MATERIALS FOR THE PRODUCTION OF STEEL

24 October 1951

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MATERIALS FOR THE PRODUCTION OF STEEL

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GENERAL HOLMAN: Gentlemen, last week in our studies on natural resources we were given a survey of the world-wide petroleum situation. This morning we turn to steel production and the materials and other requirements for steel production, which, of course, is the backbone of any modern industrial economy. In searching for a speaker to give you a clear picture of the steel industry and the materials required to have a good strong steel industry, one would look for a man who, through research, was very well acquainted with materials, not only iron, coal, and limestone, but the alloys, and a man who has had wide experience in the industry itself, and one who has both a national and an international outlook.

The Industrial College is very fortunate this morning in having such a man as our guest speaker, Mr. R. E. Zimmerman, Vice President and Chairman of the Research Policy Committee of the United States Steel Corporation. Mr. Zimmerman, it is a great honor to have you with us and a real privilege to hear you on this important subject. We welcome you to the college.

MR. ZIMMERMAN: Good morning, gentlemen. I hope that we may have an interesting and profitable time together.

Introduction

The steel industry of the United States of America is now producing steel ingots at an annual rate of more than 104,000,000 net tons. Installed capacity is being increased as rapidly as feasible. By 1 January 1952 it should be approximately 107,000,000 net tons, representing an increase of more than 25,000,000 tons, or approximately 31 percent over that existing in 1939. To support the production which is possible with that capacity, and more to be added in 1952 and 1953, it is evident that enormous quantities of raw materials will have to be provided, and finishing facilities will have to be equated against the estimated demands for a wide variety of steel products.

This country is fortunate in having available within its borders much of the material from which steel is produced, but for certain essential constituents it is dependent upon imports, many of which must be transported long distances by water and rail. In times of peak demand and in periods of emergency, the problem of supply is intensified. An objective appraisal of the current situation, with only the necessary minimum of statistics, is the purpose of the following discussion.

Pig Iron, Blast Furnace Iron (Hot Metal)

The assembly of the basic raw materials, iron ore, coal (coke), and limestone, is the first step in the sequence of operations leading to the production of finished products by the steel industry. These raw materials are charged into the blast furnace, where the reduction of iron ore takes place through a series of chemical reactions dependent upon the combustion of coke, and at the same time, impurities are fluxed away by the action of lime at high temperature. The blast furnace produces molten iron and a liquid slag, each of which is drawn off separately from the furnace at regular intervals. To produce one ton of pig iron requires about two tons of ore, one ton of coal, previously converted into coke, one-half ton of limestone and four to five tons of preheated air in the form of the "blast."

The iron produced by the blast furnace is high in carbon, silicon, and certain other elements, and may be thought of as an intermediate product in the conversion of iron ore to finished steel. However, it constitutes the first instance in which iron as a metallic substance comes into existence in the steelmaking process. The molten iron as it emerges from the blast furnace may be cast into "pigs" for subsequent use in steel plants or foundries, or more usually may be taken directly to the steelmaking furnaces (open hearth, electric, or Bessemer) where it is refined to molten steel by controlled elimination of the excess of carbon and other unwanted constituents and then cast into ingots for further processing.

The actual and estimated annual blast furnace capacity of the U.S.A. for the production of iron and ferroalloys in certain significant years is shown below:

Year	Net tons
1939	56,325,830
1951	72,471,780
1953	79,324,000 (Estimated)

The foregoing blast furnace capacity, expressed as percentages of total U.S.A. capacity, is distributed over the country in districts as shown in the following table:

Year	Pittsburgh-Youngstown	Chicago	Eastern	Cleveland-Detroit	Southern	Western
1939	41.4	21.7	19.7	9.6	6.2	1.4
1951	37.3	21.7	19.2	9.8	7.3	4.7
1953	36.8	20.7	20.1	10.6	7.3	4.5

All six districts have made and are scheduled for substantial increases in blast furnace capacity.

Transportation aspects.--The primary raw materials, or some of them, ore, coal (coke), and limestone must be transported to the blast-furnaces, in most cases over very considerable distances. The transportation problems are discussed later to some extent under the separate raw material topics and it will suffice to say here that transportation of these bulk tonnage materials is a substantial problem in the steel industry, involving consideration of such diverse factors as climate and seasonal changes, availability of railroad and marine equipment, overseas shipping and terminal facilities, relations with foreign governments, duties and tariffs, and the all-important question of whether the pertinent sea routes will be open to us in case of hostilities. In addition there is the economic question of cost of this transportation which must enter into the cost of the final steel product. In a few instances, the steelmaking facilities are within short hauling distance of the primary raw materials, but even in such cases the use of increasing amounts of foreign ore is being provided, in the interest of conserving domestic supplies.

Certain steelmaking plants depend upon cold pig iron and scrap as their basic materials, because they are not equipped with blast furnaces. Such plants are relatively heavy users of steel scrap, and are dependent upon others for their supply of the blast furnace iron used in their steelmaking process.

Scrap

Pig iron and scrap together constitute the main source of metallics upon which the steel industry is based. One ton of scrap is approximately the equivalent of two tons of iron ore.

Scrap may be divided into two categories depending upon source:

1. So-called "home" or "produced" scrap which is generated within the steel-producing industry itself, consisting of ingot butts, crop ends of slabs, blooms, and billets, edge shearings and trimmings from plates, strip, sheets, and other flat rolled products as well as scrap from miscellaneous sources such as bars, rods, wire, castings, and other steel mill and foundry products.

2. So-called "purchased" scrap from (a) the metal working industry which machines, forges, fabricates, or otherwise fashions new iron and steel into consumer and capital goods, (b) recovered steel accruing from dismantling operations, abandonment of obsolete and worn equipment, and (c) miscellaneous discarded iron and steel items. The record of purchased scrap consumption by steel plants and foundries for a few significant years is shown below (Scrap Institute Yearbook 1951):

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Year	Net tons	
1942	26,880,000	(Biggest war year)
1948	32,480,000	
1950	32,930,000	
1951	35,280,000	(Estimated from early months)
1952	39,760,000	(Based on 118,000,000 net tons of ingots and 20,000,000 net tons of castings.)

Approximately 11,200,000 net tons of the 1950 total moved promptly into consumption in the steel industry, most of it through scrap dealers or brokers after segregation and preparation in accordance with official specifications. It is said that the supply of prompt industrial or factory scrap bears a direct relationship to the tonnage of rolled steel and iron castings produced in a given period.

Of the remaining approximately 22,000,000 net tons of scrap in 1950, the largest identifiable portion is the 4,500,000 net tons marketed by the railroads resulting from scrapping of obsolete equipment. It is estimated that obsolete automobiles average about one ton of scrap per car and that between 1.5 and 2 million tons may have come from this source in 1950. Automobiles and the lay-up fleet of 1,500 liberty ships are regarded as the two largest sources of potential scrap for 1951 and 1952. This lay-up fleet represents 5 to 5.5 million net tons of high-grade scrap, but the Maritime Commission is not releasing much of it until larger and more modern ships become available. Farm scrap is another large potential source and in 1950 may have accounted for more than 1.5 million tons. Other miscellaneous sources account for the balance of the purchased scrap supply.

