THE IRON AND STEEL INDUSTRY OF THE UNITED KINGDOM UNDER WAR CONDITIONS.

A RECORD OF THE WORK OF THE IRON AND STEEL PRODUCTION DEPARTMENT OF THE MINISTRY OF MUNITIONS.

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PREFACE.

On account of the vastness of the field covered, the variety and complexity of the technical problems involved and the far-reaching industrial questions raised, the war activities of the Iron and Steel Production Department of the Ministry of Munitions form a subject of surpassing interest and importance. When, therefore, I was asked by Sir John Hunter to write an account of the work of that Department I gladly consented. Its records constituted an ample reservoir on which to draw for material, and every possible assistance in the work of compilation was given me by the heads of the different sections of the Department. Their names appear in the appropriate chapters.

From an historical point of view the narrative falls naturally into two divisions: first, that of the small Steel Department which was first formed as a branch of the Materials Department, of which Sir Leonard Llewelyn was Director, and second, that of the much larger organization formed by Sir John Hunter when he became Director of Iron and Steel Production in August, 1916.

In assuming this direction Sir John Hunter was confronted by a difficult task. The demand for steel for munitions and for shipbuilding was growing rapidly, while the supply of the raw materials essential for its manufacture was, by the activity of the enemy submarines, threatened with curtailment, if not with complete suspension, so far as foreign sources were concerned. The obvious remedy was the development of home resources. But the substitution of a lean phosphoric ironstone, such as constitutes the main portion of British iron-ores, for the rich ores imported from abroad, involved such sweeping changes in plant, supplies, inland transport, labour, &c., that it could only have been carried out with difficulty even in peace time. Under war conditions it was evident that the problem would require the most skilful handling by a carefully organised department. I have endeavoured to show in the following pages that, in spite of difficulties which at times appeared to be well-nigh insuperable, Sir John Hunter's Basic Iron Programme obtained a high measure of success, and enabled the urgent and incessant calls of the great Service Departments for ship-plates, shells, and other munitions requiring steel in their manufacture, to be punctually and duly met.

It is a remarkable tribute to the latent organising power of the nation that, under the adverse conditions of a great war, it should have been possible to raise the steel production of the country to the highest point it has ever reached in the history of the industry. Under the stress of necessity, raw materials, that had been allowed to lie dormant in this country, were rapidly developed and brought to the producing stage. Ironstone in Oxfordshire, coking coal in Scotland, ganister for silica-bricks, moulding sands for foundry work, and refractory sands for open-hearth furnace bottoms, are instances in point.

I venture to suggest two main reasons for Sir John Hunter's success: first, the trust reposed by him in the members of his staff—a trust which, I may say, was entirely reciprocated; secondly, the fact that manufacturers, appreciating the position taken up towards them, cordially co-operated in the plans of the Ministry, and loyally concentrated on war work. Many firms readily fell in with the suggestions of the Department to depart from routine practice and to embark on experimental work, often at considerable financial loss to themselves. Material assistance was given in other directions by individual makers of iron and steel, particularly in placing their special knowledge at the disposal of the Department. Thus, for example, the manufacture of shell-steel was, at the beginning of the war, in the hands of a very few firms. The unprecedented demands of the Army necessitated a sudden expansion of production; and, in bringing this about, the Ministry derived great assistance from the action of these firms in imparting to manufacturers, who were unaccustomed to this class of work, the technical details of processes of which they had unique knowledge. Others placed their designs for new plant at the entire disposal of their competitors. By such public-spirited action many firms undoubtedly rendered a great service to the nation, and have earned its gratitude.

F. H. HATCH.

14, Great Smith Street,
Westminster,
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CHAPTER I.

EARLY HISTORY AND ORGANIZATION OF THE IRON AND STEEL PRODUCTION DEPARTMENT.

Early in June, 1915, the Cabinet decided to form a Ministry of Munitions to provide the large quantities of shells and guns required for the Army, and Mr. Lloyd George became the first Minister. In introducing to Parliament, on the 23rd of June, a Bill for furthering the efficient supply of munitions, Mr. Lloyd George explained that the whole of the Munitions Department, except the Section dealing with explosives, had been placed under the direction of Sir Percy Girouard. He also pointed out the urgent necessity of mobilizing raw materials and of having periodic returns made of the production of raw and semi-manufactured materials.

Before the formation of the Ministry the supply of munitions had been the work of the Armament Outputs Department (a small department of the War Office), which comprised Sir Percy Girouard, Mr. George Booth and Sir Eric Geddes. Lt.-Col. J. F. H. Carmichael was in charge of the Materials Section of this Department and also dealt with the release of men from the Colours to supply the needs of manufacturing firms engaged in war work. On the formation of the Ministry Sir Percy Girouard became Director-General of Munitions Supply with Sir Eric Geddes, Mr. George Booth and Sir Glynn West as Deputy Directors-General; but Sir Percy Girouard very soon resigned and was succeeded by Sir Frederick W. Black. Sir Leonard Llewelyn became Director of Materials and Lt.-Col. J. F. H. Carmichael was instructed by the War Office to join the Ministry as Assistant-Director to Sir Leonard.

The nucleus of the present Iron and Steel Department was brought into being by the appointment, on the 22nd of June, of Colonel W. Charles Wright, of Messrs. Baldwins Ltd., who was asked to supervise the supply of steel and the distribution of orders for steel. To assist him in this work he obtained the services of Mr. W. T. MacLellan in July, 1915, and of Mr. James Peech of Messrs. Steel, Peech and Tozer, in the beginning of August, 1916: the former to look after the requirements of the Allies, the latter to deal with the supply of shell-steel. It should be pointed out that Mr. W. T. MacLellan had already been assisting the Government before the formation of the Ministry of Munitions. At the request of Mr. Runciman he went in the first week of October, 1914, to the War Office, in an honorary capacity, to assist in obtaining supplies of iron and steel goods for the immediate equipment of the army; and until March, 1915, he was occupied with this work. It covered an extraordinarily wide range, including the provision of entrenching tools, soup-cans, mess-tins, saddlery, bits, spurs, etc. In addition to this work Mr. MacLellan assisted Major Hausser in placing contracts for French shell-steel, a duty which he continued to perform up to the end of the war. In the first week of April, 1915, he was also asked to assist Mr. George M. Booth in increasing the supplies of shells, there being an immediate and urgent enquiry for those of the 18-pounder, 4.5-in. and 6-in. types. In connection with this part of his work Mr. MacLellan went to Woolwich to prepare, for the information of the shell-makers, pamphlets describing in detail the methods of manufacture and giving particulars of the processes and temperatures needed.

In July, 1915, Mr. F. W. Harbord was appointed as Honorary Metallurgist to the Ministry and in September Mr. Frank Merricks joined as Honorary Mining Engineer, Mr. W. R. Lysaght, although appointed as Honorary Spelter Adviser to the Ministry, was consulted on many questions connected with iron and steel, and attended most of the conferences bearing on that subject.

In September, 1915, a Section of the Raw Materials Department was formed to deal with high-speed and carbon tool steel and placed under the direction of Mr. H. B. Jacks. Early in December, 1915, Mr. John Hall was appointed to control supplies of steel (other than shell-steel) which had been dangerously reduced owing to the great increases made in the output of shell-steel while the total production of steel remained constant. At the end of December, 1915, difficulties with fuel-supply necessitated the formation of a Coal and Coke Section which was placed in the charge of Mr. P. G. Lewis.

On 16th February, 1916, Colonel Wright left the Department to return to military duties, and the Steel Section was then placed under the direction of Mr. W. T. MacLellan. In the spring of 1916 it was felt that the pig-iron position had become critical and Mr. B. Walmsley, who joined the Department in May, was asked to make arrangements for an improved supply. Mr. W. J. Jones joined the Department in the middle of 1916 to deal with the supply of refractory materials in which a shortage was beginning to make itself felt.

Early in August, 1916, a committee presided over by Dr. Addison decided that the Steel Section should be separated from Raw Materials and formed into a new department to deal with steel production, the Raw Materials Department being renamed the Non-ferrous Materials Supply Department. The new department was placed under the direction of Sir John Hunter, as from the 16th of August. Previous to taking over this direction Sir John Hunter had been Director of Factory Construction, a post that he assumed in October, 1915, at the request of Mr. Lloyd George, then Minister of Munitions, at the same time relinquishing the Managing Directorship of Sir Wm. Arrol and Company and other important interests. As Director of Factory Construction he was responsible for the erection of 17 large National Factories in London, Glasgow, Sheffield, Newcastle, Leeds, Nottingham and Lancaster and of other munitions factories and works.

In taking up his new duties as Director of Steel Production Sir John continued his direction of Factory Construction. In August, 1917, when Mr. Churchill formed the Munitions Council, Sir John was appointed Member of Council for the "S" Group, which then comprised the Departments of Iron and Steel Production and of Factory Construction. At a later date the Department of Forgings, Castings and Stampings, that controlling Building Bricks, and the Munitions Coal Supply were added. Although it does not actually fall within the limits set to the present historical statement it should be pointed out that, in addition to these heavy responsibilities, Sir John Hunter was appointed a Member of the Air Council and also took over the whole building programme of that Ministry under the title of Administrator of Works and Buildings.

At the time when Sir John Hunter became Director of Steel Production the following gentlemen were assisting the Department in various capacities: Mr. W. T. MacLellan (Deputy-Director), Mr. J. Peech (shell-steel), Mr. John Hall (steel other than shell-steel), Mr. B. Walmsley (pig-iron and limestone), Mr. P. G. Lewis (coal and coke), Mr. W. J. Jones (refractory materials), and Captain R. J. Wallis-Jones (iron-ore). Mr. F. L. MacLeod was appointed Official Adviser of Foreign Iron-Ore in September, 1916. Mr. F. W. Harbord continued to act as Consulting Metallurgist and Mr. Frank Merricks acted as Consulting Mining Engineer until the beginning of March, 1917, when a section was formed comprising himself and Dr. F. H. Hatch to stimulate the mining and quarrying of home iron-ore and limestone. Colonel Wright, who had been away from the Department since the 16th of February, 1916, and while away had visited Italy on a special mission for the Department regarding the supply of shell-steel for the Italian Army, returned to assist as Deputy-Director on the 2nd of January, 1917.

During the autumn of 1916, it had become apparent that, in order to meet the demands of the additional blast-furnaces it was proposed to operate for the production of basic pig, it would be necessary to increase the supplies of ironstone and limestone. It was decided, therefore, that certain ironstone and limestone quarries, which had been reported as suitable for the purpose by Mr. Frank Merricks, should be taken over by the Ministry and worked by German prisoners of war. Camps for the accommodation of the prisoners were erected, and by the end of 1916 about 1,500 prisoners were at work.

By December it was evident that further steps were necessary if supplies were to be ensured against any possible development of the submarine menace. The position was undoubtedly serious ; the working stocks of hematite ore were much depleted and at some ironworks had practically disappeared, with the result that furnaces were entirely dependent on the arrival of shipments and several had to be put out of blast. It was decided, therefore, to undertake a more comprehensive survey of our iron-ore resources and with that end in view Mr. G. E. Stephenson was sent under Mr. Merricks' direction to the Midlands and to the Cleveland district. As a result of this enquiry Mr. Lloyd George was able to announce in the House of Commons on the 23rd of February that there were ample supplies of low-grade ore if labour could be found to work them.

A meeting was held in Dr. Addison's room on the 23rd of February to consider ways and means ; and as a result of this meeting Sir John Hunter was asked to take whatever steps he considered necessary for securing an increased production of iron-ore in the United Kingdom. He at once obtained the services of a number of mining engineers and of experts versed in the different branches of the iron and steel industry, with whom he formed sections of the Iron and Steel Department to deal respectively with the mining and quarrying of iron-ore and limestone, with the supply of fuel, refractory materials and labour, and with the reorganisation of both blast-furnaces and steel-furnaces. These measures were reported to Dr. Addison in a Minute dated the 7th of March, 1917.

The next step was the formation of a Committee on Home Iron Ore Supply with Sir John Hunter as Chairman, Colonel W. Charles Wright as Deputy Chairman, Major R. A. Laws as Secretary and the following members :—

A. K Reese C. G. Atha	... ... to deal with basic pig-iron and steel production.
B. Walmsley	,, ,, ,, the allocation of pig-iron to steel furnaces.
F. Merricks F. H. Hatch	... ... ,, ,, ,, the mining and quarrying of iron and manganese ores and of limestone.
W. J. Jones	,, ,, ,, the supply of refractory materials.
P. G. Lewis	,, ,, ,, the supply of coal and coke.
T. M. McAlpine	,, ,, ,, the supply of mining machinery.
Major R. A. Laws ...	,, ,, ,, the supply of labour.
R. E. Palmer	,, ,, ,, transport.
F. L. MacLeod ... Capt. R. J. Wallis-Jones	,, ,, ,, foreign ore.
F. W. Harbord	to act as Metallurgical Consultant.

On Sir John Hunter's appointment as Member of the Munitions Council on the 20th of August, 1917, Colonel Wright became Controller of Iron and Steel Production and took over the Chairmanship of the Committee. Mr. Atha resigned from the Committee and from the Iron and Steel Department on the 5th of September, 1917, owing to pressure of work in connection with his General Managership of the Frodingham Iron and Steel Company. On May the 30th, 1917, the Labour Supply Section was taken over by Mr. A. C. Williams who also, on the 17th of April, 1918, became Secretary to the Committee on the transference of Major R. A. Laws to the Air Ministry.

Kettering and Holwell and on construction work at Frodingham; altogether some 500 Cornishmen are at present employed. In South Wales tinplate workers were recruited and sent to work on extensions to steel-works and blast-furnaces; they proved to be of inferior physique and unable to undertake successfully the heavy work required of them. Irish labour was also tried, but without success; and a suggestion to import Italian miners was dropped for political reasons. A certain number of men were obtained through the Labour Exchanges.

Considerable use has been made of prisoners of war (both civilian and combatant). For working ironstone in the Midlands, non-combatant prisoners of war were allocated to camps at Corby and Stainby and combatant prisoners to large camps at Rothwell near Kettering, at Pattishall south of Northampton, and at Uppingham and Wakerly near Stamford. Both combatant and non-combatant prisoners from these camps worked on a piece-rate system introduced by Mr. H. K. Scott, the Ministry's Representative at Kettering, in consultation with the camp commandants.

In view of the difficulties attaching to the employment of combatant prisoners of war the efficiency, as compared to British labour employed on similar work in the same neighbourhood, did not as a rule exceed 40 per cent. for baring, and 60 per cent. for loading ironstone (the actual figures ranged from 11 per cent. to 46 per cent. for baring and from 45 per cent. to 80 per cent. for loading). For interned aliens, who were more favourably disposed to effort, the efficiency ratio ranged from 65 per cent. to 80 per cent.

Combatant prisoners of war were employed in quarrying limestone; and camps were established for that purpose at Eastgate and Stanhope in Weardale and at Peakdale and Ladmanlow in Derbyshire. The Weardale prisoners worked with considerable success on piece-rates arranged by Mr. Hackney, the Ministry's Representative for that district. The output of a prisoner working in the Weardale quarries averaged about 17 tons per week as against 35 to 40 tons per week for British labour. In August, 1918, the total number of German prisoners at work in these quarries was about 1,000. The number allocated to the Derbyshire camps was 500, and this was subsequently increased to over 1,000.

Combatant prisoners were used in ganister quarries; and camps for that purpose were established at Harperley near Wolsingham and Healyfield in County Durham, the total number so employed being about 340. Prisoners of war to the number of 300 also worked in the iron-ore mines of the Isle of Raasay, off the West Coast of Scotland.

The efficiency of prisoner labour was much diminished by the restrictions of the War Office in regard both to rations and payment. Where it was possible to relax in some degree the regulations, as in the case of interned civilian labour, much better results were obtained.

