric power is generally more available than either the fuel oil or natural gas required for open hearths.

(4) Due to improved technology, the cost of electric power has been reduced gradually over the past several years.

Production Costs

Production costs have been developed for Steps I, II, and III of the proposed semi-integrated plant. These costs are based on the Step I flow diagram shown as Figure 2, and the following assumptions:

(1) 70% of the metallic charge to the electric furnace will be reduced material with a 94% total iron content, and a delivered price of $35.00 per MT.

(2) 5% of the charge will be pig iron priced at $60.00 per MT.

(3) The price of scrap will be $42.50 per MT.

(4) Alloy additions will amount to 20 lb per MT of liquid steel, with an average price of $210 per MT.

(5) Burnt lime at $16.00 per MT will amount to 3.0% of the charge.

(6) Fluorspar will be 3.0 lb per ton of liquid steel.

(7) Plant generated scrap will be credited to the appropriate operation at $2.50 per MT less than the price of scrap.

Table 6 shows a breakdown of the costs for Step I. As noted later, production costs for Steps II and III were derived from the Step I costs.

TABLE 6
PRODUCTION COST - STEP 1
SEMI-INTEGRATED PLANT

	Material MT per Year	Product MT per Year	Material Cost $ per MT	Product Cost $ per MT
	Electric Furnace - 85,260 MT per Year			
Metallics				
Reduced Ore (94% Fe)	67,776		$ 35.00	$27.82
Plant Scrap	9,848		42.50	4.91
Purchased Scrap	12,904		42.50	6.43
Pig Iron	4,550		60.00	3.20
Mill Scale (Fe)	810		21.25	0.25
Alloy Additions	853		210.00	2.10
Total Metallics		85,260		$44.71
Fluxes				
Burnt Lime	2,730		$ 16.00	$ 0.51
Fluorspar	128		40.00	0.06
Total Fluxes				$ 0.57
Other Costs				$17.00
Total Cost Liquid Steel		85,260		$62.28
	Continuous Casting - 81,000 MT per Year			
Metallics				
Liquid Steel	85,260		$ 62.28	$65.56
Scrap Credit	2,558		40.00	1.26
Net Metallics		81,000		$64.30
Cost - Above Metallics				8.00
Total Cost Billets		81,000		$72.30
	Rolling and Finishing - 72,000 MT per Year			
Metallics				
Billets	81,000		$ 72.30	$81.34
Scrap Credit	7,290		40.00	4.05
Net Metallics		72,000		$77.29
Cost - Above Metallics				-16.00
Total Cost Bars		72,000		$93.29

In Step II, the cost per MT for metallics and fluxes to the electric furnaces will remain the same. However, other costs will be reduced to about $16.00 per MT. Also, the cost above metallics for continuous casting will be reduced to $6.00 because of greater utilization of the machine, and for rolling and finishing the cost will be reduced to about $15.00. The net result is a reduction in the total cost of bars from $93.29 to $88.85 per MT.

In Step III, again there will be no reduction in cost for the metallics and fluxes to the electric furnaces, but other costs will drop to about $15.00 per MT. However, the cost above metallics for continuous casting will increase to $7.00 per MT because installation of the second machine will decrease utilization. Also, the cost of rolling and finishing will be further reduced to about $14.00 per MT. Therefore, the total cost of products will be $87.79 per MT for Step III.

Capital Costs

Along with production costs, estimates have been made of the capital expenditures required for each of the three steps in the development of the semi-integrated plant being considered. These costs are summarized in Table 7 and details can be seen in Appendix D:

TABLE 7
ESTIMATED CAPITAL COSTS - SEMI-INTEGRATED PLANT

ELEMENT OF COST	
Step I	
Site Development	$ 1,860,000
Process Equipment including Electric Furnace, Continuous Casting Machine, Bar and Rod Mill, and Finishing Equipment	21,000,000
Plant Auxiliaries including Buildings, Cranes, Utilities Roll Shop, etc.	5,340,000
Engineering, Construction, Supervision, Procurement, etc.	6,600,000
Contingency (10%)	3,500,000
Total Cost for Step I	$38,300,000
Step II	
Electric Furnace, Utilities, and Finishing Equipment	$ 2,650,000
Engineering, Construction, Supervision, etc.	600,000
Contingency (20%)	650,000
Total Cost for Step II	$ 3,900,000
Total Cost for Steps I & II	$42,200,000
Step III	
Electric Furnace, Continuous Casting Machine, Buildings, Cranes, Utilities, Site Work, etc.	$12,300,000
Engineering, Construction, Supervision, etc.	2,860,000
Contingency (20%)	3,040,000
Total Cost for Step III	$18,200,000
Total Cost for Steps I, II & III	$60,400,000

It is recognized that the above estimated costs may be higher than those reported recently for several small semi-integrated plants, particularly in the United States. However, these plants in the United States have single-purpose mills rolling a limited range of products. The mill considered in the above estimate would produce a wide range of products from 3x3-in. angles and 3-in. diameter rounds down to 7/32 in. diameter wire rod in coils weighing up to 900 lb.

Because the plant would probably not be located in a highly industrialized area, a considerable capital expenditure would be required to bring in the necessary utilities, and a large inventory of spare parts must be maintained. Equipment reliability is also important where repair facilities are not available, and this factor will increase equipment costs. The above estimates, influenced by the foregoing factors, result in a somewhat higher cost than might be anticipated.