The unprecedented rates of steel production in recent months have drained the scrap yards bare. Likewise, the mills and foundries have used up their inventories and stockpiles, with many mills now having only a few weeks' or even a few days' supply on hand. This tight supply situation has led to allocation of all industrial and railroad scrap by government edict. Intensive scrap salvage drives are now under way and every effort is being made by both the steel-producing and scrap industries to bring dormant scrap into the open and get it on its way to the preparation yards and steel mills. An important factor in the scrap situation is the availability of open top railroad equipment for transportation of the scrap to its destination.

For the year 1950 the total charge of metallics in open-hearth furnaces was as follows:

	Percent
Purchased scrap	20.3
Home scrap	25.7
Pig iron	54.0
Total	100.0

Electric steelmaking furnaces are heavily dependent on special grades of steel scrap, which together make up more than 97 percent of their metallic charge. These furnaces are reported as having used 4,280,000 net tons of purchased scrap in the year 1950. Altogether the steel industry consumed 22,260,700 net tons of purchased scrap in its various steelmaking operations.

Imports of scrap in 1950 totaled 730,625 net tons and exports were at 208,774, both off sharply from the previous year.

Iron Ore

Iron ore is the fundamental, primary raw material upon which the iron and steel industry is based. Usable iron ores are found widely distributed throughout the world, every continent having some proved deposits, although those in North America and Europe have been most extensively exploited to date.

Early in 1950 the proved iron ore reserves of the U.S.A. stood about as given here. This excludes ores with iron ore content below the given percentages as follows:

District	Gross tons	Percent
Northeastern	1,108,000,000	30
Southeastern	1,558,000,000	30
Lake Superior	73,370,000,000	35
South Central	880,000,000	35
Western	418,000,000	45

From this it is seen that the Lake Superior district is the predominant factor in the domestic iron ore supply for the domestic steel industry. It is credited with having available at least 1,365,000,000 gross tons of ore of the kind it is currently supplying.

Notwithstanding offhand opinions to the contrary, there is no shortage of iron ore reserves in this country. The high-grade, so-called "direct shipping" ores of the Lake Superior district were never expected to last forever. The American steel industry has been squarely facing this fact for some years and has been taking active steps to prepare for the future. In the first place many companies in the industry have been developing new processes and new beneficiating plants designed to increase the use of the vast quantities of lower-grade iron ores of the Lake Superior district, thus conserving the supply of higher-grade ores for future needs. They are even devising processes for the production of usable iron ore from the lower grades of taconite deposits, of which there are enormous quantities, estimated in hundreds of billions of tons. In the second place, various steel and ore-mining

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companies are undertaking large-scale development of extensive new ore bodies in both North and South America and in Africa to supplement and conserve our domestic iron ore reserves. These two approaches to the problem entail the expenditure of vast sums of money and will require several years for completion. However, substantial progress has already been made and increasing amounts of iron ore from these new sources are assured for the near future.

A word about the trend in the quality of Lake Superior ores over the years may be in order at this point. In the early years of the steel industry, the ores being mined carried in excess of 60 percent iron. This gradually dropped to 55 percent as larger tonnages were required until by 1925 it was down to about 51.5 percent iron on the average. Since World War II a further decrease has occurred, with the 1949 shipments averaging 50.4 percent iron. This gradual reduction in the quality of iron ores led the industry to explore beneficiating processes, and activities in this direction were begun as early as 1910. These beneficiating processes have been improved in efficiency over the years and there has been a gradual increase in the proportion of beneficiated ores shipped each year. In effect, this has resulted in an increase in the potential volume of usable iron ore reserves in the U.S.A.

Comparative U.S.A. iron ore figures for the past two years are reported in gross tons as follows:

	1949	1950
Production	84,937,447	98,160,000
Shipments	84,687,275	97,580,000
Imports	7,394,569	8,215,865
Exports	2,715,748	2,855,669

World production of iron ore in 1949 was reported as 218,000,000 Metric tons (2,204.6 pounds each).

Transportation aspects.--Within the United States, iron ore has to be transported over relatively long distances from the mines to the blast furnaces and steelmaking centers. Much of this transportation is mainly over inland waterways, for example, by way of the Great Lakes supplemented where necessary by rail, to the Pittsburgh, Chicago, Cleveland, and other inland steelmaking districts. The more expensive rail haulage is kept to a minimum wherever possible. In the western district, intermediate hauls of ore are involved, but all of it must be by rail. In the southern district much of the ore is close to the steelmaking centers and transportation is a relatively minor item of cost.

Foreign ores from South America and Africa, naturally, must undergo extensive overseas transportation. In many cases the development of

these foreign ore sources involves the building of railroads over difficult terrain, the dredging of rivers and harbors and the construction of docks, and loading facilities, in out-of-the-way places in the world where construction materials and supplies must be shipped great distances to the site. Likewise, new ore bodies which are now being opened up in Canada and Labrador involve similar engineering and construction problems under difficult conditions of climate and terrain. The vast sums of money which are being spent for such foreign ore developments give no assurance, of themselves, that the sea lanes to and from these sources will be open in time of war. When and as necessary, full reliance may have to be placed upon domestic deposits, whether they are direct-shipping ores, or concentrates prepared from the relatively leaner formations.

Coke

Coke, which is charged into the blast furnace along with iron ore and limestone is the essential reducing agent which converts the ore to metallic iron. To be suitable for use in such blast-furnace operations, the coke must be of so-called "metallurgical grade" and can be made only from certain selected types of bituminous coals. The coke is made by heating the coal to high temperature in sealed ovens and distilling off certain of the volatile constituents. In the older, so-called "beehive" process the volatile products are vented to the atmosphere and wasted. In the modern by-product coking process, the volatile products are recovered in a closed system, yielding large quantities of coke oven gas, which is an excellent industrial fuel, and a whole series of useful coal chemicals, many of which are further processed by the chemical and pharmaceutical industries.

The bulk of the coke made today is produced in by-product ovens, although in times of high demand as much of the remaining beehive oven capacity as possible is brought back into production to supplement the by-product oven capacity.

In 1949, 73,239,614 net tons of coal were used in the production of coke. In 1950 the figure rose to 82,579,141 net tons.

Production of coke in the U.S.A., of which more than 83 percent is accounted for by ovens of the iron and steel industry, is reported in net tons for three years as follows:

	1948	1949	1950
Total Coke Production	74,861,928	63,637,429	72,097,669
By-product Coke	68,284,357	60,222,481	66,437,651
By-product percentage of total	91.2	94.6	92.1

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A recent statement by the Defense Solid Fuels Administration indicated that the expected production of coke in 1951 probably will set a new record of about 80,000,000 tons. The previous record production of 74,862,000 tons occurred in 1948 (Journal of Commerce, 28 August 1951).