To furnish the proportion of ore, which it had been estimated the Cleveland mines would contribute to the total called for by the basic iron programme, additional labour, amounting to 2,700 men, was required. At the same time it was not anticipated that it would be possible to obtain the release of local men who had joined the Colours; and in any case no risks could be taken. Since no housing accommodation was available for imported labour it was decided to erect hutments, and these were located in seven different camps in order to secure an adequate distribution of the men in relation to the mines.

As it turned out, the Department was able to obtain the release from the Army of over 1,000 miners belonging to the district; and, since these men were accustomed to the work, they were probably equivalent to double the number brought in from outside. On the other hand, the whole of the large increase in production, for which provision had been made, was not required, since the basic iron programme, for reasons that have already been given (see p. 50), was not completely carried out. Thus it happened that the camps were not put to the use for which they were originally intended; and ultimately they were converted to military purposes, a part being made over to the Air Board and the remainder loaned to the Army.

Valuable assistance was rendered to the Department by Mr. Harry Dack, the Agent and President of the Cleveland Miners' and Quarrymen's Association, who worked patriotically in the national interest. During four years of exceptional strain he and the Resident Engineer, working in harmony, so tactfully handled the difficulties that arose in various directions (*e.g.*, the application of the War wage, the use of German prisoners in the Weardale limestone quarries, the calling-up for the Army of the men born in 1898–99, etc.), that work was carried on in the Cleveland district without any mine or quarry standing idle for a single day ; in many instances even the recognised annual holidays were foregone, the owners making an extra allowance in wages to the miners for the holidays so worked.

Camps were also established in Cumberland ; and 800 miners from the Scottish coalfield were brought into the district to assist the local miners in increasing the production of hematite. Reference to the special labour problems of this district is made in another Chapter (see p. 81).

When the scope of the Section was enlarged to embrace the supply of labour for extensions to steel-works and other buildings erected under the Direction of the Factory Construction Department, the protection of men of military age employed by the contractors employed on essential work became a matter of importance ; and schedules were drawn up by the Labour Supply Department and the Ministry of National Service, in agreement with the War Office, to show the trades and ages of the men it was decided should be protected. All applications to the Ministry of National Service for certificates of protection were first submitted to the Section for verification.

Previous to May, 1917, all men employed by controlled firms engaged on munition work were badged and entitled to protection from military service. At the end of April, 1917, these badges were withdrawn, and the Munition Area Recruiting Scheme was introduced. Under this scheme

CHAPTER X.

THE BASIC IRON PROGRAMME—*continued.*

(*d*) The Supply of Home Ore.

In the beginning of March, 1917, a Section was formed to deal with the mining and quarrying of iron and manganese ores, and of limestone. At headquarters it at first consisted of Mr. Frank Merricks, who up to that time had acted as Honorary Mining Engineer to the Ministry, and Dr. F. H. Hatch, Past-President of the Institution of Mining and Metallurgy, with Mr. Merricks as responsible head. Later on, as the work at headquarters grew, Mr. S. J. Lett was appointed Technical Secretary to the Section and Lieut. R. Butler, Technical Assistant, with special reference to the supply of limestone. In order to keep in close and sympathetic touch with the producing firms, Mr. Merricks divided up the country into districts, each of which was placed in charge of a responsible Resident Mining Engineer. These Resident Engineers took up their duties at the beginning of March, 1917, the different districts to which they were appointed and the stations assigned to them being as follows:—

District.	Station.	Resident Engineer.
Cumberland and Lancashire ...	Whitehaven ...	Mr. W. Selkirk.
Cleveland	Saltburn ...	Mr. G. E. Stephenson.
Midlands	Kettering ...	Mr. H. K. Scott.
North Lincolnshire	Scunthorpe ...	Mr. E. Edwards.
Oxfordshire	Banbury ...	Mr. A. A. Dolan.

Mr. N. G. Hackney had already been appointed (in August, 1916) to take charge of certain limestone and ganister quarries in County Durham, which were being worked by prisoners of war, and was stationed at Wolsingham.

Mr. Stephenson resigned his post at Cleveland to take up other duties on the 30th of November, 1917, and was replaced by Mr. H. B. White. Mr. Selkirk, who became Deputy Controller of the Cumberland and Lancashire iron-ore mines on the 24th of September, 1917, resigned in January, 1918, and Mr. W. T. Anderson, who succeeded him, was appointed Controller, with Mr. C. D. Wilkinson and Mr. M. MacLachlan as Deputy-Controllers. Mr. H. K. Scott was appointed Director of Home Ore Supplies for the Midlands on the 9th of March, 1918.

The preliminary organization having been completed, the next step was to obtain accurate statistics of the production of home iron-ore; and with this end in view producing firms were asked to furnish weekly returns to the Resident Engineers stationed in their respective districts. Over ninety per cent. of the production was from districts to which Resident Mining Engineers had been appointed, as will be seen in the following table, which gives the tonnage ratio of the output of the different districts to the total production for the year 1918 :—

Districts where Resident Engineers were Stationed.	Tonnage Ratio of Output to Total Production. Per cent.	Per cent.
Cumberland and Lancashire (hematite ore)	10·3	
Northamptonshire and Rutlandshire (Inferior Oolite ironstone)	23·1	
Cleveland district (Middle Lias ironstone)	30·2	
S. Lincolnshire, Leicester and Oxfordshire (Middle Lias ironstone)	10·0	
N. Lincolnshire (Lower Lias ironstone)	17·5	
		91·1
Other Districts.		
English and Scottish Coalfields (blackband and clay-ironstone)	7·5	
Raasay (Lias ironstone)...	0·6	
Wales (hematite and brown iron-ores)	0·5	
Forest of Dean (hematite and brown iron-ores) ...	0·1	
Weardale (spathic ore)	0·1	
Antrim, Ireland (Tertiary ores)	0·1	
		8·9
Total	...	100·0

In these latter districts local conditions did not warrant the stationing of a Resident Engineer; consequently it was arranged that the returns of output should be made direct to headquarters. But in the case of Scottish coalfields, where there are a great number of small producers, it was found more convenient to obtain the returns through the instrumentality of the Scottish Advisory Committee on Iron and Steel Production, of which Mr. Fred Lobnitz was Chairman, and Messrs. Wallace Thorneycroft, A. K. M'Cosh and G. A. Mitchell, members.

IRON ORE PRODUCTION OF THE U.K. IN DISTRICTS.

Districts.	1917.		1918.	
	Tons.	Tons.	Tons.	Tons,
West Coast—				
Cumberland	1,256,393		1,229,231	
Lancashire	330,036		320,731	
		1,586,429		1,549,962
Cleveland		4,809,861		4,570,892
North Lincolnshire ...		2,699,532		2,639,712
Midlands—				
Kettering	2,275,314		2,390,847	
Melton Mowbray ...	780,025		757,161	
Market Overton ...	585,121		730,407	
Uppingham	168,760		200,145	
S. Lincolnshire	216,408		199,625	
Blisworth	81,189		95,243	
		4,106,817		4,373,428
Oxfordshire		434,435		580,659
Raasay		65,985		88,047
Coalfields—				
N. Staffordshire ...	761,230		694,803	
S. Staffordshire ...	17,766		29,192	
Scottish	371,424		357,373	
Sundry	44,462		37,847	
		1,194,882		1,119,215
Wales and Forest of Dean—				
Wales	69,291		71,921	
Forest of Dean	21,477		13,498	
		90,768		85,419
Miscellaneous—				
Ireland (Tertiary ore) ...	20,649		17,215	
County Durham and Devonshire	18,544		19,824	
		39,193		37,039
Total		15,027,902		15,044,373

CHAPTER XIII.

FUEL.

The Coal and Coke Section of the Ministry under Mr. P. G. Lewis was formed at the end of December, 1915. At that time several blast-furnaces had been put on slack blast owing to the inadequate supply of coke. In order to be in a position to deal with this and generally with the increasing shortage of the coal required for various munition purposes, it was decided that it would be necessary to control prices. In January, 1916, therefore, maximum prices were fixed for metallurgical coke in Scotland, Durham, South Wales and the Midlands, the latter area including for the present purpose Lancashire and Yorkshire. Subject to certain adjustments, made from time to time, the system then arranged has continued in force from January, 1916, to the present date (end of 1918); and, on the whole, it has worked extremely well.

The production and distribution of metallurgical coke was complicated by its fluctuating price. At the outbreak of war there was a serious glut of this material. This brought about a great fall in price, and the coke was, in many cases, actually sold at a figure equal to the cost of the coal put into the ovens, with consequent heavy losses to the makers. The production of pig-iron had rapidly decreased in 1914, while the output of coke was increasing owing to the introduction of by-product ovens. But in the early part of 1915 a considerable number of inefficient ovens of the beehive type were put out of operation; and this and the extra demand for coke, owing to the increased manufacture of pig-iron for munition purposes, caused a rapid advance in price. The production of large quantities of benzol and toluol required for war purposes soon reversed this position, so that by September, 1915, a committee had to be appointed by the Explosives Department of the Ministry to advise on measures for the disposal of the surplus coke produced in the manufacture of these materials. This committee made a number of valuable suggestions; but before their report

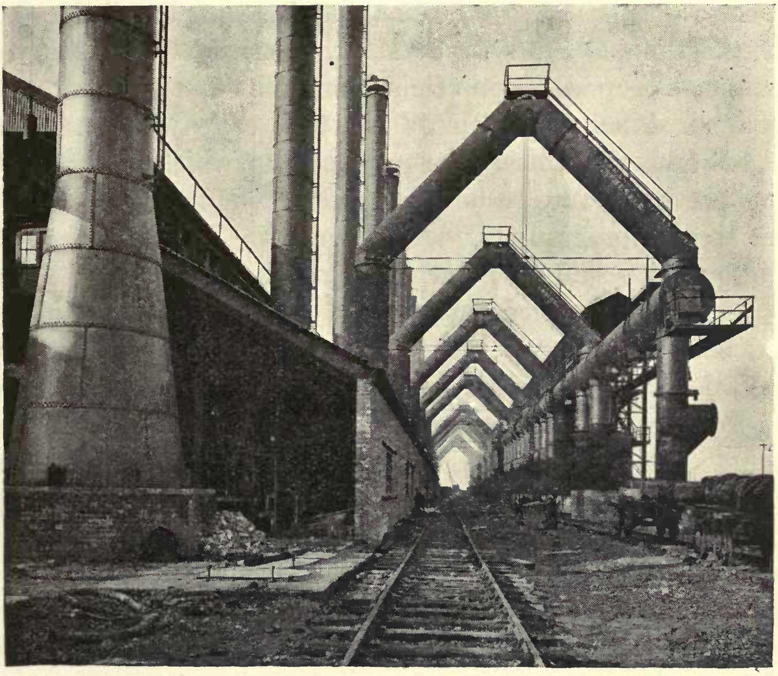


Fig. 13.—Extension to William Beardmore & Co.'s steel-works at Mossend, near Glasgow—Gas-producer plant.

was published the position had been again entirely changed by the shortage mentioned at the beginning of this chapter as occurring in December, 1915. It was accentuated by large demands from France and Italy, amounting in the aggregate to over a million tons per annum. Consequently the newly formed Section had to face a complicated situation at a time when coke-makers were quite unable to understand the meaning of such violent fluctuations, and had lost confidence in the future of their industry.

The new Section at once made arrangements with the War Trade Department and the Coal Exports Committee, by which a system of licences for the export of coke was introduced. Urgent appeals were also issued to all coke-makers to increase their production as rapidly as possible, and by the end of March, 1916, current requirements were being met.

During the next six months, detailed plans were formulated to meet the large additional requirements entailed under the programme laid down by Mr. Hall and Mr. Walmsley for the increased production of pig-iron. The first printed programme, dated the 27th June, 1916, called for an extra 39,546 tons of furnace-coke per week, of which over 21,000 tons per week were to be furnished in four months. Under the second programme, dated the 30th September, 1916, this quantity had been increased to 53,462 tons per week, representing the needs of over 57 blast-furnaces, which it had been arranged with the owners should be brought into operation as quickly as possible, chiefly to produce basic pig-iron from home ores. Unfortunately, these arrangements entailed demands for coke on collieries situated in the Midlands, where the output of coking coal was already short, and was being steadily further reduced by the recruitment of coal-miners for the Army. Owing to the necessity of furnishing coke to the blast-furnaces at a reasonable price, it was not possible to bring coke to the Midlands from South Wales or Durham, where adequate supplies of coal suitable for its manufacture could be obtained.

The whole of the year 1916 was devoted to organising production on a rapidly increasing scale and under conditions that would at the termination of hostilities enable pig-iron and steel to be produced at a price permitting competition with other countries.

Owing to the lack of confidence above referred to, difficulty was experienced in persuading owners of coke-ovens to increase their plant. At the end of 1916, the shortage of shipping affected the supply of imported hematite iron-ore, with the result that blast-furnaces that had been listed for the manufacture of hematite pig-iron had to be diverted to basic pig-iron. This led to a further demand on collieries producing coking coal, which was most difficult to satisfy under conditions of efficient commercial practice.

Various expedients were adopted to meet the situation, the chief of which was an increase in the output per oven by the use of higher temperatures, and, in some cases, by the reduction of the moisture in the washed coal charged into by-product ovens. By these means the average output of coke per oven was in the year 1916 raised to 1,320 tons per annum as compared with 1,133 in 1915—an increased efficiency of 17 per cent. A considerable amount of labour and cost was thus avoided, apart from the saving of the time which would have been required to build additional batteries of ovens. Time being an important factor, it was also found necessary to repair and put into operation over 800 beehive ovens, which had been abandoned. The result of these measures may be seen in the following returns of output during the war period :—

OUTPUT OF METALLURGICAL COKE.

Year.	Tons.
1914	11,050,000
1915	12,137,000
1916	13,422,000
1917	13,862,000
1918	13,301,548

It will be seen that the output for 1917 shows an increase of $2\frac{3}{4}$ million tons (equivalent to about 25 per cent.) over that for the year 1914. To furnish this increased production more than four million tons of coal per annum was forthcoming, notwithstanding the loss in output caused by the recruitment of miners. The quantity of coke exported during the year 1916 was 1,130,000 tons, of which 65 per cent. was exported to France and 15 per cent. to Italy, the remainder being sent to neutral countries in exchange for copper, lead, and other important munition commodities. In 1917 the export fell to 879,000 tons and in 1918 to 635,000 tons.

The home consumption of metallurgical coke for the last four years has been as follows :—

CONSUMPTION OF METALLURGICAL COKE.

Year.	Tons.
1915	11,515,000
1916	12,292,000
1917	12,923,000
1918	12,667,000

The consumption of coke in blast-furnaces in the United Kingdom during 1917 was 11,140,000 tons.

During the war period over 1,750 by-product coke-ovens were laid down at a cost of nearly £5,000,000, to which the Ministry contributed £1,250,000. It is anticipated that the total output of coke from these ovens will be about 16½ million tons per annum, when the plants are in full operation—approximately a 50 per cent. increase upon the pre-war output. This increase in the production of coke will require 8¼ million tons additional coal per annum, representing the labour of 33,000 coal miners. The total quantity of coal that will then have to be carbonised for the manufacture of metallurgical coke will be 30 million tons per annum, or 11 per cent. of the pre-war total output of coal in the United Kingdom.

Metallurgical coke was produced in 1917 in the following districts and in the proportions given :—

DISTRICTS PRODUCING METALLURGICAL COKE.

District.	Percentage Ratio to Total Production.
Durham	39
Yorkshire	26
South Wales	12
Shropshire, Staffordshire and Worcestershire	5
Derbyshire, Lincolnshire and Nottingham ...	5
Lancashire and Cheshire	5
Cumberland	4
Scotland	4
	100

Furnace coke (amounting to 80 per cent. of the total production of metallurgical coke) was consumed in 1917 in the following districts and in the proportions given :—

DISTRICTS CONSUMING FURNACE COKE.

