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Economic Aspects of DIRECT REDUCTION OF IRON ORE IN ILLINOIS

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ABSTRACT

Direct reduction of iron ore by one or more processes under study by steel companies will not displace the blast furnace but should supplement or complement ore reduction by blast furnaces. Direct-reduction plants will be developed in locations where small-scale local production is desired but coking coal is not available, or where costs are high.

Direct reduction of iron ore may be used to increase the capacity of either old or new plants to produce material that can be substituted for scrap iron in the charge to the open hearth furnace or to enrich a normal blast furnace charge. It may be used near a market and where ore and coal can be assembled cheaply, conditions that are especially favorable along the waterways in Illinois.

INTRODUCTION

The steel industry has been interested for a long time in a simple, workable process for direct reduction of iron ore, and every major steel producer in the United States is investigating such processes. Some 15 or more methods have been developed on a laboratory or pilot plant scale; one or two of them are being used commercially abroad. Several plants are in the planning stage in the United States and the next decade should witness further expansion of these processes.

Interest in direct reduction, a term commonly applied to all processes other than the blast furnace process, arises because of costs and raw material supply. The cost of scrap, an important ingredient in charging the steel furnace, has been rising and may continue to do so. Synthetic scrap produced by direct reduction may be used to supplement present supplies of blast furnace hot metal and natural scrap

A second reason for interest in direct reduction processes is the mounting costs of blast furnace construction. The capacity of existing blast furnaces could be expanded by enriching the charge with low-quality iron from a direct reduction process.

Another reason is the limited distribution and increasing cost of coking coal that is suitable for the preparation of metallurgical coke.

Most of the current research and development work in direct reduction involves treatment of ore in a kiln, a fluidized bed, or a shaft furnace, processes which permit more flexibility in reductants. Some methods use hydrogen, methane, or other gases, but solid fuels lacking the rigid specifications for coking purposes are more suitable for others. Some processes also provide more flexibility in the ore that can be treated.

One or more of the methods under study will find application in the steel industry. New processes are not expected to replace the blast furnace but they may supplement or complement present steel-making methods.

Conditions in Illinois appear to be unusually favorable for the introduction of one or more of the processes of direct ore reduction. Ores are accessible by water transportation from the Lake Superior district or Latin American sources. Iron ores of about 50 percent natural iron content also may be available in adjacent Missouri. Coal is mined efficiently in the mechanized and highly productive mines of Illinois and can be delivered to plants along the waterway at small additional transportation cost. Climatic conditions are favorable for year-round operation of waterways carrying Latin American ores to points in southern Illinois. Economical transportation of imported ores is possible because of efficient ore-handling facilities at the Gulf tidewater.

A potentially large market exists in the St. Louis industrial area within the steel industry and in iron and steel foundries. In addition, a large area to the south and west, much of it within reach of barge transportation, offers an expanding market for iron and steel and products made from them.

This report was prepared to bring attention to these favorable conditions and to analyze the factors which account for them.

IRON AND STEEL PROCESSES

The producer of steel must reduce the iron ore, refine the resulting iron, and carefully control the removal of carbon and the addition of other ingredients in order to give the finished steel its desired properties.

The blast furnace, the traditional equipment for reducing iron ore, has produced an estimated 97 percent of the world's output of iron. Limited quantities of iron have been produced by electric furnaces and a number of other processes, but these procedures have never provided the advantages which the blast furnace offers.

Blast Furnace

The blast furnace is essentially a large hollow shaft or tower of steel, lined with fire-resistant brick. From a maximum diameter of 25 to 30 feet a short distance above its base, the shaft tapers slightly toward the top. The furnace height ranges up to 120 feet or more.

Iron ore, fuel (coke), and fluxing material (limestone and dolomite) are fed periodically in alternate layers into the top of the furnace. A blast of hot air enters near the bottom of the furnace and passes upward through the charge. Partial combustion of the coke causes formation of carbon monoxide gas which acts as an agent to reduce the ore (mostly iron oxide) to metallic iron. At the high temperature in the lower part of the furnace both the iron and limestone become molten. The iron, being heaviest, settles to the bottom, and the limestone slag, containing the impurities from the ore and coke, floats on top of it. The slag and molten iron are drawn or tapped from the furnace at different levels five or six times a day. The molten iron is transferred directly to steel-making furnaces as hot metal, or cast into molds and allowed to cool to form pig iron.

The daily capacity of modern blast furnaces in the United States ranges between 600 and 2,000 tons of iron.

As the blast furnace offers an efficient and economical process for reducing iron ore in large quantities, it is not likely to be replaced by any other method in the foreseeable future. Nevertheless it has limitations and disadvantages that may be briefly noted as follows:

1) For economical operation a blast furnace must be large enough to have a minimum capacity of about 1200 tons per day. The tremendous capital investment required is justified only if there are resources within a reasonable distance to supply raw materials throughout the life of the furnace. There also must be an effective transportation system to handle the large quantities of materials involved and a market for the iron produced.

2) Raw materials for the furnace charge, especially coke and ore, must meet certain rigid specifications.

a) Coke. Blast furnace coke must be strong enough to support a heavy burden of material above it and porous enough to permit passage of the blast and to provide good contact with the air for the chemical reactions that must occur. The coke must be low in sulfur and other impurities that would contaminate the iron and have to be removed later. The size and distribution of reserves of coals suitable for making such coke are limited.

b) Ore. The average grade, or iron content, of iron ore available within the United States is steadily declining. Economic use of a high-cost blast furnace, however, demands that it be operated for fullest iron output at all times. This means that low-grade ores must be up-graded by removing at least a portion of the waste material before being charged into the blast furnace. Some natural ore must be crushed and ground to separate the iron-bearing particles from the waste. Because a coarse and fairly uniform sized ore is required in the furnace, finely ground particles cannot be charged until they are formed into pellets or sinter. The upgrading or concentrating involves costly equipment and processes.

