C152

FOREWORD

In April, 1962, the information obtained from the review of some 96 articles on iron ore pelletizing was summarized and presented at the annual meeting of the Canadian Institute of Mining and Metallurgy. This paper was published in the Bulletin of the Institute for December, 1962. Since that time, additional articles have been reviewed, and the scope of the survey has been broadened to include many articles dealing with the principles involved in the close-packing of particles, porosity of agglomerates, binding forces, etc.

John Convey,
Director, Mines Branch

Ottawa,
August, 1963

Mines Branch Information Circular IC 152

IRON ORE PELLETIZING
A Literature Survey

by

G. N. Banks*, R. A. Campbell** and G. E. Viens**

ABSTRACT

A survey of the literature reveals wide differences in the procedures used in making iron ore pellets, and in the properties of the pellets obtained. In this paper the methods of production and the properties of pellets, as reported in the literature, are examined in an effort to determine what correlations exist between them. An attempt also is made to determine the levels of the properties of pellets which are considered acceptable and desirable in modern practice. A few cost data are included.

*Scientific Officer, and **Senior Scientific Officers, Pyrometallurgy and Corrosion Section, Extraction Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

Direction des mines

Circulaire d'information IC 152

BOULETTAGE DU MINERAI DE FER
Étude bibliographique

par

G.N. Banks*, R.A. Campbell** et G.E. Viens**

RÉSUMÉ

Une étude bibliographique révèle un large éventail de procédés utilisés pour obtenir des boulettes de minerai de fer, et de grandes différences entre les propriétés des boulettes ainsi obtenues. Dans le présent travail, les auteurs étudient les procédés de production et les propriétés des boulettes afin de déterminer les corrélations qui existent en eux. Ils tentent également de déterminer quelles sont les propriétés moyennes que doivent posséder les boulettes jugées acceptables et désirables dans les usines de nos jours. Les auteurs mentionnent quelques données relatives aux coûts.

*Chargé de recherches et **chargés de recherches principaux, Section de la pyrométallurgie et de la corrosion, Division de la métallurgie extractive, Direction des mines, ministère des Mines et des Relevés techniques, Ottawa, Canada.

CONTENTS

INTRODUCTION

Much has been written regarding the important changes which have been taking place recently in the iron ore industry. As the demand for ore has increased and the supply of direct-shipping ore has dwindled, the problems associated with the utilization of lower-grade ores have been intensely investigated and important advances in both beneficiation and agglomeration techniques have taken place. In particular, there has been a great deal of activity in connection with the pelletizing method of agglomeration. The superiority of pellets over raw ore has been demonstrated in blast furnace tests (38, 133, 137-140, 145).

This development has particular significance for Canada which, in the past twenty years, has moved from a position of exporting little or no iron ore to the point where it is now one of the great iron ore exporting nations of the world (10, 30). In 1960 Canada produced 19 million gross tons of iron ore, and it has been estimated that this can be tripled in 10 years' time. It is believed that most of this increase will be in the form of high-grade pelletized ore concentrates.

It is believed that sufficient work now has been done on the pelletizing of a wide variety of ores and concentrates to justify the preparation of a review of the literature on this subject. Such a review is given in the present paper.

In making this survey it was hoped to obtain answers to such questions as:

1. What equipment and techniques are favoured for making pellets?

2. What strength is required in pellets to withstand the effects of shipping, and the crushing load in the blast furnace?

3. What are the major factors affecting the strength of pellets in the fired state?

4. Are there any generally accepted procedures for measuring the strength of pellets?

5. What is considered the optimum size of pellet, and is the close sizing of pellets important?

6. How important are the other properties of pellets, e.g. porosity, reducibility, etc.?

Many articles have been written about pelletizing in recent years, and a survey of this literature was published by Goldstick (33) in 1962. However, answers to questions such as those posed above have not been clearly given in this or any other single article known to the authors.

The following definitions given by Goldstick have been adopted in the present paper:

> Agglomeration: A general term referring to the process of forming a physically larger body from a number of smaller bodies. Denotes the entire process, including firing if this is used.
>
> Pelletizing: The entire process of making an agglomerate (in this case called a pellet) by first forming a ball and then firing it.
>
> Balling: The process of forming an unfired (green) agglomerate by rolling fine material on a surface, while applying no direct pressure.
>
> Green: Applied to any unfired agglomerate. The term "green pellet" is equivalent to "ball".

This survey covers 165 articles which were available to the authors. Although it was impossible to refer in the text to all of these articles, the authors hope that those which were included will give an adequate picture of the present status of pellet production. Although reference information regarding the various articles is given at the end of the paper, the pertinent reference numbers are given at the end of each section.

THEORETICAL CONSIDERATIONS

This aspect has been thoroughly discussed in Goldstick's review. The "Capillary Theory" proposed by Tigerschiold and Ilmoni (89) to explain the balling of fine concentrates, appears to be accepted by most workers in the field. According to this theory, the surface tension of the thin film of water surrounding the ore particles tends to have a compressing effect on the ball produced. It is suggested that the compressing force on the surface of the ball is a function of the fineness of the concentrate, the distribution of the particle sizes, and the effectiveness of the balling method. The optimum water content is extremely important, as an excess of water will neutralize the effect of capillary pressure, and a deficiency of water will permit the existence of greater air inclusions within the ball, which will reduce the effect of the capillary pressure.

Extensive investigations have been performed on the mechanism of bonding of fired pellets. Most workers agree that the ultimate strength of fired pellets is mainly due to the recrystallization of hematite grains. Natural magnetite pellets, fired in an oxidizing atmosphere, show a gradual increase in strength up to 1000°C, which is believed to be due to the oxidation of the magnetite to hematite (19). A rapid increase in strength then occurs as the temperature is further increased, which is believed to be due to the recrystallization of the hematite (21). The increase in strength of magnetite pellets fired above 900°C in a neutral or reducing atmosphere, is believed to be due to the grain growth of the magnetite (19).

The presence of slag-making constituents can promote more rapid strengthening of pellets at slightly lower temperatures (16, 19). When slag bonding replaces bonding by grain growth of freshly-formed hematite, the pellet strength normally is decreased (42).

Reference numbers: 7-9, 12, 15, 16, 18-21, 24, 27-29, 32, 33, 39, 42, 43, 51, 58, 60, 61, 67-69, 71, 72, 75, 76, 78, 81, 82, 88-90, 97, 106, 114, 115, 117-122, 124, 125, 127, 131, 135, 136, 144, 146-149, 155, 157, 158, 160-162, 165.