District.	Percentage Ratio to Total Production.
Cleveland, Durham and Northumberland ...	36
Midlands, including South Yorkshire ...	24
Cumberland	14
Shropshire, Staffordshire and Warwickshire	9
South Wales	8
Lancashire, Cheshire and North Wales ...	5
Scotland	4
	100

Efforts have been made to reduce the output of beehive coke and to replace it by by-product coke as rapidly as practicable, on account of the saving of coal thereby effected. At the present time, 80 per cent. of the production of metallurgical coke is obtained from by-product ovens, 16 per cent. from beehive ovens, and 4 per cent. from the non-recovery Coppée retort-ovens. In the year 1913, 58 per cent. only was made in by-product ovens, with the result that not only were the valuable by-products lost, but there was a serious additional loss from the cost of the extra labour and coal. In 1913, 13,167 beehive ovens were in operation; in October, 1918, this number had been reduced to 6,399. As a result of this change the same amount of coke is produced with a saving of over 800,000 tons of coal per annum. The resulting by-products were during the war at the disposal of the Department of Explosives Supplies. It may be of general interest to know that they comprised the following commodities :—

Material.	Output per Annum.
Sulphate of ammonia (the present price of which is about £18 per ton)	165,000 tons
Crude benzol (the price of which is 11*d.* per gallon)	34,000,000 gallons
Crude tar (the price of which is 30*s.* per ton)	450,000 tons

The total value of crude by-products obtained, at the present controlled prices, exceeds £4,500,000 per annum, the value of the coke output being about £24,000,000 per annum. The number of ovens in operation on the 31st October, 1918, was: by-product—8,375; retort—1,334; and beehive—6,399.

In Scotland, where a large proportion of the fuel used in the blast-furnaces is splint, or hard coal, the tar, ammonia and other constituents of the coal are recovered as by-products.

According to present practice in Scotland, the average consumption of fuel per blast-furnace is 504 tons per week, of which 79 per cent. is splint, or hard coal, 16 per cent. furnace coke, and 5 per cent. gasworks char. The total consumption of fuel for the 92 blast-furnaces at present in existence would amount to 46,000 tons per week, and for the 27 new furnaces, which would be required to balance the steel-making capacity (see p. 25), 13,600 tons of fuel would be required in addition, making a total of 59,600 tons per week. The Scottish Advisory Committee reported that coal for the new furnaces could be provided during the war; but in consideration of the limited reserves of splint coal, it was obvious that this supply could not be for long maintained under economic conditions. The following is a summary of the Committee's report:—

The output of metallurgical coke in Scotland at the end of December, 1916, averaged 10,265 tons per week, 20 per cent. of which was made in beehive ovens and 80 per cent. in by-product ovens. It is, therefore, clear that in order to provide for the 27 new blast furnaces, referred to, it would be necessary to erect 50 new by-product coke-ovens.

In order to study the possibility of substituting coke for splint coal in working new blast-furnaces, an enquiry into the coking coal seams of Scotland was carried out for the Ministry of Munitions by the Advisory Committee. Coal owners were asked to make returns of the quantities available and to send samples of their coking coal for examination to the Technical College, Glasgow. The samples, to the number of 367, were examined by Professor Gray, and for the purposes of his report the following classification was made :—

Description.	Caking Index.	Number of Samples.
Coals unsuited for coke-making	below 11	208
„ possibly suitable for mixing	11	33
„ suitable for mixing	12 to 14	59
„ possibly suitable for making coke ...	15	8
„ suitable for the manufacture of coke ...	16 and over	59
Total number of coals examined		367

With regard to the sulphur and phosphorus contents, the coke made from these coals will contain one-half of 1 per cent. and upwards of sulphur; while in most of the coke the phosphorus is not sufficiently high to militate against its use in the manufacture of hematite pig.

With regard to quantities, the Committee was of the opinion that the reserves in Scotland of good coking coal (that is with a caking index of 16 and over) were not less than 80,000,000 tons. According to present practice, this class of coal is separated by screening into *large coal* for gas making or navigation purposes, and *small coal*, which can be used for coking. Before coking, the small coal is washed and crushed. The yield of good metallurgical coke is 60 per cent. of the small coal or 30 per cent. of the coal as mined. On this basis the 80,000,000 tons would yield 24,000,000 tons of good metallurgical coke.

The present output of Scottish coke is about 10,000 tons per week, or say 550,000 tons per annum, of which, at the time the Committee's report was made, 70 per cent. was used for blast-furnaces and 30 per cent. for other purposes and export. In order to keep 119 furnaces in blast an additional 140,000 tons per annum would be required, making the total requirements for all purposes 690,000 tons per annum. On this basis the 24,000,000 tons of furnace coke would be consumed in about 55 years, provided the make of furnace coke was not increased by coking some of the large coal.

No doubt the use of gas char or inferior coke will be increased, but it is obvious that the known reserves of coking coal do not appear to warrant the erection of many large modern blast-furnaces using coke alone.

The rapid depletion of the Lanarkshire coal reserves is a very serious matter for the heavy coal-consuming industries of the Clyde valley and for the ship-building and engineering works dependent on them; and the Committee was of the opinion that the question of long-distance carriage for assembling material essential to blast-furnaces and steel-works, is one calling for consideration.

CHAPTER XIV.

LIMESTONE.

In the autumn of 1916 it was found necessary to increase the supply of limestone in order to feed the additional blast-furnaces which, it was anticipated, would be put on to basic pig. With this end in view Mr. Merricks was commissioned by Sir John Hunter to inspect certain limestone quarries in the Weardale district of County Durham, in Yorkshire, in the Buxton district of Derbyshire, and in Cumberland and Lancashire. As a result, a number of these quarries were taken over by the Ministry and arrangements made to work them with prisoner labour. Camps for the accommodation of the prisoners were erected at Eastgate and Stanhope in Durham, at Stainton in Lancashire, at Rowrah in Cumberland, and at Peakdale and Ladmanlow in the Buxton district of Derbyshire. By the end of 1916 some 1,500 prisoners were at work. Mr. N. G. Hackney was appointed as the Ministry's representative in County Durham, with Mr. H. D. Keown as assistant, to take charge of the quarries, both of limestone and ganister, that were being worked by prisoners of war in that district. In May, 1917, Mr. Hackney also became responsible for the administration of the limestone quarries which were being worked in Derbyshire with prisoner labour by the Buxton Lime Firms Company, Limited; and in April, 1918, he took over the supervision of a dolomite quarry worked by prisoner labour in the Oswestry district of Shropshire. Mr. Lamotte was placed in charge of the Oswestry quarry and also of the Knitsley Fell ganister quarry in Weardale, which had been reopened by the Ministry to supply material for making high-grade silica bricks. Altogether Mr. Hackney's organisation was responsible for 14 quarries worked by prisoner labour. Of these the following limestone quarries were in Weardale: Heights, Newfield, Newlandside and Rogerley, the prisoners being lodged in camps at Eastgate and Stanhope. The ganister quarries in Weardale were Knitsley Fell and Healyfield, the camps for these being at Harperley and Healyfield. In the Buxton district seven limestone quarries were worked with prisoner labour, namely, Grin, Harpur Hill, and Brierlow, with prisoners from Ladmanlow camp; Peakdale, Perseverance and Smalldale, with prisoners from Peakdale camp; and Alsop-en-le-dale, with prisoners from Ashbourne camp. In the Oswestry district of Shropshire the Whitehaven dolomite quarry was worked by prisoners from a camp at Parkhall.

Piece-rates were introduced both in Weardale and Buxton, and much to the advantage of production. In Weardale their introduction trebled the output per man; but the Ministry was prevented from reaping the full benefit of this increase by the opposition of the Cleveland Miners and Quarrymen's Association. At first the difficulty was overcome by placing the stone won by prisoner labour into reserve stock at the quarries; and by the end of December, 1917, approximately 65,000 tons had been accumulated on this account. But on further opposition from the Association it was found necessary to prohibit quarrying by prisoners altogether, and to utilise this labour solely for removing over-burden preparatory to the quarrying of the stone. In June, 1918, the question was finally settled by an agreement with the Cleveland Miners and Quarrymen's Association, under the terms of which prisoner labour was to be used for quarrying at the discretion of the Ministry, provided no British quarrymen suffered detriment or loss thereby.

In reporting on the use of prisoner labour Mr. Hackney remarks that the main obstacle to satisfactory results was the limitation of inducements to work. Work could not be compelled either by force, this being forbidden by the War Office regulations, or by a reduction of rations since a minimum was prescribed. The difficulty was overcome, as already stated, by the introduction of piece rates. Here again, however, the best results could not be obtained since earnings beyond a fixed daily limit were prohibited. Further, there was no outlet for surplus earnings, the canteen supplies having been reduced, on account of the general shortage of food.

According to returns made to the Ministry, the present total consumption of limestone in blast-furnaces amounts to $4\frac{1}{2}$ million tons per annum. Of this amount 41 per cent. is taken by furnaces in the Middlesbrough district, and is supplied from Weardale and East Yorkshire. Ironworks situated in the Midlands and in Staffordshire are the next biggest consumers, taking 23 per cent., mainly from Buxton and North Staffordshire. The remaining 36 per cent. is taken by furnaces on the West Coast (Cumberland and Lancashire), in Scotland, and in South Wales.

TABLE SHOWING THE CONSUMPTION AND SOURCE OF SUPPLY OF THE LIMESTONE USED IN BLAST-FURNACES.

District.	Percentage Ratio of Total Consumption.	Source of Supply.
East Coast	41 per cent.	Weardale and East Yorkshire.
Midlands (including Staffordshire)	23 ,,	Buxton and North Staffordshire.
West Coast	15 ,,	Local (Cumberland and Lancashire).
Scotland	12 ,,	Mainly imported from North Wales, Yorkshire and Buxton.
South Wales ...	9 ,,	South Wales.

CHAPTER XV.

REFRACTORY MATERIALS.

The chief refractory materials used in iron and steel making are :—

(1) FIRECLAY. (Firebricks, nozzles, stoppers, blast-furnace linings, etc., etc.)

(2) REFRACTORY SANDS.

(3) GANISTER AND SILICA-ROCK. (Silica-bricks and blocks.)

(4) MAGNESITE. (Magnesite-bricks and cement.)

(5) "BASIC MATERIAL." (Shrunk dolomite.)

Fireclay goods are used in all processes of iron and steel manufacture, refractory sands chiefly for moulding purposes in the foundries and acid steel-melting furnaces, silica-linings in acid steel-furnaces, whilst magnesite and "basic material" are used for the lining of basic steel-furnaces.

At the outbreak of war refractory sands were being imported in considerable quantities from the Continent; and home resources were either neglected or unknown. But recent investigations undertaken by Dr. Boswell,* of the Liverpool University, at the instance of the Steel Production Department, have demonstrated the entire suitability of the home materials for the purposes required and have made the United Kingdom independent in the future of foreign supplies.

With the exception of magnesite there were ample supplies of refractory materials in this country at the outbreak of war;

* P. G. H. Boswell: A Memoir on British Resources of Refractory Sands. published at the Instruction of the Ministry of Munitions of War by the Imperial College of Science and Technology and the University of Liverpool.

and the grinding and calcining plants, then at work, were capable of meeting the pre-war requirements of the steel-makers. This satisfactory position led manufacturers, who did not realise the increased demands that would eventually be made upon them, to encourage their younger and, in many cases, best employees to join the new armies. When first asked to increase their output they were able to respond by procuring and training additional labour; moreover, the majority of them had for a number of years been accustomed to carry large stocks; consequently they experienced no difficulty at first in meeting the increased demands. But early in 1916 it was realised that it would be necessary to take other measures to augment the output of refractories of all kinds; and for this purpose a Section of the Iron and Steel Department was created in July, 1916, under the administration of Mr. W. J. Jones. At first the Section dealt only with fireclay and ganister; but magnesite was taken over in November, 1916, and basic material in March, 1917.

Fireclay Materials.

In regard to these materials, the outlook in July, 1916, was not specially serious except in regard to blast-furnace linings. On enquiry it was found that the capacity of the works was approximately 120,000 tons of fireclay and bricks per month, equivalent to a monthly output of 40,000,000 bricks of 9 in. × 4½ in. × 2½ in. dimensions. The output for the month of July, 1916, was 110,000 tons, and while the manufacturers were all well booked ahead, it did not appear that any great difficulty would be experienced in coping with orders, 90 per cent. of which were for war purposes. The monthly output continued at a steady average of 110,000 tons until April, 1917, in spite of the repeated withdrawal, for military service, of skilled and other labour from works in all parts of the country. Manufacturers generally were encouraged to maintain their output by a judicious dilution of their depleted staffs and by the installation of modern labour-saving machinery; and from May, 1917, onwards no difficulty was experienced in meeting the increased demands put forward. By April of 1918 the output had reached an average of 135,000 tons per month, at which figure it has since been maintained.

Early in 1917 the demands for blast-furnace linings, both for repairs and for new construction, caused some anxiety, largely because consumers would insist on having the products of a limited number of firms. The problem was immediately taken in hand, and special returns were procured of the output of, and of the orders placed for, blast-furnace bricks and blocks. New requirements were carefully examined and a source of supply indicated. By the end of the year the arrears had been overtaken, since when all demands have been met without difficulty.

The requirements of the by-product coking industry gave some trouble. Prior to the outbreak of war, there were few firms in this country capable of supplying a brick suitable for the inside walls of coke-ovens; and the unfortunate experiences of the past had made coke-oven builders chary of using any but proved materials. This tended to restrict the home supply, and before the war the majority of the oven wall bricks in use were obtained from Germany, Belgium and France. The programme for the erection of a large number of by-product coking plants (see p. 98) created a demand which the English makers were quite incapable of meeting, and this for some time caused serious delay in the erection of new plants. Special returns of orders and of production were called for from makers of coke-oven bricks, and steps were taken to ensure that the best quality of bricks were restricted to the vital parts of the ovens, the use of equally suitable, but inferior, qualities being enforced in the remainder of the plants. A system of priority was devised for all new construction, and firms, possessing clays suitable for coke-oven wall bricks, were induced to undertake their manufacture.

By these means the total output of coke-oven bricks was increased from approximately 3,000 tons per month in August, 1916, to 6,700 tons in July, 1917. Since then the output maintained a steady average of 6,000 tons per month, and all demands were overtaken.

GANISTER AND SILICA.

These refractories are in great need for steel-melting furnaces, as well as for non-ferrous furnaces, the combustion chambers of gas-retorts, etc.

The bulk of the goods are produced in South Yorkshire, Wales and Weardale, and to a smaller extent in Scotland. The South Wales manufacturers are fortunate in having ample supplies of high-grade silica-rock near at hand; while the South Yorkshire manufacturers have an excellent quality of ganister in the neighbourhood of their works. Owing, however, to a shortage of quarrymen the supply of Sheffield ganister was, early in the war, insufficient. It was sought to overcome this deficiency by grading and by mixing certain grades with a special stone quarried in North Yorkshire and North-west Durham, and as regards the quality of the material produced, the results were not unsatisfactory.

But the extensions to iron and steel works in progress in 1916 at length made the supply of high-grade silica goods totally inadequate, with consequent delay to construction; the maintenance of existing furnaces was even jeopardised, and this in some cases led to furnaces standing idle at a time when their output was most needed.

The total output of silica goods for July, 1916, with the works at their fullest capacity, was 7,966,000 "squares" of 9 in. × $4\frac{1}{2}$ in. × $2\frac{1}{2}$ in., an output by no means equal to the requirements. To cope with the position it was decided to allocate the entire output to the steel-makers in proportion to their needs, and to restrict the use of first-grade bricks to steel-melting furnaces engaged upon essential munitions work, and to the vital parts of copper-smelting furnaces and of glass-furnaces. The requirements of other furnaces were met by the use of second-quality bricks, of which there was at this stage no acute shortage.