By-passing the Blast Furnace

The problems and limitations of the blast furnace are becoming increasingly important. The large high-grade ore deposits within the United States are being depleted rapidly so that lower grade materials (such as the taconites of Minnesota) and smaller isolated deposits of ore must be used, and increasing quantities of ore must be imported from abroad. Reserves of high-grade coking coals are limited, and soon less suitable coals that require treatment and blending will have to be used (Risser, 1958). Continuing inflation is making the construction of new plants more costly. The demand for iron and steel, however, and the necessary capacity to provide them are steadily increasing. As a result, the steel industry is investigating numerous processes that appear to offer some promise of a solution to these problems.

Attempts at direct reduction of iron ore are not new. As early as 1876 patents for such processes were issued in the United States, and since that time dozens more have been issued (Barrett, 1949). At present several processes are in use on a limited scale and others are undergoing detailed study. The general principles involved in some of the processes are described briefly below, with more detail on those that seem to be particularly suitable to Illinois' resources and geographic location.

Several of the direct reduction processes operate on the principle of the fluidized bed in which finely ground iron ore is held in suspension by an upward flow of hot reducing gases (carbon monoxide and/or hydrogen). In most cases the reducing gases are obtained from re-formed natural gas. The fine particles of iron obtained by these processes generally are pressed into briquettes and used as a substitute for pig iron or scrap in the steel-furnace charge.

In some other processes, the reducing gas is passed upward through coarse ore in a vertical shaft furnace, a rotary or tunnel kiln, or other types of hearth or grate furnaces to produce lumps or particles of "sponge" iron.

Some direct-reduction processes use coke, char, anthracite fines, or coal as a reducing agent. Unlike the blast-furnace process, direct-reduction processes do not require a pure and high-strength coke so that coals considered unsuitable for manufacture of metallurgical coke may be used satisfactorily.

It has been suggested (Mining World, Nov. 1958, p.44) that direct-reduction processes might be used to:

1) Give additional capacity to existing plants.
2) Provide a substitute for scrap iron for use in open hearth furnaces.
3) Provide material to enrich normal blast-furnace charges and thus gain operating economies.
4) Produce iron in areas where flux and fuels are not readily available.

Among the most publicized methods, at least three of the rotary kiln processes appear suitable for use in Illinois, the Krupp-Renn, R-N, and Strategic-Udy processes. All three can satisfactorily use Illinois coal or char or coke made from Illinois coal.

Krupp-Renn Process

The Krupp-Renn process (fig. 1) was developed in Germany during the 1930's, and by the end of World War II 38 kilns with an annual capacity of 1,000,000 tons

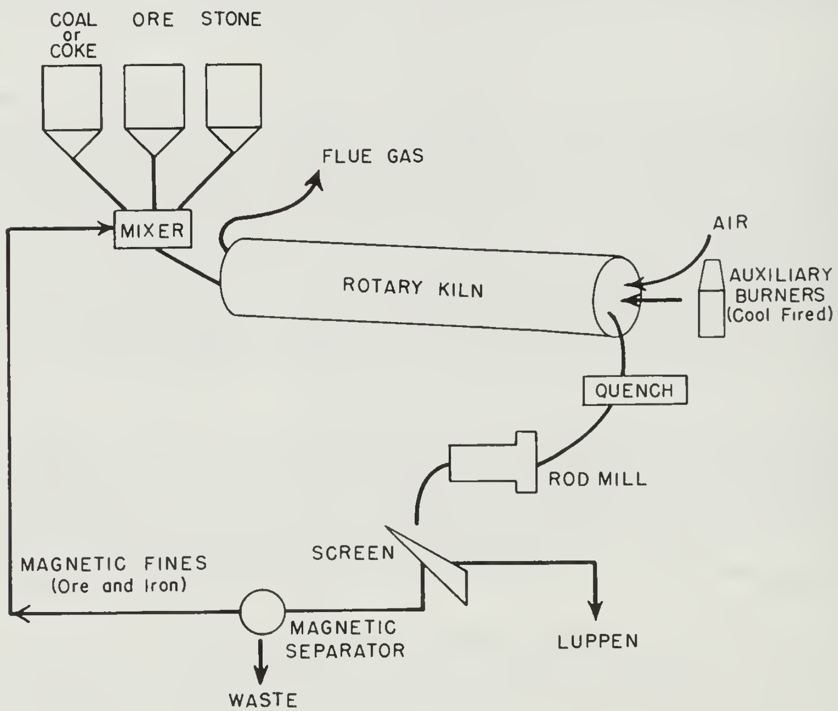

Fig. 1. - A simplified flow sheet of the Krupp-Renn process, a European development used in several foreign countries.

of "luppen" were in operation in Europe and the Far East (Mining World, Nov. 1958, p. 44). After the war most of the original plants were dismantled, but since 1950 several new ones have been built. Plants are being operated in Spain, Greece, and Germany, and others are under construction.

The Krupp-Renn process uses a rotating cylindrical kiln about 15 feet in diameter and 360 feet long. A mixture of iron ore, solid fuel, and limestone for flux is crushed to 1/4-inch size and fed into the kiln (Wuerker, 1951). Combustion of the solid fuel within the mixture provides carbon monoxide to reduce the iron ore, and the limestone forms a slag to pick up the impurities. As the feed materials are gradually moved through the kiln and mixed by the rotating motion, the ore is continuously exposed to the reducing gasses. Additional heat for the process is provided by hot air and gases generally from coal-fired burners mounted near the discharge end of the kiln.

As the feed travels through the first 20 percent of the kiln length, it is dried and preheated to a temperature of approximately 1100°F. Throughout most of the remainder of the kiln length, ore reduction occurs at temperatures ranging from 1100° to 2000°F as carbon monoxide reacts with the iron-oxide ore forming carbon dioxide and metallic sponge iron. Near the end of the kiln the finely disseminated iron ore, at a temperature of 2300°F to 2800°F collects into nodules or "luppen," ranging from 1/16 to $1\frac{1}{2}$ inches in diameter, that are entrapped within the pasty or viscous slag.