Economic Feasibility

The economic feasibility of the semi-integrated plant that has been discussed rests primarily on whether the prices now paid for the products are more than the anticipated production costs. In this instance, the production cost should include not only those direct costs based on Table 6, but also selling and general administrative expenses, depreciation interest on loans, and taxes, if any.

Selling and general administrative expenses can only be approximated, but they may amount to about 5.0% of the selling price. Assuming that an average price might be $120 per MT, these expenses would be $6.00 per MT.

As to depreciation, it has been assumed to be straight line for a period of 25 years, or 4.0% of the required capital investment. For interest, the assumption is that 60% of the required financing would be loans, and that the interest rate on the loans may be as low as 6.0%. Finally, it has been assumed that there would be no taxes, since it is difficult to anticipate fiscal policies in this regard.

On the above basis, following are the production costs for each step in the development of the semi-integrated plant at an initial operating level, and also at a capacity operating level. These costs should be compared with the present and probable future prices charged at each site for products similar to those produced by the proposed plant. Since such prices vary widely in time and place, it is not possible to make an overall recommendation on the general economic feasibility of the semi-integrated plant. However, it has been shown that such a plant is feasible for a wide range of economic conditions and should be investigated by those countries considering the establishment of a steel industry.

STEP I

Production Level - 72,000 MT Per Year

Direct Production Cost	$ 93.29 per MT
Selling and Admin. Expenses	6.00 per MT
Depreciation	21.28 per MT
Interest	19.15 per MT
Total Cost	$139.72 per MT

Production at Plant Capacity - 92,900 MT Per Year

Direct Production Cost	$ 93.29 per MT
Selling and Admin. Expenses	6.00 per MT
Depreciation	16.49 per MT
Interest	14.84 per MT
Total Cost	$130.62 per MT

STEP II

Production Level - 144,000 MT Per Year

Direct Production Cost	$ 88.85 per MT
Selling and Admin. Expenses	6.00 per MT
Depreciation	11.72 per MT
Interest	10.55 per MT
Total Cost	$117.12 per MT

Production at Plant Capacity - 185,800 MT Per Year

Direct Production Cost	$ 88.35 per MT
Selling and Admin. Expenses	6.00 per MT
Depreciation	9.09 per MT
Interest	8.18 per MT
Total Cost	$112.12 per MT

STEP III

Production Level - 216,000 MT Per Year

Direct Production Cost	$ 87.79 per MT
Selling and Admin. Expenses	6.00 per MT
Depreciation	11.18 per MT
Interest	10.07 per MT
Total Cost	$116.04 per MT

Production at Plant Capacity - 278,700 MT Per Year

Direct Production Cost	$ 87.79 per MT
Selling and Admin. Expenses	6.00 per MT
Depreciation	8.67 per MT
Interest	7.80 per MT
Total Cost	$110.26 per MT

NON-INTEGRATED PLANTS

There may be some potential for non-integrated plants producing small shapes, bars, and wire rod in the same countries that have been considered for semi-integrated plants; however, the economic advantages will probably not be as great.

At the present time, the quoted market price of re-rolling billets in the United States is $89.00 per net ton or $98.08 per metric ton. The shipping costs to the possible site of a non-integrated plant from the United States are about 10% more than in Table 5, to which must be added about $1.50 per MT for handling. Hence, except for Peru, the total transportation costs from the U.S. to the site of the rolling mill range from $13.60 to $21.30 per MT. Assuming an average cost of $15.00 per MT, the delivered cost of re-rolling billets will be about $113.00 per MT. This is a comparable figure to the $72.30 cost for continuous cast billets in Table 6. Certainly, other countries may also be sources of re-rolling billets, probably at comparable prices.

To both of the above figures must be added selling and administrative expenses, depreciation, and interests. In both the semi-integrated and non-integrated plants selling and administrative expenses are probably the same at $6.00 per MT. However, the non-integrated plant will have a capital cost of about $27,000,000 compared to the initial cost of

$38,200,000 for the semi-integrated plant. Therefore, on the same basis of depreciation and interest as previously used and including selling and administrative expense, Table 8 has been prepared showing comparable figures for the cost of producing small shapes, bars, and rods in the two types of plants at various levels of production.

TABLE 8

COMPARABLE COSTS PER MT PRODUCT

Level of Production MT of Product per year	Semi-Integrated	Non-Integrated
72,000	$139.72	$145.46
92,900	130.62	138.66
144,000	117.12	132.23
185,800	112.12	129.27
216,000	116.04	127.82
278,700	110.26	125.83

However, there are other possibilities that might warrant the building of a non-integrated plant. For example, as shown in Table 3, Iran had imports of 185,400 MT of tubular products in 1965, and Saudi Arabia imported 143,900 MT. Both of these countries could import wide, hot-rolled skelp as coils. When slit, this is an ideal material to feed an electric-weld mill for the production of small and medium diameter line pipe and tubing for the petroleum industry. The capital cost of such a 70,000-MT-per-year plant, including a stretch reduction mill to broaden the product mix, is only about $3,750,000; this is a complete installation. However, the economic feasibility of this plant is beyond the scope of this paper.

Another possibility would be to install galvanizing facilities in the several countries listed in Table 3 that import 100,000 tons or more per year of sheets. In this instance, feed to the galvanizing line would be cold-reduced sheet in coils.

