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DEPARTMENT OF JUSTICE

WAR DIVISION

ECONOMIC WARFARE SECTION

REPORT ON THE IRON ORE CRUSHING AND CONCENTRATION PLANT OF THE MITSUBISHI MINING COMPANY, LTD., AT MOZAN IN NORTHWESTERN KOREA

May 15, 1943

Submitted by: Charles C. Baldwin
Economic Warfare Unit
Department of Justice
New York, New York

Economic Warfare Section
Department of Justice

Confidential Report
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EXHIBITS

1. Map of Northern Korea showing the location of (a) the Mozan Iron Ore Concentration Plant, and (b) the port of Seishin where the blast furnaces and Krupp Renn kilns are situated and from which the processed ore is shipped to steel plants in Japan.

2. A sketch showing the relative positions of (a) the Mozan mine, (b) the coarse crushing plant, (c) the crushed ore bins, and (d) the fine grinding and concentrating mills.

3. Plan view and sections of the ore crushing plant.

4. Flow sheet for unit #2 of the concentrating mill.

5. Chart showing number, sizes, and relative location of feeders, red mills, screens, separators, classifiers, ball mills, thickners, and filters of concentration unit #2.

6. View of the Tuman River Valley, near the Mozan Mine, in North Kankyo Province, Korea.

7. View of the harbor of Seishin, in North Kankyo Province, Korea, from which Mozan's pig iron is shipped to Japan for further processing.

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Washington, D. C.

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INTRODUCTION

The iron ore concentration plant of the Mitsubishi Mining Company at Mozan on the Korea-Manchukuo border, 75 miles west of Seishin, is a vital factor in Japanese war production because

1. As the largest iron ore concentrating plant in the world, it produces over 70% of the iron concentrate produced by Korea and Manchukuo, and almost 50% of the concentrate produced by the Japanese Empire and Manchukuo.

2. The plant is the most modern, the most efficient, and the nearest source of iron concentrate to the steel mills of Japan.[1]

The Mozan plant is part of an integrated mining and milling operation which converts the lean iron ore of the Mozan mine into a high-grade furnace mixture. The mine is on the crest of a hill. The ore moves by gravity from one crushing and grinding and refining stage to the next; and from the mill by rail to the Government's blast furnaces at Seishin.

Dislocation of this plant would seriously hamper the production of Japanese war material, forcing Japan to increase materially her imports of iron ore from Malaya and the Philippines. This would place a tremendous burden upon her already strained shipping facilities.[2]

DEVELOPMENT OF MOZAN PROPERTIES

Prior to the opening of the Mozan mines in 1938, 75 per cent of the iron ore, 33 per cent of the pig iron and 50 per cent of the iron and steel scrap consumed in Japan had to be imported from abroad, notably from British Malaya, North China, the Philippines, Australia, and the United States.[3] In 1938, with self-sufficiency as the national objective, the Government initiated a five-year plan for the iron and steel industry. Under this plan the state-owned Japan Steel Manufacturing Company was instructed to erect a number of blast furnaces at Seishin to utilize the iron to be derived from the Mozan properties.[4] That same year the Mitsubishi Company began the construction of the Mozan concentration plant at a cost of over $3,000,000.

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The Mozan plant has a capacity of 4,620,000 metric tons of crude ore a year.[5] Allowing for waste, this represents an annual productive capacity of 2,520,000 tons of concentrate which is more than twice the capacity of the concentrating plant at the Showa Steel Works, which has an annual production of 1,000,000 tons of sintered concentrate.[6]

Together, prior to December 1941, Mozan and Showa were the most important sources of iron under Japanese control.[7] Mozan is the more important of the two, not only because of its larger capacity, but primarily because of the relatively short haul from the mines to the steel plant and foundaries of Japan.