Consumption in net tons of coke by blast furnaces in 1948 was 59,128,129; in 1949, 51,356,617; and in 1950, 61,039,227.

The supply of metallurgical coke is none too easy and additional capacity is being provided. There are ample reserves of coal in the United States to take care of the requirements of industry, but new mines must be developed, in step with increased consumption of coke.

Transportation aspects.--In the U.S.A. coking coals are mined principally in Pennsylvania, West Virginia, Kentucky, Alabama, Colorado, and Utah. Other states contribute importantly to the coal supply of the country. Beehive coke is usually made near the mine that supplies the coal. By-product coke is usually made near the blast furnaces or steelmaking plants from coal that frequently has undergone some preparation or beneficiation at the mine site. Thus the major portion of the transportation involved in the metallurgical coke industry takes place while the material is still in the form of coal. It should be noted that the sources of coking coals are not far removed from the major steelmaking centers; in fact, for many years, the location of these centers was determined by the accessibility of good coking coals. In general iron ore has to be transported over much greater distances than coal.

Limestone and other Fluxes

Limestone, the third of the primary raw materials charged into the blast furnace along with iron ore and coke, is used as a flux to aid in separation of the metallic iron and the unwanted impurities which constitute a substantial portion of the iron ore. Many of these impurities are of a highly refractory nature and if they are not rendered fusible, they may interfere with the smooth operation of the blast furnace. The fluxed impurities form a liquid slag which floats on top of the molten metal bath on the hearth of the blast furnace. The slag and metal are drawn off through separate tap holes at regular intervals. Fluxes are also used to condition the slags in open-hearth and electric steelmaking furnaces; these are mainly "burnt lime" and fluorspar, the latter containing about 81 percent calcium fluoride.

The chief natural basic fluxes are limestone and dolomite. Limestone contains slightly over 52 percent calcium oxide while dolomite contains about 30 percent calcium oxide and 20 percent magnesium oxide. Both limestone and dolomite may be used in the blast furnace, whereas only limestone is used in the open hearth, in which case it is usually added as burnt or calcined lime containing about 94 percent calcium oxide.

Limestone of fluxing quality is distributed widely in the central portion of the U.S.A. Most of that used in the Pittsburgh steelmaking district comes from western Pennsylvania, while that of the Great Lakes steelmaking centers comes from lower Michigan and northern Ohio. In the southern district, limestone is close at hand to the steelmaking centers. Dolomite comes chiefly from West Virginia for use in the Pittsburgh and eastern districts and for other centers from sources local to those districts. Fluorspar comes primarily from western Kentucky and southern Illinois, although some is now being imported from Europe. Thus, it is seen that the transportation problem with respect to steel industry fluxes is not too serious, much of the transportation being accomplished over domestic waterways or by relatively short rail hauls.

The tonnages involved are substantial, although they do not approach those of the iron ore and coke used by the steel industry. Consumption of fluxes in steelmaking operations for two years was reported in net tons as follows:

	1949	1950
Limestone	27,524,500	33,218,000
Lime	735,579	969,457
Fluorspar	197,018	232,014
Other fluxes	179,469	220,713
Total	28,636,566	34,640,184

In general, it appears that the supplies and production of steelmaking fluxes are adequate for the foreseeable future and there is no cause for apprehension about the supply of these materials.

It may be of interest to note that the flux materials, after performing their useful metallurgical functions as slag formers in a particular process, are not entirely lost to the economy, but often are of value for other purposes. For example, open-hearth slags are often used as an addition to the blast furnace burden; blast furnace slag of suitable composition is used for making Portland cement, for railroad ballast, road building materials, insulating materials, brick, glass, and a variety of other products. In the southern district blast furnace and basic open-hearth slags are often employed for agricultural purposes where they are useful as soil conditioners.

Refractories

Refractories are the chief materials used in the steel industry in the construction of furnaces, in the lining of retaining vessels for molten metal, and in flues or stacks through which hot gases are conducted.

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Abrupt failure of refractories may result in serious loss of time, equipment, and production. Refractories are expensive and economics figure largely in their selection and in the solution of problems involving them. For example, a refractory best suited for a given application may not necessarily be the one with the longest life, but one that provides the best balance between initial installed cost and service performance.

Steel plant refractories are used in a wide variety of forms depending upon the particular application. The major forms may be classified as:

1. Massive (bricks or blocks).
2. Granular.
3. Finely divided.

These forms may be installed in the raw, fired, or chemically bonded condition.

Refractories may be further broadly classified into the following categories.

1. Siliceous group comprising the various types of silica brick containing from about 80 to 98 percent silica.

2. Fireclay group comprising various grades of brick containing about 50 to 70 percent silica and 23 to 43 percent alumina.

3. High alumina brick group comprising materials containing approximately 21 to 47 percent silica and 47 to 71 percent alumina.

4. Basic brick group consisting of a wide range of materials containing approximately 1.5 to 34 percent silica, 1 to 30 percent alumina, 16 to 96 percent magnesia, and 0 to 42 percent chrome oxide (Cr_2O_3).

In addition to the above general groups there are the following types of refractories which are widely used for special purposes:

1. Dead-burned magnesite containing 78 to 84 percent MgO.

2. Dead-burned dolomite containing 50 percent CaO and 34 to 38 MgO.

3. Chrome ore containing 12 to 28 percent alumina, 10 to 20 percent magnesia, and 32 to 50 percent chromium oxide.

4. Carbon block containing 88 to 92 percent carbon with 4 to 6 percent silica and 3 percent alumina.

It is impracticable in a brief discussion of this subject to give a comprehensive picture of the sources of raw materials, methods of preparation, or the many different applications of the wide range of refractories used in the steel industry. The particular use to which a given refractory is put depends upon its physical and thermal properties. The science and technology of refractories constitute a highly specialized subject. A great deal of research and development work is now going on in this field by both the refractory producers and the steel industry consumers, as a result of which the quality and performance of refractories is constantly being improved. The productive capacity of the refractories industry is expanding in proportion to the present expansion of the steel industry.

The raw materials for the refractories industry are widely scattered as indicated below:

1. Fireclays--Pennsylvania, Kentucky, Ohio, and Missouri.
2. Silica--Pennsylvania, Alabama, Wisconsin, Utah, and Ohio.
3. Magnesite--Washington, California, New Jersey, and Austria.
4. Dolomite--Ohio, Illinois, Pennsylvania, and Maryland.
5. Chrome Ore--Philippines, Cuba, and South Africa.
6. High Alumina (above 50 percent)--Missouri, India, and Guiana.