Other than these two last suggestions it would appear that a semi-integrated plant using a reduced or metallized iron ore as the basic raw materials provides the best solution for the development of an iron and steel industry with other than fully integrated plants.

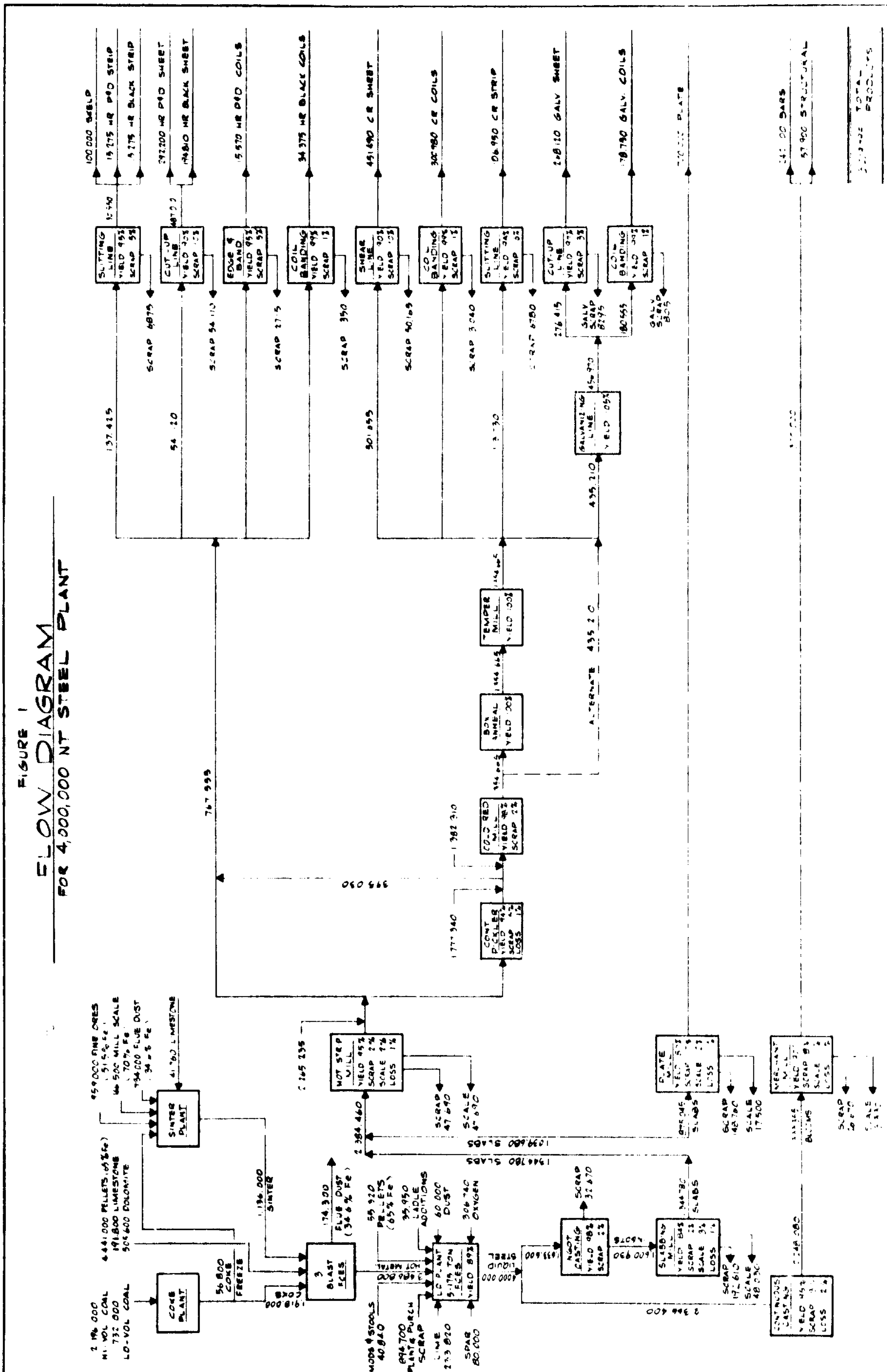
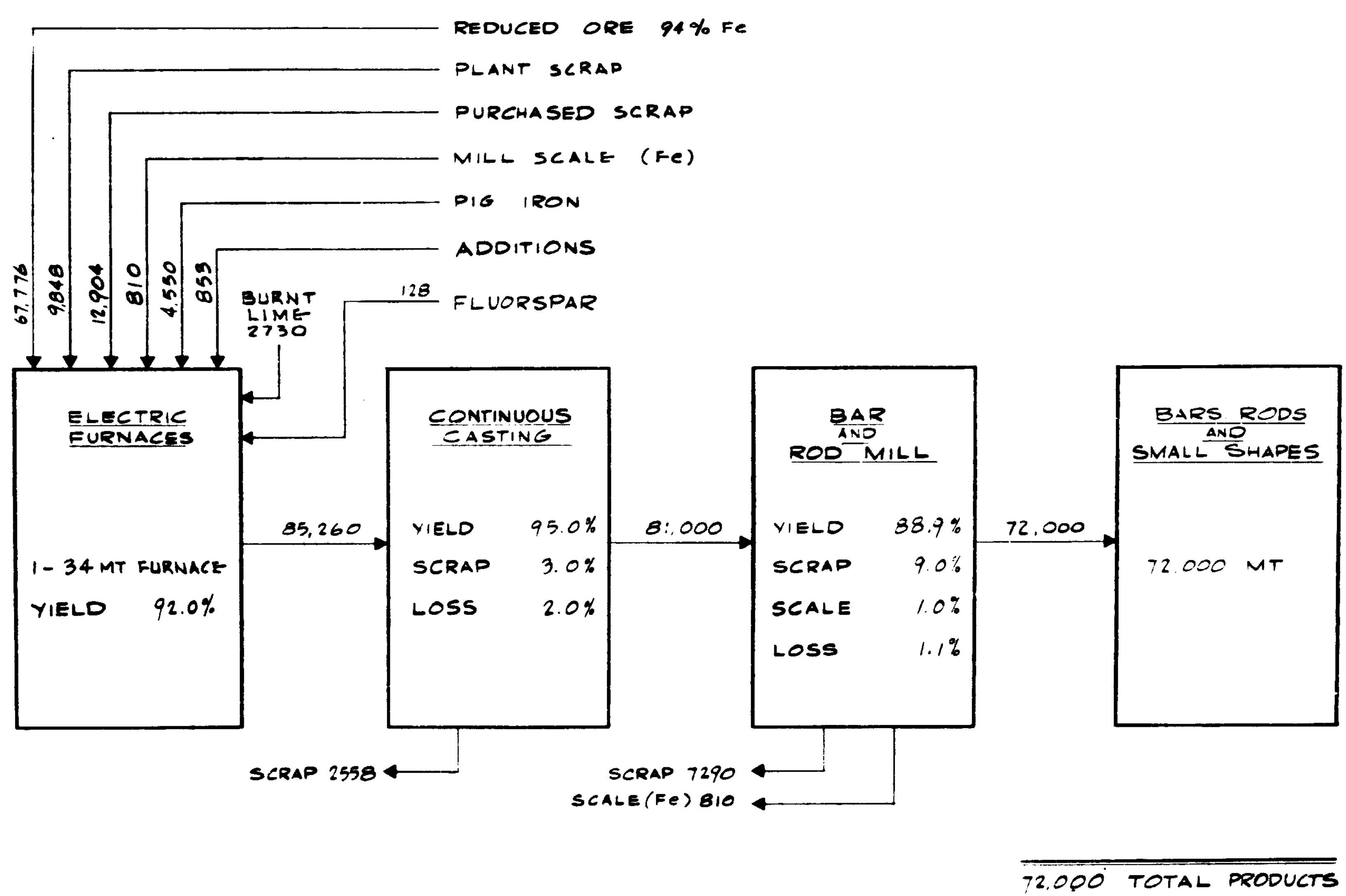