OPERATION OF MOZAN PROPERTIES

The Mozan mills are situated in plain view on the southeast slope of a mountain near Mozan on the Manchukuo-Korea border, in North Kankyo Province, about 100 kilometres west of the port of Seishin (Exhibit #1). The plant has two units, each consisting of a coarse crushing plant and a concentration mill. The first unit was erected in 1938. Construction of the second unit was begun in 1939 and completed early in 1942.[8] The buildings of concrete and steel, with corrugated roofs, are the usual type universally employed for the concentration of low-grade iron ore.[9] They cover an area of approximately 1,000 feet by 1,000 feet. Working 24 hours a day, 350 days a year, they employ upwards of 3,000 men, mostly Chinese and Koreans, classified as 25 per cent skilled and 75 per cent unskilled, under Japanese supervision.[10]

The Mozan mine is located on the crest of a mountain looking across the Tuman River Valley west and north towards Manchuria.[11] The crude ore is trucked down the mountain to a coarse crushing plant (Exhibit #2). From the crushers the ore is carried by conveyors to the concentration mills at the foot of the hill. The concentrated ore is sent to a sintering plant which may be at Mozan. If there is no sintering at Mozan, then the concentrate is shipped by rail to Seishin. At Seishin the sinter is sent to blast furnaces and Krupp Renn kilns to be converted into pig iron. The pig iron is shipped across the sea of Japan to foundries on the west coast or by way of Shimoeski and Moji through the Inland Sea to the steel plants at Yawata, Osaka, Kobe, and Hokkaido.[12]

THE MOZAN MINE

The Mozan iron mine is worked in benches cut into the side of the mountain (Exhibit #2).[13] The ore is scooped up by steam shovels to be loaded into trucks and carted down a winding road to ore bins which feed the coarse crushing plant. The crude ore contains a preponderance of magnetite (Fe^3O^4) known as "black rust", together with some non-magnetic iron oxide (martite). Tested at the concentrating plant of the Scrub Oaks Mine, Dover, N. J., it was found that, ground to between 65 and 80 mesh, the crude ore produced a concentrate containing 65 per cent to 67 per cent Fe, with a fine tailing of less than 2-1/2 per cent Fe. This concentrate proved to be very low in silica: 4 per cent to

6 per cent.[14] This low silica content means that excellent sinter (partially fused ore) can be made from the high-grade Mozan concentrate, thereby speeding up furnace practice by increasing output through the reduction of slag volume, coke consumption, and other costs. This makes for better control of the hot metal or pig iron, which, in turn, makes possible a cheaper, simpler, and more uniform operation in the steel plants using Mozan iron.

COARSE CRUSHING PLANT

The Mozan crushing and concentrating plant is divided into two units: a small experimental plant erected in 1938, producing 50 tons of concentrate an hour; and unit #2, erected in 1940-41, with an hourly capacity of 225 tons of concentrated ore. Unit #1 is in no way unusual, consisting of bins and chutes to feed the crushers, runways down which coolies with barrows wheel the crushed ore to the concentration separators and grinders. Unit #2 is a modern, efficient, well-designed plant.

Three drifts were driven into the hillside to carry the crude ore from underground bins to the three sections of the coarse crushing plant of unit #2.[15] The outside drifts are tunnels to house conveyors delivering materials to the end sections. The inside drift not only houses a conveyor, but is high and wide enough to pass a car of machinery. The coarse crushing machinery is housed on ledges blasted out of the rock (Exhibit #3). The arrangement of this equipment allows for the discharge of all materials by gravity from one crushing stage to the next. Each section consists of a Ross feeder to supply the coarse ore across a stationary grizzly bar to the jaws of a heavy-duty crusher; a vibratory screen to sift off waste matter; a large gyratory crusher; and a belt conveyor to deliver the crushed ore to concrete storage bins further down the mountain slope.

Operating at capacity, this plant will crush 900 tons of ore an hour, roughly half of which will be discarded as waste.

CONCENTRATING MILL

Ore concentration is a series of grindings, separations, regrinding of the middlings and concentrate, and further separation to take out the refined concentrate and remove waste, sand, and other impurities.[16]

At Mozan there are three crushed ore bins, the two largest having a capacity of about 10,000 tons each. Belt feeders, 30 inches wide, carrying the crushed ore from the bins to double-decked Ty-Rock screens which sift the ore into material for magnetic cobbing, and material for further screening. The Minus 5 mm. material is sent directly to a 10,000 ton rod mill feeder bin. (see 5 lines below). The three coarser sizes are cobbed over magnetic pulleys to eliminate coarse waste.[17]

