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PRODUCTION & FABRICATION OF MAGNESIUM ALLOYS

I. G. FARBENINDUSTRIE, BITTERFELD AND AKEN

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COMBINED INTELLIGENCE OBJECTIVES
SUB-COMMITTEE
LONDON—H.M. STATIONERY OFFICE

PRODUCTION AND FABRICATION OF MAGNESIUM ALLOYS
I. G. FARBENINDUSTRIE, BITTERFELD AND AKEN

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CIOS Target No. 21/24
Metallurgy

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE
G-2 Division, SHAEF (Rear) APO 413

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TARGET

The Bitterfeld plant was visited on the 25th, 26th, 27th and 28th of June, and the Magnesium plant at Aken on the 27th June, the team devoting its time almost entirely to investigating what had been done by I.G. in:

(a) Extraction of metal from the ore.
(b) Discovery and Production of new alloys.
(c) Fabrication and protecting of magnesium alloys.
(d) Usages during war, and probable usages during peace.

The I.G. personnel interviewed were:

Dr. Buergin, Managing Director of the Bitterfeld Group of I.G. plants.
Dr. Bauer, Deputy Managing Director of the Bitterfeld Group of I.G. plants, and also of the I.G. plant at Aken.
Dr. Schichtel, Head of the Metallurgical Research Laboratories.
Dr. Nachtigall, Research chemist.
Dr. Ostermann, Foundries Superintendent.
Dipl. Ing. Weeber, Assistant Foundries Superintendent.
Dr. Gossrau, In charge magnesium powder plants.
Ober Ing. Rocke, In charge of all new engineering construction and all maintenance.
Herr Ziegler, Sales Manager, Elektron Works.
Ober Ing. Spitaler, Foundry Expert.
Dr. Buch, Legal and Patents.

Despite the confusion reigning amongst the remaining Technical Staff at Bitterfeld, and the general uncertainty regarding their future movements, we were able to make contact with some who had been in England pre-war, and from them to gather the following information.

PRODUCTION

(a) On the Production side, i.e. the extraction of magnesium metal from its ores, the practice generally followed by I.G. was to extract MgO. from Dolomite, convert this to oxychloride, briquet in extrusion or ring presses, and chlorinate in the usual furnace.

The main changes between pre-war and present practice in Germany and between German and English practice were:

(1) Increase in the amperage of the cells, and in the latest cases the size of the cells ......
Bitterfeld ... 18,000 amps.
Aken .... 24,000 amps.
Stassfurt .... 32,000 amps.

<u>NOTE:</u> I.G. personnel was not yet quite satisfied that the increase to 32,000 amp., which necessitated a larger cell, conferred such advantages additional to those obtainable by an increase to 24,000 amps. which can be done with existing cells, as to make worthwhile the higher cost of the larger cell.

(2) The re-conversion of the MgO extracted from Dolomite to $MgCO_3$, to obtain a material of high reactivity and purity.

(3) The use of large instead of small Chlorinators.

(4) The use of Mercury Arc Rectifiers instead of Motor Generators.

(5) The mechanical extraction of the metal from the cells.

(6) The transfer of all cell metal molten in 2-ton crucibles to the Foundry.

The total tonnage of magnesium produced in Germany was extracted by Electrolytic processes, either the I.G. present process or the I.G. original process as used by Wintershalle at Herringen. Work was continued on thermal reduction with Ferro-silicon and distillation, but the results obtained from the furnaces designed and built in 1938/39 to produce two tons each per day were unsatisfactory. These furnaces only produced in operation rather less than one-third of their estimated output.

The I.G. has worked on a new design but only on a small technical scale, i.e. a furnace with output of 250 Kilos. per day.

Dr. Bauer did not believe that this thermal distillation process would be able to compete with the electrolytic process after various improvements had been completed, unless there were special circumstances which might favor thermal reduction for small quantities.

Dr. Schichtel, previously employed at Radenthein, stated that in 1940 a company was formed for the development of the Radenthein carbothermic process, and experimental work was carried on at Bitterfeld by a team of ten until the end of 1942. The Economic Control ordered its cessation in order that all available manpower should be concentrated on production. Two technicians returned to Radenthein with the technical reports, and should be interrogated as soon as possible. The opinion was expressed that, when fully developed, the carbo-thermic process might compete with the electrolytic under favorable conditions.