The slag containing the iron nodules is discharged from the kiln and quenched in water. It is then crushed and the iron is separated magnetically from the particles of slag.

Among the advantages claimed for the Krupp-Renn process is flexibility in the range of ore grades that can be processed. Low-grade ores, pyrites, and ores containing titanium, nickel, and other metals can be treated.

Because a highly silicious slag is desirable for proper formation of nodules, the Krupp-Renn process is especially adaptable to fine iron ores with a high silica content. A further advantage is in the wide variety of suitable fuels which include coal, anthracite, coke breeze, char, and low-temperature coke.

A major disadvantage of the Krupp-Renn process is that about 30 percent of any sulfur in the charge is carried into the luppen. Another problem is the difficulty of controlling fluidity of the slag.

At some places the luppen produced by the Krupp-Renn process may be used as a charge for electric or open hearth steel-making furnaces. But if the iron is not pure enough to use in steel furnaces, because of ore or fuel characteristics, the luppen can be used as a high-grade feed material to improve blast furnace performance.

R-N Process

The R-N process (fig. 2) for the treatment of iron ores was developed jointly by the Republic Steel Corporation and the National Lead Company. A semi-commercial demonstration plant with a capacity of 50 to 75 tons per day has been in operation at Birmingham, Alabama, since 1954 and has produced more than 120,000 tons of iron to date (Stewart, 1958; Moklebust, 1959).

The R-N process uses a cylindrical rotary kiln 150 feet long and $7\frac{1}{2}$ feet inside diameter. Feed material consists of a mixture of iron ore, limestone, and solid fuel. The size of ore required depends to some extent on its porosity and density. In some instances $1\frac{1}{2}$" X 0 material is satisfactory; in others a finer size

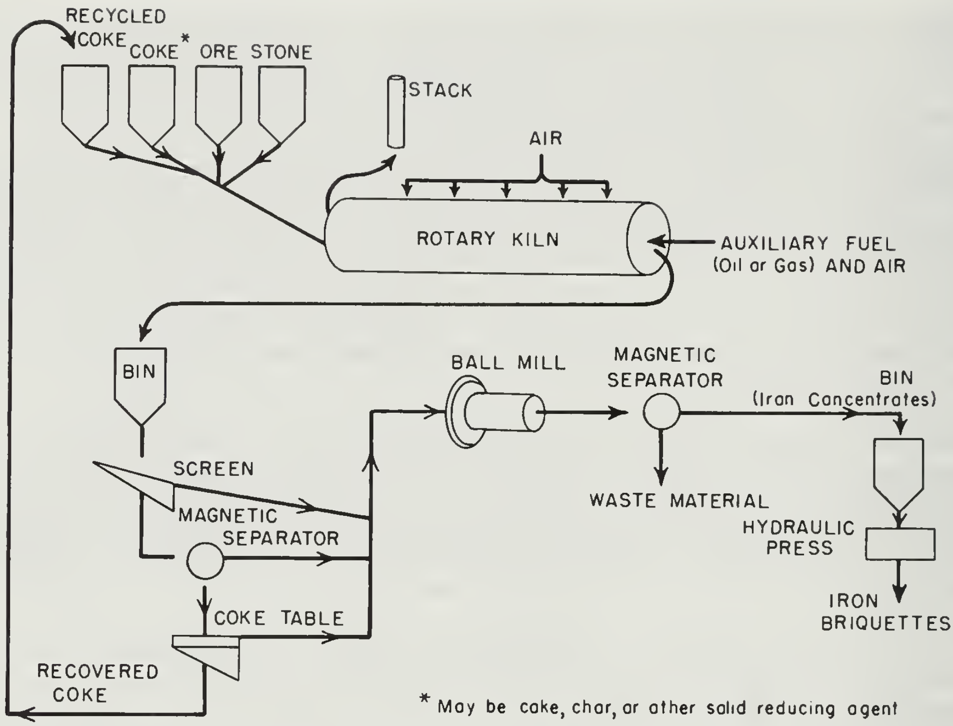

Fig. 2. - A simplified flow sheet of the R-N process which uses solid fuel as a reducing agent.

is needed. The fuel may be char, breeze, disco, anthracite, or low-temperature coke. The limestone is used to remove any sulfur and phosphorous in the charge.

Heat for the process is provided by preheated combustible gases introduced at the discharge end of the kiln. The gas may be natural gas, various manufactured gases, the volatile matter obtained from charring coal, or gas formed by combustion of fuel oil.

By accurate control of combustion the temperature within the kiln is carefully kept below the melting point of the fired materials. As the combustible gases are introduced in the kiln, a deficiency of air retards combustion. Controlled air introduced into the kiln at intervals along its length regulates the rate of combustion so that a relatively constant temperature of 1950°F is maintained throughout most of the kiln. An excess of coke (or other reducing agent) combined with adequate control of air gives a reducing atmosphere within most of the kiln. At the same time, enough air is provided for full utilization of the fuel. The ratio of coke in the charge to gas fed into the kiln must be varied depending on the iron content of the ore and the reduction temperature. At higher temperatures less gas and more coke is used because the reactivity of the coke increases as the temperature becomes higher.

The kiln operation produces a mixture of metallized ore, lime, coke, and coke ashes. The mixture is cooled and the unused coke is screened out and returned to the feed bin. The metallized ore is ground in a ball mill and the metal separated magnetically from the waste material present. The magnetic concentrates, containing about 95 percent iron, are pressed into five-pound briquettes and can be used as feed material for either open-hearth or electric steel-making furnaces.