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The first grinding in the #2 concentration mill is done by means of Symons cone crushers. From these crushers the ore passes to screens for further separation, the refined ore being carried off to the storage bins and the unrefined ore passing on to rod mills for further grinding.[18] Up to this point the ore has been ground by breaking. Now it is to be ground by attrition. Water is added;[19] the cylinders revolve; the fine ore passes through screens to conveyors that carry it to the storage bins; the remainder goes back into the mill. After passing through a Crockett separator, the overflow runs through a Dorr Thickener where part of the water is taken off.[20] Dorr Classifiers now remove low-grade clay impurities.[21] The overflow passes over another magnetic separator. Some concentrate is taken off; and a final separation of the remainder is made by shaking tables. The lighter material flows over the table riffles and is discharged as waste. The concentrate now moves to a row of thickeners outside the building for dewatering,[22] and then through Dorrco Filters. The product from the filters and the bins is ready for sintering.

The entire operation requires 2 to 3 hours. About 15,000 gallons of water a minute are used; and it is the purpose of the thickeners and filters to recover as much of this water as possible, both to conserve water and to prevent the flooding of the plant area by the tailings.[23]

SINTERING PLANT

Though no sintering plant existed in 1939, there can be but little doubt that one has since been erected. Such a plant would remove the 10 per cent of moisture in the concentrate, thereby reducing freight costs and providing a dry product which would not freeze in the railroad cars on the 100-kilometre rail haul from Mozan to Seishin, during the five months of Korean winter. Sinter is a partially fused ore that can be shipped to blast furnaces anywhere, whereas a finely ground concentrate can only be handled by roasting furnaces.[24]

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NOTES

1. Manchurian and Korean ores are about equal in iron content; but whereas the Showa plant at Anshan in Manchuria produces a concentrate with 55 per cent Fe, the Mozan mill (designed by Mr. R. E. Crockett of Dover, N. J. and equipped with modern American machinery) produces a concentrate with 65 per cent to 67 per cent Fe.

2. Ore from Malaya (60 per cent iron) and the Philippines (47 per cent to 65 per cent iron) would have to be shipped to Japan for conversion, since suitable grades of metallurgical coal are not available in Malaya and Philippine coal is of low grade and difficult to mine.

3. F. Foster Bain, in "The Trans-Pacific" of Tokyo, August 12, 1937, stated that the cost of high-grade iron ore (60 per cent iron) imported from Malaya was often less than the cost of exploiting the inferior ores (35 per cent iron) of Manchuria. In 1936 Malayan iron ore accounted for 45 per cent of ore imports from abroad into Japan proper, while Chinese ores represented 33 per cent, the balance coming from the Philippines and Australia.

4. Prior to the construction of the Seishin furnaces in 1938, there were only 26 blast furnaces in operation in the Empire, with an annual productive capacity of 2,400,000 metric tons. Korea was then producing about 200,000 tons of pig iron a year; while a million tons a year (of which 400,000 tons came from Manchuria) were being imported from abroad. Japan was then by far the largest importer of pig iron in the world, her imports equal to the combined imports of the ten next largest importers. This caused grave concern lest in the event of war a "pig iron famine" develop. The Government, therefore, initiated a 5-year plan for the iron and steel industry, suggesting the construction of enough new blast furnaces to increase production by something over 800,000 tons for each year from 1938 through 1941. The Seishin blast furnaces were the first to be built under this plan.

5. As shown on Exhibit #5, units #1 and #2 have a daily capacity of 7,200 metric tons of concentrate. Add 6,000 metric tons of waste a day, and the two units, working 350 days a year, will have an annual capacity of 4,620,000 tons of crude ore. Mr. Hitch of the Dorr Company states that in figuring capacities it is well to allow 15 days a year for shutdowns overhauling, and repairs.

6. The Showa Steel Works, then called the Anshan Iron Works, was the first to develop the so-called hematite reduction and magnetic concentration process, and in 1925 at Anshan erected the first concentration plant capable of producing (from low-grade Manchurian ores, with an iron content of 35%) a concentrate with 55% iron.

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7. Exclusive of Mozan, Korea produces an average of 500,000 tons of iron ore a year. Japan proper produces an average of 500,000 tons a year. Manchurian ores are never exported, but are converted into pig iron locally. See also #11.

