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SPONGE IRON*

A great deal has been said about sponge iron, and not everything has been correct. I want to clarify at the start one of the points on which there has been misinformation and controversy. Sponge iron is not going to replace mass production of pig iron and steel - as made by the orthodox methods in blast furnaces and steel furnaces - certainly not in a hurry, if ever. Sponge iron is made from iron ores by removing most of their gangue and oxygen content without melting the iron. There are many ores from which the silica can only be separated economically by melting in the blast furnace. Furthermore, it is not in the province of sponge iron to replace the ordinary grades of iron and steel; but being a virgin metal of high purity it should be reintroduced as a leading quality metal for the production of the finest steels and for many special products requiring metal of the highest quality. In bringing about the rebirth of this old art, advantage can be taken of all that modern science has to offer as well as the latest technique in metallurgy and handling of materials.....

Sponge iron is the oldest form of iron known to man. The unsurpassed quality of the ancient irons as represented by Damascus swords, Toledo blades, the Delhi iron column in India, is due to the fact that they were forged from unadulterated virgin metal produced directly from the ores. Charcoal was the fuel. About the middle of the last century sponge iron went into the discard in the Western countries with the depletion of a handy supply of charcoal and of accessible, easily mined ores, under the growing competition of pig iron produced in blast furnaces using anthracite and coke, and of steel made from such pig iron and scrap, the supply of which was rapidly increasing. The puddling process, Bessemer steel, and finally, open hearth and electric steel, took its place.

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Anticipate Mesabi Range Exhaustion

Vitally important changes in the American iron and steel industry may soon begin to take shape. For nearly half a century the iron ore market has been dominated by the cheap and vast output of the Mesabi Range in the Lake Superior region; but now its great open pits are commencing to show signs of exhaustion. The demands of two world wars and the great building period of the twenties have brought this about sooner than expected. The Lake Superior region will be forced into more and more expensive underground mining and beneficiation of low-grade ores on a much larger scale than is practiced today. Concentrates made from the lean ores will gradually take the place of the cheap open-pit ores--but ores found in other parts of the country, low-grade as well as richer ores, may then again come

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*Parts of an address by Mr. H. A. Brassert made at Hartford, Connecticut, at an all-industry conference on strategic materials; and quoted from the Congressional Record of the 78th Congress under date of April 22, 1943.

into their own. If they are located near suitable supplies of solid, gaseous, or liquid fuel and near consuming centers, economics may once more be in their favor.....

There can be no question as to the suitable quality of the ores consumed in the old days. They were proved over a century and a half; the important question now is the actual tonnage and quality of the ores remaining in the untouched reserves; the possibilities for economic exploitation; the cost of production.....

Ways of Making Sponge Iron

There are many ways in which sponge iron can be made. The ancients mixed the iron ore with carbon and brought it to a sufficient temperature so that a pasty or liquid slag was formed which could be squeezed or hammered out of the mass of metal. The metal was forged or reheated and forged--sometimes several times--for the production of the highest quality bars. The original forges were open fires blown with hand bellows, and later with bellows driven by water wheels. Out of these small Catalan fires, shaft furnaces were developed; but still the metal produced was a low carbon metal which could be forged directly and which was not brought to the molten state. It was only when the height of the furnace was increased so that the metal absorbed more carbon from the charcoal and its fusion point was thereby lowered that molten pig iron could be produced. As long as this pig iron was made from charcoal blown with cold blast, it was still reputed as a superior metal. When the furnace grew larger, hot blast was introduced, and the fuel became anthracite and finally coke, more impurities were absorbed by the pig iron and some of them went into the steel. Metal made in the puddling process was also adulterated by the use of half of the metal in the form of pig iron and some of the gangue of the ore was retained. The removal of the silicon, carbon, surfur, phosphorus in the pig iron has been the task of the steel processes developed in the past 75 years, first the Bessemer, then the open hearth and last, the electric furnace. But the removal of sulfur and phosphorus could never be complete; and in these processes nitrogen and hydrogen, which we know are detrimental, are absorbed by the metal, though present in exceedingly small quantities. Whether the absence of nitrogen and hydrogen in sponge iron made without melting--especially of that made at relatively low temperatures--is the answer, modern scientific research will soon tell us. At any rate, the quality of the original virgin metal made directly from pure ores in the Catalan forges without melting has never been reached.