FIGURE I
FLOW DIAGRAM
FOR 4,000,000 NT STEEL PLANT

FIGURE 2

FLOW DIAGRAM

STEP I - SEMI-INTEGRATED PLANT



APPENDIX A

PRODUCTION COST CALCULATIONS

	Material NT Per Year	Product NT Per Year	Material Cost Per NT	Product Cost Per NT
Coke Plant				
Hi-Vol Coal	2,196,000		$ 9.00	$10.30
Lo-Vol Coal	732,000		12.25	4.68
Total Materials	2,928,000			$14.98
Byproduct Supplies				$ .10
Cost Above				5.20
Total Cost		1,918,000		$20.28
Credit Breeze		278,000	7.00	(1.01)
Credit Byproducts		29,280,000 gal.		(2.90)
Credit C.O. Gas		14,640 MMBtu	.38 MMBtu	(1,60)
Net Cost of Coke		1,918,000		$14.77
Sinter Plant				
Fine Ores (51,52 Fe)	959,000		$ 9.02	$ 7.61
Mill Scale (70% Fe)	166,500		3.75	.55
Flue Dust (34.6% Fe)	174,300		3.75	.58
Limestone	181,760		2.20	.35
Coke Breeze	56,800		7.00	.35
Total Material		1,136,000		$ 9.44
Cost Above				.85
Cost of Sinter		1,136,000		$10.29
Blast Furnace				
Sinter (57% Fe)	1,141,000		$10.29	$ 3.35
Pellets (65% Fe)	4,441,000		14,63	18.63
Coke	1,918,000		14.77	8.12
Limestone	191,800		2.20	.12
Dolomite	505,600		2.80	.41
Total Materials				$30.63
Cost Above				5.70
Total Cost	3,486,800			$36.33
Credit Slag	1,220,400		.50	(.17)
Credit B.F. Gas			.38	(2.53)
Net Cost of Hot Metal		3,486,800		$33.36 ($37.06 per MT)

