O T T A W A   November 14, 1941.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1120.

Information on Powdered Iron
Production and Fabrication.

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Foreword

The information listed herein was obtained from the following sources:

1.	Mr. T. R. Vreeland	-	Associated with American Electro Metal Corp., Yonkers, N. Y.
2.	Dr. P. Schwartzkopf	-	do do
3.	Dr. C. G. Goetzel	-	do do
4.	Col. L. B. Lent	-	U. S. Government Official, Washington, D. C.
5.	Mr. W. N. Trimble	-	do do
6.	Mr. H. K. Masters	-	do do
7.	Mr. G. W. Vreeland	-	do do
8.	Mr. E. S. Patch	-	Moraine Products Division of GENERAL MOTORS, Dayton, Ohio.
9.	Mr. E. Gordon	-	Powder Metallurgy Incorporated, Long Island City, N. Y.
10.	Dr. R. Seelig	-	do do
11.	Dr. L. Clark	-	do do

The Second Powder Metallurgy Conference was attended on September 25 and 26. Information secured at this conference is given in an attached memorandum dated October 28, 1941. Additional information secured at this time from Mr. Charles Hardy of Hardy Metal Corporation, Mr. R. P. Koehring of Moraine Products Division of General Motors, Mr. B. Hall of Metals Disintegrating Co., Mr. J. Q. Adams of General Electric Co., and Mr. A. Langhammer of Amplex Division of Chrysler Corporation is listed below.

Mr. T. R. Vreeland

Mr. Vreeland called at the Metallic Minerals Laboratories in the middle of September. He was interested in securing information with regard to powder metallurgy developments in Canada and stated that he was attempting to obtain manufacturing facilities and funds for the development of the powdered iron business of the American Electro Metal Corporation. He stated that the O. P. M. is very seriously considering giving financial support to a powder iron process developed by the American Electro Metal Corporation's Chief Metallurgist, Dr. P. Schwartzkopf. He supplied the names of the U. S. officials listed above as being those interested in powdered iron developments.

Mr. Vreeland submitted cost figures on the Schwartzkopf process. He estimated the capital costs of a 5 ton a day and 25 ton a day plant at respectively $192,000 and $364,000 and considered that six to eight months would be required to complete the installation. It was estimated that the following operational charges would be encountered:

	5 Ton Plant	25 Ton Plant
Wages	38,700	116,000
Mill Scale	37,500	187,500
Power (.60¢ k.w.)	10,500	52,500
Hydrogen (.50¢ m.)	20,000	140,000
Total	106,700	496,100
+ 50% Overhead or wages, raw material, etc.	73,800	292,900

It was estimated that powdered iron could be produced in the 5 ton unit at a cost of 7½¢ a lb. and that this cost would be lowered to 6¢ a lb. if a 25 ton unit were operated.

Mr. Vreeland showed a year old letter from John M. Evans which stated that Shawinigan Chemicals Ltd. had an unused capacity of 400,000 cu.ft. a day of electrolytic cell hydrogen and that this gas could probably be obtained at 25¢ a thousand. This situation is undoubtedly altered by now. American Electro Metals are investigating the possibilities of a Shawinigan Falls location for their powdered iron process.

Additional information secured from Mr. Vreeland was supplemented by Dr. Schwartzkopf and Dr. Goetzel and is listed below.

Electro Metals Corporation, Yonkers, N. Y.

Dr. Schwartzkopf is primarily interested in the fabrication and manufacture of tungsten and molybdenum and their carbides. In the past he has worked with powdered iron and he is now actively interested in its production and fabrication. Dr. Schwartzkopf originally co-operated with Krupps in the manufacture of tungsten and molybdenum powders and operated in Reutte, Austria. In 1933 he moved to Holland where he continued work in the same field. At that time he investigated tungsten carbide as a projectile and as a projectile tip. He claims to hold patents for the production of tools made from mixed carbides such as the tungsten carbide titanium carbide tools which are widely used in steel cutting operations. Apparently Carboloy do not pay him any royalty in this regard. He claims to be associated with Cutanit Ltd. of Buxton, England, a hard carbide tool distributor, and is associated with A. C. Wickman of Canada Ltd. who recently opened a carbide tool factory in Toronto.