There are about 130 manufacturers of refractory products in the U.S.A. The largest and best known of these companies are as follows:

1. Harbison-Walker Refractories Co.
2. General Refractories Co.
3. A. P. Green Refractories Co.
4. LaClede-Christy Refractories Co.
5. Hiram Swank's Sons
6. McLain Firebrick Co.
7. E. J. Lavino and Co.
8. National Carbon (carbon block) (Div. of Union Carbide and Carbon Corp.)

At the present time the supply situation on silica brick, superduty clay brick, magnesite, and double-burned dolomite is tight; the supply of carbon block could easily become tight with only one supplier in the field. Otherwise the supply of refractories for steel industry use is reasonably easy.

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Fuels--Gas, Tar, Oil, Coal, Electric Power

Since so many operations and processes of the steel industry are carried out at very high temperatures, the industry is inevitably a consumer of vast quantities of fuel. These fuels may be broadly classified as gaseous, liquid, and solid.

The principal gaseous fuels used in the steel industry are blast furnace gas, coke oven gas, natural gas, and producer gas. With the exception of natural gas, these fuels are produced right at the steel-making centers and thus they are immediately accessible for steel mill operations.

Natural gas, almost always associated with petroleum, comes from any of the great petroleum-gas fields in this country, of which the following are the most important: Appalachian, Indiana, Illinois, Mid-Continent, Gulf, and California. Many of these fields are linked by pipelines and gas is now transported over great distances to many of the consuming centers.

The gross heating value of these gaseous fuels is shown below:

Fuels	Btu/cu. ft.
Blast Furnace Gas	92
Coke Oven Gas	574
Natural Gas	1129
Producer Gas	163

The steel industry uses these gases in decreasing amounts in the order shown above, that is, blast furnace gas in largest volume with coke oven and natural gas next in order; the use of producer gas in the steel industry is rapidly fading.

In 1949 the steel industry consumed 398,885 million cubic feet of natural gas and in 1950 the consumption rose to 533,435 million cubic feet. The supply of natural gas is related to the exhaustion of existing petroleum fields and the discovery and development of new wells.

The availability of blast furnace and coke oven gas is related to the rate of blast furnace and coke plant operations as well as to the supply of coal. There is ample coal in the ground in the U.S.A. for at least some hundreds of years at present rates of consumption.

The principal liquid fuels used in the steel industry are petroleum base fuel oils and pitch-tar mixtures, the latter resulting from coking operations. The petroleum oils most widely used in steel mill operations

are known as bunker "B" and bunker "C", the former usually being a cracking still tar and the latter a straight-run or cracked residual, or a mixture of the two blended to reduce the viscosity.

In 1949 the iron and steel industry consumed 1,835,296,633 gallons of fuel oil and in 1950 the figure rose to 2,294,204,238 gallons. Much of the fuel oil for steel industry use must be low in sulphur (maximum 1 percent sulphur) in order to minimize sulphur pickup in melting and heating operations. At the present time the supply of this low sulphur fuel oil is very tight and everything indicates that during the coming winter this fuel will be in critically short supply. This comes about as a result of a number of factors, namely, price ceilings, changes in oil refinery technology which have resulted in less residual fuel oil being produced, the cutting off of oil supplies elsewhere in the world (closing of the Abadan refinery in Iran) which has caused an increased drain on U.S.A. oil resources, and a number of other circumstances, all of which point to less fuel oil for the steel industry in the immediate future.

Tar, as produced in by-product coke ovens, consists of a mixture of substances ranging from tar acids to neutral oils and aromatic hydrocarbons. The residue pitch resulting from the distillation of tar is highly viscous and contains free carbon and high-boiling complex organic compounds. Tar and pitch-tar mixtures must be delivered hot (200 to 250°F.) to the furnace burners in order to maintain the correct viscosity to permit flow through pipes, etc. In 1949 the consumption of tar and pitch by the steel industry for melting and other heating purposes was 280,238,319 gallons and in 1950 the figure rose--only slightly--to 280,518,601 gallons. As long as by-product coke plants continue to operate at present rates, there is no anticipated shortage of pitch and tar for fuel purposes in the steel industry.

Coal, for purposes other than the production of coke, is of course, another important fuel in the steel industry. In 1949 the industry consumed about 8.8 million net tons of coal for steam and other miscellaneous purposes. In 1950 the figure rose to about 9.2 million net tons.

Electric power consumed by the steel industry amounted to 19,701 million kilowatt hours in 1949 and in 1950 the figure rose to 24,664 million kilowatt hours. Of the 1950 amount of power consumed, approximately 36 percent was generated within the steel industry itself and 64 percent was purchased from outside sources.

Manganese

Ferromanganese, an alloy of manganese and iron, is one of the most important of the ferroalloys used in steelmaking and is employed both

as a deoxidizer and as an alloy addition agent. It is available in various grades ranging from 78 to 85 percent manganese. Silico-manganese, silico-spiegel and spiegeleisen containing various proportions of manganese (16 to 68 percent) and silicon (1 to 20 percent) are also used to some extent in steelmaking operations. Manganese ore is the important raw material in the production of these ferroalloys.

Ferromanganese is made in blast furnaces and electric furnaces from manganese ores, the chief sources of which are India, Africa, Brazil, Cuba, and Russia, although very little is coming to the U.S.A. from Russia at the present time. Mexico and French Morocco are among the minor suppliers. Domestic production and imports of manganese ore in net tons for three years were as follows:

	1948	1949	1950
Domestic	131,000	126,136	138,992
Imports	1,260,000	1,550,000	1,840,000
Total	1,391,000	1,676,136	1,978,992

To these figures may be added those for imported ferromanganese, which in terms of manganese ore in 1948 was 195,000 net tons; in 1949, 130,000 net tons; and in 1950, 222,000 net tons. This makes the grand total for the year 1950, for example, 2,200,992 net tons of manganese ore. It is estimated that such an amount of ore will be just about sufficient for requirements of 1951, and that as steel production increases, additional manganese will have to be provided. As an emergency measure, experiments are well under way for the reclamation of manganese from steelmaking slags, and extraordinary efforts are being made to increase imports from old and new sources. Concentration of low-grade domestic ores is also under study, and for special purposes, commercially pure electrolytic manganese is being produced in relatively small quantities from American ores.

In general the supply of manganese ore is critical at the present time. The imports from Russia, originally our largest single supplier, have sharply decreased in recent years and, while our imports from other sources have been stepped up materially, we are far from being in an easy position with respect to this raw material. Moreover, the long overseas hauls involved in these import operations could easily mean difficulties in times of emergency.

Production of ferromanganese in net tons for sale in the U.S.A., that is, excess over the producers' own requirements in 1949 was 389,305 and in 1950, 420,336.

The chief producers of ferromanganese in the United States include the following:

1. United States Steel Corporation.
2. Bethlehem Steel Company.
3. Electrometallurgical Division, Union Carbide & Carbon Corp.
4. Anaconda Copper Company.
5. E. J. Lavino & Company.