	Material NT Per Year	Product NT Per Year	Material Cost Per NT	Product Cost Per NT
L-D Plant - Melting				
Hot Metal	3,486,800		$ 33.63	$29.31
Scrap*	894,700		24.00	5.37
Molds & Stools (Scrap)	40,840		33.50	.34
Pellets	55,320		14.62	.20
Ladle Additions	35,960		210.00	1.89
Lime	233,820		13.00	.76
Fluorspar	20,000		37.00	.19
Oxygen	306,740		15.00	1.15
Total Materials		4,000,000		$39.21
Cost Above				6.10
Total Cost				$45.31
Credit Scrap		80,000	19.00	(.38)
Net Cost of Liquid Steel		4,000,000		$44.93
*Includes:				
Plant Scrap	855,355			
Purchases Scrap	39,345			
L-D Plant - Ingot Pouring and Stripping				
Liquid Steel	1,633,600		$ 44.93	$45.84
Cost Above				5.70
Total Cost		1,600,930		$51.54
Credit Scrap		32,670	19.00	(.39)
Credit Molds and Stools		40,840	32.50	(.83)
Net Cost of Ingots		1,600,930		$50.33

	Material NT Per Year	Product NT Per Year	Material Cost Per NT	Product Cost Per NT
L-D Plant - Continuous Casting Slabs				
Liquid Steel	2,015,500		$44.93	$47.29
Cost Above				5.40
Total Cost		1,914,725		$52.69
Credit Scrap		60,465	19.00	(.60)
Net Cost of Slabs		1,914,725		$52.09
L-D Plant - Continuous Casting Blooms/Billets				
Liquid Steel	350,900		$44.93	$47.29
Cost Above				12.25
Total Cost		333,355		$59.54
Credit Scrap		10,525	19.00	(.60)
Net Cost of Billets		333,355		$58.94
Soaking Pits and Slab Mill				
Ingots	1,600,930		$50.33	$59.91
Cost Above				3.50
Total Cost		1,344,780		$63.41
Credit Scrap		192,110	19.00	(2.71)
Credit Scale		48,030	3.75	(.13)
Net Cost of Slabs		1,344,780		$60.57

	Material NT Per Year	Product NT Per Year	Material Cost Per NT	Product Cost Per NT
Plate Mill				
Concast Slabs	875,045		$52.09	$65.12
Cost Above				12.00
Total Cost		700,000		$77.12
Scrap Credit		148,760	19.00	(4.04)
Scale Credit		17,500	3.75	(.09)
Net Cost of Plate		700,000		$72.99
Merchant Mill				
Concast Billets	333,355		$58.94	$65.50
Cost Above				13.25
Total Cost		300,000		$78.75
Scrap Credit		26,670	19.00	(1.69)
Scale Credit		3,330	3.75	(.04)
Net Cost of Bars and Struct		300,000		$77.02
Hot Strip Mill				
Concast Slabs	1,039,680		$52.09	$23.91
Rolled Slabs	1,344,780		60.57	35.96
Cost Above				6.75
Total Cost		2,265,235		$66.61
Scrap Credit		47,690	19.00	(.40)
Scale Credit		47,690	3.75	(.08)
Net Cost of Hot Bands		2,265,235		$66.14
Hot Bands From Continuous Cast Slabs		987,695		$61.11
Hot Bands From Rolled Slabs		1,277,540		$70.03

	Material NT Per Year	Product NT Per Year	Material Cost Per NT	Product Cost Per NT
Continuous Pickling - Concast Steel				
Hot Bands	695,335		$61.11	$65.19
Cost Above				2.50
Total Cost		651,795		$67.69
Scrap Credit		34,765	19.00	(1.01)
Net Cost of Pickled Strip		651,795		$66.67
Continuous Pickling - Ingot Steel				
Hot Bands	1,197,375		$70.03	$74.49
Cost Above				2.50
Total Cost		1,125,545		$76.99
Scrap Credit		59,870	19.00	(1.01)
Net Cost of Pickled Strip		1,125,545		$75.98
Cost Reduction Mill - Concast Steel				
Pickled Strip	375,260		$66.67	$68.03
Cost Above				4.00
Total Cost		367,755		$72.03
Credit Scrap		7,505	19.00	(.38)
Net Cost of Cold Rolled Strip		367,755		$71.65
Cold Reduction Mill - Ingot Steel				
Pickled Strip	1,007,050		$75.98	$77.53
Cost Above				4.00
Total Cost		986,910		$81.53
Credit Scrap		20,140	19.00	(.38)
Net Cost of Cold Rolled Strip		986,910		$81.15