The New Sponge Iron Process

The process I prefer to use is a new method for making sponge iron--by gaseous, low temperature reduction and compacting to produce a dense, metallic structure. It uses gases instead of solid carbon as a reducing agent, and operates at very low temperatures, between 1,300° and 1,500° F. for most hematites, and between 1,100° and 1,300° F. for magnetites, in accordance with the kind of gas used, pure hydrogen requiring the lowest temperatures. The blast furnace works at a temperature of 3,000° F. The gases I prefer to use are hydrogen or gases containing high percentage of hydrogen. The process produces a continuous stream of porous, spongy, reduced fines which are immediately compressed or briquetted into a dense, heavy stock while still hot and protected by a reducing atmosphere against reoxidation. These briquets can be made into finished steel either by melting in the open hearth or electric furnace, or they can be used directly for the production of bars and shapes by forging, rolling, or extrusion; or the reduced powder, if made from sufficiently pure ore concentrates, may be used by itself or mixed with other metals or suitable substances in the powdered metal industry for the production of many high quality metal parts and new commercial articles.

The Brassert-Cape reduction unit which is now being installed at the Republic Steel Corporation's plant at Warren, Ohio, is a modification of the well-known Herreshoff furnace, with a slotted hearth installed for final reduction in the bottom of the structure. The Herreshoff furnace is a highly developed unit long used for many purposes such as roasting, calcining, drying, and desulfurizing materials. Its use for reducing iron ores at low temperatures by hydrogen, however, is new. The main structure of the furnace has not been changed except for the addition of one or several slotted hearths at the bottom of the usual 10 or 12 superimposed rabbling hearths. In the slotted hearth, the reducing gas bubbles through the ore bed in such a manner that no grain of material can leave the furnace without having been in contact with the gas. In fact, the charge is moved across the hearth and out of the furnace primarily by the gas.

The Herreshoff furnace is a simple cylindrical vertical unit with a slowly revolving, hollow shaft in the center. Rabbles or teeth are mounted on the shaft and move the ore across the hearths successively, inwardly and outwardly, turning the ore and exposing all of it to the gas. The ore drops from one hearth to the other while the gas flows upward, each time flowing through the dropping ore and passing over the ore in each hearth as it is turned over by the rabbles. An additional quantity of gas is injected directly into the ore through the rabble arms which are hollow, and get their supply of gas from the central shaft. On the upper Herreshoff hearths the ore is dried and preheated, and on the lower hearths it is partially reduced. If it requires roasting on account of sulphur, or if requires calcining, this is also accomplished in the top hearths. At any rate, the ore is preheated and prereduced to the desired degree before it reaches the final slotted reducing hearth or hearths in the bottom.

We have designed two forms of this hearth, one a V-type, in which there are a number of concentric small V-shaped troughs placed across a large V which serves as gas container. The gas bubbles through the fine slots in the bottom of the multiple V's, and imparts to the ore bed a state equivalent to fluidity so it flows around the hearth to the discharge end. The gas ducts are so designed that any ore fines falling through, in case the gas flow is interrupted, may be easily removed through the bottom.

The other type of hearth is built of radial segments, forming inclined slots between them which resemble the blades of a turbine. The gas flows through these slots into the ore bed, moving the bubbling, fluent ore stream spirally outward toward the point of discharge. This hearth design has been adopted for the Republic plant. The gas is introduced into the ore bed, and the rate of travel of the ore fines is retarded and regulated by the rabble teeth. The hearth is constructed of easily-removable sections. The design of the slots prevents any ore fines falling through when the gas flow is interrupted.

The only mechanical parts in the furnace are the rabbles which propel the ore charge in the Herreshoff hearths and which are meant to break up any possible gas locks in the slotted hearths. The operation of the reducing furnace is entirely automatic and thermally controlled. Provision is made for the introduction of gas at various levels and exact temperatures can be maintained in all of the hearths. The problem of sticking, due to local temperature rises, the bane of former reduction processes, has thus been solved successfully.

Apparatus is Simple

Hundreds of Herreshoff installations have given many long years of satisfactory service at higher temperatures than are required for the gaseous reduction of iron ores. Compared to the blast furnace which, with its auxiliary equipment, is an intricate apparatus, the Brassert-Cape low temperature reduction unit is a comparatively simple apparatus. It works at low temperatures, whereas the blast furnace in its lower portion has to deal with temperatures of around 3,000° F. As stated before, the blast furnace lining has to be protected at the various stages against abrasion by the descending stock, against corrosion by gases, slags, and sheer fluxing by the high temperatures in the bosh and hearth. The armament of the lower part of the blast furnace is not unlike that of a battleship. The blast furnace is about 100 feet high and charged not continuously, but by batches with an intricate electrically controlled apparatus. The Herreshoff furnace on the other hand, is only about 40 feet high and smaller in diameter. Operating temperatures in our process will in no case exceed 1,500° F. The wear and tear in the Herreshoff is, of course, infinitely smaller, if only on account of this temperature difference. The ore is charged at the top continuously by a simple, well-known type of feeder; it moves through the furnace at a controlled rate. At the bottom, the revolving rabbles control and insure uniform delivery of the reduced fines into the chute which feeds the briquetting rolls.