PRACTICAL CONSIDERATIONS

Scale of Operation

The results obtained in early laboratory investigations of iron ore pelletizing appear to have been reasonably well confirmed by later pilot and commercial scale operations. The relative newness of the field is attested to by the fact that of 55 articles referring to commercial operations, 41 have been published since 1955. Most of the articles dealing with pilot scale operations also have been published during this same period, and the first major research paper on the subject appeared as late as 1944 (32).

Reference numbers:

Laboratory: 7-9, 12, 13, 16-21, 23-25, 28, 29, 32, 35, 40, 42-44, 46, 47, 52, 60, 61, 63, 66, 67, 69, 71, 74-76, 80-82, 84, 87-90, 93, 94, 97, 105, 108-110, 112, 115, 119, 120, 123-126, 128-131, 134, 144, 147-150, 152, 155-157, 160, 161, 163, 164.

Pilot scale: 1, 4, 7, 12, 17, 19, 23, 24, 26, 31, 32, 37, 42, 44, 49, 61-63, 71, 77, 83, 84, 86-89, 94-96, 104, 107, 113, 137, 138, 140, 141, 143, 150, 153, 154, 162.

Commercial: 2-6, 10, 14, 22, 26, 30, 31, 34, 37-39, 41, 42, 44, 45, 48, 50, 52, 53, 54, 64, 65, 70, 73, 78, 79, 87, 88, 91, 92, 96, 98-102, 106, 113, 132, 133, 138, 139, 142, 143, 145, 150, 151, 153, 158, 162, 165.

Material Treated

The balling characteristics of limestone (87) and silica sand (67) appear to be similar to those of iron ore concentrates such as magnetite, hematite, limonite, etc., indicating that the balling mechanism is relatively independent of the chemical or mineralogical composition of the material (18) (33)(67). Specular hematite is regarded as being more difficult to pelletize than magnetite, but it is believed that this difference is due partly to the fact that specular hematite is normally obtained as a coarser concentrate than magnetite concentrates, and partly because of the platy structure of the hematite grains (93). The pelletizing of magnetite concentrate, especially that of magnetic taconites, has received the greatest amount of attention. This is largely due to the fact that these ores are present in a large proportion of the lower-grade deposits, particularly in the Mesabi range, and because they are more amenable to concentration than are other types.

Reference numbers:

Magnetite: 4, 8-10, 14, 16-26, 28-32, 35, 37-39, 42-44, 47-54, 60-64, 69, 71-75, 77, 78, 82, 83, 86, 88, 89, 92, 95, 96, 98, 99, 104, 105, 108-110, 112, 113, 123, 124, 126, 131, 134, 137-140, 142, 143, 145, 150, 151, 154, 162-164.

Hematite: 3, 5-8, 10, 12, 16-18, 20, 22, 24, 25, 28-30, 32, 35, 42, 43, 49, 51, 59, 62, 63, 69, 71-75, 78-80, 82, 91-94, 96, 101, 104, 105, 112, 119, 123-126, 128-132, 134, 141, 150, 154, 156, 162-164.

Other: 4, 8, 9, 11-14, 16-18, 20-22, 24, 25, 30, 42-44, 46, 49, 51, 63, 67, 69, 71, 72, 74-76, 78, 81, 84, 86, 87, 90, 97, 100, 104-107, 112, 115, 118, 120, 121, 134, 142, 144, 146-149, 152-155, 157, 160, 161.

Additives

Although various binders for pellets have been investigated, bentonite appears to be the most common one in commercial use. Sometimes soda ash is added to insure maximum performance of the bentonite. Limestone or dolomite, added along with the bentonite, appears to increase the green, dry and fired strengths of pellets (8, 61, 94). At times coal is added to the balls either externally or internally when more heat is required in the firing process (61), but in some plants at least this practice appears to be diminishing (37).

Reference numbers:

No additive: 7-9, 12, 16, 18-21, 23-25, 28, 29, 31, 32, 35, 42, 46, 47, 60, 63, 67, 69, 71, 75-78, 80, 81, 84, 86-89, 100, 104, 108-110, 112, 119, 130, 131, 134, 142, 150, 151, 153, 156, 157, 161.

Bentonite: 3, 6-9, 16-18, 24, 26, 31, 34, 37, 39, 42, 46, 53, 60-62, 79, 80, 82, 83, 87, 88, 91-96, 104, 108-110, 126, 130-132, 140, 141, 143, 146, 150, 162.

Lime or limestone: 3, 6-9, 16, 21, 25, 28, 29, 32, 42, 46, 47, 60, 61, 69, 75, 77-79, 88, 94, 100, 109, 110, 123, 125, 126, 130, 132, 141, 143, 160, 162.

Coal: 6-8, 23, 24, 26, 31, 37, 39, 42, 46, 49, 53, 60, 61, 71, 75, 79, 83, 94, 96, 107, 108, 113, 123, 125, 126, 129, 140, 143, 161.

Other: 4, 8, 16-18, 21, 24-26, 32, 42, 46, 47, 60-62, 67, 69, 71, 87, 88, 106, 107, 109, 110, 112, 115, 116, 121, 123, 126, 131, 146, 147, 152, 155, 157, 160, 161.

Balling Equipment

The disc and the drum are the most popular machines now used in balling fine iron ore concentrates. We are unaware of any references in which a detailed comparison of these machines is given. Although certain authors have stated that commercial-size drums have a greater capacity than commercial-size discs, the basis of comparison is not given. Most workers seem to believe that the disc will give a more uniform product (41, 63), thus eliminating the need for screening (36). Stirling (82), who recently constructed a multiple-cone drum pelletizer, states that this machine takes advantage of the better rolling action occurring in a drum, while also possessing the classifying action which is attributed to the disc. Bazanov et al (9) describe a Russian method for balling in which the fine ore is briquetted in band presses, at 142 - 213 psi, and the resulting green briquettes are rolled in a drum. The claim is made that spherical green pellets of more uniform size than those produced by either a drum or disc, with sufficient strength to withstand normal handling, are produced by this method.

Reference numbers:

Drum: 4, 7-9, 13, 16, 19, 21, 23-26, 31, 32, 34, 36, 37, 39, 41, 42, 47-49, 52, 53, 61, 62, 67, 69, 71, 77, 82, 83, 85, 86, 88, 89, 91-96, 101, 107, 112, 126, 132, 134, 137, 140, 143, 150, 160, 162, 165.

Disc: 3, 6, 7, 12, 35, 36, 41, 63, 76, 79, 82, 85-87, 94, 96, 104, 108-110, 123, 130, 134, 140-142, 150, 154, 162, 165.

Other: 4, 9, 14, 17, 21, 32, 46, 48, 60, 68, 69, 74, 81, 84, 100, 106, 115, 116, 119, 131, 143, 150, 152, 153, 155, 157, 165.