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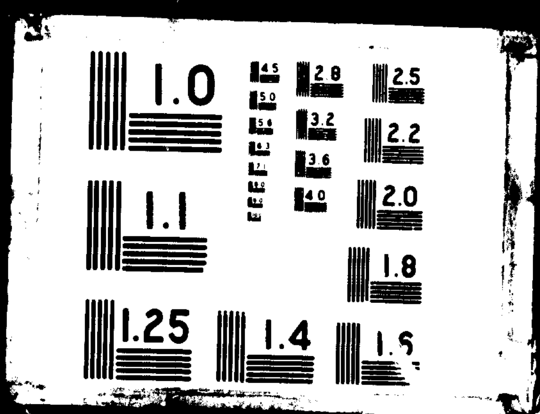
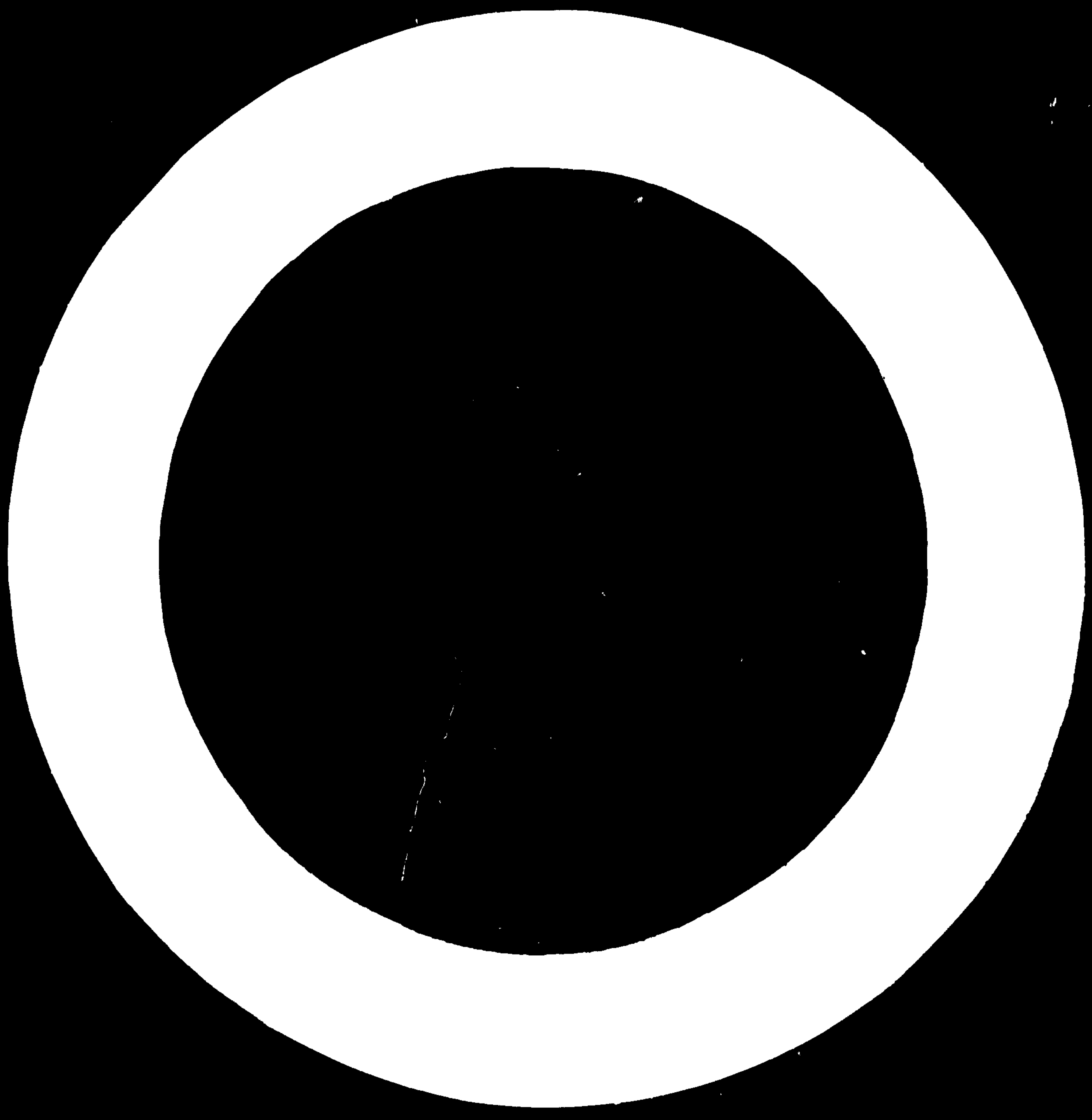


	Material NT Per Year	Product NT Per Year	Material Cost Per NT	Product Cost Per NT
Box Annealing - Concast Steel				
Cold Rolled Strip	367,755		$71.65	$71.65
Cost Above				3.00
Total Cost of Annealed Strip		367,755		$74,65
Box Annealing - Ingot Steel				
Cold Rolled Strip	986,910		$81.15	$81.15
Cost Above				3.00
Total Cost of Annealed Strip		986,910		$84.15
Temper Mills - Concast Steel				
Annealed Strip	367,755		$74.65	$74.65
Cost Above				2.10
Total Cost of Tempered Strip		367,755		$76.75
Temper Mills - Ingot Steel				
Annealed Strip	986,910		$84.15	$84.15
Cost Above				2.10
Total Cost of Tempered Strip		986,910		$86.25
Hot Rolled Skelp				
Concast Hot Rolled Coils	105,265		$61.11	$64.32
Cost Above				3.75
Total Cost		100,000		$68.07
Scrap Credit		5,265	19.00	(1.00)
Net Cost of Skelp		100,000		$67.07

	Material NT Per Year	Product NT Per Year	Material Cost Per NT	Product Cost Per NT
Hot Rolled P&O Strip				
Concast P&O Strip	11,260		$66.67	$49.15
Ingot P&O Strip	4,820		75.98	23.97
Cost Above				3.75
Total Cost	16,080	15,275		$76.88
Credit Scrap		805	19.00	(1.00)
Net Cost of P&O Strip		15,275		$75.88
Hot Rolled Black Strip				
Concast Hot Rolled Coils	11,260		$61.11	$45.04
Ingot Hot Rolled Coils	4,820		70.03	22.09
Cost Above				3.75
Total Cost	16,080	15,275		$70.89
Credit Scrap		805	19.00	(1.00)
Net Cost of Black Strip		15,275		$69.88
Hot Rolled P&O Sheet				
Concast P&O Strip	227,275		$66.67	$51.86
Ingot P&O Strip	97,390		75.98	25.33
Cost Above				3.00
Total Cost	324,665			$79.57
Credit Scrap		32,465	19.00	(2.11)
Net Cost of P&O Sheet		292,200		$78.07
Hot Rolled Black Sheet				
Concast Hot Rolled Coils	151,530		$61.11	$47.53
Ingot Hot Rolled Coils	64,925		70.03	23.34
Cost Above				3.00
Total Cost	216,455			$73.87
Credit Scrap		21,645	19.00	(2.11)
Net Cost of Black Sheet		194,810		$71.76