Dr. Schwartzkopf and his associates are interested in both the fabrication and production of powdered iron. Their work with tungsten and molybdenum powders has given them considerable experience in the fabrication field, a field in which knowledge of die design, die materials, die lubrication, etc. is of paramount importance. American Electro Metals Corporation, however, have not been producers of powdered iron parts but have only been working experimentally in this field.

Amplex Division of Chrysler Corporation is interested in Dr. Schwartzkopf's powdered iron process. At present they are using iron manufactured by the Glidden Corporation. The purity of this iron is not high with the result that Chrysler in many cases still follow the outmoded technique of bonding the iron powder with a copper matrix. Amplex have found the Schwartzkopf iron pure and of good compressability and this is of interest to them even at a price of 10¢ a lb.

Incidentally Dr. Schwartzkopf considered that the Moraine Products Division of General Motors was scientifically more advanced than the Amplex Division of Chrysler Corporation, the other large American fabricator of powdered iron, but he thought that the latter firm might be ahead commercially. He stated that they were now making self lubricating copper-iron bridge parts up to a ton in size.

Dr. Schwartzkopf did not have a great deal to say on ordnance uses of powdered iron. He said that Baldwin Locomotive Works were interested in this development. He stated that he had had a query from the U. S. Government with regard to the possibilities of making sintered powder iron practice bombs. Dr. Schwartzkopf stated that it was quite possible to make these bombs by powder methods but that cheap powder would be required. He claimed that the bombs which weighed 2.5 to 3.0 lbs. are now being made of zinc and that about a million were required monthly.

The use of powdered iron in radio cores was discussed. It was said that for this use the iron powder must be dense and of quite small particle size. Schwartzkopf powder made to date has not been suited to this application but Dr. Schwartzkopf stated that he had in Europe made iron by hydrogen reduction methods which had given satisfactory service in radio cores. He also said that he had an inquiry from Westinghouse asking for six tons a day of such powder.

I was then taken through the company laboratories where control and development work for the Lewiston molybdenum and tungsten plant is done as well as development work on powdered iron.

I was first shown the equipment in which the company had manufactured powdered iron. The layout of the furnace is shown in the following diagram.

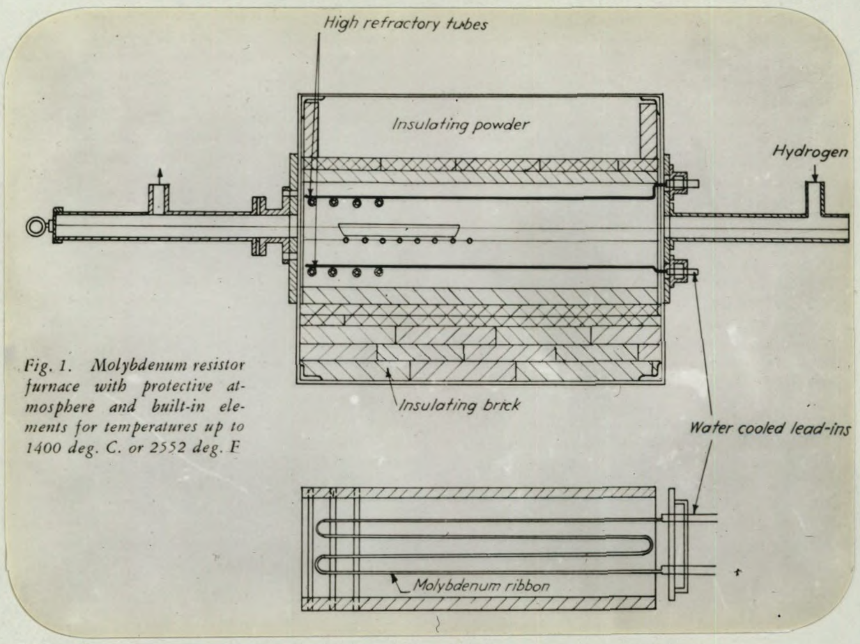

Fig. 1. Molybdenum resistor furnace with protective atmosphere and built-in elements for temperatures up to 1400 deg. C. or 2552 deg. F