The total production in Germany was almost exactly the figure of the estimates provided by M.E.L. and others, and as described in the Report by Mr. S.S. Taylor and others, dated 19.2.42, on "Magnesium - Axis Occupied and Neutral Europe", plus a possible additional 6,000 tons at Wintershalle, Herringen.

The output of magnesium in 1944 was given as follows:

	(Bitterfeld	4,000	tons.
I.G.	(Aken	11,500	"
	(Stassfurt	12,000	"
	Wintershalle	12,000	" . ±

giving a total of 35,000 - 40,000 tons.

No work was done on the direct production of high purity magnesium, and no magnesium cells were used for the production of anything other than magnesium.

The major extensions planned were of the electrolytic type, one in Norway near Oslo for 12,000 tons and one at Moorsbierbaun near Vienna for 12,000 tons production. The Norwegian plant was bombed on the very day it started and has not worked since; the Vienna plant was only in construction.

METALLURGICAL.

(b) Discovery and production of New Alloys.
A large number of Reports from the I.G. Metallurgical Laboratories were gone through, covering the period September 1939 to December 1944. All those which appeared to be of interest in the magnesium field were extracted and brought away.

A bolt passed through holes at A A and could be tightened so as to give any desired stress at B. Both types of test pieces were attched to the periphery of large drums (perhaps 1 meter in diameter), the lower edge of which dipped into the corroding medium and which rotated (it is believed) once in 3 hours. The depth of solution seemed to be so arranged that the specimens were immersed for ½ hour and dry for 2½ hours.

(c) Fabrication and Protection of Magnesium Alloys.

Castings. In an endeavor to improve further the purity of the AZG and AZF alloys and to raise the mechanical properties, the I.G. introduced a new process for the reduction of iron content and hydrogen. This is called the "Elfinal" process, and is really a treatment of the molten material by anhydrous ferric chloride, $FeCl_3$. It is claimed by I.G. that this process avoids the need to superheat and is successful in almost eliminating hydrogen content in the melt, of which there is likely to be considerable quantity if use is made of inferior scrap in making the alloy.

The following figures were given for material grain refined by "Elfinal" treatment and by superheating. The alloy composition is not known;

Treatment	Grains/Sq.mm.	Kg/Sq.mm.	Elong.%
"Elfinal" ...	100	28 - 30	8 - 14
Superheating .	8±	22	6 - 8

They had formed the opinion that the introduction of iron in the finely divided condition which results from the decomposition of ferri chloride, is a substitute for the finely divided iron from the sides of the pots which is spread through the melt during superheating.

There would seem to be no doubt that hydrogen is very largely eliminated, and it is equally certain that that a fine grain size is obtained, but whether the improved properties claimed are worth the extra cost involved, practical experience on a large scale alone would show.

There is a further difficulty in regard to this process insofar as that it can be highly dangerous. Ferric chloride is extremely hygroscopic, and as the amount required is roughly .5% of the weight of melt for ingot, .2% by weight for wrought, and it has to be plunged in a long container with a maximum of 200 grs. of $FeCl_3$ into the molten metal, if the material is not completely anhydrous a kind of explosion may occur which may easily result in fatal casualties. See Reports Nos. 1 and 63 by Dr. Schichtel.

I.G. do not believe that grain refinement can be brought about by mere stirring, though it does diminish the gas content of the metal. The results given in their reports are contradictory. High frequency treatment was not tried. They suggest that superheating appears to be more efficacious in a new crucible than in an old one.

An interesting feature was the use of sulphur as an inhibitor in all the sand, not only facing sand. It is claimed that in a good foundry only 3.5% S. is used in the sand, together with 0.01% Boric acid, no glycol or any other binder is employed.

Wrought Materials.

In the field, the outstanding achievement is certainly the production of forgings by the very large hydraulic presses of 30,000 and 15,000 tons respectively, of which blue prints have been taken by the various U.S. teams, and of which the tools have been removed by U.S. authorities.

A 30,000 ton hydraulic press was built for and started to forge large sections of gun carriages for heavy German artillery to lighten the dead weight and improve mobility.