The feeding of the ore, its movement through the furnace, its discharge into the briquetting rolls, are continuous and entirely automatic. In the blast furnace, charging of the raw materials, discharging of the slag and iron is done in batches. It is not continuous. The danger of explosions in the Brassert-Cape reduction furnace has been eliminated, since the entire apparatus is enclosed and constantly under a positive gas pressure.

The complete low temperature gaseous reduction plant consists of a number of units. First, there is the gas preparation plant; if the gas contains sulfur, gas desulfurizing apparatus must be installed; where natural gas is used a gas re-forming or cracking plant is needed. The prepared gas next passes through a heat exchanger and then through a preheater before entering the furnace. For the compacting of the reduced ore at the bottom of the furnace, briquetting rolls are provided, placed immediately underneath the discharge of the reduced ore fines. Here the iron powder is compressed while still hot and under a reducing atmosphere, forming dense melting stock briquettes. Miscellaneous equipment for the handling of the raw material and of the finished product, such as cranes and endless belts, a gas washer for the cleaning of the spent gases, control apparatus and instruments, complete the installation.

The gas from the coke oven mains flows through the various preparatory stages and into the reduction unit. The spent gases issuing from the top are washed to remove the water vapor, the product of the reaction. Half of the gas is returned into the direct reduction unit; the other half is sent back into the steel mill gas main, there to be consumed in steel making and heating furnaces. The removal in the process of ore reduction of some of the hydrogen contained in the coke-oven gas results in an increase of its heating value and its luminosity, so that the gas becomes more suitable both as fuel in the steel works furnaces and for other uses.

Low Operating Costs

The cost of operation and maintenance of a low temperature unit will naturally be less than that of a high temperature melting apparatus such as a blast furnace, with all its expensive machinery and equipment. The operation of the low temperature reduction plant is entirely continuous, practically automatic and under complete control. It is certainly cheaper to operate than a blast furnace and its coke plant, both of which are high-temperature equipment which have to be discharged periodically, and still have manual and intermittent features in the operation and much complicated auxiliary equipment.

In my experience, a great many ores have been investigated; and it was found that it was easier to work with our high-grade eastern magnetite concentrates than with any other ores. Most minerals in which the gangue is free can be used for this purpose. Such ores will be subjected to magnetic concentration before or after reduction and before briquetting. Iron ores become magnetic upon being reduced wholly or partially to the metallic state. Therefore, magnetic concentration becomes possible after passing the ore through the low-temperature gaseous-reduction process, even when using hematites and other non-magnetic ores. As long as the temperature remains below the limit of magnetic permeability, as it does in this case, this magnetic concentrating step might be taken after reduction while the reduced ore fines are still hot. Or they can be submerged in a cooling liquid and then subjected to wet magnetic concentration, reheated in a reducing atmosphere and briquetted. At any rate, the continuity of my process need not be interrupted.

There are however, ores in which the gangue, although free, is so intimately associated with the iron oxides that separation by washing, flotation, magnetic, electrostatic separation, or air tabling is not economically feasible. In that case, the excess gangue left in the ores after possible concentration enters the sponge iron briquettes with the reduced iron. The briquettes can then be melted in a cupola, a rotary or tilting furnace, and the molten gangue separated by the usual way from the molten metal by flushing it off with the molten slag. The molten metal, free from gangue, is transferred to the open hearth or electric furnace for conversion into steel.

Then there are many ores in which the iron oxides are so finely dispersed or intermingled with the gangue that no adequate separation is possible except by exceedingly fine grinding, causing the formation of slimes which cannot be handled. Or the oxides may be chemically combined with all or some of the gangue compounds. Such ores cannot be used for the production of iron and steel except by melting in the blast furnace or by chemical solution.

I believe that the direct reduction process offers the proper method for the recovery of titanium, vanadium, and chromium values contained in ores which cannot be worked economically at present. Pyrites residues and roll scale are other possible raw materials.