Mill scale is reduced in the hydrogen atmosphere of the furnace. The scale is either purchased from steel plants or made artificially by heating thin scrap. When necessary it is cleaned from dirt by air table classification after first being sized between -20 and +40 mesh. It is then ground to -100 mesh in a ball mill and placed in stainless steel trays which are shoved through the furnace by a pusher type mechanism. Gas seals at inlet and exit allow for entrance and discharge of the products from the furnace. The hydrogen used is obtained from cylinders. Water produced in the reduction is removed by circulating the gas through drying equipment. Some experiments were made in which pressed oxide cakes were reduced, the pusher mechanism working directly on these cakes rather than on stainless steel trays. Molybdenum furnace resistors made it possible to maintain the high 1100°C reduction temperature. It was said that the oxide was only in the reducing zone for twenty minutes and in the furnace proper for about an hour's time. No trouble was encountered in the iron sticking in the trays but the trays shortened owing to the creep effect with the result that adjustments had to be made in the furnace time cycle. Experiments made with pressed oxide briquettes had been fairly satisfactory however which would eliminate this trouble. The powder iron cake was broken up to the required size (all -100 mesh, 20% through -325 mesh) in a hammer mill. The average particle size is -200 mesh.

The Schwartzkopf and Fahrenwald processes operate on very much the same principle. The furnace apparatus designed by Dr. Fahrenwald however is greatly superior not only because it more nearly approaches the commercial installation, but also because of its incorporation of the endless belt method for handling the oxide. About the same depth of oxide is reduced in both cases. In this regard Dr. Goetzel reported that they discovered different mill scales reduced at considerably different rates and that reduction times had to be varied to suit the oxide used. It was claimed that the high reduction temperature and the hammer mill preparation of the finished production led to the production of a very compressible powder which formed an aggregate free from grain growth up to quite high temperatures, lack of cold work in the particles being responsible for this latter property which made it possible to conduct high temperature heat treatments without impairing physical properties. Higher temperature reduction might also be more economical as it is much faster. At present the Fahrenwald apparatus operates at 1600°F but it could be run up to 1800°F and if radiant tubes were used as heating elements to even higher temperature. Hammer milling could also be substituted for the final ball milling without any patent infringement.

The Schwartzkopf apparatus has made as much as 1000 lbs. a day of powdered iron. It is not now in production as the cost of cylinder hydrogen is prohibitive. Although it was claimed that iron made from oxide produced as a by-product in the Wescott sulphur process was difficult to compress owing to its fine particle size, it is evident that the Schwartzkopf process like the Fahrenwald process would benefit if it were assured an adequate supply of very pure material as it would then be operating on a perfectly uniform product and there would be no need of producing oxide experimentally, a process which must necessarily be fairly expensive. It is quite probable that particle size of the Wescott iron oxide (which governs the particle size of the finished iron powder) can be controlled by adjusting conditions in the oxidizer furnace.

Cost calculations for the Fahrenwald process have been based on the use of Wescott oxide. As a result, it has been estimated the iron made by this method can be sold at a profit for 4¢ a lb. The Schwartzkopf process based on the reduction of artificial or natural mill scale is not a low cost method of reduction. It claims only to produce an excellent grade of iron powder at approximately the present price of 10¢ a lb.

The remainder of the laboratories which is devoted to experimental work on tungsten molybdenum and iron powder is very well equipped, x-ray-diffraction, spectrographic, metallographic, and magnetic testing equipment being available for use. Much work has been done on compressed conductors of the copper-molybdenum, silver-molybdenum type. This work has been nearly finished. The development of refractory enclosed resistance elements of tungsten and molybdenum is of the greatest interest. The use of these elements is described in an article by Dr. Schwartzkopf which appeared in January 1941, Metals & Alloys. These elements which bear the name Stratit are not at present being sold commercially. However, they seem to be something new in the field of resistance elements as they are said to give a longer life than globar and can operate at a temperature up to 2900°C. The rod end is of special design to allow for contraction and is water cooled. The molybdenum type element is used horizontally, the tungsten type vertically. All laboratory furnaces are heated with these elements.

Experiments are being conducted on the hot and cold pressing of sintered iron aggregates and excellent physical properties are being obtained in parts so treated. In the ferrous field the laboratory is not confining its work to iron or iron graphite mixture but is also making steel parts by mixing powdered iron and 1.00% carbon steel powder. The part produced has the structure of 0.40% carbon steel and excellent physical properties. Difficulties are experienced, however, in preventing surface decarburization in the fabrication and heat treatment operations.