While some manganese is used in the production of nearly all varieties of steel, one of the most interesting alloys is the 13 percent manganese helmet steel, an extremely tough, strong material from which "trench hats" are made.

Ferrosilicon

Ferrosilicon is another very important deoxidizing and alloying agent in steelmaking operations. The low silicon grades of ferrosilicon containing 10 to 17 percent silicon are usually made in the blast furnace, whereas the higher silicon grades containing 25, 50, 75, 85, and 90 to 95 percent silicon are electric furnace products. The U.S.A. supply is all made domestically and there are some 8 to 10 chief producers including the following:

1. Electrometallurgical Division, Union Carbide & Carbon Corp.
2. Vanadium Corporation of America.
3. Pittsburgh Metallurgical Company.
4. Ohio Ferro-Alloys Corporation.
5. Tennessee Products and Chemical Corporation.
6. Keokuk Electro-Metals Company.

U.S.A. production of ferrosilicon in 1949 was 667,000 net tons and in 1950 the figure rose to 840,000 net tons. With the exception of the 50 percent silicon grade, there is nothing critical in the supply situation of ferrosilicon at the moment. It is reported that additional facilities are under construction to ease the shortage in the 50 percent silicon grade, and the situation should be easy by November this year.

One of the most important uses for the higher grades of ferrosilicon as an alloying element is the production of the "electrical steels," which are used for such items as armatures, transformers, and rotors.

Nickel

Nickel is one of the most important alloying elements in numerous widely used low-alloy constructional and mechanical steels, in many steels for military equipment, or armament, and in all of the austenitic stainless and heat-resisting steels. It is added to the molten steel in the form of metal of about 99 percent minimum nickel content, or as

sinter containing 75 percent nickel, or sometimes as nickel oxide. Nickel ores are not produced in the United States. Imports of the metal in 1950 are estimated at 183,106,000 pounds. Total consumption of nickel in this country in 1950 was 198,043,618 pounds of which 79,135,000 pounds, or almost 40 percent, were used in stainless and other steels. Stocks of nickel held by consumers in the U.S.A. as of 31 December 1950 were 11,813,000 pounds, equivalent to slightly more than three weeks' requirements at the 1950 rate of consumption.

The whole problem of nickel supply is extremely critical. The principal sources of nickel for the U.S.A. are the International Nickel Company of Canada, Ltd., and Falconbridge Nickel Mines, Ltd., also of Canada. Both of these producers anticipated that the demand in 1950 would exceed the available supply and instituted rationing programs for equitable distribution of nickel. In addition it is reported that the International Nickel Company has increased its production by 1,000,000 pounds per month to a total of 21,000,000 pounds per month. In spite of these measures the demand for nickel has continued to increase and the present shortage promises to grow worse. Some nickel is produced in New Caledonia, Norway, and in Finland, but little if any of this production now reaches the U.S.A. The recently reactivated Nicaro plant in Cuba is a potential source of nickel oxide, but it will be some time before these facilities are ready for production. Everything indicates that the steel industry will have to use its available supply of nickel where it is most urgently needed. Attempts to develop substitute or alternate alloy steels with low nickel contents are actively under way at the present time.

Chromium

Chromium is another one of the very important alloying elements in many grades of low-alloy steels and is present, in much larger amounts, in all of the stainless and heat-resisting steels. It is widely used in the production of armor and other military equipment, and is a constituent of a long list of steels used in making machinery. It is also an important element in a great many tool steels. Chromium is added to the molten steel in the form of ferrochromium containing 65 to 72 percent chromium and a maximum of 2 percent silicon. There are various grades of ferrochromium ranging in carbon content from 0.06 to 2 percent along with the most commonly used and cheapest grade containing 4.5 to 8.5 percent carbon. Practically all of our chromium ore supplies come from foreign sources, the chief deposits being found in Russia, South Africa, Turkey, Philippines, Cuba, and Southern Rhodesia. Ferrochromium is made in electric furnaces in the U.S.A. and Canada, the chief suppliers including the following companies:

1. Electrometallurgical Division, Union Carbide & Carbon Corp.
2. Ohio Ferro-Alloys Corp.
3. Vanadium Corporation of America.
4. Pittsburgh Metallurgical Company.

Consumption of chromium in the manufacture of steel for the past three years is indicated by the following figures:

Year	Pounds
1948	212,708,500
1949	148,442,800
1950	247,649,000

At the present time the supply of low carbon grades of ferrochromium is very tight. Currently it is estimated that there is a 25 percent shortage of chromium in this country.

In the case of chromium, as well as with the other important alloy steels, our metallurgists have devised new or modified compositions which will reduce the consumption of critical materials, without thereby impairing the usefulness or service value of the product. A notable step in this direction is the further development of the boron-treated alloy steels, which will carry the economy of alloying elements beyond the point attained by the National Emergency Steels of World War II.

Molybdenum

Molybdenum has attained an important place as an alloying element in many low-alloy constructional steels, in certain tool steels, and in a few of the stainless and heat-resisting grades as well as in the so-called "superalloys" designed for severe high temperature service. It is added to the molten steel in the form of ferromolybdenum containing 55 to 75 percent molybdenum or sometimes in the form of the oxide or calcium molybdate. Numerous steels employed for military purposes carry a content of molybdenum as an alloyed constituent, either alone or in combination with other metals.

The chief sources of molybdenum ore are located within the U.S.A., the following states being the principal producers: Colorado, Utah, New Mexico, California, Arizona, and Nevada.

There are two principal suppliers of molybdenum products for steel industry use, namely, Climax Molybdenum and Molybdenum Corporation of America. Several copper companies are now producing small amounts of molybdenum concentrates. Because of the fact that the demand for molybdenum is about twice the available supply, the situation is very

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tight, and molybdenum is under allocation. The steel industry is making great efforts to reduce the amount of molybdenum in many alloy steels and to develop substitute alloys wherever possible.

In 1948 the consumption of molybdenum by the steel industry was 16,348,800 pounds; in 1949, 11,243,780 pounds; and in 1950 the figure rose to 17,242,931 pounds.

Vanadium

Vanadium is added to some grades of low-alloy constructional steels and to many grades of tool steels to improve their heat-treating characteristics and mechanical properties. It is added to the molten steel in the form of ferrovanadium containing 35 to 55 percent vanadium.

Vanadium ores occur in Peru, Northern Rhodesia, South-West Africa, and in the Colorado-Utah region in the U.S.A. with some small amounts coming from Arizona, Nevada, and New Mexico.

The principal producers of ferrovanadium in the U.S.A. are: Vanadium Corporation of America, and Electrometallurgical Division of Union Carbide and Carbon Company. There appears to be an ample supply of vanadium for present needs.

Consumption of vanadium by the steel industry in 1948 was 1,550,147 pounds; in 1949, 1,079,024 pounds; and in 1950 it rose to 1,825,831 pounds.