At a meeting of the leading makers, held at the Ministry on the 8th of November, 1916, further measures were concerted for increasing the output; and, in spite of the continued shortage of labour, the output of silica- and ganister-bricks was by May, 1917, brought to a total of $10\frac{1}{2}$ million bricks per month, at which figure it was maintained until the end of November, 1917. During this period, provision had to be made not only for home requirements, but also for the needs of the Allies and of the new steel-works in India and Australia; and shipments were also being made to Sweden to assist works engaged in the manufacture of special steels to the order of the Allies.

Magnesite.

Prior to the outbreak of war, the magnesite-brick industry was almost wholly in the hands of the Austrians, who not only possessed in their own country extensive deposits peculiarly suited for brick-making, but had devoted both skill and money to the perfecting of their products, with the result that they commanded practically the entire custom of the steel trade of this country. One, or two, at the most, of the British manufacturers had made small quantities of bricks from magnesite imported from Greece, but with little success.

On the outbreak of war energetic measures were at once required to make up for the loss of the Austrian material and to ensure an adequate supply to the manufacturers of basic steel. Arrangements were therefore entered into with a number of makers for the manufacture of magnesite-bricks at an agreed selling price, subject to the Ministry arranging for the tonnage necessary for the shipment of the raw material to this country, the price being regulated from time to time in accordance with the c.i.f. cost of raw magnesite.

In the latter part of 1916 a great increase in the demand for magnesite-bricks and cement was foreshadowed by the plans formulated by the Home Ore Supply Committee for an increased manufacture of basic iron. The total requirements for the year 1917, so far as could be foreseen on 31st December, 1916, amounted in terms of raw magnesite to 102,000 tons. This amount was far greater than the consumption of any previous year.

CHAPTER XVI.

FORGINGS, CASTINGS AND DROP-STAMPINGS.

A Section to control forgings and drop-stampings was started in September, 1915, under Sir Alfred Herbert, Deputy-Director-General of the Machine Tool Department.

Early in 1917 the demand for forgings for guns and for Admiralty work became so acute that it was felt that some re-organization was necessary. The Gun Consultative Committee were anxious to increase the output of guns, and Sir John Hunter was asked to form an organization in connection with the Iron and Steel Department to deal with this work. As a result the Department of Forgings, Castings and Drop-Stampings came into being, and Mr. D. M. Anderson was appointed Controller.

The first difficulty that Mr. Anderson had to contend with was the absence of suitable plant in this country, since prior to the war the trade was, to a large extent, in the hands of the Germans, and many forges in this country had ceased to operate on account of the severity of competition. The armament firms of this country were mostly employed on high-class Admiralty work, and a large number of heavy forgings came from Germany. Mr. Anderson immediately took steps to bring existing plant up to date, and to erect new plant of a more modern design so as to eliminate, as far as possible, manual labour, and to provide facilities for the necessary heat-treatment. The Department was responsible for all types of forgings; and, in order to secure an equitable distribution among the different departments requiring them, a committee was formed, on which were representatives of the Admiralty, Merchant Shipping, the Air Ministry, and the departments dealing with railway materials, land and naval guns, etc. This committee advised as to the placing of the orders, and kept in touch with the manufacturers so as to ensure deliveries to date, as far as was possible in each case.

Later on the Department was extended to embrace steel castings, malleable iron and grey castings, and Commander A. E. Smithson was appointed Assistant-Controller for forgings, Mr. Ernest Wells, Assistant-Controller for castings, and Mr. A. Stubbs, Assistant-Controller for drop-stampings.

With regard to steel castings, it was found that the total capacity of the country was unable to meet the demand; consequently extensions to works and plant were made and improved methods of production established, especially in regard to repetition work, such as track-links for tanks (which were required at the rate of 75,000 per week), shells, agricultural machinery and miscellaneous repetition work. The supply of heavy castings for the stern-frames, rudders, etc., of battle-cruisers, destroyers and battleships, caused some trouble to the Department; but the necessary extensions to works were made, and ultimately the Department was able to meet all the calls made upon it. Large demands for steel castings came forward from Italy in connection with the merchant shipping programme of that country, and these were also met in due course.

With regard to malleable castings, the requirements of the army and the agricultural industry could not be met before existing works had been extended.

There was a big demand during the war for drop-stampings in connection with the production of aeroplanes, tanks, guns, shells, bombs, agricultural machinery, railway and other transport material. Before the war this was an industry employing about 4,000 hands. The increase of this number to over 12,000 during the war gave some difficulty, as it was necessary to train a large amount of unskilled labour. This was done partly by means of a Government instructional factory, partly by the goodwill of the stamping-firms throughout the country. The great majority of drop-stampings are made of high-class alloy steel, and require a thorough knowledge of heat-treatment. Notwithstanding the difficulties that had to be contended with, the Department was able to meet the whole of the demands of the increased programmes.

In order to co-ordinate supply and production, a Committee of representatives of the State departments concerned, together with representatives of the trade, was formed.

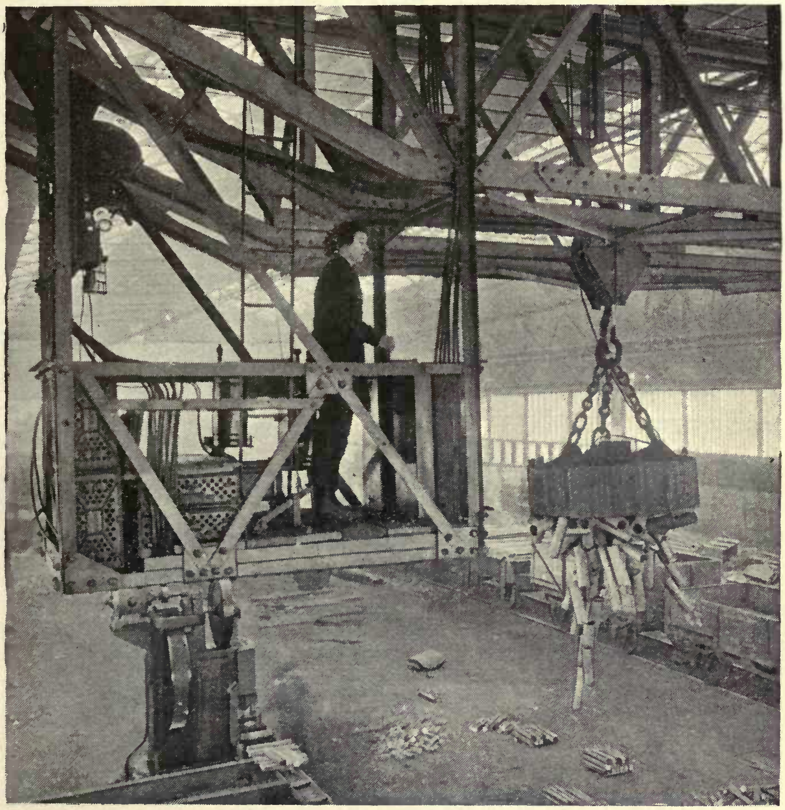


Fig. 17.—Electro-magnet in use at Messrs. Dorman, Long & Co.'s works at Middlesbrough.

The success of the Department as a whole was due to the fact that its technical staff was composed of men conversant with the respective trades, and able to tackle successfully the difficult problems as they arose. Much assistance was rendered by the forge-masters, the steel, iron and malleable iron-founders and the drop-forgers, who worked together with one end in view, namely, to increase the production of all the materials required. The new plant erected during the war will enable the firms to take on post-war work, and they should now be in a position to compete successfully with foreign countries.

CHAPTER XVII.

SUMMARY OF STATISTICS RELATIVE TO THE PRODUCTION OF RAW MATERIALS, PIG-IRON AND STEEL DURING THE WAR PERIOD.

In this chapter comparative statistics are given for the years 1913 to 1918 inclusive. They are grouped under: A, Semi-manufactured Materials; B, Raw Materials.

The semi-manufactured materials for which statistics are given comprise pig-iron and ingot-steel.

The raw materials for which statistics are given are:—

1. Iron ore: imports, production and ore available for consumption in British blast-furnaces.
2. Manganese ore: imports and production.
3. Coke: home consumption, exports and production.
4. Limestone: deliveries.
5. Refractory materials: imports and exports, production and consumption of magnesite, dolomite, magnesite-bricks, silica-bricks and fire-bricks.

A.—Semi-manufactured Materials.

1. *Steel.*

The following table gives the production of Steel Ingots and Castings in the United Kingdom since 1913.

The figures for the years 1913-1915 (inclusive) are taken from the Iron and Steel and Allied Trades Federation Statistical Report for 1917; those for the years 1916, 1917 and 1918 are compiled from returns made to the Ministry of Munitions.

PRODUCTION OF STEEL.

Year.	Acid.	Basic.	Total.
	Tons.	Tons.	Tons.
1913	4,860,154	2,803,722	7,663,876
1914	4,477,920	3,357,193	7,835,113
1915	4,912,160	3,637,855	8,550,015
1916	5,421,583	3,570,146	8,991,729
1917	5,673,150	4,043,394	9,716,544
1918	4,992,106	4,547,333	9,539,439

It will be seen that there was a considerable increase in total production. Since the beginning of 1917 the output of basic steel increased in conformity with that of basic pig-iron, while the output of acid steel fell off. This resulted from the increased use of home iron-ores. The rise in the output of basic steel from the first quarter of 1917, when the Home Ore Supply Committee was formed, was more than sufficient to off-set the fall in the output of acid steel. During the first half of 1918 the total production was at the rate of close on 10,000,000 tons per annum; but it fell off during the latter half of the year, owing to the recruitment of men from iron and steel works to supply the urgent need of the armies in the field. Of the total output of steel in 1916, 39·7 per cent. was basic; whereas in 1918 the proportion was 48 per cent.

2. *Pig-iron.*

The production of pig-iron in the United Kingdom since 1913 was as follows:—

PRODUCTION OF PIG-IRON.

Year.	Hematite.	Basic.	Forge and Foundry.	Alloys.	Total Pig-iron.
	Tons.	Tons.	Tons.	Tons.	Tons.
1913	3,604,823	2,529,800	3,801,547	324,145	10,260,315
1914	3,225,403	2,002,500	3,369,516	326,354	8,923,773
1915	3,564,276	2,272,684	2,701,215	255,484	8,793,659
1916	4,042,014	2,290,549	2,423,575	291,845	9,047,983
1917	3,921,927	2,722,791	2,378,870	298,190	9,321,778
1918	3,556,748	2,986,827	2,301,802	240,975	9,086,352

The figures for the years 1913 and 1916 (inclusive) are taken from the Iron and Steel and Allied Trades Federation Statistical Report for 1917 ; those for the years 1917 and 1918 are compiled from returns made to the Ministry of Munitions. It will be seen that there has been a steady increase in the total output of pig-iron since the beginning of 1916 up to the beginning of 1918, against a decrease in the output of hematite pig-iron since March, 1917. The increase is due to an augmented production of basic pig-iron, since the output of foundry and forge makes remained practically stationary.

B.—Raw Materials.

1. *Iron-ore.*

The imports of iron-ore into the United Kingdom since 1913, according to H.M. Customs returns, were as follows :—

IMPORTS OF IRON-ORE.

Year.	Manganiferous Iron Ores.	Other Iron Ores.	Total Imports.
	Tons.	Tons.	Tons.
1913	211,644	7,230,600	7,442,244
1914	165,493	5,539,255	5,704,748
1915	138,968	6,058,187	6,197,155
1916	81,992	6,823,944	6,905,936
1917	135,061	6,054,594	6,189,655
1918	123,606	6,442,254	6,565,860

Of these imports the bulk came from Spain and the Mediterranean and from Scandinavia. The proportions in which they were consigned from these countries is expressed in the following table :—

ORIGIN OF IMPORTED IRON-ORES.

	1913.	1914.	1915.	1916.	1917.	1918.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Spain and the Mediterranean	80·5	83	86	84	94	91
Scandinavia ...	11·5	11	12	15	5	8
Sundry... ...	8·0	6	2	1	1	1

Speaking generally, the imports from Scandinavia consist of magnetic ore, rich in phosphorus (1 per cent. and over), and in such ores the phosphorus is a valuable asset in connection with the production of basic slag. On the other hand the ores from Spain and the Mediterranean are as a rule hematites low in phosphorus. Some of the Spanish ore, however, falls into the phosphoric class. It is impossible to divide the imports sharply into the two classes of "phosphoric" and "non-phosphoric," since there are ores on the border line which, according to the needs of the ironmasters, are used sometimes for making hematite pig and sometimes for basic pig.

Of the manganiferous iron-ores—*i.e.*, ores containing less than 30 per cent. of manganese—95 per cent. come from the Mediterranean. They are imported for use in making spiegeleisen, and for mixing with other ores to produce special pig-irons.

The production of home iron-ores since 1913 has been as follows :—

PRODUCTION OF HOME IRON-ORES.

Year.	Hematite (Cumb. & Lancs.).	Phosphoric Iron-ores.	Total Outputs.
	Tons.	Tons.	Tons.
1913	1,767,088	14,230,240	15,997,328
1914	1,630,682	13,236,900	14,867,582
1915	1,656,494	12,578,518	14,235,012
1916	1,608,353	11,886,305	13,494,658
1917	1,586,429	13,441,473	15,027,902
1918	1,549,962	13,494,411	15,044,373

The figures for the years 1918 and 1917 are compiled from returns made direct to the Mining Section of the Iron and Steel Production Department of the Ministry by the mine and quarry owners. Those for the previous years are from Home Office returns.

The production of home iron-ore in 1917 shows an advance on the previous year of over $1\frac{1}{2}$ million tons. The increase was in the production of phosphoric ore, since the output of hematite decreased slightly in the same period.

The bulk of the increase was in the Midlands and was due to the more extended application of steam-shovels, transporters and other mechanical devices for uncovering, breaking and loading the ironstone. In the early part of the year 1918, 13,000 tons of ironstone from the North Lincolnshire, Northamptonshire and Oxfordshire districts, were being sent weekly to the Cleveland district and 5,000 tons to South Wales, special measures having been taken by the Transport Section of the Department to meet the heavy strain put thereby on the railway services.

During the first half of 1918 the increase was continued and, if maintained, would have brought 1918 on a level with the record year (1913). Unfortunately, the shortage in labour caused by the Army requirements and the sickness caused by two epidemics of influenza led to a serious falling off in output during the second half of the year, and the total production for the year was no better than that of 1917.

Iron-ore available for Blast-furnaces.—The following table gives for the years 1913–1914 the iron-ore available for consumption in British furnaces, *i.e.*, the total quantity of iron-ore, exclusive of scale, tap, cinder, etc. It is got by adding to the home production the imports and the production of "purple ore" (which is the residue of cupreous iron pyrites, calculated at 66·6 per cent. of the raw cupreous pyrites imported) and deducting the exports. The second table gives the ratio of imports, "purple ore" and home production to consumption.

ORE AVAILABLE FOR BRITISH FURNACES.

Year.	Imports.	"Purple Ore."	Home Production.	Exports.	Ore available for British Furnaces.
	Tons.	Tons.	Tons.	Tons.	Tons.
1913 ...	7,442,244	521,140	15,997,328	6,378	23,954,334
1914 ...	5,704,748	535,432	14,867,582	13,529	21,094,233
1915 ...	6,197,155	602,312	14,235,012	1,669	21,032,810
1916 ...	6,933,767	633,330	13,494,658	1,100	21,060,655
1917 ...	6,189,655	569,494	15,027,902	667	21,787,051
1918 ...	6,565,860	557,802	15,044,373	160	22,167,875

In the above table the figures for the imports and exports are from Board of Trade returns; those for the home production, up to the year 1916 (inclusive), are from Home Office returns, and since that date from returns made to the Ministry of Munitions. The figures for "purple ore" are calculated from Board of Trade returns for imported raw cupreous pyrites. It will be seen from this table that the iron-ore available for consumption during 1918 was at a higher rate than any previous year during the war.

TONNAGE PERCENTAGES.