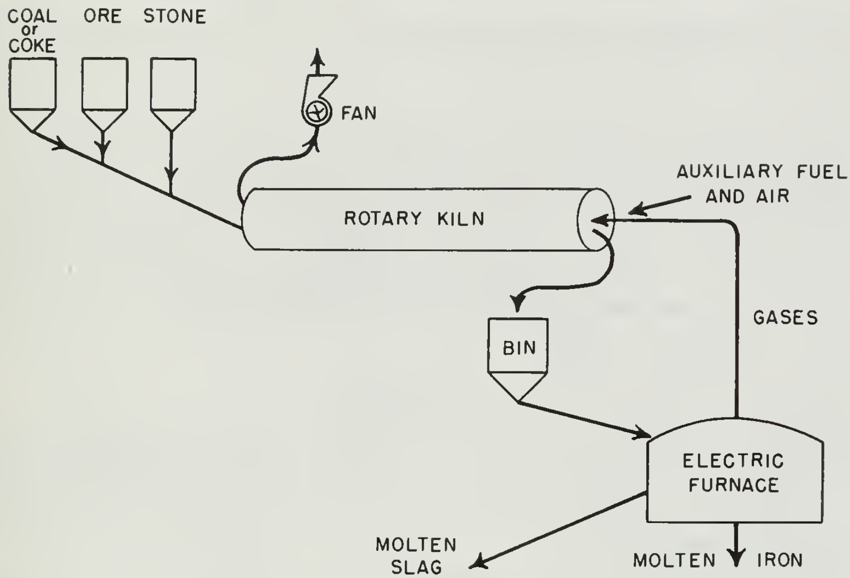

Fig. 3. - Flow Sheet of the Strategic Udy process which uses solid fuel as a reducing agent. Electric power supplies heat for the process.

Advantages reported for the R-N process include its ability to utilize both low-grade fuel and low-grade iron ore. Char made from non-coking coals and from coals of high sulfur content can be used because 90 to 94 percent of the sulfur in the fuel can be eliminated during the processing operation. There was no distinguishable difference in sulfur content of the iron produced whether high-sulfur (8 percent) fuel or low-sulfur (1.15 percent) fuel was used (Stewart, 1958).

Ores with iron contents ranging from 20 to 70 percent were successfully processed in the demonstration plant at Birmingham.

The low capital cost of the equipment as compared with the cost of a blast-furnace plant is another advantage of the process. It has been estimated that for a unit having an annual capacity of 400,000 gross tons, the cost per annual ingot ton will run between 40 and 50 dollars, or perhaps a third that of cost of the blast-furnace coke-oven combination commonly used.

Strategic-Udy Process

The Strategic-Udy process (fig. 3) was developed by a group of researchers headed by Dr. Marvin Udy working in the large scale plant of the Strategic Materials Corporation in Niagara Falls, Ontario. Commercial application of the process is under the joint control of Strategic Materials Corporation and Koppers Company Incorporated.

The Strategic-Udy process involves the use of a rotary kiln coupled to an electric smelting furnace (Udy, 1958). Ore, limestone, and a fuel or reducing agent are fed continuously into the kiln. The ore may be low-grade and complex, containing contaminating elements such as nickel, chromium, copper, or titanium, without affecting the purity of the iron produced. Unlike the blast furnace, the kiln can use fine ore or finely ground concentrates without special pelletizing or sintering treatment.

The reducing agent can be almost any type of carbon - bituminous coal, anthracite, lignite, char, coke breeze, or coke. Fuel of a fine particle size is preferable.

The electric smelting furnace is coupled to the discharge end of the kiln so that the heat and carbon monoxide gas from the furnace pass through the kiln and over the charge. The carbon monoxide and the reducing agent in the kiln reduce the iron ore. About 50 percent of the reduction takes place within the kiln. The material from the kiln is discharged into the smelting furnace where the reducing operation is completed. The final product leaves the smelting furnace in a molten state. Operation of the smelting furnace may be controlled to produce either a pig iron or a low-carbon semi-steel.

The entire process requires 13 to 18 million Btu's and 1100 to 1500 kilowatt hours of electrical power per ton of iron produced.

There are a number of advantages of the Strategic-Udy process. Fine ores or fine concentrates can be used directly without agglomerating, sintering, or nodulizing as the blast furnace requires. Ores containing titanium, manganese, chromium, or other impurities can be used directly, which broadens greatly the resources of suitable feed material.

A variety of fuels, including bituminous coal, anthracite, peat, lignite, or coke, may be used as a combined reducing agent and source of heat.

Units can be developed to operate economically in sizes that have a capacity of 50 tons or more per day. The estimated capital cost of a plant producing 500 tons per day ranges from $30 to $50 per annual ingot ton of capacity as compared with an estimated $135 to $150 for the standard blast-furnace coke-oven combination.

Under proper conditions of the Strategic-Udy process, the carbon content of the product can be controlled between 0.2 and 3.5 percent, in producing metal for foundry, electric furnace, or open hearth use.

IRON ORE SUPPLY

The iron ore supply for the United States is reviewed in great detail by the United States Tariff Commission (1959). Quoting from the report (p. 19):

> It is the consensus of iron and steel producers that domestic reserves of high-grade, direct-shipping ore and ore that can be beneficiated by simple methods are insufficient to provide the large quantities of iron ore that will be required in the future. . . .

(p. 21):

> It is apparent that additional iron ore supplies in the future will come principally from imports and from low-grade taconite deposits in Minnesota and jasper ore deposits in Michigan.

Development of a direct-reduction process in downstate Illinois does not necessarily depend solely upon a supply of ore from the Lake Superior district. Recent discoveries of ore bodies in Missouri and increasing supplies of ore available in Latin American nations should also be considered as possible sources of iron ore.

Lake Superior Ores

Iron ore from the Lake Superior district (fig. 4) is transported by ore-carrying railroads in Minnesota, Michigan, Wisconsin, and Ontario, by lake transportation to Chicago ports, and by river barge transportation over the Illinois and Mississippi waterways.