Pellet Hardening Equipment

The shaft furnace, travelling-grate, and grate-kiln system are the most common types of commercial equipment used to harden iron pellets. While the greatest assets of the shaft furnace are its simplicity of design and its high degree of heat recuperation (26), its greatest disadvantage is the difficulty frequently experienced in maintaining a uniform combustion zone. At the hot spots which may occur, the pellets tend to fuse together into large masses, producing serious discharge problems (94). The greatest asset of the travelling-grate is the close control which can be maintained at each step of the pellet hardening process, and any difficulty can quickly be remedied. The necessity of constructing the pallet frames of expensive heat-resistant alloys to withstand the high temperatures required for hardening the pellets, is a definite disadvantage (37). It would appear that updraft firing assists in reducing this difficulty (94), but the authors of this survey are aware of only one pelletizing plant using updraft firing. This was one of the earlier plants, and the fact that additional plants of this type have not been built suggests that other difficulties may be associated with this system. The grate-kiln system incorporates the close control advantages of the travelling-grate for drying and preheating the pellets, and uses the more simply designed rotary kiln for the higher temperature firing. Commercial production of high-quality pellets from a grate-kiln system began in 1960 (91, 92).

Reference numbers:

Shaft furnace: 19, 23, 24, 26, 32, 37, 42, 47, 48, 53, 61, 62, 71, 77, 86, 88, 96, 113, 137, 140, 151, 158.

Travelling-grate: 3, 6, 7, 9, 31, 34, 35, 37, 39, 41, 42, 45, 63, 78, 79, 83, 86, 91, 94-96, 101, 108, 142, 143, 150.

Other: 4, 8, 13, 14, 16, 19-21, 24, 42, 46, 49, 52, 60, 61, 69, 74, 75, 89, 91-93, 96, 107, 109-111, 119, 126, 129, 130, 132, 140, 141, 143, 152, 154, 162.

Strength of Agglomerates

(a) Green Strength

The strength of iron ore green pellets usually is determined by drop and compressive tests. The former test consists of dropping a number of the pellets individually from a certain height, and determining the average number of drops required to produce breaking. There is a wide variation (from 4 to 36 in.) in the height used by different investigators (32, 71). In discussing the paper by Tigerschiold and Ilmoni (89), DeVaney suggested that the height should be at least 12 in. because this is about the distance the pellets must fall in being transferred from conveyor belts. Merklin and DeVaney (61) stated that 18 in. has been adopted as the standard height for drop tests at the Hibbing laboratory of Pickands-Mather and Co., and that green pellets must withstand at least five drops from this height to be considered satisfactory. Violetta (94) stated that 3/8 in. dia green pellets should withstand five 8 in. drops to be considered satisfactory as travelling-grate feed.

The compressive strength test for green pellets is performed by subjecting a number of them to a compressive force and then calculating the average force required to break or deform one. Values noted in the literature varied from 0.6 to 15.0 lb, depending on the physical characteristics of the concentrates being balled, the ball size, the additives used, and the balling technique. Merklin and DeVaney (61), working with 1 in. dia balls, considered 12.0 lb to be the minimum satisfactory value. Violetta (94) stated that 3/8 in. dia pellets should have a green compressive strength of 2 lb to be acceptable as travelling-grate feed. A foundry sand core-testing machine can be adapted to perform these compression tests.

Recently, a new device for evaluating green pellet strength has been built and tested by the Allis-Chalmers Manufacturing Co. (80). With this the quality of the balls is evaluated by determining their load-deformation curves. It is claimed that those balls whose load-deformation characteristics fall within a certain range can be handled and fired successfully, whereas those whose characteristics lie outside this range will be either too soft or too brittle.

Reference numbers:

7, 9, 16, 23, 24, 31, 32, 39, 42, 51, 60-63, 67, 71, 76, 80, 82, 87-90, 93, 94, 104, 108-110, 121, 123, 130-132, 134, 141, 146-148, 150, 151, 161, 162.

(b) Dry Strength

In most laboratory investigations the green pellets are dried in a ventilated oven and then tested for dry strength. The drop test is of little significance for dried pellets because they are not required to withstand much handling in this condition in normal commercial operations. On the other hand, their compressive strength is considered to be quite important, especially when a shaft furnace is to be used for the firing operation. Most workers report that when normal balling techniques are employed and no additives are used, the compressive strength of dried pellets is lower than that of the original green pellets (18, 63, 71, 88). However, when binders are used, the reverse may be true (60, 62, 63, 71, 93). Merklin and DeVaney (61) considered 30 lb to be the minimum requirement when 1 in. dia dried magnetite pellets are used. Violetta (94) claimed that 3/8 in. dia dried hematite pellets should have a value of 8 lb to be considered suitable for travelling-grate feed.

Reference numbers:

8, 16-19, 21, 23, 24, 31, 39, 42, 60-63, 67, 69, 71, 87-89, 93, 94, 108-110, 112, 121, 130, 132, 141, 146-148, 151, 155, 161, 162.

(c) Fired Strength

Fired pellet strength is most commonly determined by tumbling and compression tests. In general each laboratory seems to have developed its own specifications for these tests. For instance, Merklin and DeVaney (61) have described a test in which 25 lb of pellets are tumbled in an ASTM coke tumbler for 200 revolutions at 24 rpm, the tumble index being the % of +10mesh material present at the end of the test. They considered an index of 85 or higher to be satisfactory for commercially produced pellets.

Other authors (39, 93) described a test which is similar, except that the tumble index is based on the % of -28 mesh material in the product. This latter test is standard for pellets produced at the Reserve Mining Company's Silver Bay taconite operation (37). Pellets passing this test have an index of about 6 and have been found to give a satisfactory performance during shipping (39). In a laboratory investigation with a specular hematite, Urich and Han (93) found that this index decreased as the concentrate was ground finer and increased as the size of the fired pellet increased.

The compressive strengths of fired magnetite pellets, reported in the literature, varied from 242 lb (19) to 5588 lb (89) depending on pellet size, firing procedure and temperature, balling technique, additives used, mineralogical composition, and physical properties of the concentrate. Variations in the equipment and techniques used in the tests also would tend to produce variations in the reported pellet strengths (8, 93). Ridgion, Cohen and Lang (71) reported that in the laboratory they obtained compressive strengths as high as 3000 lb for one in. dia hematite pellets containing 3 per cent sodium carbonate and fired at 1300°C. Urich and Han (93) reported strengths as high as 3000 lb for 3/4 in. dia specular hematite pellets containing bentonite and fired at 1400°C. No statements have been found as to a minimum compressive strength that is generally accepted in the industry, but Merklin and DeVaney (61) used 1500 lb as a minimum value for one in. dia pellets produced from magnetite concentrate. Strengths as low as 300 lb (39) for 1/4 in. dia pellets, and 800 lb (86) for one in. dia pellets have been reported by other authors as being commercially acceptable. No article was found in which the compressive strength was correlated with either the performance of the pellets during shipping or their behaviour in the blast furnace.