Year.	Imports.	"Purple Ore."	Home Production.	Ore available for Consumption.
	Per cent.	Per cent.	Per cent.	Per cent.
1913 ...	31·0	2·2	66·8	100
1914 ...	27·0	2·5	70·5	100
1915 ...	29·5	2·8	67·7	100
1916 ...	32·8	3·0	64·2	100
1917 ...	28·4	2·6	69·0	100
1918 ...	29·6	2·5	67·9	100

This table gives the proportion of the ore available for consumption attributable to each source. On account of the disparity of the iron-content of these different ores, the importance of the home sources as regards iron production is less than it would appear to be. Thus the ratio of imports, "purple ore" and home ores, worked out on an average metallic iron content of 50 per cent. for imported ores, 63 per cent. for "purple ore," and 30 per cent. for home ores, is for 1918 as follows:—

Imported ores	40.3
Purple ore	4.4
Home ores	55.3
	100.0

In other words, the iron yield of the home ores was in 1918 not much more than half the total yield from all ores. In this calculation no account is taken of the iron recovered from scrap, cinder, etc., which is, of course, a very important factor in the iron-smelting of this country.

2. *Manganese Ore.*

Manganese ores, properly so-called, contain not less than 45 per cent. of manganese; but inferior grades, containing down to 25 per cent. manganese, have been mined in this country during the war.

The imports and home production of manganese ores since 1913 have been as follows:—

IMPORTS AND PRODUCTION OF MANGANESE ORES.

Year.	Imports.	Production.	Total (representing Consumption).
	Tons.	Tons.	Tons.
1913	601,177	5,393	606,570
1914	479,435	3,437	482,872
1915	372,724	4,640	377,364
1916	440,659	5,140	445,799
1917	331,264	13,094	344,358
1918	365,606	14,942	380,548

The figures for the imports are from Board of Trade returns; those for the home production to the year 1916 (inclusive) from Home Office returns, and since that date from returns made to the Ministry of Munitions.

Before the war, imports came mainly from India, Russia and Brazil in the following proportions (1914): India, 47 per cent.; Russia, 37 per cent.; Brazil, 10 per cent.; and other countries, 6 per cent. Since 1914 they have been drawn almost entirely from India. In 1917 shipments were commenced from Sekondi on the West Coast of Africa. Amounting to only one per cent. of the total importation in that year they were four per cent. in the first half of 1918, and by the month of August, had grown to about 15 per cent.

The home production in 1917 showed an increase of 155 per cent. on that of the previous year, and in 1918 there was a further increase of 25 per cent. on the 1917 figures. This augmentation of home production was brought about by the

Ministry in order to relieve, as far as possible, the stringency in importation caused by the want of ship tonnage. The manganese mines of the United Kingdom are confined to North Wales (Merionethshire and Carnarvonshire), where the ores consist of mixed silicate and carbonate, in part changed to the richer oxides near the surface.

Of the 1917 consumption, 85 per cent. went to the makers of ferro-manganese, the remaining 15 per cent. being used in connection with basic pig manufacture.

3. *Coke.*

The production, home consumption and export of metallurgical coke since 1914 has been as follows :—

Year.	Home Consumption.	Export.	Production.
	Tons.	Tons.	Tons.
1914	—	—	11,050,256
1915	11,515,312	621,533	12,136,845
1916	12,291,992	1,130,203	13,422,195
1917	12,922,896	878,711	13,801,607
1918	12,666,775	634,773	13,301,548

The high figures for export are due to the war demands of the Allies, a large quantity of coke having been exported to France and Italy for foundry purposes, which, before the war was furnished by Belgium and Germany. France had to draw still more largely on this country in 1916, owing to the loss of the coke-ovens in the Pas de Calais coalfield. Since the beginning of 1917, however, the French demands have been reduced owing to her increased production.

The rise in home consumption is accounted for by the greater number of blast-furnaces put into operation in the United Kingdom. In 1917 blast-furnace requirements amounted to 79 per cent. of the output; 6 per cent. was exported, the remaining 15 per cent. being used for miscellaneous purposes, such as foundry work, and in the manufacture of high-speed steel.

Of the total production of metallurgical coke, 80 per cent. was furnished by by-product ovens, together with benzol, sulphate of ammonia and crude tar. The coal required for the manufacture of metallurgical coke was 22,000,000 tons per annum. Under the programme for increasing the output of steel to 12,000,000 tons per annum, large additional quantities will be required. The additional by-product ovens, which it is proposed under this programme to provide, will ultimately place the total production of metallurgical coke in this country on the basis of 16½ million tons per annum. The use of 8¼ million tons more coal, representing the work of 33,000 coal miners, will be entailed.

4. *Limestone.*

Previous to the last quarter of 1917, the Ministry kept no record of the deliveries to, and the stocks kept at, blast-furnaces.

The returns for 1918 show a consumption in blast-furnaces of 4⅓ million tons per annum, thus :—

	Tons.
Deliveries to works	4,364,734
Added to stocks at works	43,270
Consumption in blast-furnaces ...	4,321,464

5. *Refractory Materials.*

The raw refractory materials used in steel-making consist of magnesite, dolomite, ganister and fire-clay. The first named is imported from abroad (Greece or India), while the others are produced in this country.

Magnesite is used for the manufacture of magnesite bricks for the lining of basic steel furnaces. Dolomite in the calcined ("shrunk") state is termed "basic material," and before being used to form the hearths of basic steel-furnaces is ground and mixed with dehydrated tar. Ganister goes to make the silica-bricks required for the construction of acid steel-furnaces and converters, while fire-clay is used for making fire-bricks.

The imports of magnesite for the years 1917 and 1918 are as follows :—

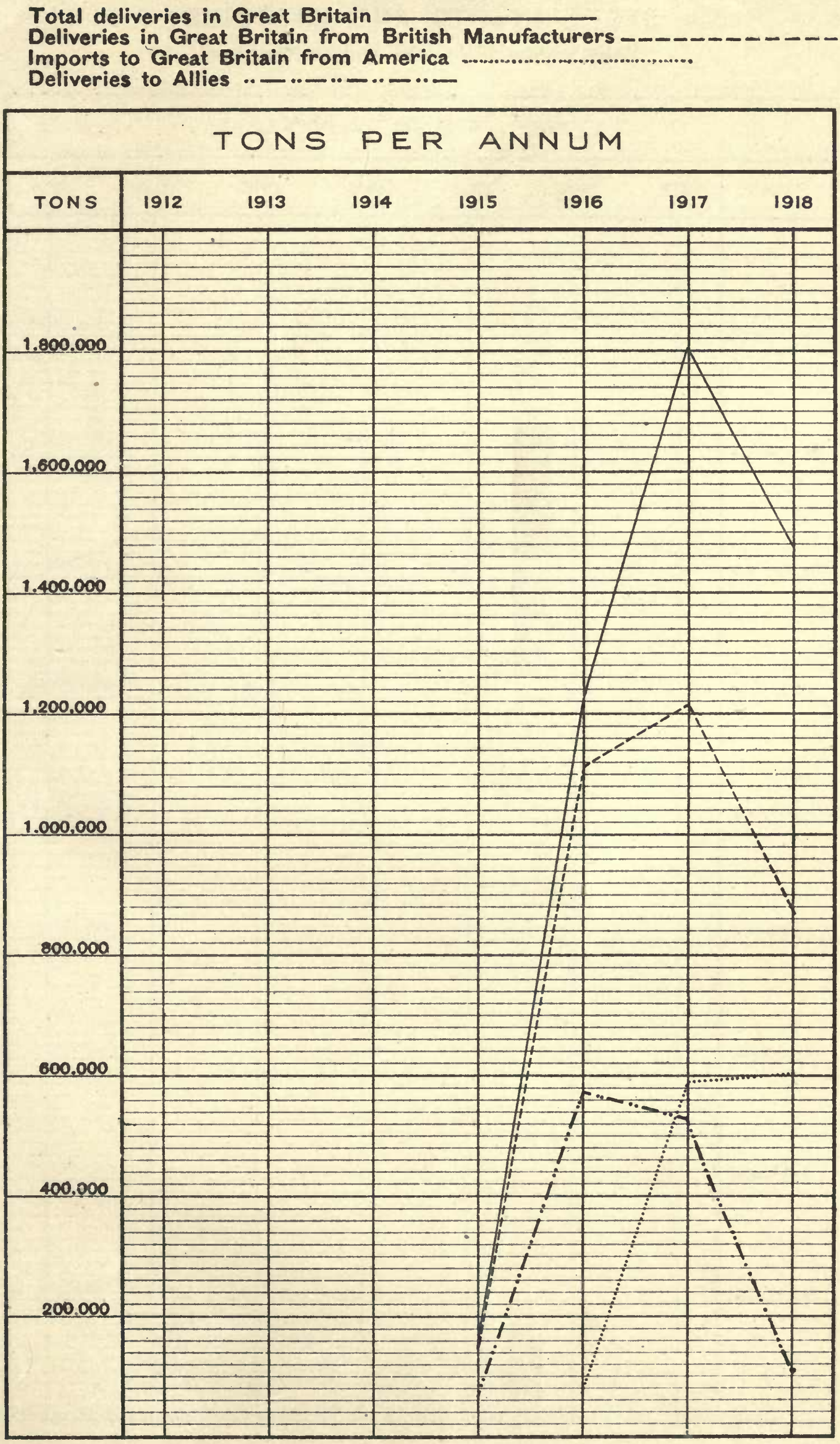
	1917. Tons.	1918. Tons.
Raw magnesite	65,369	39,930
Caustic calcined magnesite...	4,570	1,424
Hard burnt magnesite ...	4,454	Nil
Dead burnt magnesite ...	6,414	447
Total equivalent raw ...	95,045	43,672

APPENDIX II.

Graphs showing the Production during the war period of Shell Steel, Steel Ingots and Castings, Acid Steel, Basic Steel, Total Pig Iron, Hematite Pig Iron, Basic Pig Iron, Forge and Foundry Iron, Ferro-Alloys, Iron Ore, Manganese Ore and Metallurgical Coke.

Also the Imports into the United Kingdom of Iron Ore and Manganese Ore ; and the Consumption in the United Kingdom of Iron Ore, Manganese Ore, and Metallurgical Coke.

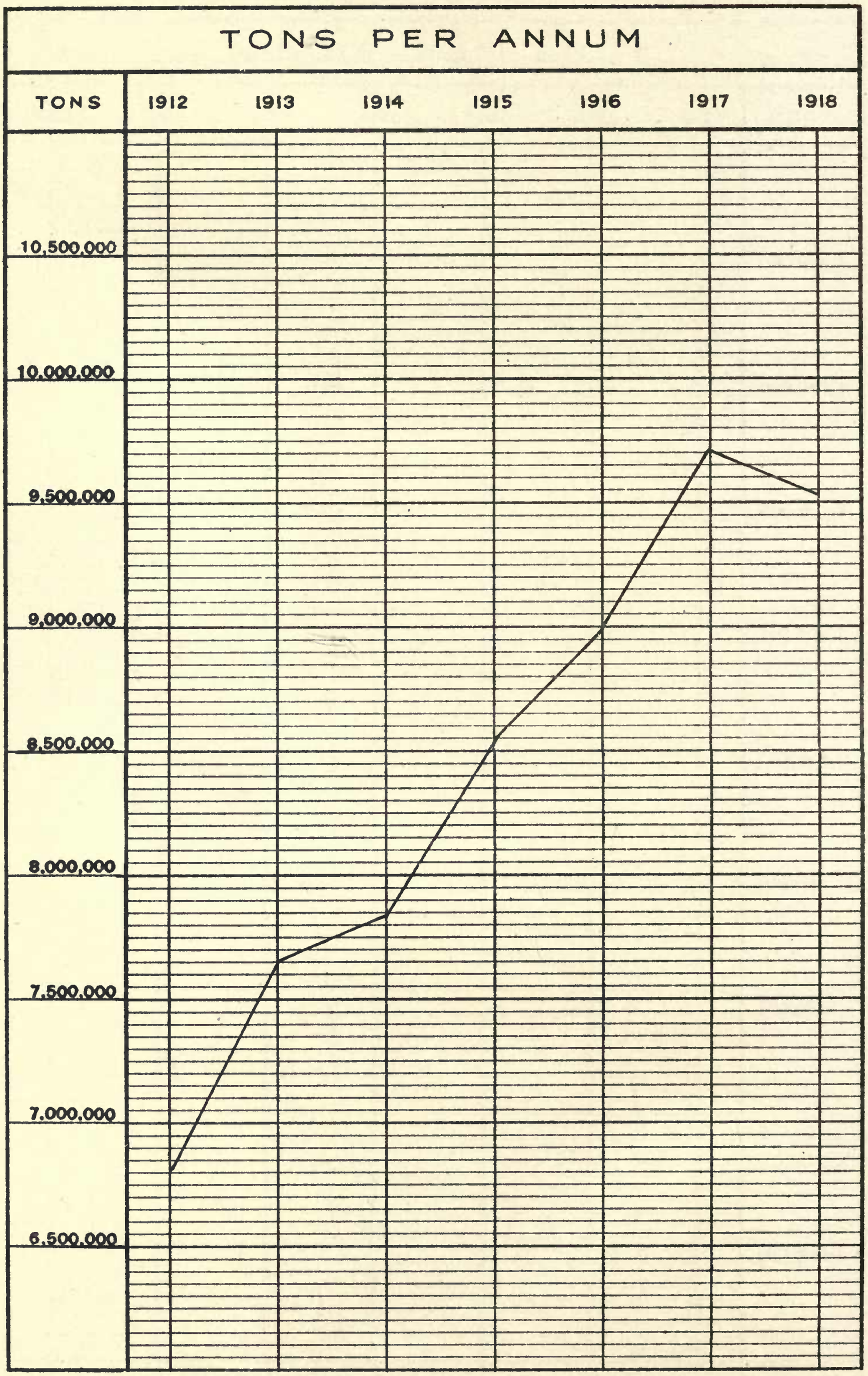
DELIVERIES OF SHELL STEEL



Iron and Steel Industry: F. H. Hatch.