Complete forgings have been removed by the U.S. authorities.

The presses were then used largely for forging aircraft propellers in Duralumin, the big press making two at a stroke.

Extrusions.

On the extrusion side, a good deal of work was done in improving methods of multiple extrusion by large presses, but we understand that this has been reported on at length by previous C.I.O.S. teams, particularly those from the U.S.A.

For various reasons, most of which appear to arise from confusion within the Luftministerium as to what quantities of magnesium would or would not be available, very little magnesium sheet was rolled during the last two years of the war.

Three methods are used for continuous casting of ingots for extrusion, rolling, etc.

The first is a slight modification of the Junghans process. The main feature of the modification appears to be that the mould is considerably shortened compared with the original Junghans one. Presumably this means that less solid metal has to be drawn past the crucible walls.

In the second method the metal is slowly drawn by an hydraulic ram out of the crucible in which it is solidifying and continually water-sprayed as it emerges from the base of the crucible, corresponding to the D.C. method largely used in the U.S. and Great Britain.

The third method is known as the Water Dip process, the use of which is highly recommended by I.G. This process was bought by M.E.L. and transferred to England in the early part of 1939. In this process a thin-walled mould is used in which the metal is kept molten by a hood with independent heating elements. For instance, a mould 350 mm. diameter and approximately 1,000 mm. long is filled with molten metal and the hood lowered over it to keep the metal molten. The mould stands on a ram which emerges from a pit filled with water. The hood is kept over the mould for 40/60 minutes to permit of segregation of impurities. The ram is then slowly lowered into the water, and solidification takes place from the bottom upwards. This method can be used only for aluminium-containing alloys, but AM503 cannot be treated as settling of the manganese takes place. The billet is extracted from the mould by an hydraulic ram, which process straightens the moulds and gives them a much longer life.

Protective Coatings.

Improvements in the chromate process for inhibiting corrosion consist (1) in pre-treating materials (particularly pressure die castings) in caustic soda; (2) in adding to the chromate bath phosphoric acid and H_2SO_4; (3) in adding chrome alum to the chromate bath. The addition of the chrome alum improves the color of the deposit and reduces the bichromate used to 1/10 or 1/20 of the norm.

Electrolytic processes for protecting magnesium have also been developed. One bath consists of a 40% aqueous solution of ammonium fluoride + ½% of ammonium phosphate. D.C. or A.C. may be used at a pressure of 150 volts. The bath is kept at room temperature and the deposition is carried out for five minutes. An initial current of 6 - 8 amps. per dcm^2 falls as the metal becomes coated. The pH of the bath should be 5 to 6 and if direct current is used the metal being coated is made to anode. A white opaque coat, probably an oxychloride one 2 to 5 u thick is produced.

Both these films, though chemically resistant, are porous and should be lacquered or cellulose painted, the paint being thinned so that it penetrates the pores. The second coat is harder and less porous than the first one but it is very brittle.

Ikarol paint, (polyvinylchloride with an acrylic ester) is still considered the best for magnesium alloys.

Messrs. Wood and Johnson reported in detail on this process.

A method was worked out for welding high manganese-content alloys to high aluminium-content alloys, and this method also is reported on fully by Messrs. Wood and Johnson.

Mechanical Tests.

A lot of work has been carried out on the ultimate stress at high temperatures and also fatigue tests at high temperatures and also fatigue tests at high temperatures, but only under steady load. (Note. it is difficult to reconcile this with the number of alternating stress machines seen in the laboratory).

Work was also carried out on impact machines and slow bend machines. It was found that the properties of cast materials vary according to the shape of the test piece used but that this is not so in the case of extruded materials. Specimens for tensile test are always polished. No work has been done on twinning since the outbreak of war. Electrical resistivity methods have been used to detect cracking, but very little use has been made of supersonics or infra red tests. X-rays have been used to a very great extent on cast material and also on extruded metal, but not on forged or rolled metal. They have not been used in any work on residual stresses or in microradiography. Microporosity is considered to be mainly a foundry problem and not one to be tackled metallurgically.

(d) Usages.