Reference numbers:

3, 7-9, 16, 18-21, 24, 26, 28, 32, 37, 39, 40, 42, 52, 60-63, 66, 69, 71, 74, 77, 78, 83, 86-89, 92, 93, 108-110, 126, 129, 130, 132, 133, 138-141, 143, 145, 150, 151, 162, 164.

Other Properties of Fired Pellets

Reducibility, porosity and bulk density are believed to be important properties of fired pellets that are to be used as blast furnace feed (32, 44, 45), but the relationship between these factors and the performance of the pellets in this furnace does not appear to have been intensively studied as yet. Laboratory studies indicate that the reducibility of fired pellets having 30 per cent porosity is in the same range as that of the most readily reduced ores (44). With iron ores and sinters the reducibility increases as the porosity increases, and it is expected that the same correlation would be found with pellets (43). Evidence has been presented that pellets are reduced much more readily than sinters, which is attributed to a more uniform pore distribution and the absence of vitrified solid sections in the pellets (44). The porosity and bulk density of fired specular hematite pellets can be varied between 9 and 45 per cent voids and between 150 and 89 lb/ cu ft respectively, depending on the particle size of the concentrate, the size of the pellet, and the firing conditions (93).

Reference numbers:

Reducibility: 9, 17, 25, 28, 29, 32, 35, 39, 40, 42-45, 50, 57, 61, 66, 71, 88, 105, 123, 125, 128-130, 132, 133, 152, 156, 163, 164.

Porosity: 3, 6, 8, 9, 17, 32, 35, 39, 43, 44, 57, 63, 66, 67, 76, 77, 87-89, 92, 93, 117, 122, 130, 132, 144, 147, 155.

Other: 6, 8, 9, 16, 17, 32, 39, 40, 42-45, 52, 57, 60-63, 66, 75, 77, 87-89, 92, 93, 120, 121, 124, 132, 139, 141, 143, 146-148, 152, 155, 156, 161, 163, 164.

Heat Consumption and Costs

In 1944 Firth (32) estimated the operating cost of hardening magnetite pellets in a 1000 long ton/ day plant to be $0.55/ ton. This estimate was based on a calculated heat input to an experimental 48 in. x 20 in. shaft furnace of 2,123,520 Btu/ long ton and included $0.25 for fuel, $0.13 for electric power, $0.12 for labour and $0.05 for repairs and supplies. In 1950 Davis (23) stated that the total heat required for pellet hardening is about 600,000 Btu/gross ton of feed, and that the oxidation of one ton of 65 per cent magnetic iron ore concentrate to hematite liberates about 300,000 Btu. In 1955 Joseph (42) reported that the Erie Mining Company had reduced the thermal requirements for pelletizing magnetic taconite in a commercial shaft furnace to less than 500,000 Btu/ton of pellets. Haley (37) reported that the fuel requirements for hardening magnetic taconite pellets on Reserve Mining Company's travelling-grate machine had been reduced from 1,595,000 Btu/ton in 1956 to 708,307 Btu/ton in 1960. In an economic evaluation of agglomerated iron ores in a Russian paper in 1959 (45), it was stated that not only is the capital expenditure for a pelletizing plant lower than for a sintering plant, but also the "intensity" of the smelting process in a blast furnace is about 10 per cent higher with pellets than with sinter. It also was stated in the same paper that the operating expenses for pelletizing a magnetite concentrate, containing 62 per cent iron, will be $1.01/net ton of pellets. This includes $0.54 for fuel, $0.12 for electrical power, $0.03 for labour and $0.32 for plant depreciation, supplies and routine maintenance. The Northern Miner (99) estimates the cost of pellets from the Kukatush magnetite ore body at $4.83/ton, which includes $1.83 for mining, $1.47 for concentrating, $1.33 for pelletizing and $0.20 for overhead.

Reference numbers:

3, 7, 9, 17, 23, 24, 26, 30, 32, 37, 39, 42, 44, 45, 47, 48, 55, 61, 71, 73, 83, 88, 95, 96, 99, 108, 143, 150, 151.

CONCLUSIONS

The importance of pelletizing as a method of agglomerating iron ore concentrates appears to be increasing rapidly. The superiority of pellets over raw ore has been demonstrated in blast furnace tests.

Although the present survey has shown that a great deal of investigational work has been done in this field, the need for

(1) standard methods for testing pellets, and

(2) the correlation of the results of standard tests with the performance of the pellets during shipment, in the blast furnace, etc.,

is quite evident. Eventually it should be possible to formulate specifications for pellets by means of which their performance in various circumstances can be predicted. Adequate answers to all of the questions listed on page 2 have not been found in the literature. This would indicate that there is a great need for further work in this field.

REFERENCES

1. Anon. "Ashland, Ky. Pilot Plant to Make Iron Pellets." Eng. and Mining J. 149, 108 (1948).

2. Anon. "Blast Furnace Men Report on Carbon Block Hearths." Steel 122, 125-126, April-June (1948).

3. Anon. "Marquette Starts Second Jasper Plant." Eng. and Mining J. 158, 76-79 (1957).

4. Anon. "Agglomeration." Chem. Eng. 58, 161-174, October (1951).

5. G.O. Argall. "The Big Events in 1956 Mining--Preview of 1957." Mining World 19, 48-52, 102-103, January (1957).

6. G.O. Argall, jr. "Eagle Mills Pellet Plant Opens New Era for Michigan Hematite." Mining World 18, 42-46, December (1956).

7. T.E. Ban. "Agglomeration of Hematite Concentrates Using Updraft Grate-firing Techniques." Trans. International Mineral Dressing Congress, Stockholm, 365-392 (1957); Almqvist and Wiksell, Stockholm (1958).

8. T.E. Ban and L.J. Erck. "Laboratory Procedures for Determining Pelletizing Characteristics of Iron Ore Concentrates." Trans. A.I.M.E. 196, 803-811 (1953).

9. F.M. Bazanov, F.F. Kolsanov, I.L. Malkin and S.I. Sharov. "Pelletizing of Iron Ore Concentrates and Iron Ore Fines." Soviet Metal Technology 1, No. 3, September (1958).

10. C.M. Beck. "Production of Iron Ore in Canada." Can. Mining Met. Bull. 54, 807-808, November (1961).

11. W.C. Bell. "Proper Pelletizing Technique --Key to Efficient Sintering of Aggregate." Brick and Clay Record 120-121, 46-52 (1952).