STEEL INGOTS AND CASTINGS

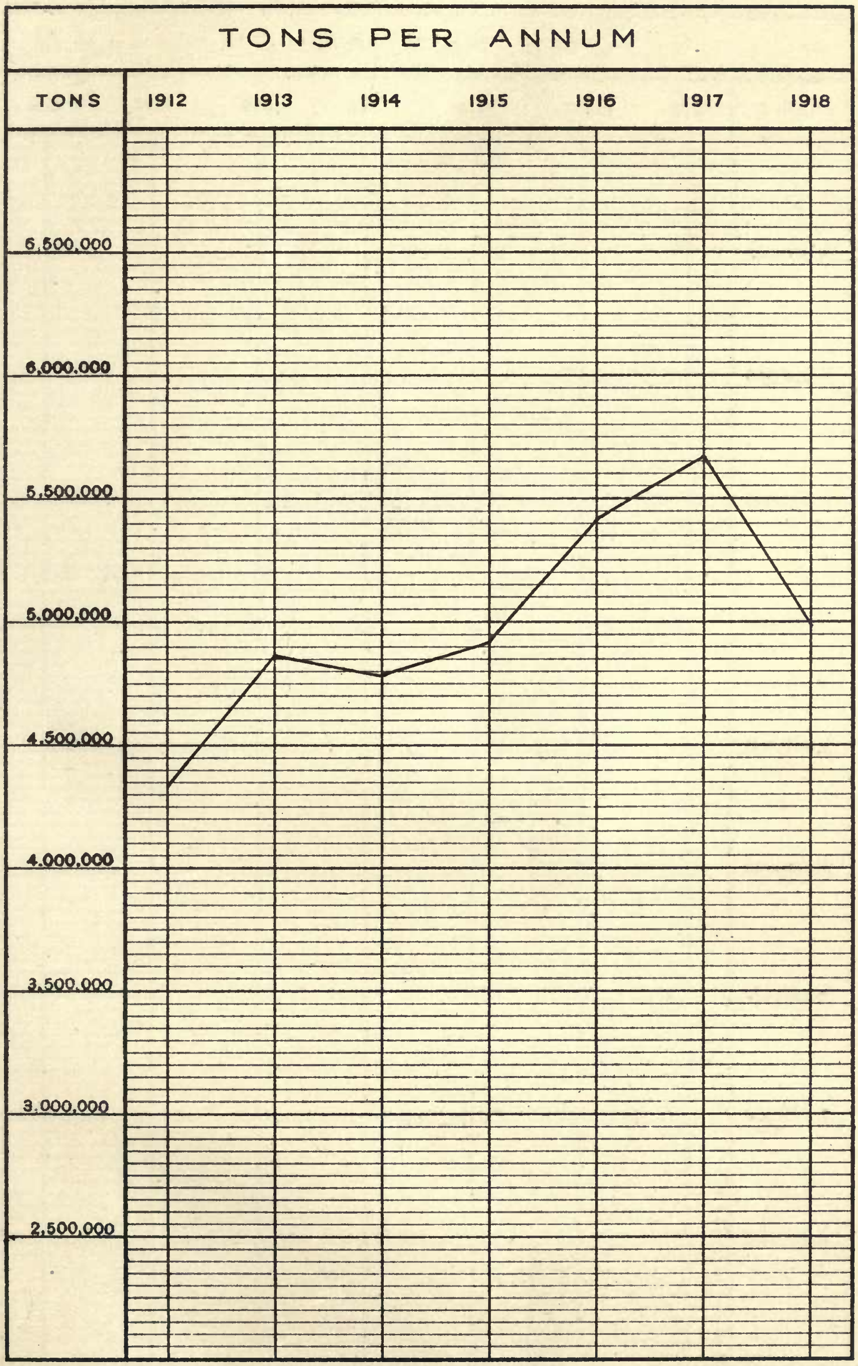
Total production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

ACID STEEL

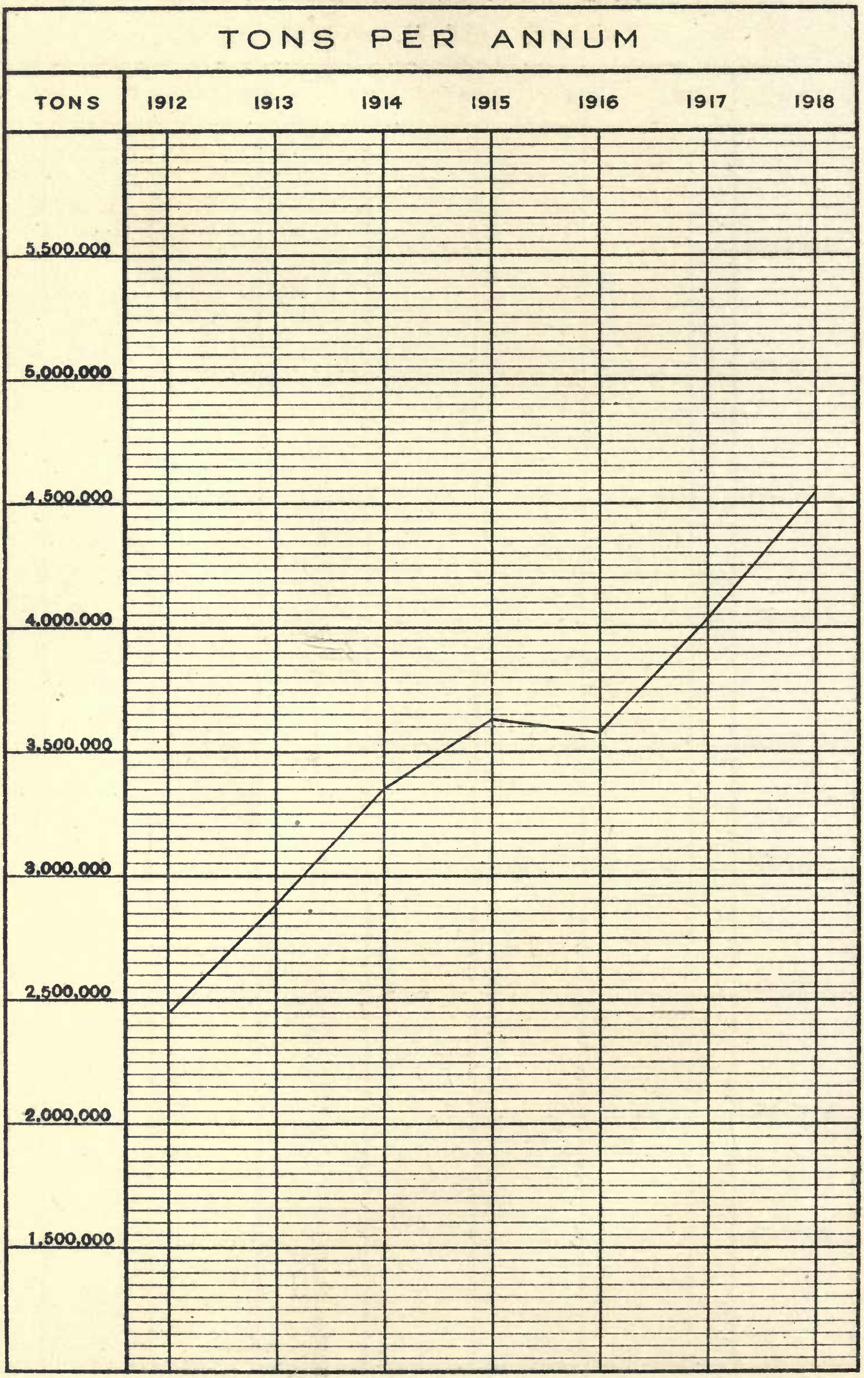
Production in the United Kingdom



Iron and Steel Industry : F. H. Hatch.

BASIC STEEL

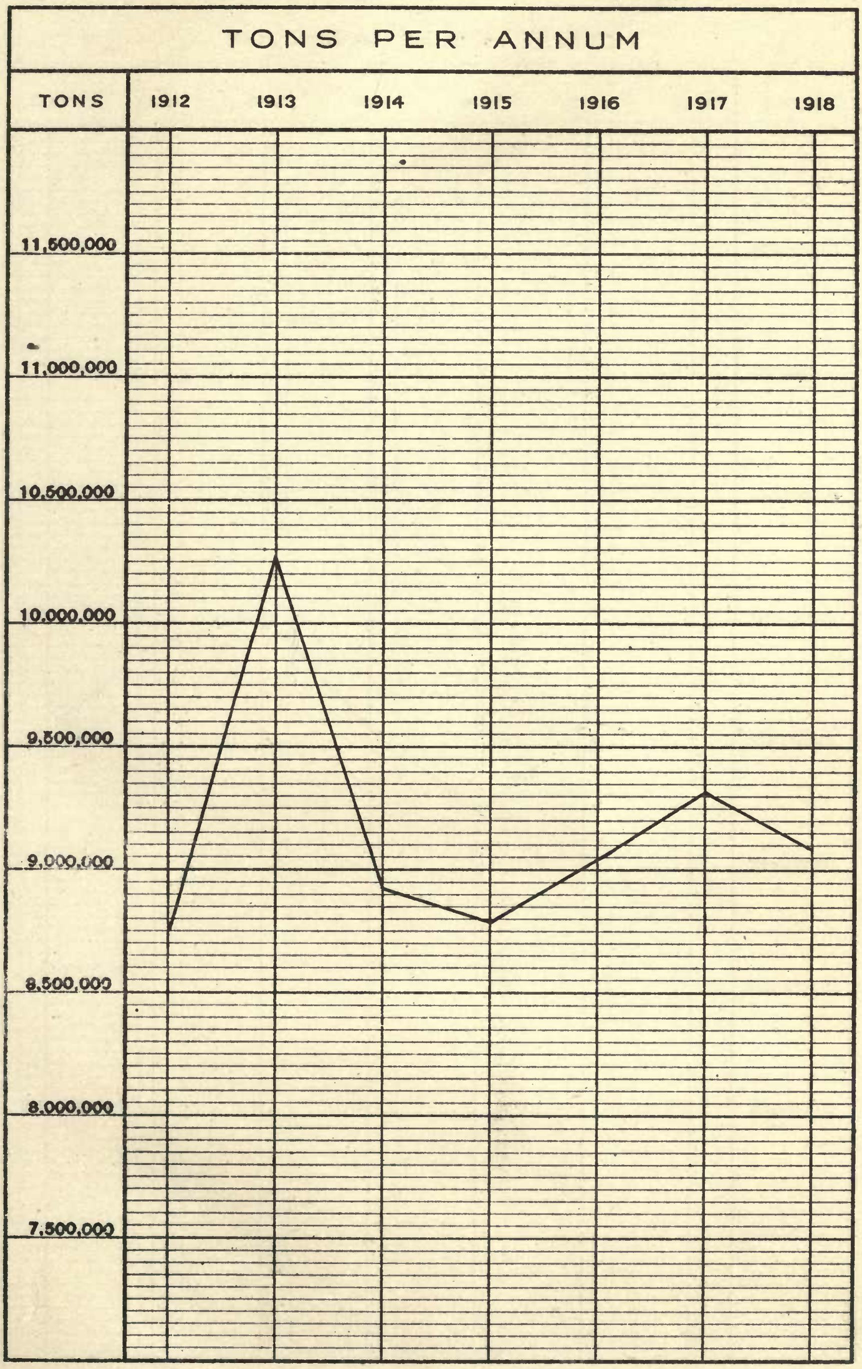
Production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

PIG IRON

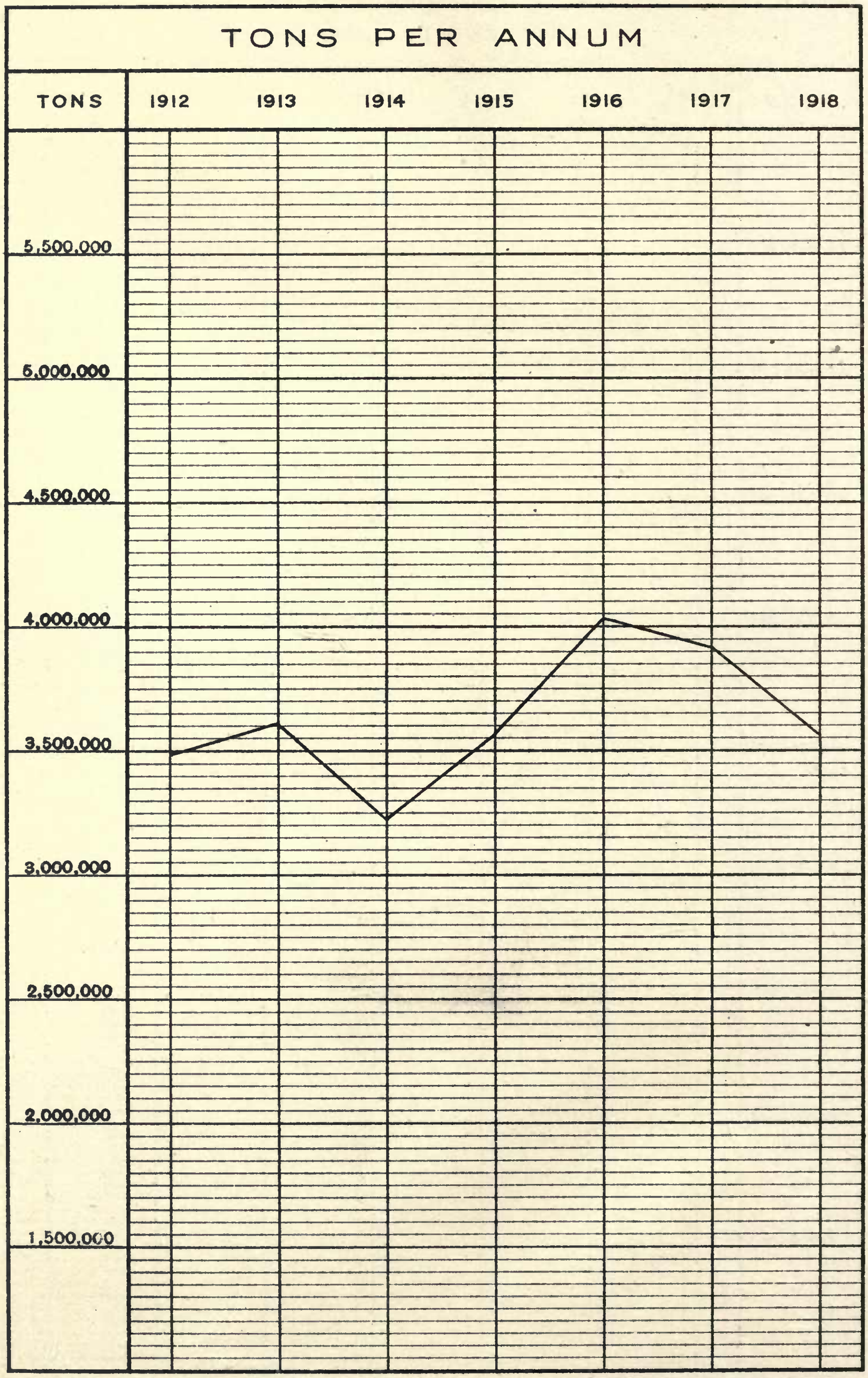
Total production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

HEMATITE PIG IRON

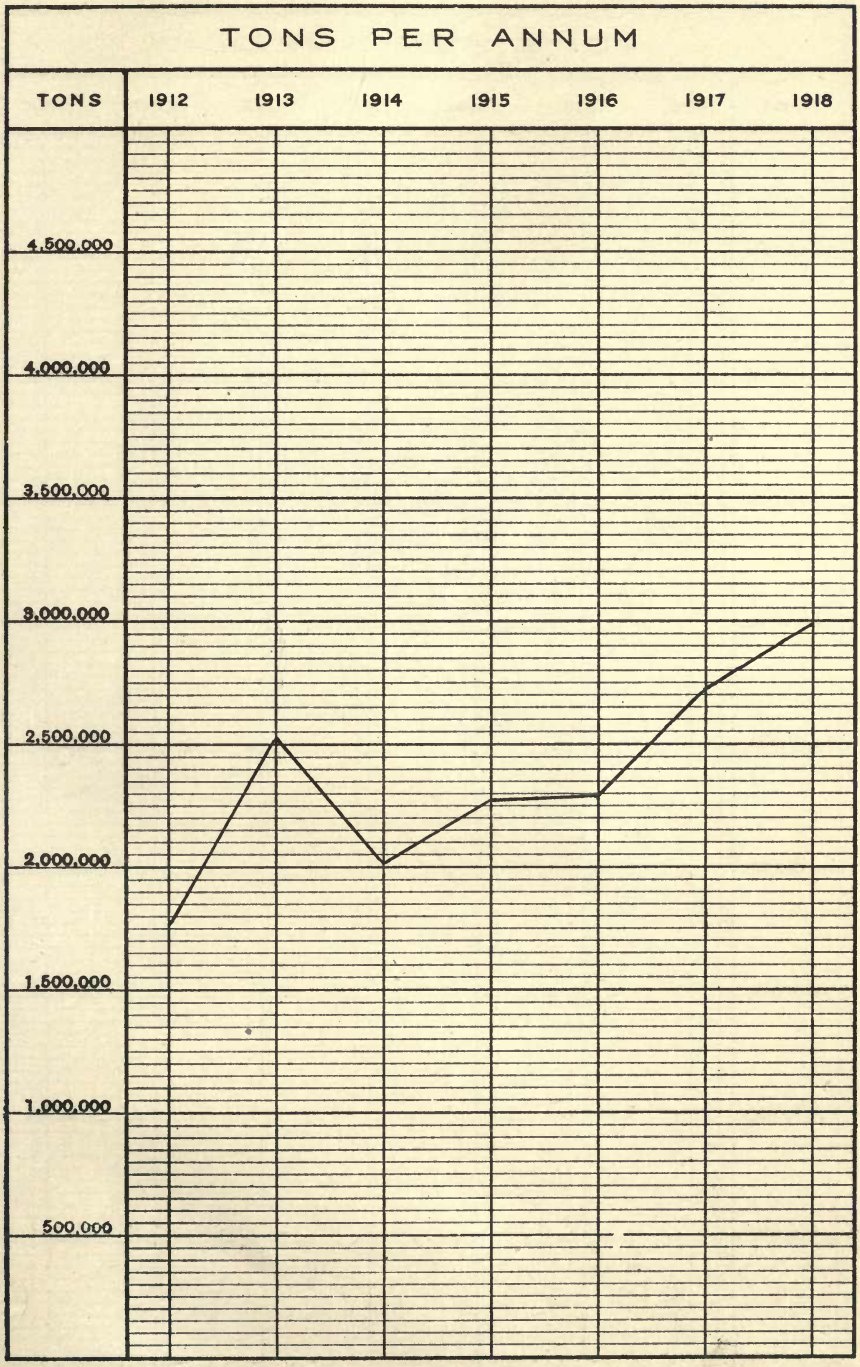
Production in the United Kingdom



Iron and Steel Industry : F. H. Hatch.