Sponge iron is an excellent raw material in the manufacture of high-quality steel on account of its great purity, the practical absence of sulfur and phosphorus, the fact that it is not contaminated like scrap with harmful and uncertain constituents, and also the absence of nitrogen and other harmful gases.

Far Too Good To Replace Scrap

The sponge iron produced in the low-temperature reduction process is far too good a material merely to replace scrap, even the highest grade of scrap, although in the present emergency that will be its first function. The full value of this product can only be shown when used substantially alone in the making of the finest steels.

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Thus the new low-temperature gaseous reduction process offers a chance to industry to revert from the highly centralized integrated units to economical small-scale operation. This makes possible the distribution of a number of small sponge-iron plants feeding local industries and creating employment in small towns and rural communities without disturbing the economic equilibrium of the industry at large.

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MINING NOTES

Southwestern Oregon

The Pacific Company, which has leased the Sordy Chrome property south of Galice, has shipped its fifth carload of ore in 1943. Work was delayed this spring by unusually heavy snowfall. The access road to the Sordy property, built last year by the Siskiyou National Forest Service, is in good condition. Gravel has been placed on the softer spots. One chrome area is being diamond-drilled by the company. The ore shipped was mined on the Violet claim.

Some chrome has been shipped from the Illinois River area throughout winter. William Robertson of the Oregon Chrome Mines, and Hammer and Neubert were the principal shippers. Both Fisher and Anderson, and James G. Gallaher, have chrome ready to ship from their claims on Red Dog Creek. Chromite property owners west of the Illinois River are active and are preparing to ship. The Sinnick interests are building a road to the Chetco divide where their property is situated.

Several chrome operators have been investigating the possibilities of concentrating low-grade ores. These ores contain high-grade chromite grains mixed with gangue. Baker Brothers and Jones have a small concentrator in operation on Bloody Run about 3 miles east of Grants Pass. It is reported that the plant has a capacity of 18 tons of ore per 8-hour shift.

Work on chrome properties in northern California was held up by snow conditions until late in the spring. A period of pleasant spring weather was followed by rain storms which softened the roads and made hauling difficult. Heavy hauling from some of the properties was begun during the latter part of June. At the High Plateau mine a lower adit has been driven to cut new ore. It is reported that the Crescent-Pacific Company has encountered additional ore on their property west of the High Plateau. Development work is being done at High Divide, where a shaft is being sunk to cut additional ore. It is reported that the Tyson or French Hill deposits are showing up remarkably well. Men and equipment have gone into the Cyclone Gap property of J. K. Remsen and shipments will be made as soon as road conditions will permit. Mr. Remsen is also operating the Snowy Ridge chrome property on the Oregon-California boundary, southwest of Ashland, Oregon.

Anthony Brandenthaler, O'Brien, Oregon, is preparing to ship copper ore from the old Waldo copper mine in the Takilma district, southern Josephine County.

The Grants Pass field office of the Department has been moved from 400 East "I", to 714 East "H" Street. Part of the laboratory equipment has been moved to the Portland office of the Department where the assaying will be done. Although no assaying will be done in Grants Pass for the duration, samples from western Oregon should be submitted to the Grants Pass office where assay records are filed as they were before suspension of local assay work.

Northeastern Oregon

The Mother Lode quicksilver property near Round Mountain, east of Prineville, Crook County, operated by Gilkey Brothers, is installing a washing and concentrating plant to treat ore from surface mining. A contract has been let to Louis Johnson of Eugene to supply the plant with about 1000 yards of material per day. About 10 tons of concentrates will be produced and furnaced. The plant is expected to be in production by the last of July.

Anthony Brandenthaler has taken an option on the Gray Eagle antimony mine near Baker. Extensive development work is planned and antimony ore now in sight will be shipped. Operations are expected to start about July 20.

The Ellis Mining Company with extensive holdings in the Bourne district, Baker County, supplies siliceous ores to the Tacoma smelter.

The Shanghai Gulch placer mine owned by Mr. H. P. Lambert, Sparta, Oregon, has been leased to Mrs. L. Muegge and Mrs. E. Warfel, Baker. A vein of quartz crystal found on the property is being investigated in order to determine optical quartz possibilities.

The Iceland Spar claims located about 25 miles south of Vale, Malheur County, and owned by William Metavia and M. P. Tonning, Boise, Idaho, are under lease to W. M. Schmeykal and F. L. Muckensturm, Boise, Idaho, who are doing development work. This property was investigated by the State Department recently and specimens of possible optical grade have been obtained from near the surface. Better quality material is being sought by deeper development work.

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