12. U.N. Bhrany, R.T. Johnson, T.L. Myron and E.A. Pelczarski. "Dynamics of Pelletization." Paper No. 10, "Agglomeration," Interscience Publishers Inc. (1962).

13. C.A. Brackelsberg. "Method and Apparatus for Producing Rolled Bodies from Powderous Materials." U.S. Patent 1,921,114, August 8, 1933.

(References, cont'd)

14. E.F. Brownstead. "Manufacture of Nodules at Ironton, Ohio, Using Mesabi Fines and Blast Furnace Flue Dust." Proc. Blast Furnace, Coke Oven, and Raw Materials Conference, A.I.M.E. 8, 139-145 (1949).

15. R.D. Cadle. "Particle Size Determination." Interscience Publishers Inc., New York (1955).

16. W. Callender. "Heat Hardening of Artificial Magnetite Pellets." Paper No. 23, "Agglomeration," Interscience Publishers (1962).

17. P.E. Cavanagh. "Pelletizing of Iron-bearing Fines by Extrusion." Proc. Blast Furnace, Coke Oven, and Raw Materials Conference, A.I.M.E. 9, 54-80 (1950).

18. S.R.B. Cooke and T.E. Ban. "Agglomerating Iron Ore Concentrates." Chem. Eng. Progress 51, 364-368, August (1955).

19. S.R.B. Cooke and T.E. Ban. "Microstructures in Iron Ore Pellets." Trans. A.I.M.E. 193, 1053-1058 (1952).

20. S.R.B. Cooke and R.E. Brandt. "Solid State Bonding in Iron Ore Pellets." Mining Eng. 6, 411-415 (1954).

21. S.R.B. Cooke and W.F. Stowasser, jr. "The Effect of Heat Treatment and Certain Additives on the Strength of Fired Magnetite Pellets." Trans. A.I.M.E. 193, 1223-1230 (1952).

22. E.W. Davis. "Iron Ore--Its Mining, Beneficiation and Reserves." Parts I, II and III. Steel 25 (1949).

23. E.W. Davis. "Agglomeration by the Pelletizing Process." Eleventh Annual Mining Symposium, University of Minnesota, January 1950.

24. E.W. Davis and H.H. Wade. "Agglomeration of Iron Ore by the Pelletizing Process." Information Circular No. 6, Mines Experiment Station, University of Minnesota, January 1951.

25. R.S. Dean. "Treatment of Ores." U.S. Patent 2,131,006, September 20, 1938.

26. F.D. DeVaney. "Pelletizing in Shaft Furnaces." J. Metals 10, 122-128, February (1958).

(References, cont'd)

27. F.G. Donnan. "The Agglomeration of Granular Masses." Trans. Faraday Soc. 14, 12-13 (1919).

28. J.O. Edström. "Reactions in Pelletizing and Iron Ore Reduction." Part I. Jernkontorets Annaler 142, 401-428 (1958). (Brutcher Translation 4559.)

29. J.O. Edström. "Reactions in Pelletizing and Iron Ore Reduction." Part II. Jernkontorets Annaler 142, 428-466 (1958). (Brutcher Translation 4638.)

30. R.B. Elver. "Mineral Reviews--Iron Ore." Can. Mining J. 83, 88-94, February (1962).

31. A. English and M.F. Morgan. "Downdraft Taconite Pellet Hardening." J. Metals 10, 122-124, February (1958).

32. C.V. Firth. "Agglomeration of Fine Iron Ore." Proc. Blast Furnace, Coke Oven and Raw Materials Conference, A.I.M.E. 4, 46-69 (1944).

33. T.K. Goldstick. "A Survey of the Literature Pertinent to Iron Ore Pelletizing." Paper No. 36, "Agglomeration", Interscience Publishers Inc. (1962).

34. M.J. Greaves and A. English. "Engineering Contributions to New Techniques of Iron Ore Agglomeration." Paper No. 16, "Agglomeration", Interscience Publishers Inc. (1962).

35. G.V. Gubin, V.L. Karmazin and G.D. Shkovyra. "Some Peculiarities of the Reduction of Hardened Pellets from Southern Concentrates by Gases." Izvest. Akad. Nauk SSSR, OTN, Met. Topl. No. 1, 147-149 (1961). (Brutcher Translation 5181.)

36. D.J. Hains. "The Agglomeration of Iron Ores and Concentrates." Can. Mining Met. Bull. 54, No. 590, June (1961).

37. K.M. Haley. "Reserve Mining Company Pelletizing Practice." Can. Mining Met. Bull. 54, No. 590, June (1961).

38. K.R. Haley. "Operating Results Using Taconite Pellets on Armco's Middletown Blast Furnace." Proc. Blast Furnace, Coke Oven and Raw Materials Conference, A.I.M.E. 20, 15-31 (1961).

39. K.M. Haley and W.E. Apuli. "Pelletizing on a Horizontal Grate Machine." Paper No. 31, "Agglomeration", Interscience Publishers Inc. (1962).

(References, Cont'd)

40. F. M. Hamilton. "Physical Tests and Results on Some Agglomerated Iron Ores." Proc. Blast Furnace, Coke Oven, and Raw Materials Conference, A. I. M. E. 10, 135-140 (1951).

41. E. N. Hower and J. A. Anthes. "Recent Developments--Sintering and Pelletizing." Iron Steel Eng. 33, No. 2, 60-67 (1956).

42. T. L. Joseph. "Pelletizing of Iron Ore Concentrates." Parts I and II. Blast Furnace Steel Plant 43, 641-646, 745-751 (1955).

43. T. L. Joseph. "Porosity, Reducibility, and Size Preparation of Iron Ores." Trans. A. I. M. E. 120, 72-98 (1936).

44. T. L. Joseph and G. Bitsianes. "Some Comparisons Between Iron Ore, Sinter and Nodules as Blast Furnace Feed." Proc. Blast Furnace, Coke Oven, and Raw Materials Conference, A. I. M. E. 4, 70-91 (1944).

45. I. S. Kagan, Kh. P. Zaitsev, N. S. Snagovskaya, E. N. Volkova and I. A. Volokh. "An Economic Evaluation of the Use of Iron Ore Pellets (as Against Sinter) in the Blast Furnace." Izvest. VUZ-Chern. Met. No. 6, 145-154, June (1959). (Brutcher Translation 4935.)

46. T. A. Klinefelter. "Evaluation of Some Binders for Use in Pelletizing Slimes." U. S. Bureau of Mines R. I. 3846 (1946).

47. Z. Krotkiewski and B. Seweryński. "Pelletizing of Iron Ores." PRACE IMH (Poland) 7, 101-105 (1955). (Brutcher Translation 3707, slightly abridged.)