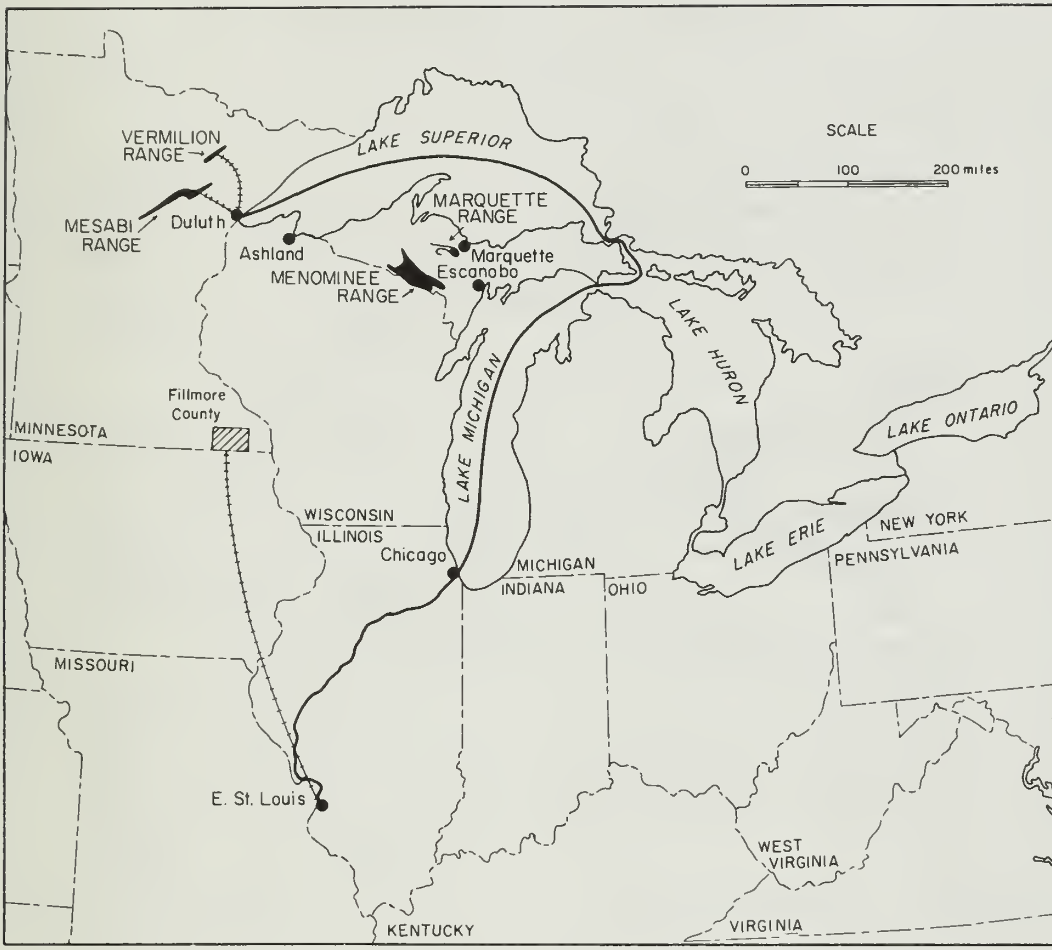

Fig. 4. - Lake Superior iron ores are available from the Mesabi and Vermilion Ranges through the port of Duluth and from the Menominee Range through the port of Escanaba. Ore from Fillmore County is shipped by all-rail haul to Granite City. Rail connections shown do not portray the actual route.

Ore produced in Minnesota is shipped mainly through the Duluth and Superior ports, via Lake Superior and the Soo locks. Ore produced in Michigan and Wisconsin is shipped through the port of Marquette, Michigan, on Lake Superior, or through the port of Escanaba, Michigan, on Lake Michigan.

Iron ore of 47 percent iron content is produced in Fillmore County, southeastern Minnesota. Production over a ten-year period averaged 309,000 long tons per year. Reserves are estimated at 800,000,000 long tons.

The cost of delivered ore at the point of processing varies with differences in rail and water rates of transportation from point of origin (Wade and Alm, 1958). As an example, four tabulations of costs are given in table 1.

Missouri Iron Ores

Missouri produced 530,000 long tons of iron ore in 1957, according to U. S. Bureau of Mines statistics. Hematite ore is being produced at Iron Mountain in St. Francois County. This operation is located on the Missouri Pacific Railroad

Table 1. - Delivered Cost per ton of Ore from Various Sources, 1958

Point of Origin		Cost
Mesabi Range		
Cost of ore at mine		$ 7.79
Rail rate - Mesabi to Duluth		1.47
Head of Lake Superior to Lower Lakes		2.28[a]
Rail rate - Chicago to Granite City[b]		2.91
	Total	$14.45
Gogebic		
Cost of ore at mine		$ 7.79
Rail rate - Gogebic to Escanaba		2.19
Escanaba to Chicago		1.48
Rail rate - Chicago to Granite City[b]		2.91
	Total	$14.37
Marquette and Menominee		
Cost of ore		$ 7.79
Rail rate - to Escanaba		1.44
Escanaba to Chicago		1.48
Rail rate - Chicago to Granite City[b]		2.91
	Total	$13.62
Fillmore County, Minnesota		
Cost of ore		$ 7.79
Rail rate - mine to Granite City		3.81
	Total	$11.60

[a] Includes unloading charge of 28 cents per ton.

[b] No rates have been published for barge transportation from Chicago to St. Louis.

84 miles southwest of St. Louis (fig. 5). Rail shipments of ore to Granite City are routed through the Terminal Railroad Association of the St. Louis district.

Brown ores (limonite) are being produced by open pit methods mainly in Howell, Oregon, and Wayne Counties in southern Missouri at operations that are on or near the St. Louis - San Francisco Railroad to Memphis. Much of this ore is sent to furnaces in Alabama.