Cobalt

Cobalt is used in the ferrous industry mainly as an alloying element in magnet steels and permanent magnet alloys, in special alloys for severe high temperature service and in some grades of tool steel. It is also used extensively in hard facing materials and cemented carbide tools. Substantial amounts of cobalt oxide are used in ground-coat frit in the enameling industry. The U.S.A. is the largest consumer of cobalt in the world.

The Belgian Congo is the chief source of cobalt, with smaller amounts coming from North Rhodesia, Canada, and French Morocco. About a dozen dealers in cobalt in the U.S.A. are listed; the principal supplier of the metal is said to be African Metals Corporation, New York City.

Consumption of metallic cobalt in the manufacture of steel in 1949 was 991,645 pounds and in 1950 it rose to 2,040,118 pounds. Other uses require approximately twice that amount. The cobalt supply situation is very tight at the present time, all cobalt distribution being under government allocation.

Tungsten

Tungsten is an essential alloying element in many tool steels, particularly the high-speed steels, and in some of the "superalloys" for severe elevated temperature service. It is also an important ingredient in cemented carbide tools. Some very special steels used in the production of munitions carry a tungsten content if that element is available for the purpose.

China is the chief source of tungsten ores, with Burma, Portugal, Bolivia, Korea, and the U.S.A. producing substantial amounts. In this country California, Nevada, and North Carolina are the principal tungsten producing states. Tungsten is supplied in the form of ferrotungsten, tungsten powder, and tungsten salts. Among the principal suppliers in this country are the following:

1. Electrometallurgical Division, Union Carbide & Carbon Corp.
2. Wah Chang Corporation.
3. Fred H. Lenway & Co., Inc.
4. C. Tennant Sons & Co.
5. Molybdenum Corporation of America.
6. Climax Molybdenum Company.
7. Frank Samuel & Co., Inc.

Consumption of tungsten by the steel industry in 1948 was 4,313,518 pounds; in 1949, 2,170,483 pounds; and in 1950, 3,929,779 pounds.

At the present time the tungsten supply situation is very tight and unpromising, probably due to interruption of ore shipments from Asia. Available quantities are apportioned amongst the most critical needs.

Aluminum

Aluminum is used in the steelmaking process as a deoxidizer and degasifier and is usually added in the form of secondary aluminum of 85 percent purity or better. It may be added as shot or bars in either the ladle or ingot molds or occasionally in the steelmaking furnace, depending upon the grade of steel, and other circumstances. At the present time the supply of aluminum for deoxidizing purposes is very critical. The principal suppliers of grades 1, 2, and 4 aluminum for deoxidizing purposes are as follows:

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1. U.S. Reduction Company.
2. Aluminum Smelting and Refining Company.
3. Alloys and Chemicals Company.
4. Keystone Metal Company.
5. Tomke Aluminum Company.

Exact figures for the consumption of aluminum by the steel industry in its production processes are not available, but reasonably good estimates place the amount at approximately 62,000,000 pounds for the year 1951.

Aluminum is also used to a limited extent as a coating material on some steel products, notably wire, strip, and sheet. In this application virgin aluminum of relatively high purity is used, although it is frequently alloyed with silicon, copper, or other elements to improve adherence, spangle, or other characteristics of the coating. The principal suppliers of virgin aluminum are:

1. Aluminum Company of America.
2. Reynolds Metals Company.
3. Permanente Metals Company.

Imports from Canada augment the domestic supply of metallic aluminum. While there is a substantial production of aluminum ores in the United States, the industry leans heavily on importations from South America.

In general the supply situation on virgin aluminum is tight and, according to reports, there is little likelihood of improvement for the first three quarters of 1952.

Copper

Copper, in the form of pure metal or as copper-bearing scrap, is added to some grades of steel in small amounts, usually under 0.5 percent, chiefly to enhance resistance to atmospheric corrosion. It is also used as a coating material for certain steel products.

Copper ores are found widely distributed over the world; large mines are operating in the United States, Canada, and Mexico. Much copper is also produced in South America and Africa as well as in Europe. Within the U.S.A. the principal copper producing states are Utah, Arizona, New Mexico, Montana, and Nevada. The leading copper producing companies are as follows:

1. Kennecott Copper Corporation.
2. Phelps-Dodge Corporation.
3. Anaconda Copper Mining Company.
4. American Smelting & Refining Company.

There are also many other large producers in the United States and Canada, of almost equal importance.

Consumption of copper in pounds by the steel industry for the past three years was as follows:

	1948	1949	1950
For Coatings		51,622,000	45,992,000
All Other Uses		74,438,000	85,092,000
Total	133,176,000	126,060,000	131,084,000

The amount of copper taken by the steel industry for alloy and coating purposes is of course relatively small compared to that involved in power lines and electrical equipment in the industry which, of course, is a tremendous consumer of electric power.

At the present time the copper supply is very stringent. The strike of mine and smelter workers in the copper industry on August 27th was an adverse development. Producers stocks of copper at the end of July comprised only about two weeks' supply as compared to a normal supply of two to three months. Recently, 25,000 tons of copper from the United States stockpile were released to users.

Titanium

Titanium is used in steelmaking as a deoxidizer and degasifier as well as a carbide stabilizing element in some of the stainless and heat resisting grades. It is usually added in the form of ferrotitanium of low-medium--or high-carbon content or sometimes in the form of alloys containing aluminum, silicon, or other metals.

Within the United States, titanium ores, the reserves of which are considered abundant, are mined in New York, Florida, North Carolina, and Virginia, the U.S.A. being the world's leading producer of titanium. India, Norway, Australia, Malaya, and Brazil also produce substantial quantities.

Among the principal suppliers of titanium alloys in this country are:

1. Titanium Alloys Manufacturing Division of National Lead Company.
2. Vanadium Corporation of America.
3. Molybdenum Corporation of America.
4. Metal and Thermit Corporation.
5. C. Tennant Sons & Company (distributor for Murex, Ltd.).

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Consumption of titanium in the manufacture of steel in 1948 was 3,784,965 pounds; in 1949, 4,222,221 pounds; and in 1950, 4,932,319 pounds. At the present time the supply of medium-carbon and high-carbon ferrotitanium is very tight.

Columbium

Columbium is used as a carbide stabilizing element in certain grades of stainless and heat-resisting steels and as an alloying element in some of the "superalloys" for severe elevated temperature service. It is usually added in the form of ferrocolumbium, the principal supplier of which in the U.S.A. is the Electrometallurgical Division of Union Carbide and Carbon Corporation. C. Tennant Sons & Company also supply ferrocolumbium. Metallic columbium is produced by Fansteel Metallurgical Corporation and by Metal Hydrides, Inc.

The principal sources of columbium ores and concentrates are Nigeria, Belgian Congo, Belgium-Luxembourg.