Government Officials

Very little information was secured from U. S. Government officials listed above. These men were visited at the suggestion of Mr. T. R. Vreeland. The O. P. M. are apparently considering advancing funds for the development of the Schwartzkopf process but they have little information on "war uses" of powdered iron. It was said that the material was being used in radio cores, in self-lubricating bearings for anti-aircraft guns and tank parts, and in some bomb sight parts. It is quite possible, however, that the iron powder has other ordnance uses as the gentlemen interviewed seemed to be not too familiar with the situation.

Mr. E. S. Patch, Moraine Products Division of General Motors, Ltd., Dayton, Ohio

Although not of the promoter type, Mr. Patch appeared to be one of the infant powdered iron industry's best salesmen. He had the advantages that naturally follow a long association with Moraine Products Ltd., one of the largest and most progressive firms in the industry, i. e. he knew difficulties of powdered iron manufacture and was completely familiar with difficulties likely to be encountered in fabricating sintered powdered iron parts and in addition, knew conditions under which the use of powdered iron parts might prove to be economic. In spite of his long association with the industry, Mr. Patch, unlike the usual powdered iron enthusiast, did not try to oversell the product. He realized that one failure in ordnance application would condemn the powdered iron industry forever so he preferred to make haste slowly.

The scope of Moraine Products Ltd. production has been reveiwed previously in the Bureau of Mines report which deals with the Fahrenwald Oxide Reduction Process. The company is one of the leading firms in the fabrication of iron powder in the U. S. A.

Mr. Patch stated he knew of Dr. Schwartzkopf as a man with considerable knowledge of powder fabrication but also as a man who had difficulty in agreeing with his business associates. He agreed with Dr. Schwartzkopf's statement that practice bombs could be made by powder methods but he did not think this method of manufacture would be economic.

Moraine Products Division were said to be making powdered iron by shotting converter metal on a wheel, grinding the quenched shotted metal and then giving it a deoxidizing anneal in hydrogen to remove cold work effects and any oxide that has formed on the powder. Mr. E. S. Patch claimed that it should be possible to make this powder for 4½¢ a lb. but thought the iron made by the Wescott-Fahrenwald method had much greater possibilities on grounds of cheapness, purity, and uniformity. He intimated that his firm were definitely interested in this development.

Before the production of sintered powdered iron can become economic very many parts must be required as otherwise the die cost would become excessive. Mr. Patch emphasized this in pointing out that the fields of ordnance where powdered parts might find an application were in consumable goods such as shells or parts of the individual soldier's equipment. Although he considered that powdered iron bullets and powdered iron driving rings for shells might prove successful and that many of the non operating parts of small arms might be made by powder method, he preferred to first prove his case in more simple applications. As a result he had concentrated on projectile parts. Recently the Army and Navy had approved of a dummy fuse for the 37 mm shell. Major Turner located in the

Social Security Bldg., Washington, D. C., was said to be familiar with this development. About 10 to 14 million of such parts are required and each part weighed 1/5 lb. It was said that this fuse had previously been made from aluminium or brass at a cost of about 17¢ while the powdered iron part costs 2¢. Its use also involved a saving of strategic metals. A photograph of this part to size appears below.

Mr. Patch's company had also made a nose piece for an incendiary bomb from a sintered powdered aggregate that had been cold worked subsequent to sintering. The dummy fuse previously mentioned was porous having been only pressed and sintered. The nose piece, however, had practically theoretical density and the following physical properties:

Ultimate Strength	48,000 p.s.i.
Yield	32,000 p.s.i.
Elongation	17 per cent

Major Stubbs of the War Department Annex No. 1 in Washington,D. C. was said to be familiar with this development. This part has not yet been offered for use owing to the prevailing high cost of iron powder. At present it is being made from bar stock which is formed in screw machines. It was said that powdered iron would have to sell at from 4 to 4.5¢ a lb. to make the powder metallurgy technique economic. It was pointed out that should the powder method be used in this application less raw material would be required, fewer machine tools would be needed and less labour would be required. Mr. Patch estimated the finished part would weigh about 6/10ths of a lb. and that 30 million of such parts would be required.

Mr. Patch felt that after so much had been claimed for powder metallurgy methods it was now up to the fabricators of powder to take full advantage of opportunities presented in ordnance. He gave the impression of confidence in the industry, his only worry being the operator who might oversell his product and give the whole industry a bad name.

Powder Metallurgy Incorporated, Long Island City, N.Y.