BASIC PIG IRON

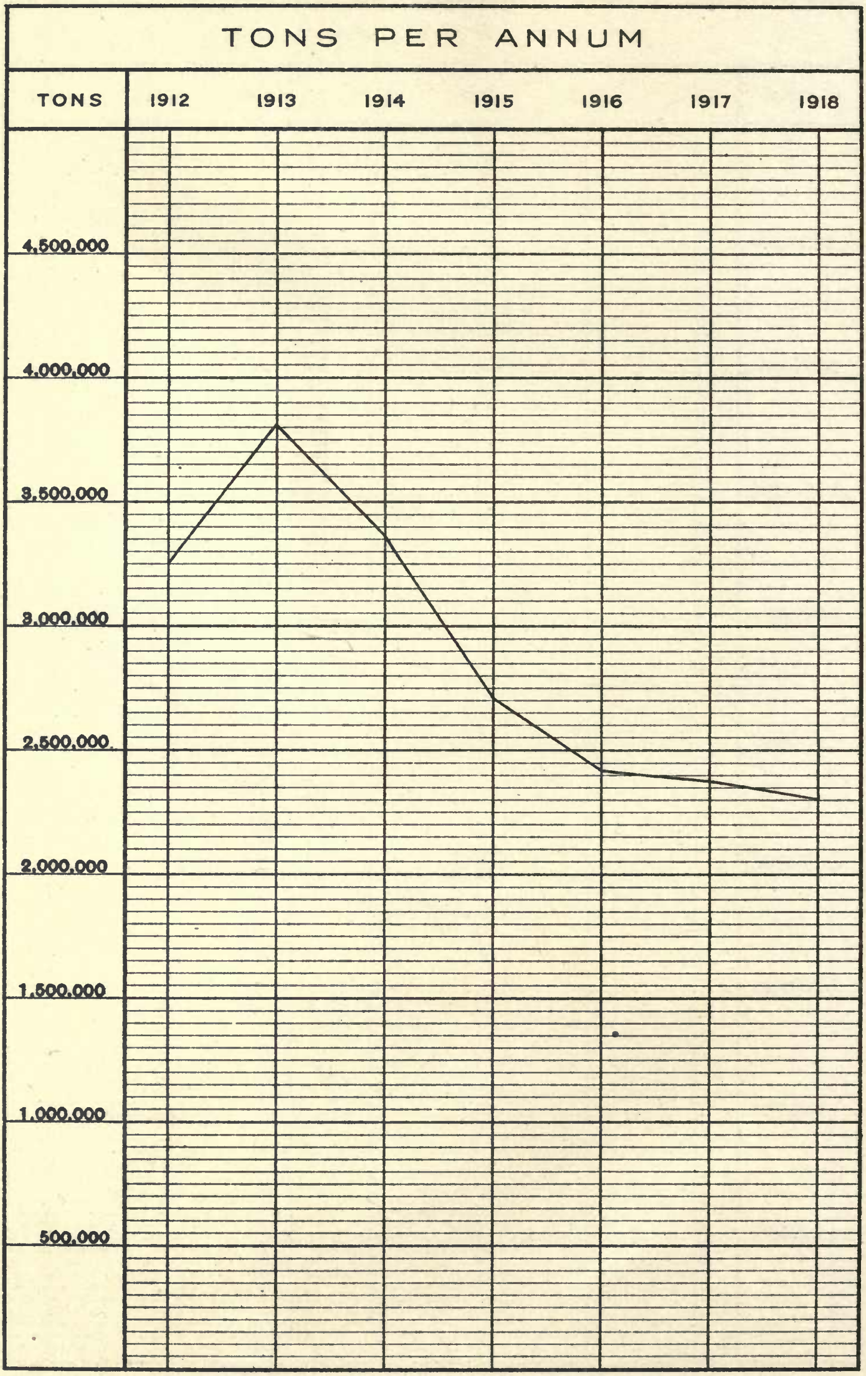
Production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

FORGE AND FOUNDRY IRON

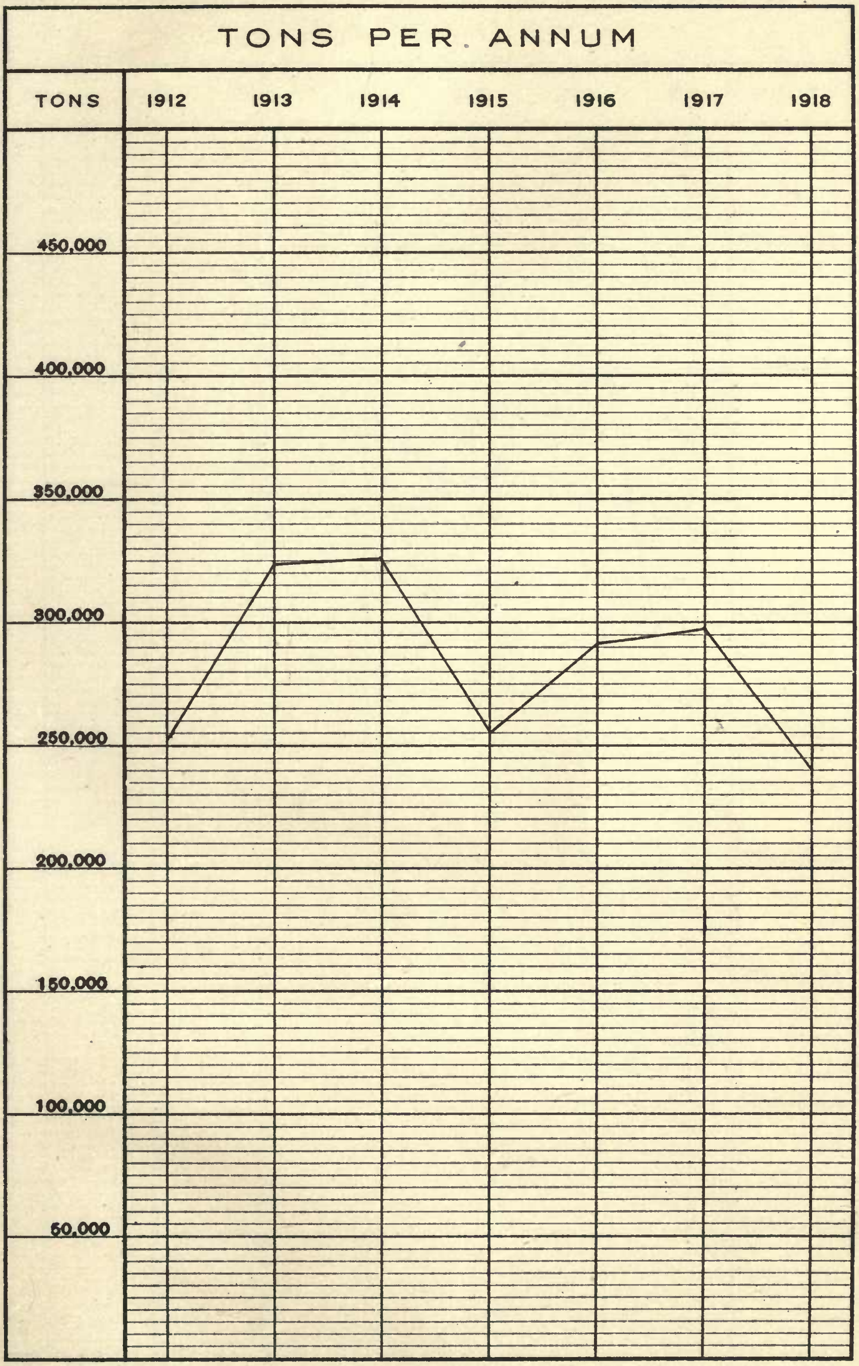
Production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

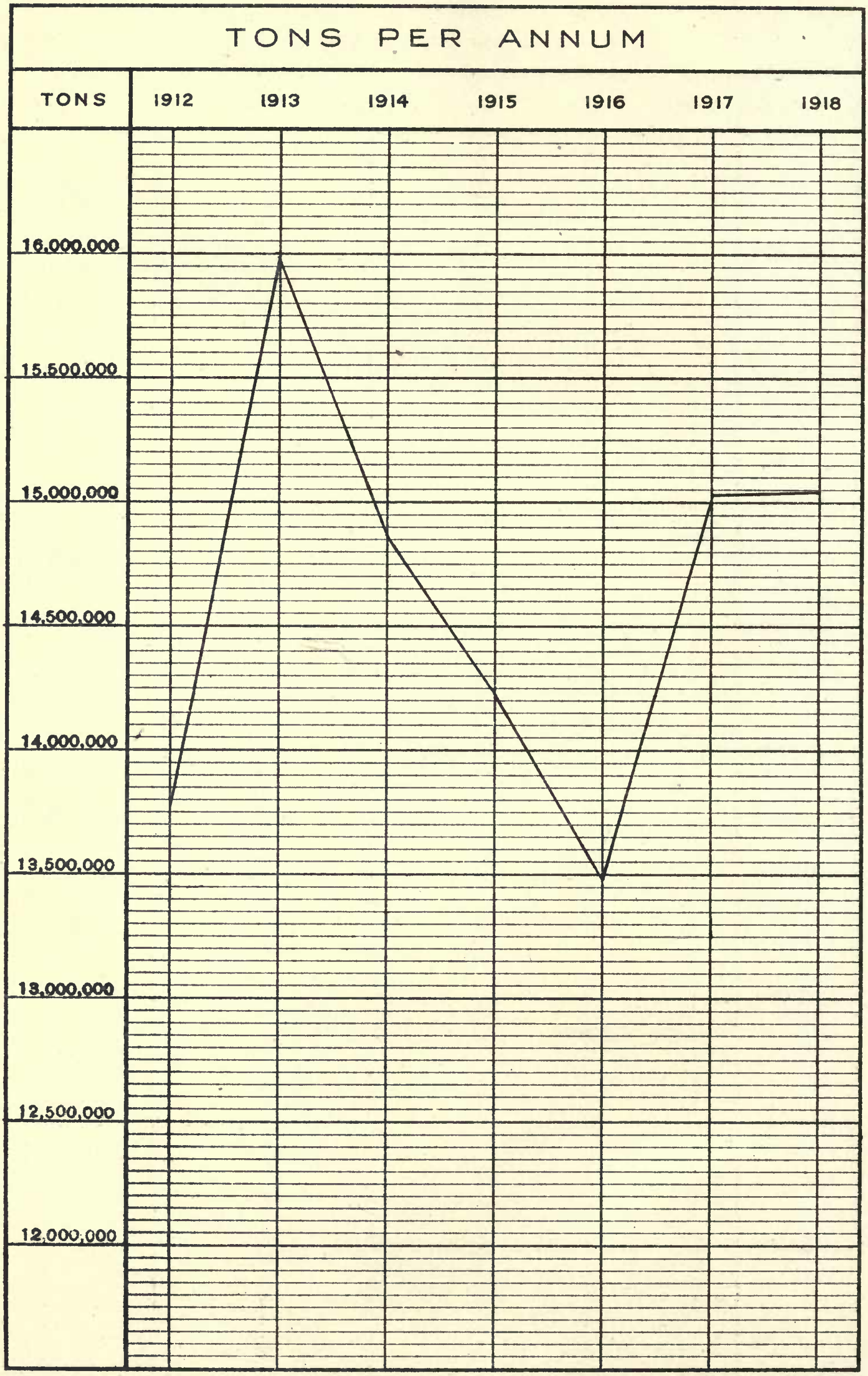
FERRO-ALLOYS

Production in the United Kingdom



IRON ORE

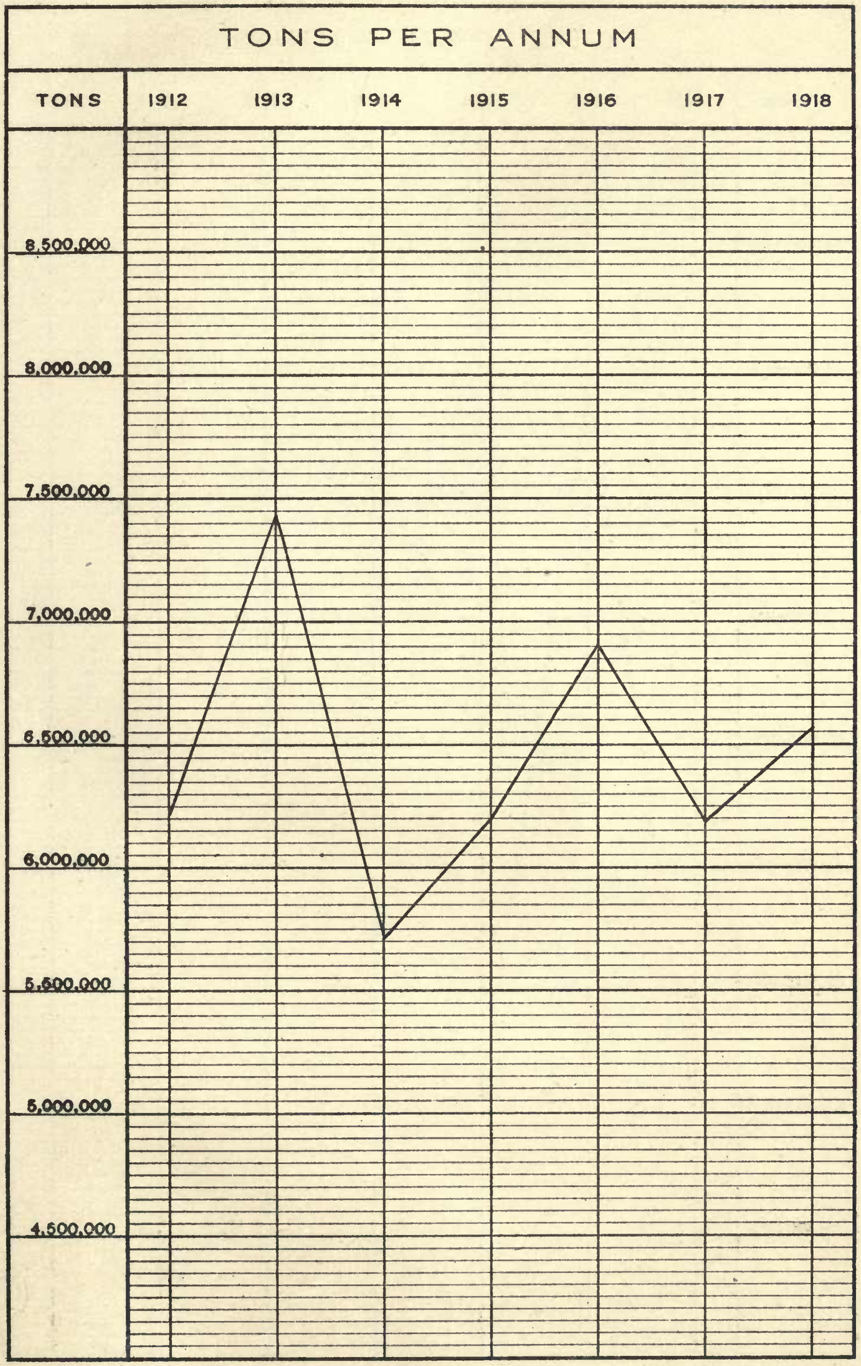
Total production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