An ore deposit of considerable promise is being developed jointly by St. Joseph Lead Company and Bethlehem Steel Corporation at Pea Ridge, about 65 miles southwest of St. Louis. They began sinking the shaft in 1957 and it should be

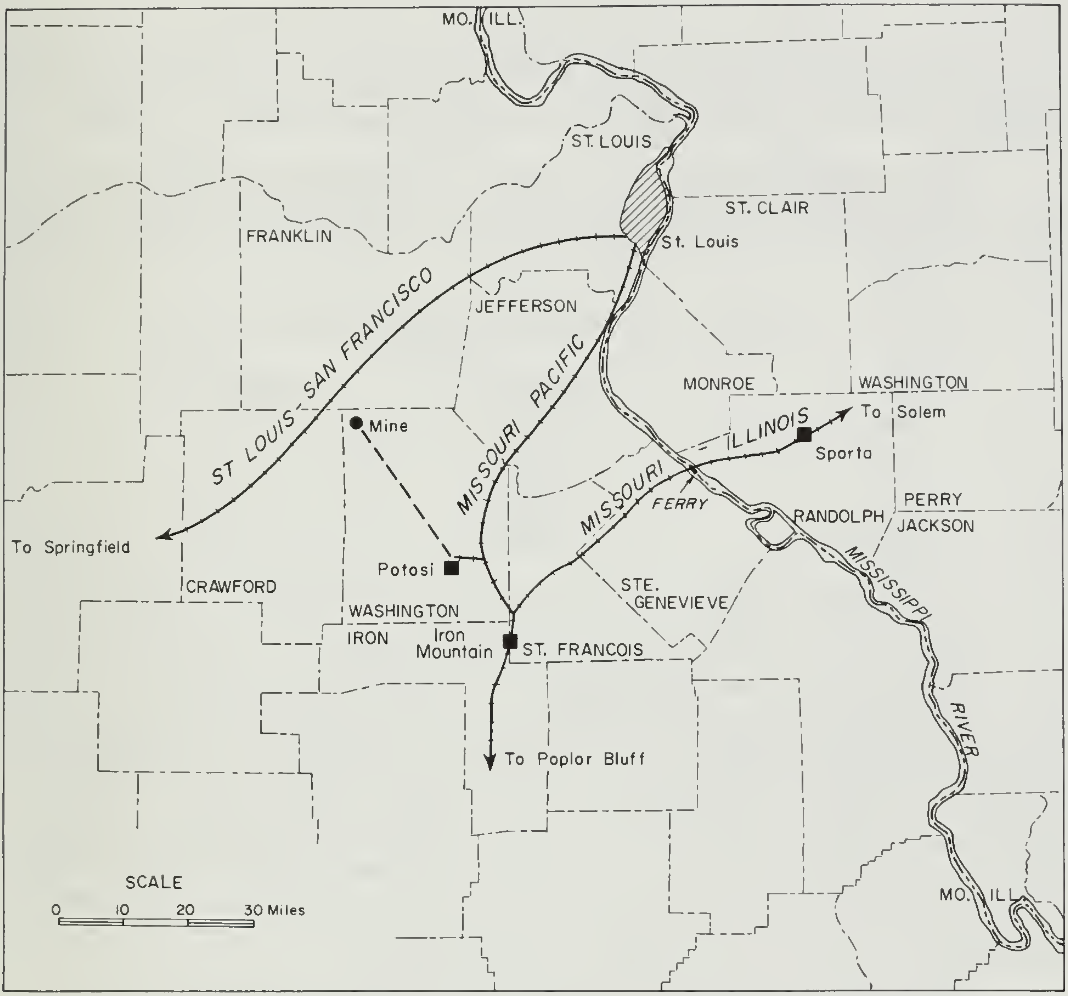

Fig. 5. - Iron mines and railroad connections in Missouri. Iron ore is now being produced at Iron Mountain and will be produced at a mine being developed in northwestern Washington County, Missouri. Rail connections make these ores accessible to Illinois industrial districts in Madison, St. Clair, and Randolph counties.

completed in 1959 or 1960. The mine is expected to be in production in 1962 and will have an eventual capacity of 2,000,000 tons a year. A spur line which is now under construction will connect the Pea Ridge operation with the Missouri Pacific Railroad at Potosi. This connection will make it possible to ship ore to a point where the railroad is adjacent to the Mississippi River below St. Louis. The cargo ore can then be transferred directly from railroad siding to river barge, without going through St. Louis.

The Missouri-Illinois Railroad also could be used for ore transportation into Illinois. Ore carried on the Missouri Pacific Railroad could be transferred to the Missouri-Illinois at Bismarck, Missouri. The Missouri-Illinois line crosses the Mississippi River by ferry at Thomure, Missouri, and terminates at Salem, Illinois, where it connects with the B. and O. Railroad and the C. and E. I. Railroad.

Foreign Ores

Iron ore imported into the United States in 1958 composed almost one-fourth of the total domestic supply. Canada and Venezuela are the principal suppliers with minor contributions from Peru, Chile, Brazil, Liberia, Sweden, and other countries.

Ores economically feasible for reduction in Illinois could enter through southern ports, via the Mississippi Waterway or by rail through the port of Mobile. Iron ore entering through these ports originates in Venezuela, Chile, Peru, and Liberia (table 2).

Table 2. - Sources of Iron Ore Shipped through Mobile in 1957 [a]

From	Long Tons	Value Per Ton
Venezuela	2,388,000	$7.09
Chile	86,000	8.90
Peru	182,000	12.38
Liberia	55,000	7.33

[a] Iron Ore: United States Tariff Commission, Washington, March 1959.

The ore from all these South American sources contains approximately 60 percent iron suitable for blast furnace use.

Deposits of iron ore in Venezuela, which is the largest of the three suppliers and the most probable source for Illinois markets, is estimated at between 500 million and 600 million tons of proven ore. The ore must be moved 2200 miles from Port Ordaz, Venezuela, on the Orinoco River to Mobile or New Orleans. The cost to this point is about 22 cents a unit (22.4 lbs. of iron) or $13.20 per long ton of ore with 60 percent iron content. From Mobile, Alabama, to East St. Louis or Granite City, the rail rate is $7.71 per long ton or $4.94 per long ton on shipments of a minimum of 1800 net tons. By Mississippi River barge to St. Louis, the rate is $3.07 a net ton, which is equivalent to $3.44 a long ton.

The apparent total cost of delivering 60 percent Venezuelan ore to St. Louis would be $16.64 per long ton or 27.7 cents per unit as compared with $14.45 per long ton of 51.5 percent Mesabi ore, or 27.9 cents per unit.