	Material NT Per Year	Product NT Per Year	Material Cost Per NT	Product Cost Per NT
Hot Rolled P&O Coils				
Concast P&O Coils	38,000		$66.67	$49.13
Ingot P&O Coils	16,285		75.98	23.99
Cost Above				3.75
Total Cost	54,285	51,570		$76.87
Credit Scrap		2,715	19.00	(1.00)
Net Cost of P&O Coils		51,570		$75.87
Hot Rolled Black Coils				
Concast Hot Rolled Coils	24,305		$61.11	$43.21
Ingot Hot Rolled Coils	10.420		70.03	21.23
Cost Above				3.75
Total Cost	34,725	34,375		$68.18
Credit Scrap		350	19.00	(.19)
Net Cost of Black Coils		34,375		$67.99
Cold Rolled Sheet				
Concast Tempered Strip	200,650		$76.75	$34.11
Ingot Tempered Strip	301,005		84.15	57.50
Cost Above				3.00
Total Cost	501,655	451,490		$94.61
Credit Scrap		50,165	19.00	(2.11)
Net Cost of Cold Rolled Sheet		451,490		$92.50
Cold Rolled Coils				
Concast Tempered Strip	121,595		$76.75	$31.01
Ingot Tempered Strip	182,425		84.15	52.57
Cost Above				2.00
Total Cost	304,020	300,980		$85.28
Credit Scrap		3,040	19.00	(.19)
Net Cost of Cold Rolled Coils		300,980		$85.09

	Material NT Per Year	Product NT Per Year	Material Cost Per NT	Product Cost Per NT
<u>Coil Rolled Strip</u>				
Concast Tempered Strip	45,510		$76.75	$ 32.66
Ingot Tempered Strip	68,270		86.25	55.05
Cost Above				3.75
Total Cost	113,780	106,950		$ 91.46
Credit Scrap		6,830	19.00	(1.21)
Net Cost of Cold Rolled Strip		106,950		$ 90.25
<u>Galvanized Sheet</u>				
Concast Tempered Strip				
Ingot Tempered Strip	263,250		$86.25	$84.68
Zinc	13,165			19.50
Cost Above				29.00
Total Cost	276,415	268,120		$133.18
Credit Scrap		8,295	19.00	(.59)
Credit Dross				(2.15)
Net Cost of Galvanized Sheet		268,120		$130.44
<u>Galvanized Coils</u>				
Concast Tempered Strip				
Ingot Tempered Strip	171,960		$86.25	$82.97
Zinc	8,595			16.40
Cost Above				24.50
Total Cost	180,555	178,750		$123.87
Credit Scrap		1,805	19.00	(.19)
Credit Dross				(2.15)
Net Cost of Galvanized Coils		178,750		$121.53