Consumption of columbium by the steel industry in 1948 was 796,495 pounds in 1949, 632,051 pounds; and in 1950, 752,121 pounds. The supply situation on columbium at the present time is very tight, all of the distribution being under allocation. Metallurgists are experimenting with tantalum as a substitute, at least in part, for columbium.

Boron

Boron is used in steelmaking to enhance hardenability, in which role it is a very powerful element indeed since amounts of the order of only one or two thousandths of 1 percent or less will accomplish the desired result. It may be added as ferroboron or in the form of alloys containing one or more of the following elements in addition to boron: silicon, titanium, vanadium, aluminum, manganese, calcium, or other deoxidizers or denitrifiers.

The strategic importance of boron at the present time resides in the fact that, to some extent it can be used in part as a substitute for certain of the customary alloying elements such as nickel, chromium, molybdenum, manganese, vanadium, etc., which are presently in critically short supply. These metallic alloying elements have in the past been used in substantial amounts in steel, varying from a few tenths of a percent up to several percent, depending upon the particular grade of steel and the properties desired. With the use of a few thousandths of 1 percent or less of boron, the amounts of these scarce alloying elements may often be reduced by one-half or even more without appreciable loss of hardenability or other essential mechanical properties related to hardenability. It should be noted that boron cannot be used to substitute for the substantial quantities of chromium, nickel, and other elements

that are used in the stainless and heat-resisting steels to confer corrosion resistance; boron is solely a contributor of hardenability.

Boron minerals, chiefly borax, are plentiful in the U.S.A., most of the production coming from California. Among the important producers of boron alloying agents are the following:

1. Electrometallurgical Division of Union Carbide and Carbon Corp.
2. Molybdenum Corporation of America.
3. Vanadium Corporation of America.
4. Titanium Alloy Manufacturing Division of National Lead Company.
5. Ohio Ferro-Alloys Company.

Cerium

Cerium, in the form of ferrocerium or master alloys of misch metal (a mixture of all the rare-earth elements with cerium predominating), is used as a deoxidizer and conditioner to improve the hot workability and other processing characteristics of some of the stainless and heat-resisting steels as well as other ferrous materials that are difficult to hot work. The use of cerium as described above is a fairly new development in the steel industry and to some extent is still in the experimental stage.

Imported monazite sand constitutes the chief basic raw material source of the rare-earth metals. Brazil is the principal source of this raw material, although some is found in Idaho and Florida. Statistics on imports and consumption are considered confidential at the present time.

Among the producers of cerium alloys are:

1. American Metals Products Company.
2. Molybdenum Corporation of America.

Possibly some of the following are producers of cerium alloys:

1. General Cerium Company.
2. Cerium Metals Corporation.
3. Kent Metal and Chemical Works.
4. New Process Metals Company.

Auxiliary Materials

In connection with a discussion of the materials required for the operations of the steel industry, it is appropriate to mention some miscellaneous items which are of outstanding importance. Tin, zinc, and lead are three of the nonferrous metals used principally in the coating of steel products. Consumption of those metals in net tons as coatings, by the steel industry, for the past three years was as follows:

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	1948	1949	1950
Tin	38,360	35,950	42,442
Zinc	252,600	267,019	331,038
Lead	22,500	19,242	15,385

Tin is used principally in the production of tin plate, an essential material in the handling and distribution of the national food supply. Metallic tin for the United States comes largely from the Far East, while imported ore concentrates, largely from Bolivia, are smelted in Texas. The total consumption of new tin in the United States for all purposes during 1950 was 75,000 net tons; the Texas City smelter produced 36,000 net tons, all from imported ores. Use of tin is under strict governmental controls.

Zinc coatings on galvanized sheets, strip, wire, pipe, and light structural shapes account for the most of that metal used by the steel industry. It is now in very scant supply because of the shortage of zinc ore in the United States. In 1950 the zinc content of zinc ores imported into the United States was 273,000 net tons, and 156,000 net tons of metallic zinc were imported. Total domestic production was 850,000 net tons.

Lead is a constituent of the alloy coating on terneplate. It is in short supply at the present time.

The steel industry consumes approximately 1,500,000 net tons of 100 percent sulphuric acid per year, all of which is produced in this country. Principal uses are for the removal of scale by the pickling process, and for the production of ammonium sulphate at the by-product coke plants. Some apprehension is felt over the adequacy of the supply of this acid on account of the shortage of elemental sulphur. Supply and demand are not now in balance. Additional recourse is being taken by the producers to iron pyrite and other sulfide ores, and newly found deposits of native sulphur are being developed.

Approximately 25,000,000,000 kilowatt hours of electric power was used by the steel industry in 1950, of which about 65 percent was purchased, and 35 percent generated within the plants.

Miscellaneous supplies such as soda ash, graphite, zirconium ores, palm oil which must be imported from the Far East and Africa, beryllium alloys, magnesium, and many other items are of concern to the steel industry, but need not be discussed in this review.

Transportation Note

The amount of transportation involved in supplying the steel industry of the United States with the wherewithal for present-day operations is

little short of amazing. For the blast furnaces alone, it is estimated that more than 111,000,000,000 ton-miles are involved. With the other items entering into the steel production process the approximation runs to a minimum of 200,000,000,000 ton-miles.

Both rail and water transportation play a large part in moving the materials on which the operations of the steel industry depend. In the case of iron ore, approximately 80 percent of the annual requirement is moved by boat on the Great Lakes, supplemented by rail haulage, where and as necessary. The water route is closed during four months of the year on account of ice. Limestone too is moved by both rail and water, and substantial tonnages of coal are transported by barges on the rivers, as well as by boats on the Great Lakes.

It goes without saying that ocean shipping enters the picture in an important way, for manganese ores and those of various alloying elements must be imported severally from practically all the continents and many of the islands. Moreover, about 6,000,000 net tons of iron ore are imported mainly from South America and Europe.

At the present rate of operations, all transportation facilities are severely taxed--ocean shipping, ore carriers, barges, and the 2,000,000 freight cars on the American railroads. Strenuous efforts are being made to increase the availability of adequate transportation equipment in this country. With respect to the problem in a number of foreign countries in which supplies of critical ores are obtained, the lack of proper transportation is a troublesome hurdle. Notably India, South Africa, and Brazil are deficient.