48. M. A. Kunde. "The Agglomeration of Taconite Concentrate." Mines Mag. 42, No. 5, 39-42 (1952).

49. C. E. Lesher. "Agglomerating Fine-sized Ores with Low Temperature Coke." Trans. A. I. M. E. 203, 1114-1118 (1955).

50. R. A. Lindgren. "Effect of Screened Ore and Sintered Ore on Blast Furnace Production." Proc. Blast Furnace, Coke Oven, and Raw Materials Conference, A. I. M. E. 3, 128-144 (1943).

51. C. Ludwig. "How and Why Solids Agglomerate." Chem. Eng. 61, 156-160 (1954).

52. W. Lund. "Agglomeration of Taconite Concentrate." J. Iron Steel Inst. (London) 162, 1-3, May (1949).

(References, cont'd)

53. C. Mamen. "Marmora's Iron Goes to Market." Can. Mining J. 76, 43-48 (1955).

54. H.K. Martin. "Proposed Flowsheet for Taconite Concentration at Babbitt." Proc. Blast Furnace, Coke Oven, and Raw Materials Conference, A.I.M.E. 7, 68-82 (1948).

55. J.M. McLeod. "Preparation of Ores--Part I, Methods of Improvement of Blast Furnace Burdens." Iron and Steel (London) 27, 48-54 (1954).

56. J.M. McLeod. "Preparation of Ores--Part II, The Sintering of Iron Ores." Iron and Steel (London) 27, 103-109 (1954).

57. J.M. McLeod. "Preparation of Ores--Part III, Theory of Sintering and Testing of Materials." Iron and Steel (London) 27, 145-151 (1954).

58. J.M. McLeod. "Preparation of Ores--Part IV, Other Methods of Agglomerating Fines, and Direct Smelting Processes." Iron and Steel (London) 27, 185-191 (1954).

59. J.S. McMahon. "The Use of Self-fluxing Sinter." Blast Furnace Steel Plant 47, 51-54, January (1959).

60. K.E. Merklin and M.H. Childs. "Some Factors Influencing the Physical Qualities of Iron Ore Pellets." Preprint No. 60B75, A.I.M.E. Annual Meeting, February (1960).

61. K.E. Merklin and F.D. DeVaney. "Production of Self-fluxing Pellets in the Laboratory and Pilot Plant." Mining Eng. 12, 266-271 (1960).

62. K.E. Merklin and F.D. DeVaney. "The Coarse Specularite-Fine Magnetite Pelletizing Process." Paper No. 32, "Agglomeration", Interscience Publishers Inc. (1962).

63. K.J.E. Meyer and H. Rausch. "The Lurgi Pelletizing Process: A Combined Updraft-Downdraft Technique." J. Metals 10, 129-133, February (1958).

64. L.O. Millard. "Taconite Pellets--Problems of Carloading, Stockpiling, and Loading Vessels." Iron Steel Eng. 34, 179-190, June (1957).

(References, cont'd)

65. D. M. Morrison. "Recent Developments in Pig-Iron Blast Furnace Construction, Raw Materials and Practice." Mines Mag. 51, 26, September (1961).

66. R. J. Morton. "Testing of Iron Ores and Agglomerates Related to Blast Furnace Use." Proc. Blast Furnace, Coke Oven, and Raw Materials Conference, A. I. M. E. 10, 122-134 (1951).

67. D. M. Newitt and J. M. Conway-Jones. "A Contribution to the Theory and Practice of Granulation." Trans. Inst. Chem. Eng. (London) 36, 422-442 (1958).

68. W. C. Peck. "Granulation: A Process of Increasing Importance." Chem. and Ind. (London), 1674-1685, December (1958).

69. A. N. Pokhvisnev and B. A. Savel'ev. "On the Mechanism of Hardening of Iron Ore Pellets." Stal' 18, No. 2, 105-109 (1958). (Brutcher Translation 4161).

70. O. R. Rice. "How are the Blast Furnaces Doing?" Paper No. 6, "Iron Ore Reduction", edited by R. R. Rogers and published by Pergamon Press (1962).

71. J. M. Ridgion, E. Cohen and C. Lang. "The Development of a Pelletizing Process for Fine Iron Ores." J. Iron Steel Inst. (London) 177, 43-63, May (1954).

72. L. A. Roe. "Iron Ore Beneficiation." Minerals Publishing Company, p. 263-274 (1957).

73. E. H. Rose. "Iron Ore: The Big Picture." Mining Eng. 13, 1052-1058 (1961).

74. H. U. Ross and A. Ohno. "Shrinkage of Iron Ore Pellets During Agglomeration." Paper No. 25, "Agglomeration". Interscience Publishers Inc. (1962).

75. H. U. Ross, B. A. Strathdee and J. E. Pierdon. "Dilatometer Investigation into Sintering of Iron Ores." Proc. Blast Furnace, Coke Oven, and Raw Materials Conference, A. I. M. E. 19, 454-468 (1960).

76. H. Rumpf. "The Strength of Granules and Agglomerates." Paper No. 15, "Agglomeration." Interscience Publishers Inc. (1962).

(References, cont'd)

77. G. Sengfelder. "Pelletizing of Dogger Ore Concentrates and of Spathic Ore Fines." Stahl u Eisen 70, 765 (1950).

78. B. Seweryński and T. Wlazińska. "Hardening of Iron Ore Pellets." PRACE IMH (Poland) 7, 30-34 (1955). (Brutcher Translation No. 3706, slightly abridged).

79. F.W. Starratt. "Iron Agglomerates from the Marquette Range." J. Metals 206, 1546-1548 (1956).

80. C.L. Stevenson and B.H. Bergstrom. "Evaluation of Green Pellets." Mining Eng. 14, 52, April (1962).

81. A. Stewart. "The Pelletizing of Granular Materials." Engineering 169, 175-177, 203-204, Jan.-June (1950).

82. H.T. Stirling. "Advances in Balling and Pelletizing." Paper No. 8, "Agglomeration." Interscience Publishers Inc. (1962).

83. W.F. Stowasser. "An Agglomeration Process for Iron Ore Concentrates." Iron Steel Eng. 32, 112-115 (1955).

84. J.D. Sullivan and A.P. Towne. "Agglomeration and Leaching of Slimes and Other Finely Divided Ores." U.S.B.M. Bull. 329, Vol. 46 (1930).

85. E. Swartzman. "The Significance of Agglomeration in the Mineral Industries." Trans. Can. Inst. Mining Met. 57, 198-207 (1954).

86. The Inco Staff. "Development of the Inco Iron Ore Recovery Process." Trans. Can. Inst. Mining Met. 59, 201-207 (1956).