APPENDIX C

NO. 1 HEAVY MELTING SCRAP - DEFINITION AND IMPURITIES

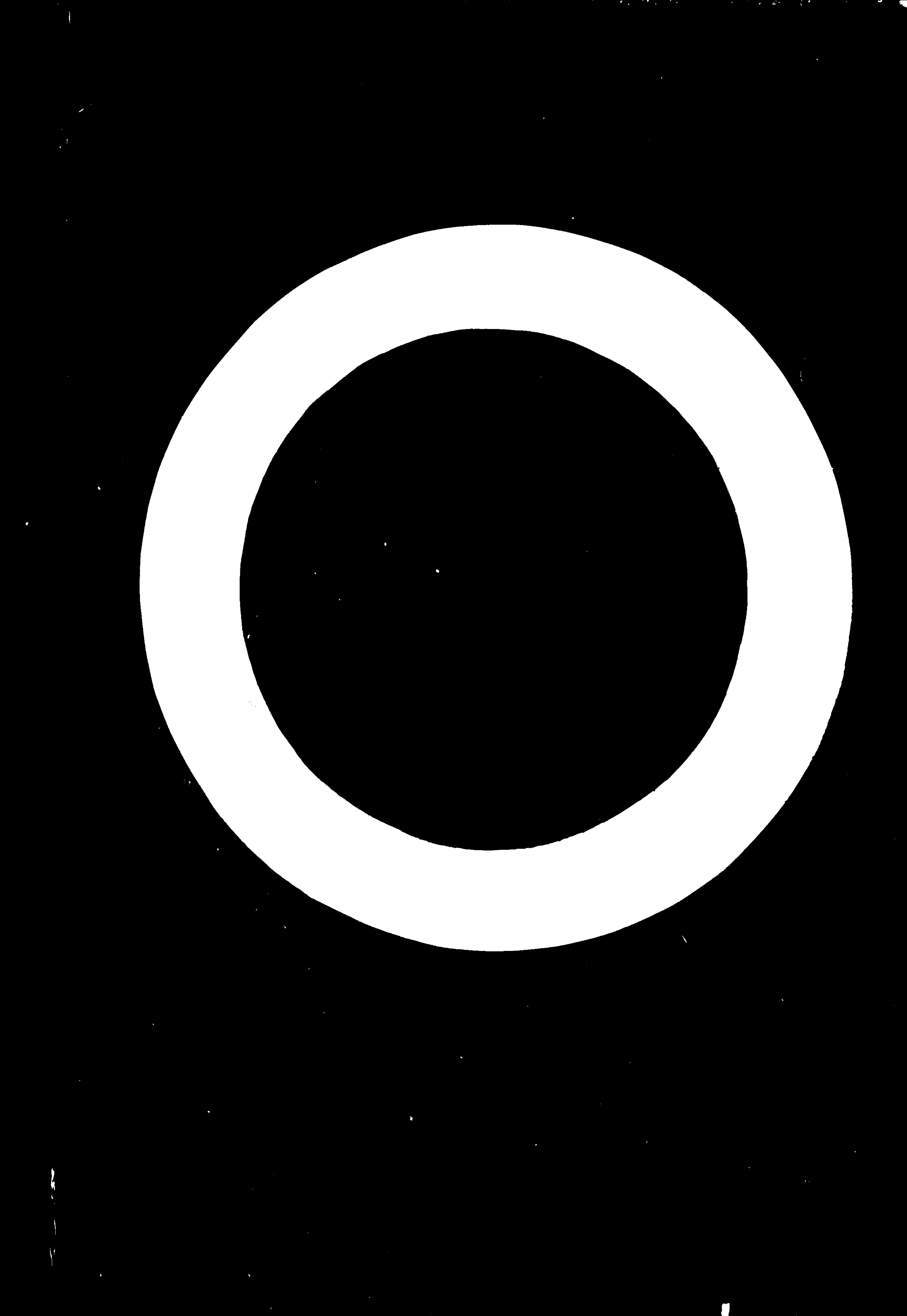
Definition

Clean wrought iron or carbon steel scrap 1/4 inch and over in thickness, not over 18 inches in width and not over 5 feet in length.

Impurities (Range and Average)

Element	Range %	Average %
Sulphur	0.030-0.040	0.035
Copper	0.075-0.100	0.100
Tin	0.006-0.010	0.010
Nickel	0.050-0.100	0.050
Chromium	0.040-0.040*	0.040
Molybdenum	0.030-0.030	0.040

*Reflects chromium last to slag which is not included.



APPENDIX D
ELECTRIC FURNACES, CONTINUOUS CASTING & BAR MILL
ESTIMATE OF CAPITAL COST

Description	Item Cost	Total Cost
STEP I		
Site Development		
Change House	$ 75,000	
Yard Piping & Sewers	330,000	
Electric Distribution	550,000	
Site Preparation	300,000	
R.R. Trackwork	230,000	
Roads & Parking	125,000	
Cooling Water Facilities	250,000	
Total: Site Development		$ 1,860,000
Plant Auxiliaries		
Buildings	$ 5,800,000	
Building Auxiliaries	2,500,000	
Distribution Piping	460,000	
Electric Distribution	1,200,000	
Auxiliary Equip. (Roll Shop, etc.)	600,000	
Total: Plant Auxiliaries		$ 5,340,000
Process Equipment		
1-40 Ton Electric Furnace	$ 1,300,000	
1-3 Strand Billet Casting Machine	3,900,000	
Auxiliary Equipment	800,000	
1-Bar Mill	12,000,000	
1-No-Twist Mill	2,500,000	
Aux Equip. (Straighteners, etc.)	500,000	
Total: Process Equipment		$21,000,000
SUBTOTAL		$28,200,000

Cont F.O.H. Const Plant & Fee @ 12%		$ 3,400,000
Eng, Supv, Proc & Fee @ 10%		3,200,000
Contingency @ 10%		3,500,000
TOTAL: STEP I		$38,300,000

STEP II

1-40 Ton Electric Furnace	$ 1,300,000	
Auxiliary Equipment	250,000	
Piping Distribution	125,000	
Electric Distribution	275,000	
Associated Equip. (Handling, etc.)	200,000	
Finishing Facilities	500,000	
SUBTOTAL: STEP II		$ 2,650,000
Cont F.O.H. Const Plant & Fee @ 12%		300,000
Eng, Supv, Proc & Fee @ 10%		300,000
Contingency @ 20%		650,000
TOTAL: STEP II		$ 3,900,000

STEP III

1-40 Ton Electric Furnace	$ 1,300,000	
1-3 Strand Billet Casting Machine	3,900,000	
Auxiliary Equipment	500,000	
Buildings	2,500,000	
Building Auxiliaries	1,300,000	
Piping Distribution	200,000	
Electric Distribution	400,000	
Site Work	1,500,000	
Associated Equipment	700,000	
SUBTOTAL: STEP III		$12,300,000

Cont F.O.H. Const Plant & Fee @ 12%	$ 1,480,000
Eng. Supv. Proc & Fee @ 10%	1,380,000
Contingency @ 20%	3,040,000
TOTAL: STEP III	$18,200,000
TOTAL: STEPS I, II, & III	$60,400,000

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