BARGE TERMINALS

Low-cost transfer of coal or iron from vessel to barge or rail, or from barge to stockpile is one of the keys to cost control. A number of barge terminals on the Illinois and Mississippi waterways (fig. 6) are designed to handle coal or steel products. A list of the Illinois terminals is given below.

Middle and Upper Mississippi River

Location	Miles north of Cairo	Company	Commodities
Ford	105.0	Missouri Pacific RR	Coal
East St. Louis	176.4	Alton & Southern RR	Coal, coke, bulk commodities

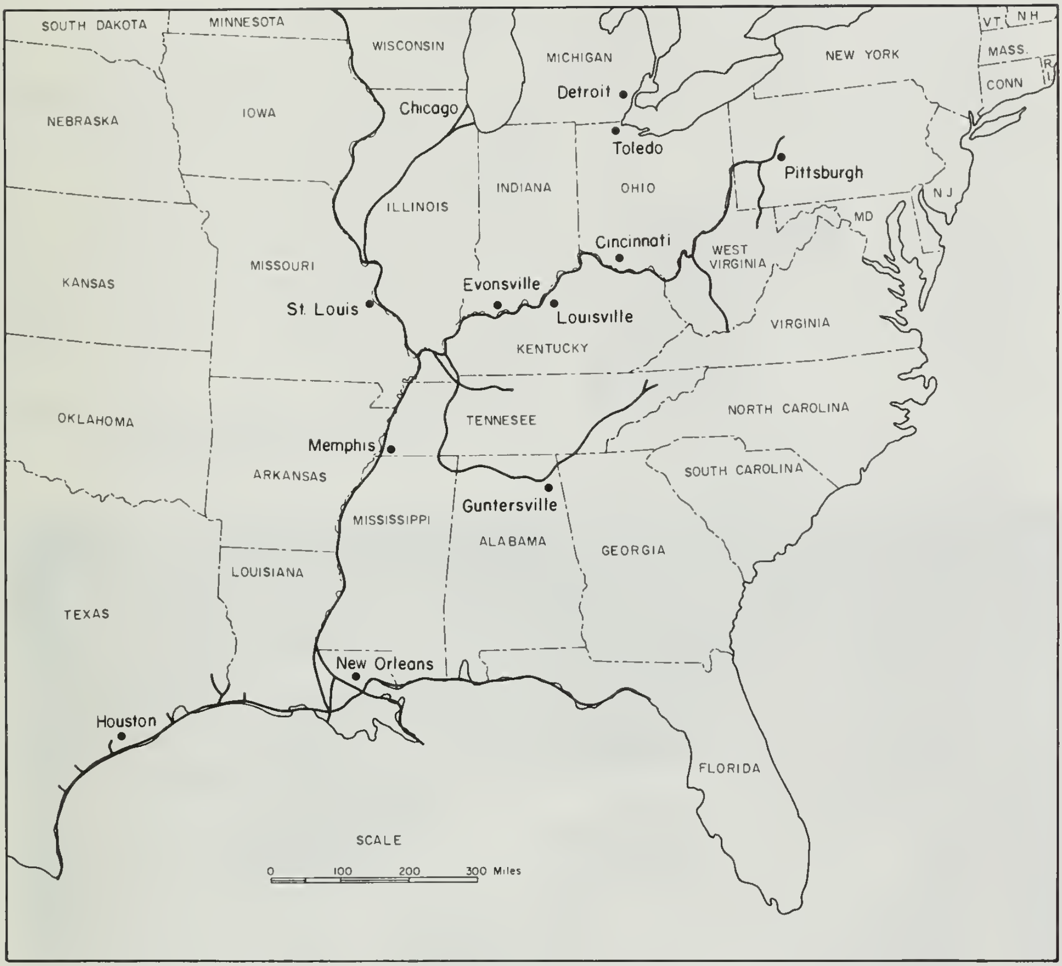

Fig. 6. - Inland waterway system. The system of inland waterways in the United States favors the state of Illinois as a site for direct reduction processes. Ore is available from the Lake Superior district via Lake Superior and Lake Michigan and the Illinois Waterway or from South America and Africa via the lower Mississippi Waterway.

Location	Miles north of Cairo	Company	Commodities
East St. Louis	179.3	Peabody Coal Co.	Coal
East St. Louis	182.3	Union Electric Venice Power Plant	Coal
Granite City	185.6	Bi-State Docks (Granite City Steel Co.)	Steel products, raw materials
Alton	204.1	Illinois Terminal RR	Coal
Rock Island	480.8	Mid-Continent Terminal & Storage Inc.	Coal, all commodities

Illinois Waterway

Location	Miles north of Cairo	Company	Commodities
Havana	336.4	Illinois Power Co.	Coal
Havana	338.7	Cimco River & Rail Terminal	Coal
Liverpool	344.4	Truax-Traer	Coal
Liverpool	346.5	United Electric Coal Co.	Coal
Copperas Creek	354.8	Ohio River Co.	Steel, coal
North Pekin	373.5	Central Illinois Dock	General, coal
Bartonville	375.8	Keystone Steel & Wire Co.	Fuel oil, steel
Spring Valley	436.3	Cargill Grain Co.	Grain
Ottawa	455.4	Libby-Owens Ford Glass Co.	Fuel oil, coal
Seneca	472.1	Chicago Bridge & Iron	Iron, steel

Courtesy of Dravo Corporation, Neville Island, Pittsburgh, Pa.

Fig. 7. - Ore handling dock at Burnside, Louisiana. Modern transfer docks keep down the cost of overseas ore shipment. This modern dock at Burnside, Louisiana, below Baton Rouge, is equipped to transfer ores from ocean vessel to river barge, railroad cars, or stock pile.

Courtesy of Alabama State Docks Department, Mobile, Ala.

Fig. 8. - Ore handling dock at Mobile, Alabama. The port of Mobile, Alabama, is equipped to transfer ores from incoming vessels directly to railroad cars where it is shipped by direct rail service from Mobile to East St. Louis, Granite City, and other Illinois cities.