87. J.R. Tonry. "Pelletizing in Cement Manufacturing." Paper No. 1, "Agglomeration." Interscience Publishers Inc. (1962).

88. M. Tigerschiöld. "Aspects on Pelletizing of Iron Ore Concentrates." J. Iron Steel Inst. (London) 177, 13-24, May (1954).

89. M. Tigerschiöld and P.A. Ilmoni. "Fundamental Factors Influencing the Strength of Green and Burned Pellets made from Fine Magnetite Ore Concentrates." Proc. Blast Furnace, Coke Oven, and Raw Materials Conference, A.I.M.E. 9, 18-53 (1950).

90. D. Train. "Transmission of Forces Through a Powder Mass During the Process of Pelletizing." Trans. Inst. Chem. Eng. (London) 35, 258-266 (1957).

(References, cont'd)

91. D.M. Urich. "Pelletizing Humboldt's Iron Concentrate by Grate-Kiln Process." World Mining 14, 36-41, November (1961).

92. D.M. Urich and R.W. Berkahn. "Grate-Kiln Pelletizing of Iron Concentrates." J. Metals 14, No. 4, 303 (1962).

93. D.M. Urich and T.M. Han. "A Progress Report on the Effect of Grind, Temperature and Pellet Size upon the Quality of Specular Hematite Pellets". Paper No. 24, "Agglomeration". Interscience Publishers Inc. (1962).

94. D.C. Violetta. "Updraft Pelletizing of Specular Hematite Concentrates". J. Metals 10, 118-121 (1958).

95. G.V. Woody. "Heat Hardening of Pellets Made from Taconite Concentrates". Blast Furnace Steel Plant 41, 314-317 (1953).

96. E.C. Wright. "Magnetite Concentrates to Supplement High Grade Iron Ore". Metal Progress 70, 97-102, September (1956).

97. F.O. Anderegg. "Grading Aggregates". Part II--The Application of Mathematical Formulas to Mortars. Ind. Eng. Chem. 23, 1058 (1931).

98. Anon. "J. and L. to Operate Largest Magnetic Taconite Operation in Canada". Ind. Heating 29, No. 5, 892, May (1962).

99. Anon. "Kukatush Seeking Market for Pellets from Iron Deposit". The Northern Miner, p. 13, November 8, 1962 .

100. Anon. "Mixing Plant Goes Granular". Chem. Eng. 60, 116, December (1953).

101. Anon. "Travelling-Grate Process to Pelletize Low-Grade Hematite Ores at Largest Canadian Facility". Ind. Heating 29, No. 5, 903 (1962).

102. C.S. Arms. "Increasing Pellet Production". Eng. and Mining J. 163, No. 11, 90 (1962).

103. C.S. Arms. "Iron Ore--1962". J. Metals 15, 116, February (1963).

(References, cont'd)

104. F.D. Ball. "Pelletizing Before Sintering: Some Experiments with a Disc". J. Iron Steel Inst. (London) 192, 40, May (1959).

105. C.A. Brackelsberg. "Pelletizing of Fine Ores and Reactivity of Product". Stahl u Eisen 52, No. 28, 690 (1932). (Brutcher Translation 3107).

106. A.H. Brisse and W.L. McMorris, jr. "Convertol Process". Mining Eng. 10, 258 (1958).

107. F.D. Calhown. "Coal Pelletizing". Mining Congress J. 48, No. 11, 38 (1962).

108. Confidential Report (1960).

109. Confidential Report (1961).

110. Confidential Report (1961).

111. F.D. DeVaney. "Nodulizing Process and Apparatus". U.S. Patent 2,590,090, March 25, 1952.

112. F.D. DeVaney. "Iron Ore Concentrate Pellets". U.S. Patent 2,596,132, May 13, 1952.

113. F.D. DeVaney and D. Beggs. "Indurating Furnace and Process". U.S. Patent 2,676,095, April 20, 1954.

114. S. Ergun. "Pressure Drop in Blast Furnace and in Cupola". Ind. Eng. Chem. 45, 477, February (1953).

115. J.R. Farnand, H.M. Smith and I.E. Puddington. "Spherical Agglomeration of Solids in Liquid Suspension". Can. J. Chem. Eng. 39, 94, April (1961).

116. A.P. Foniakoff. "Process for Agglomeration of Small Finely Divided Ores". British Patent No. 4142, February 24, 1908.

117. H.J. Fraser. "Experimental Study of the Porosity and Permeability of Clastic Sediments". J. Geol. 43, No. 8, 910 (1935).

118. C.C. Furnas. "Grading Aggregates". Part I--Mathematical Relations for Beds of Broken Solids of Maximum Density. Ind. Eng. Chem. 23, 1052 (1931).

(References, cont'd)

119. R.F.G. Gardener and D.W. Tanner. "Giant Grain Growth in Alpha Ferric Oxide". Nature 190, No. 4782, 1166, June 24 (1961).

120. J.H. Gittus. "The Influence of Grain Size Distribution on Some Properties of Sand". British Cast Iron Research Assoc. J. 5, 318 (1953-55).

121. R.G. Godding. "Core Bonding". British Cast Iron Research Assoc. J. 3, 597 (1950-51).

122. L.C. Graton and H.J. Fraser. "Systematic Packing of Spheres with Particular Relation to Porosity and Permeability". J. Geol. 43, No. 8, 785 (1935).

123. G.V. Gubin. "Metallurgical Properties of Ore-Coke Pellets". Izvest. Akad. Nauk, Ord. Tekh. Nauk, No. 6, 32, June (1957). (Brutcher Translation 4198).

124. G.V. Gubin. "Swelling of Magnetite Pellets and Briquets During Reduction". Izvest. Akad. SSSR, Ord. Tekhn. Nauk, No. 12, 76, December (1957). (Brutcher Translation 4199).

125. G.V. Gubin and L.M. Tsylev. "On the Reduction of Iron-Ore-Coal Pellets". Trudy Instituta Metallurgii im. A.A. Baikova 3, USSR Acad. Sci. Press. Moscow, 63 (1958). (Brutcher Translation 4924).

126. J.P. Hansen, N.B. Melcher and M.M. Fine. "Pre-Reduced Iron-Ore Pellets, their Experimental Preparation". J. Metals 13, 314, April (1961).

127. H. Heywood. "Fluid Flow Through Stable Particulate Systems". J. Imp. Coll. Eng. Soc. 3, 7 (1947).

128. B.O. Holland, J.B. Lean and H.K. Worner. "The Physical Degradation of Ores, Sinters and Pellets During Simultaneous Abrasion and Chemical Reduction". Paper presented at AIME Blast Furnace, Coke Oven and Raw Materials Conference, April 1962.