The Fahrenwald development was discussed with the officers of this company whose names are listed above. They were most interested in the development and would like to undertake the fabrication of the powder. This firm has only a very small output compared with that of powder fabricators serving the automobile industry. They do not make the porous type part but only parts of theoretical density and good physical properties. Apparently a small firm operating in this field can make money. They are certainly very familiar with the hot pressing technique. Although they can make parts with properties practically equal to those of conventionally made articles, their field of application is restricted because of the high price of powdered iron. This makes them most interested in the Fahrenwald development which promises to put low cost good grade powdered iron on the market.

Information Secured at the Powder Metallurgy Conference

Mr. Charles Hardy of Hardy Metals Corporation said that each week he was selling five tons of hydrogen reduced iron for use in radio cores. He said that Meffin Ltd. were making this iron for him. They were reported to be dissolving Armco iron in sulphuric acid, evaporating to a sulphate, roasting the sulphate, and reducing the oxide produced in hydrogen. Mr. Hall of Metals Disintegrating Ltd. reported that his company were also putting in a powdered iron plant and it was rumoured that they were using a production similar to Meffin's and manufacturing for the same market. Mr. Hardy said iron so made had 90% of the properties required in carbonyl iron and could be sold at a lower cost. It was said that the iron sold for around 65¢ a lb. This explains why such a high cost production method can be successful.

Mr. Koehring of Moraine Products Ltd. stated that they are only investigating the hot pressing of iron powders experimentally and did not consider that the method would be used widely in the immediate future. Mr. J. Q. Adams of General Electric Co. stated that he thought that his company would be willing to manufacture Alnico magnets in Canada should border restrictions cause a Canadian shortage of this material. He stated it was their practice to cast magnets over an ounce in weight and use the powder method in manufacturing smaller sizes.

Although he represented one of the largest companies in the powder metallurgy field Mr. Langhammer took little official part in the conference, it being his company's practice to give out little information on their operation. Mr. Langhammer, an old tool maker, gave the impression that he was completely familiar with the application and manufacture of powdered iron parts. He was not nearly as free with information as were the General Motors men and merely hinted at his company's developments. He did not agree with Mr. Koehring's opinion that the hot pressed sintered powdered iron parts had only a small immediate field of application, stating that when part quantities and shapes were such that the powder metallurgy technique could be used to escape considerable machining, savings could be effected and high quality parts could be made. Dr. Goetzel in his paper on hot pressing had stated hot pressing had reduced the cost of a part from $2.00 to 50¢. Mr. Langhammer confirmed this.

Mr. Langhammer hinted at the use of hot pressed iron in ordnance uses. He stated self lubricating iron bearings of large size were being used in anti-aircraft guns and that small sized parts of this type were being installed in the Chrysler Tank. Mr. Langhammer said his company had been experimenting with self lubricating powder metal core bullets as a replacement for the lead in ball type ammunition. He claimed these cores had increased velocity, greater accuracy, better balance, greater range, and better penetration than the lead type core and moreover they were easier to manufacture. He also claimed that the barrel remained cooler and wore better when these materials were used. These claims are being investigated.

Comment

A low cost iron powder of good quality should find a ready market. If ordnance uses develop as would appear likely under the stimulation of cheap powder and the success of early applications, it is quite possible that 100 tons of powdered iron would be fabricated daily.

Insofar as ordnance is concerned the powdered iron industry is still in its infancy. Apparently its use (apart from that in the dummy fuse of 37 mm shell) is restricted to radio cores and self lubricating parts. Indications are that the tonnage required by the radio industry is larger than would be expected, and that properly made hydrogen reduced iron will be satisfactory for the service providing the particles are small and dense. The development of high strength parts by the cold rolling or hot pressing of sintered powdered iron parts opens up new possibilities in the industry as one of the main drawbacks of the use of a powdered iron part in ordnance was its low strength. If developments proceed as they seem to be this objection should soon be removed. The powder method allows for the saving of strategic metals or the reduction in the use of raw materials. It also reduces machine tools and labour requirements. Its field of application then might be expected to increase.

Of the processes on the market at the present time, the only one which promises to produce low cost high purity iron is the Wescott-Fahrenwald process. Until such a process is in operation the full possibilities of powdered iron will not be realized as many developments are being held up because there is no good cheap powder on the market.

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