The main usages during war were generally similar to those in Allied territories. It was of particular interest to find that the Germans also, in spite of their prior experience failed to make adequate provision for the quantities of magnesium alloys demanded by the designers of the Army and the Air Force. The result was that magnesium was dropped from almost all the original Army applications, and in its wrought form cut out of many of the aircraft requirements. Designers were calling all the time for material, but the shortage did not permit usage.

One of the most successful uses of magnesium alloys was cast artillery wheels. These stood up to the hardest wear, travelling for long periods on the rims after the hard rubber tire had gone, and continuing serviceable after heavy damage from shell fire.

The Foundries were in full production on large castings for jet-propelled engines, and forgings for aircraft landing wheels were being made in substantial quantities.

Probably the development in which Germany is ahead of the Allies is in the development of pressure die castings, in the production of which the Leichmetallwerke at Cannstatt certainly appears to lead the world.

Among post war proposed usages the following are interesting.

A trailer has been designed in magnesium alloy, which is 35% lighter than the lightest steel trailer. It dispenses with metallic springing, the body being attached to the chassis by a kind of (horizontal?) pneumatic tire. This tire is inflated to a pressure suitable for the load in the body.

The use of magnesium in place of wood for shuttering for casting cement has much to recommend it. One appreciable advantage is that when the shuttering is worn out it has a considerable scrap value, whereas the wood has none. It is anticipated that this will be used to a large extent in the making of small houses.

Generally, the percentage usage of magnesium alloys other than that consumed for alloying with aluminium alloys during the war appears to be distributed as follows:

75% to castings.
17% to wrought.
8% to pyrotechnics.

POWDER.

Large quantities of magnesium leaf powder were made by the I.G. special process of scratching at high speed by carding machines, but this process has not changed essentially since 1938, at which date the first machines were erected in England.

We were told by the I.G. personnel that a Flt. Lieut. Jones of M.A.P. had arrived with instructions to remove the powder machines in Bitterfeld, and these left on Wednesday, 27th June, for Frankfurt.

An examination was made of the Metallurgical Laboratory Reports and it was found that during the war years direction of the work had changed steadily from magnesium to aluminium, because, for various reasons, magnesium had dropped into secondary importance.

Copies of these Reports were extracted which appeared to be of interest, and the numbers are shown on a list held in CIOS files.

A great deal of work appeared to have been done on the aluminium base magnesium alloys, with magnesium contents from 5% - 10%. This development was extensively examined by the Metallurgical teams which preceded us, and time did not permit of our examining this again in detail.

SCRAP RECOVERY.

At Bitterfeld we found an enormous plant devoted entirely to the recovery of aluminium and magnesium scrap from all sources, from shavings and swarf to solid castings and sections. The conception was on a vast scale, as was the expenditure.

The interesting points of the process were the Refining and Distillation sections. For refining, to the molten mass of aluminium and magnesium, quantities of iron, manganese, chromium, titanium, vanadium, zieconium, molybdenum and silicon were added. As the melting point of these metals is considerably higher than aluminium and magnesium, all impurities could be separated from the alloy by filtration. Filtration took place under vacuum in a ceramic filter.

Following filtration, the aluminium/magnesium alloy, which probably contained zinc, cadmium and lead as well, was subjected to distillation in a low frequency vacuum furnace. Vaporizing point of magnesium, zinc, cadmium and lead is considerably lower than that of aluminium so that these metals could be seperately distilled and collected, leaving a comparatively clean aluminium.

It was estimated that the plant would produce 36,000 tons of metal a year from scrap.

COST.

An inspection of costs of production showed that the cost of raw magnesium at Bitterfeld was Rm.123.60 per 100 Kilos, or RM.1.23 per Kilo, a price which does not show much advance in figures beyond the price quoted by I.G. for raw magnesium during the period 1936/1939, namely RM.1.20. It is difficult to determine exactly the correct conversion rate, but on the basis of R.M.1. : 1/- this represents a cost price comparative with that of pre-war days.

Team No. 516 left Bitterfeld on Thursday, 28 June, and reported at Camp Dentine that night. A summarized Report of the visit was left with G-2 at Camp Dentine and further copies were left at G-2, S.H.A.E.F. Frankfort.

The party returned to England on the 1st July.

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