129. J.A. Innes. "Metallized Pellets from Ore-Coke Mixtures". J. Metals 15, No. 4, 294 (1963).

130. S. Jayaram, D.D. Bhuptani and V.G. Paranjpe. "Pelletizing of Iron Ore Blue Dust". J. Tata Iron and Steel Co. of India (TISCO) 8, 210, October (1961). Microfilm 3854M.

(References, cont'd)

131. R. P. Jewett, C. E. Wood and J. P. Hansen. "Effect of Particle Size upon the Green Strength of Iron Oxide Pellets". U. S. Bureau of Mines R. I. 5762 (1961).

132. E. B. Johnson. "Production of Self-Fluxed Pellets at the Republic Mine Grate Kiln Pelletizing Plant". Preprint No. 63B45, AIME Annual Meeting, February 1963.

133. R. D. Killian, jr. "Blast Furnace Practice with Pellets and Natural Gas". J. Metals 14, No. 4, 306 (1962).

134. M. Kowalewski, A. Maslanka and S. Zielinski. "Study of Production of Pellets from Sinter Mix (Fines Preparatory to Strand Sintering)". HUTNIK (Poland) 28, No. 5, 183 (1961). (Brutcher Translation 5245).

135. F. M. Lea and R. W. Nurse. "The Specific Surface of Fine Powders". J. Soc. Chem. Ind. 58, 277, September (1939).

136. F. M. Lea and R. W. Nurse. "Permeability Methods of Fineness Measurement". Symposium on Particle Size Analysis, Inst. Chem. Eng. and Soc. Chem. Ind., Supp. Trans. Inst. Chem. Eng. 25, 47, February (1947).

137. P. Maertens and A. Poos. "Preliminary Smelting Trials of Iron-Ore Pellets in the Blast Furnace". Stahl u Eisen 81, No. 12, 778 (1961). (Brutcher Translation 5193).

138. W. E. Marshal. "Taconite Pellets in the Blast Furnace". J. Metals 13, 308, April (1961).

139. J. C. McKay and J. A. Peart. "Blast Furnace Practice with Very Low Slag Volume". J. Metals 15, No. 4, 288 (1963).

140. N. B. Melcher. "Smelting Prereduced Iron Ore Pellets". J. Metals 15, No. 4, 298 (1963).

141. K. E. Merklin and F. D. DeVaney. "The Development of Fluxed Pellets". Preprint No. 63B41, AIME Annual Meeting, February 1963.

142. W. A. Mudge. "A New Iron Ore Recovery Process". Metal Progress, 108, March (1962).

(References, cont'd)

143. A.I. Nikitin. "Pelletizing Iron Ores". Translation of two articles from Pelletirovaniya Zheleznykh Rud, 70. Date of publication not given. (U.S. OTS JPRS:14303).

144. T.R. Oliver and D.M. Newitt. "The Mechanism of the Drying of Solids; Part II--The Measurement of Suction Potentials and Moisture Distribution in Drying Granular Solids". Trans. Inst. Chem. Eng. 27, 9 (1949).

145. T.F. Olt. "Blast-Furnace Performance Using Iron Ore Pellets". J. Iron Steel Inst. (London) 200, 87, February (1962).

146. W.B. Parkes. "Composition and Properties of Sands". British Cast Iron Research Assoc. J. 3, 575 (1950-51).

147. W.B. Parkes. "Sand Testing and its Interpretation in the Foundry". British Cast Iron Research Assoc. J. 3, 627 (1950-51).

148. W.B. Parkes. "Natural and Synthetic Sands". British Cast Iron Research Assoc. J. 3, 677 (1950-51).

149. J.F. Pearse, T.R. Oliver and D.M. Newitt. "The Mechanism of the Drying of Solids; Part I--The Forces Giving Rise to Movement of Water in Granular Beds During Drying". Trans. Inst. Chem. Eng. 27, 1 (1949).

150. D.D. Phelps and J.A. Anthes. "Improvements in the Grate Pelletizing Process". Paper presented at AIME Blast Furnace, Coke Oven and Raw Materials Conference, April 1962.

151. P.H. Royster. "Heat-Treating Solids". U.S. Patent 2,608,481, August 26, 1952.

152. R.L. Rueckl. "Investigation of the Reduction of the Bond Minerals in Iron Ore Agglomerates". Paper presented at AIME Blast Furnace, Coke Oven and Raw Materials Conference, April 1962.

153. K.A. Sherwin and J.W. Stenton. "Granulation of Compound Fertilizers: Some Current Production Problems and Developments". Proc. Chem. Eng. Group, Soc. Chem. Ind. 31, 1 (1949).

154. W.A. Shockley. "New Pilot Processing Plant Designed for Heat Treating and Agglomeration". Eng. Mining J. 160, 98, September (1959).

(References, concluded)

155. H. M. Smith and I. E. Puddington. "Spherical Agglomeration of Barium Sulphate". Can. J. Chem. 38, 1911 (1960).

156. N. D. Smith and W. M. McKewan. "Reduction Kinetics for Porous Hematite Pellets with Mixtures of Carbon Monoxide and Hydrogen". Paper presented at AIME Blast Furnace, Coke Oven and Raw Materials Conference, April 1962.

157. D. I. Stock. "Micro-Spherical Aggregation of Barium Sulphate". Nature 170, 423 (1952).

158. A. W. Storm. "A Treatise on the Design Evolution of Vertical Shaft Furnaces". Preprint No. 62B62, AIME Annual Meeting, February 1962.

159. B. M. Stubblefield. "Production of Pig Iron". Steel 125, July-December (1949).

160. J. P. Sutherland. "The Agglomeration of Aqueous Suspensions of Graphite". Can. J. Chem. Eng. 40, No. 6, December (1962).

161. D. A. Taylor. "The Effect of Pitch and Coal Dust on the Properties of Sands". British Cast Iron Research Assoc. J. 3, 659 (1950-51).

162. F. M. Trasler. "Self-Fluxing Pellet Development and the Grate-Kiln System". Paper presented at CIM Annual Meeting, April 1963.

163. M. Wahlster. "Studies of the Reducibility of Ore Pellets--Part I". Technische Mitteilungen Krupp 19, No. 1, 1 (1961). (Brutcher Translation 5127).

164. M. Wahlster. "Studies of the Reducibility of Ore Pellets--Part II". Technische Mitteilungen Krupp 19, No. 1, 7 (1961). (Brutcher Translation 5359).

165. S. Zielinski, A. Maslanka and M. Kowalewski. "Pelletizing Iron-Ore Fines Preparatory to Strand Sintering". HUTNIK (Poland) 28, No. 2, 44 (1961). (Brutcher Translation 5194).

—

GNB:RAC:GEV/im