8. Dates for the construction of the two concentration mills are based upon information found in the files of the Dorr Company, continuing as late as November 1941. They conflict with statements made by Mr. R. E. Crockett, designer of unit #2, who stated: "There are three concentration mills. Construction of the first unit was begun in 1938, of the second in 1939, and of the third in 1940. I believe that all three are now in operation." Mr. Crockett left Korea late in August 1939. At that time work on unit #2 had not yet begun. It did not begin for many months. In fact, Mr. Hitch of the Dorr Company (whose classifiers, thickeners, and filters were used) stated that Mr. Crockett's designs were considerably modified, and that as late as November 1941 much of the machinery for unit #2 had not yet been delivered. It would therefore have been impossible for unit #2 to go into operation until late in the spring of 1942. Mr. Hitch is strongly of the opinion that no work has yet been done on unit #3.

9. Four similar plants for the magnetic concentration of lean iron ores have recently been erected in Northern New York State by Republic Steel, Jones & Laughlin, the Interstate Iron Company, and the M. A. Hanna Company.

10. In the United States an identical plant would employ 250-300 men. Mr. Crockett explains the large Mozan personnel by saying that labor is cheap and plentiful, though not particularly active or strong. Koreans average about 5 feet 4 inches, with oblique brown eyes, high cheek bones, and straight hair shading from russet to sloe black. They are apt to be sullen, and not above tossing a little sand into Japanese bearings. The Chinese are competent, willing workers, but not so robust as American miners or mill hands.

11. Korea is highly mineralized. Gold, silver, copper, iron, zinc, arsenic, anthracite, asphalt, and graphite occur in quantity. Chief among the iron properties are the state-owned Sainei-men mines which at one time supplied 20 per cent of the requirements of the Government's steel works at Yawata; (the Kuhara Mining Company's holdings at Heijo;) the Japan Metal Company's mines at Roryoshin; the extensive holdings of the Mitsubishi Company at Kenjiho; and the Mozan mine. As far as is known, practically all the iron mines in Korea, including those owned by the Government, are operated by the Mitsubishi Company.

12. Practically all of the raw materials produced in Korea are sent to Japan for processing. Among the leading private steel producers in Japan are the Japan Steel Tube Co. (Nippon Kokan) a producer of pig iron, bars, shapes, rails, pipes, and special steels; Kawasaki Shipbuilding & Dockyard Co. (Kawasaki Zosenjo), which produces ingots and castings for its

own use; Kobe Steel Works (Kobe Seikojo), formerly a subsidiary of the Suzuki interests, which produces ordnance for the Japanese Navy as well as bars, forgings, and castings; Asano Shipbuilding Co. (Asano Zosen) producer of plats for its shipyards; and Kokura Steel Co. (Kokura Seiko, formerly Asano Kokura), producer of ingots and castings. Several of these private companies, notably the Japan Steel Tube Co., have their own blast furnaces as well as iron ore and coal mines.

13. Iron ore is mined either by the open-pit or underground method. The former is used if the ore is soft and near the surface. First the over-burden is removed; then the ore is loaded into cars or trucks to be hauled to the furnaces. The underground method is used only where the cheaper open-cut method is impracticable.

14. Silica content is a measure of the value of iron ores. Newfoundland ores, for example, are far richer in iron than are Korean ores, but they are also higher in silica - for which reason they have never been exploited to any extent. A high silica content produces objectionable quantities of the difficult and irreducible ferrous silicate known as "fayalite". As the silica content of a concentrate increases, the proportion of fayalite in the sinter will increase even more rapidly. For example, though 8 per cent of silica in the mixture will produce only 10 per cent of fayalite in the sinter, 19 per cent of silica will produce a sinter that is 75 per cent fayalite.

15. Crushing plants are often divided into sections so that should one section break, the whole plant does not have to close while repairs are being made. This is particularly important with a concentration mill using 40,000 tons of water a day and requiring a week to fill up and get started. Such a mill must operate 24 hours a day.

16. Many ore concentration methods have been developed. The process used depends upon the exact nature of the ore to be treated, but, in general, the important processes are: (a) magnetic concentration; (b) size separation; and (c) gravity concentration. If the iron oxide is in the form of magnetite, as is Mozan ore, then the magnetic concentration process (a) is usually employed, regardless of the structure of the ore. This process is in general used in Manchuria, Korea, New York, New Jersey, and Pennsylvania. Screening the ore for the removal of coarse rock (b) is in use in the Lake Superior district. Gravity concentration (c), which includes washing, classifying, tabling and jigging, is the most important process for the treatment of non-magnetic ores.