A Few Comparisons

Steel is potentially one of the largest fundamental factors in the economic and military strength of a nation. As the whole world is now the scene of two contending ideologies, the leading countries aligned on the respective sides of the contest are devoting all possible efforts to the strengthening of their industries, prominently their steel industries. Production of steel for both civilian and military uses is of utmost importance. The situation appears about as follows:

World production of steel ingots in the year 1950 was reported as 199,628,000 net tons. Of this total, Soviet Russia is credited with 25,500,000 and its satellites with 8,277,000 making a total of 33,777,000 net tons. On the other side, the figures for the 1950 production are larger:

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1.	United States	96,836,000	7.	Belgium	4,148,000
2.	Great Britain	18,247,000	8.	Italy	2,562,000
3.	Germany (West)	13,361,000	9.	Luxembourg	2,701,000
4.	France	9,536,000	10.	Japan	5,342,000
5.	Saar	2,092,000	11.	Australia	1,596,000
6.	Canada	3,343,000	12.	Other Nations	6,087,000

It is apparent that the weight of the figures is heavily on the side of the non-Communist nations. We should realize, however, that the civilian steel requirements in Russia are very small, or are treated lightly, so that the lion's share of steel production is devoted to military purposes, thus decreasing the disparity between conditions on opposite sides of the Iron Curtain.

Deposits of iron ore in Soviet Russia are reported as being large. Much of it, however, is not high grade, having less than 48 percent iron content. There is an abundance of coal resources in the Donets Basin and in Central Siberia. Good coking coals constitute a minority of the total. Not all the raw materials are ideally located geographically with respect to the strategic location of facilities for the production of steel, so changes for improvement have been planned or already made. Even now some of the capacity of the relatively vulnerable Ukraine and the Urals may have been replaced in Georgia and Siberia.

Russia is rich in manganese ore and chromite, two of the very important items in steelmaking. As to the other alloying elements there is little reliable information, although mention is made of limited deposits of nickel, cobalt, and vanadium in the Ural region. There are also sources of titanium within Soviet territory. In distant North Korea and Manchuria, iron ore and alloy materials are available for exploitation. Nevertheless it appears that Russia is dependent upon importations for substantial proportions of numerous alloying elements and auxiliary metals.

The satellite nations are not well equipped with raw materials for steelmaking. They are not without deposits of coal, but must be furnished from the outside with much of their iron ore, manganese, nickel, chromium, molybdenum, and many other items. Thus within the Soviet orbit as a whole, the task of expanding production and at the same time of balancing the supplies of even those necessary materials which Russia can command, is formidable enough in itself, but the difficulty is intensified by the need for significant importations.

From the standpoint of steel capacity, production, sources of essential raw materials, and technical ingenuity, the scales seem to be weighted definitely in favor of the non-Communist group of nations. This is true even though they are beset with many difficulties, including

stringencies in the supply of numerous items entering into the production of steel. We must be anxious, alert, and realistic, but may remember too that our opponents are not free from serious problems and handicaps.

Insofar as figures relating to production can add to the story, the following figures, based upon data for the year 1950, show how many units of each designated material were produced by the non-Communist nations, against each unit produced by Russia and its satellites:

Material	Units	Material	Units
Aluminum	5.8	Molybdenum	23.2
Chromium	3.4	Nickel	4.8
Copper	10.1	Tin	13.5
Lead	11.8	Tungsten	1.5
Manganese	1.6	Zinc	13.6

These ratios apply to things as they now stand and depend upon the maintenance of control as it now exists. In the event of forcible realignment, the appropriate figures would change accordingly.

Our steelmaking capacity is being further increased, experts from industry and government are combing the world for additional sources and quantities of scarce materials, and stockpiling is providing a modicum of leeway in certain quarters. Would that it were more! Science and technology are devising ways and means of spreading our critical supplies and of developing substitutes where the use of substitutes may become vital.

In addition to all other measures and material things which have been mentioned, we need an abundant supply of genuine, determined, cooperative effort between and among the "free peoples" of the world who are interested in making their position impregnable.

COLONEL RINDLAUB: Mr. Zimmerman, on behalf of the Industrial College, I thank you for giving us a very comprehensive picture of the materials for the production of steel.

(22 Jan 1952--750)S/n

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SUPPLEMENT--MATERIALS FOR THE PRODUCTION OF STEEL

Table 1. Blast furnace iron

(Net tons)

Year	Capacity	Production
1939	55,265,000	34,809,000
1942	59,318,000	59,076,000
1945	66,321,000	53,223,000
1948	66,342,000	60,055,000
1949	69,475,000	53,413,000
1950	71,373,000	64,587,000
1951	72,472,000	
1953	79,324,000	

Table 2. Steel ingots and castings

(Net tons)

Year	Capacity	Production
1939	81,829,000	52,799,000
1942	88,887,000	86,032,000
1945	95,505,000	79,702,000
1948	94,233,000	88,640,000
1949	96,121,000	77,978,000
1950	99,983,000	96,836,000
1951	104,230,000	
1953	118,000,000	

Table 3. Steel ingots and castings 1/

(Net tons)

	1948	1949	1950
Ingots and castings	88,640,470	77,978,176	96,836,075
Open hearth	79,340,157	70,248,803	86,262,509
Bessemer	4,243,172	3,946,656	4,534,538
Electric	5,057,141	3,782,717	6,039,008
Total	88,640,470	77,978,176	96,836,075

1/ Total production--Classified by grades and facilities.

Table 4. Alloy steel-ingots and castings 1/

(Net tons)	1948	1949	1950
Open hearth	6,413,969	4,297,894	5,861,320
Electric	2,067,145	1,599,675	2,708,785
Total	8,481,114	5,897,569	8,570,105

1/ Total production--Classified by grades and facilities.

Table 5. Alloy steel--ingots only 1/

Stainless and H.R.	617,378	455,093	832,309
Other, alloy	7,760,820	5,342,271	7,613,740

1/ Total production--Classified by grades and facilities.

SUMMARY

Table 6. Production

(Net tons)

	1948	1949	1950
Ingots and castings	88,640,470	77,978,176	96,836,075
Manganese ore	1,391,000	1,676,136	1,978,992
Ferrosilicon	842,000	667,000	840,000

Table 7. Consumption of Auxiliary Metals

(Pounds)	1948	1949	1950
Nickel	76,764,000	51,883,000	79,135,000
Chromium	212,709,000	148,443,000	247,649,000
Molybdenum	16,349,000	11,243,800	17,243,000
Vanadium	1,550,000	1,079,000	1,826,000
Cobalt	917,000	992,000	2,040,000
Tungsten	4,314,000	2,170,000	3,930,000
Aluminum -Estimated	53,000,000	47,000,000	58,000,000
Copper	133,176,000	126,000,000	131,000,000
Titanium	3,785,000	4,222,000	4,932,000
Columbium	796,500	632,000	752,000

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Table 8. Auxiliary metals for coating steel products

(Consumption in pounds)

Metal	1948	1949	1950
Lead	45,036,000	38,480,000	30,770,000
Tin	76,726,000	71,800,000	84,800,000
Zinc	505,176,000	534,038,000	662,076,000

Table 9. Exports--finished and semi-finished steel 1/

(Net tons and approximate net tons ingots)

Year	Net tons	Net tons ingots
1948	4,697,000	6,300,000
1949	5,055,000	6,750,000
1950	3,093,000	4,100,000

1/ Does not include fabricated products.

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