TIDEWATER TERMINALS

Two terminals are located on tidewater, one at Mobile, Alabama, and the other at Burnside, Louisiana. The Mobile Ore Terminal (fig. 7) is designed to unload ore from the vessel directly to railroad cars or to two belt conveyors that carry the ore to railroad car loading pockets. The time required to unload a vessel varies with the number of rigs employed on a ship and the type of ship, but it is estimated that a 10,000-ton ore cargo can be unloaded in about 20 hours. Water depth of 36 feet is maintained at the dock and in the Mobile ship channel.

The Burnside Bulk Marine Terminal (fig. 8) of the Greater Baton Rouge Port Commission is on the east bank of the Mississippi River, 28 miles south of Baton Rouge and 62 miles north of New Orleans. The deep water port facility is approximately 180 miles from the mouth of the Mississippi River. The terminal serves as a two-way transportation center for ocean-going vessels and inland waterway barges. It currently handles iron ores from South American countries destined for up-river points that are served by barge lines.

Table 3. - Production and Reserves of Coal in Principal Coal Producing Counties

County	Number of Operations	Production (in tons) 1958	Reserves in thousands of tons Proved and Probable	Indicated	Total*
Bureau	1	477,702	1,133,219	875,291	2,008,510
Christian	1	2,902,215	3,142,381	1,272,135	4,414,516
Douglas	1	477,006	432,646	315,258	747,904
Franklin	4	4,651,455	3,863,051	1,314,014	5,177,065
Fulton	24	4,704,777	1,506,264	603,275	2,109,539
Gallatin	9	105,264	1,951,154	2,018,776	3,969,930
Jackson	7	1,189,161	502,205	178,784	680,989
Jefferson	2	3,050,354	1,831,758	3,020,740	4,852,498
Kankakee	1	373,265	104,484	18,623	123,107
Knox	4	2,187,235	300,290	392,437	692,727
Macoupin	2	437,243	3,628,496	2,853,934	6,482,430
Madison	3	646,586	1,813,492	796,088	2,609,580
Montgomery	1	1,578,623	3,987,858	1,596,167	5,584,025
Perry	7	2,992,046	2,035,741	665,922	2,701,663
Randolph	6	1,615,870	670,482	17,949	688,431
St. Clair	9	5,338,326	1,886,938	1,168,885	3,055,823
Saline	14	2,387,543	3,202,751	1,157,419	4,360,170
Schuyler	2	474,885	229,758	161,143	390,901
Vermilion	9	1,104,478	1,922,514	536,731	2,459,245
Williamson	35	6,013,423	2,255,499	1,045,758	3,301,257

* Cady, Gilbert H., Minable Coal Reserves of Illinois: Illinois Geol. Survey, Bull. 78, 1952.

Table 4. - Cost of Coal to Electric Utilities in Illinois, 1958[a]

	As consumed per ton	cents per million Btu
Rockford	$ 7.56	32.4
Lincoln	5.01	24.9
East Peoria	5.16	24.4
Grand Tower	4.66	21.3
Meredosia	5.49	26.4
Dixon	6.34	29.7
Wood River	4.30	19.8
Havana	4.94	24.1
Monsanto	4.83	21.8
Joppa	4.53	18.8

[a] Steam-Electric Plant Factors: 1958, National Coal Association, Washington, D. C.

COAL RESOURCES OF ILLINOIS

Minable coal reserves of Illinois (table 3) have been discussed in detail by Cady (1952), and strippable coal reserves in southern and southwestern sections of the state have been reported by Smith (1957, 1958).

Delivered Cost of Coal

The cost of coal for industrial purposes can be estimated from the published costs of coal purchased by electric utilities. These are given for selected communities in Illinois for the year 1957 in table 4.

REFERENCES

Barret, Edward P., 1949, Gaseous methods for the production of sponge iron: U. S. Bur. Mines Rept. Inv. 4402.

Cady, G. H., 1952, Minable coal reserves of Illinois: Illinois Geol. Survey Bull. 78.

Moklebust, O., 1959, The R-N rotary kiln process for reduction of iron ores: Society of Mining Engineers, American Institute of Mining, Metallurgical and Petroleum Engineers Preprint 59B70.

Risser, Hubert E., 1958, Emerging patterns in coking coal supply: The Mines Mag., v. 48, no. 7, p. 10-12. Illinois Geol. Survey Reprint 1958-S.

Senior, Frank, 1959, By-passing the blast furnace (A talk delivered before the New York Society of Security Analysts, February 5, 1959.) Mimeographed by Koppers Co., Inc., Pittsburg.

Smith, W. H., 1957, Strippable coal reserves of Illinois, Part 1. - Gallatin, Hardin, Johnson, Pope, Saline, and Williamson Counties: Illinois Geol. Survey Circ. 228.

Smith, W. H., 1958, Strippable coal reserves of Illinois, Part 2. - Jackson, Monroe, Perry, Randolph, and St. Clair Counties: Illinois Geol. Survey Circ. 260.

Stewart, Alex, 1958, Direct reduction of iron ores in a rotary kiln: Mining Congress Jour., v. 44, no. 12, p. 34-38.

Udy, M. J., and Udy, M. C., 1958, A new direct reduction method: Metals Progress, v. 74, no. 6, p. 92-94.

U. S. Bureau of Mines, 1957, Mineral industry of Missouri, in Minerals Yearbook: U. S. Bur. Mines, v. III, p. 607.

U. S. Tariff Commission, 1959, Iron ore: U. S. Tariff Comm. Rept. Inv. 35.

Wade, H. H., and Alm, Mildred, 1958, Mining directory: Minnesota Univ. Mines Experiment Station.

What's new with Krupp-Renn process?: Mining World, v. 20, no. 12, p. 44-49.

Wuerker, R. G., 1951, Beneficiation of taconites by pyrometallurgy: Mining Eng., v. 190, no. 1, p. 25-26.

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