17. Cobbing (hammering off waste and low-grade material) is usually done by hand. In magnetic cobbing, the crushed ore passes over a magnetic pulley which holds the true ore so that it falls down, instead of out. The waste is thrown out. In this way, a separation is effected.

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18. Rod mills are 9-ft. x 12-ft. revolving cylinders, half filled with rods.

19. It is estimated that 40,000 tons of water a day would be required to start and operate unit #2.

20. These thickeners are tanks, 24 ft. wide and 12 ft. deep, with great arms revolving from a center pin, to stir the mixture, allowing the water to overflow and the ore to be drawn off at the bottom.

21. A Dorr Classifier is a sloping tank 18 ft. x 30 ft. half filled with water, in which big rakes are manipulated to rake and separate the sand from the ore.

22. As shown on Exhibit #5, these thickeners are 80 ft. and 100 ft. in diameter. The three 80-ft. thickeners handle 7,200 tons of concentrate a day; while the four 100-ft. thickeners dewater 6,000 tons of waste a day.

23. T. B. Ford of the Dorr Company, 221 North LaSalle Street, Chicago, believes that water is the bottleneck of the Showa Steel plant at Anshan. They recently added a 250-ft. water storage tank to the three 100-ft. tanks serving the concentration mill. Mr. Ford believes that if those tanks were destroyed, the plant could not operate. With open heat the furnaces annually producing 135,000 tons of steel ingots and castings, and blast furnaces producing an additional 400,000 tons of pig iron, the Showa plant is of major importance to Japan.

24. Sintering means "partial fusion", i.e., heating the concentrate to 1,100 degrees C., or "white heat". Sintering gives size and strength to ore that has been so finely ground that it cannot be put through a blast furnace.

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SOURCES

ROBERT E. CROCKETT, superintendent of the Alan Wood Steel Company, Dover, N. J. This report is very largely based upon two interviews with Mr. Crockett, who, in the late spring and summer of 1939, spent five months in Manchukuo and Korea as a consulting and construction engineer on loan to the H. H. Brassert Company of 310 South Michigan Ave., Chicago, Ill. His assignment took him first to Manchuria where he made a detailed study of the raw materials available to the Showa Steel Company's plant at Anshan. Next, he visited the limestone quarries at Dairen. From there he went to Mozan, where he designed additions to the iron concentration plant. Of the Showa Steel Works, he said: "I was able to suggest methods for mining and concentrating the iron ores, magnesite, dolomite, and limestone available near the plant, all of them in quantity, and all, except the iron ore, of good grade. The plant is a completely integrated unit, with magnetic roasting furnaces, a concentration mill and eight blast furnaces capable of converting a million tons of crude ore into finished steel in a year. Located to the west of the railroad tracks, in a sizable city, it employs upwards of 40,000 Chinese laborers under Japanese foremen and technicians. They get their coal from the Tobenda Mines and the open pits at Fushun, twenty miles east of Mukden. The limestone comes from Kanseishei across the bay from Dairen. But all of their raw materials are obtained in the vicinity of Anshan, with the ore coming from Taikaosan, about six miles to the south. The coke ovens are made of brick and should prove especially vulnerable. Next in importance I would place the concentration mill which is located on a small hill in the center of the city of Anshan. The blast furnaces are more substantially constructed."

J. D. HITCH, export manager, the Dorr Company, 570 Lexington Ave., New York City. Mr. Hitch was stationed in Japan and Manchuria from 1932-1937, leaving just as the Mitsubishi Mining Company began the development of their Mozan properties; but as export manager of the Dorr Company, familiar with the Japanese steel industry, he helped to sell some of the equipment installed in the concentration plant.

A. T. HASTINGS, assistant general manager, the Dorr Company, 570 Lexington Ave., New York City. Mr. Hastings supplied most of the details as to the operation of the Mozan concentration plant.

A. B. KINZEL, chief metallurgist of the Union Carbide & Carbon Research Laboratory, New York, New York.