IRON ORE

Imports into the United Kingdom



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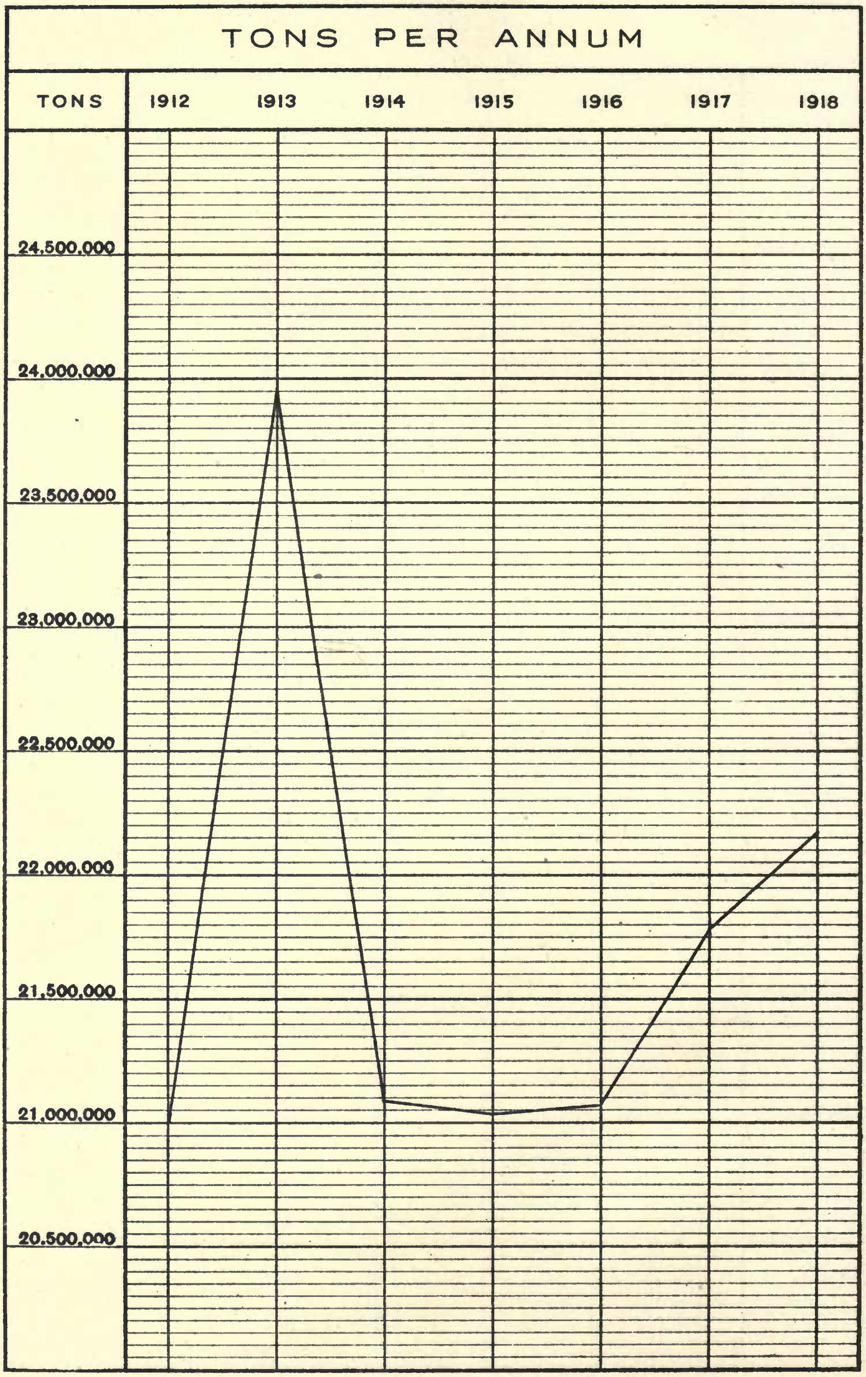
IRON ORE

Consumption in the United Kingdom



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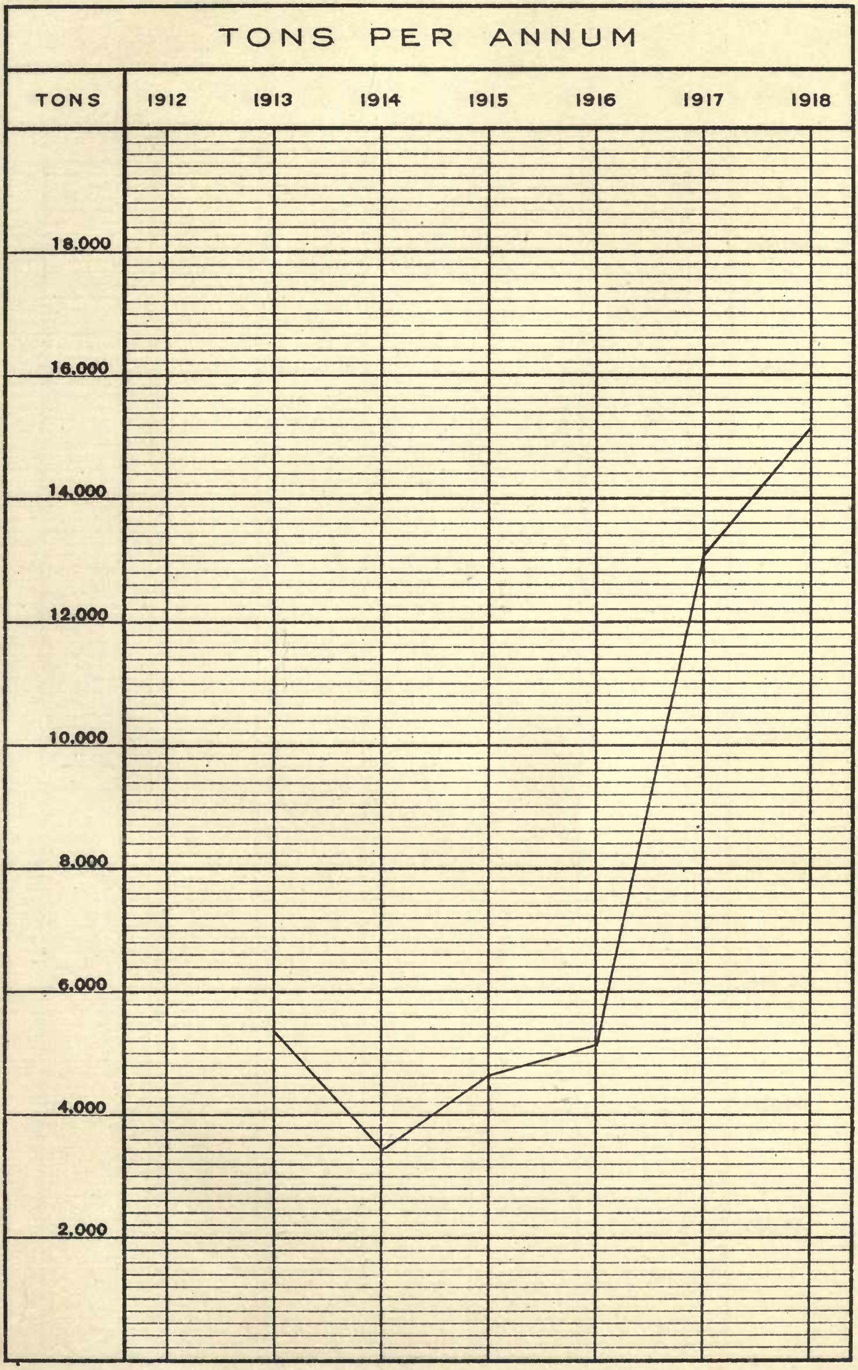
MANGANESE ORE

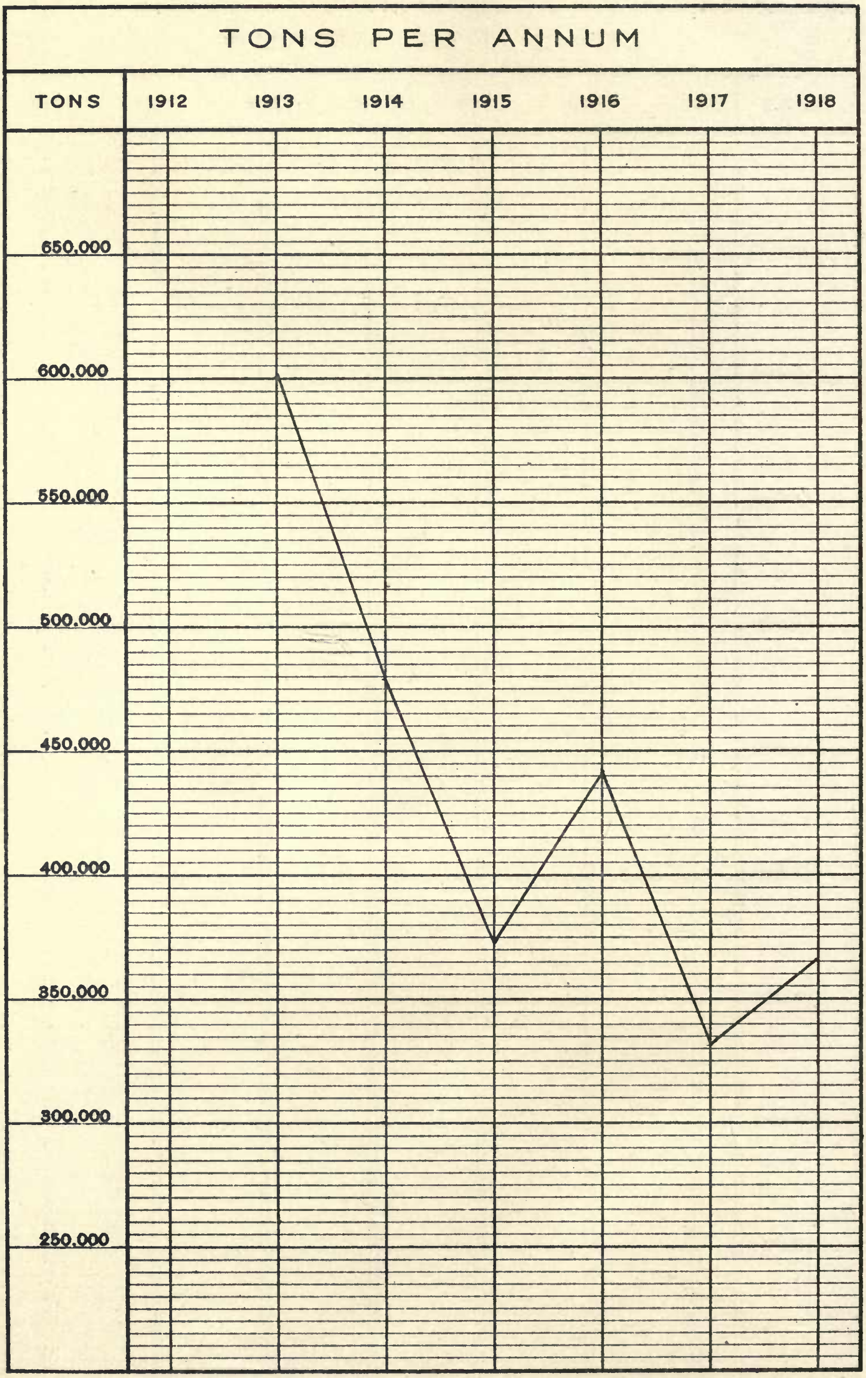
Production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

MANGANESE ORE

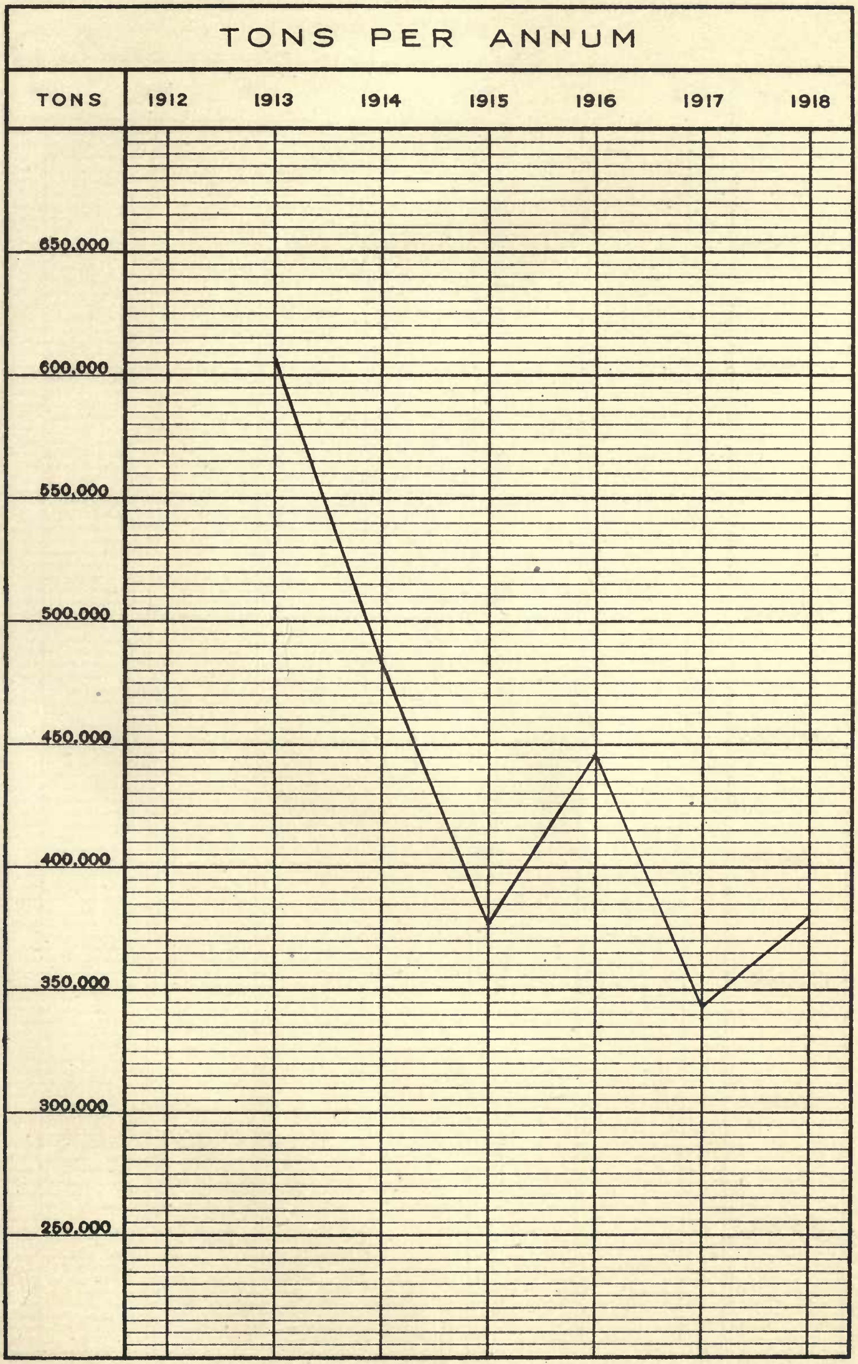
Imports into the United Kingdom



Iron and Steel Industry: F. H. Hatch.

MANGANESE ORE

Consumption in the United Kingdom



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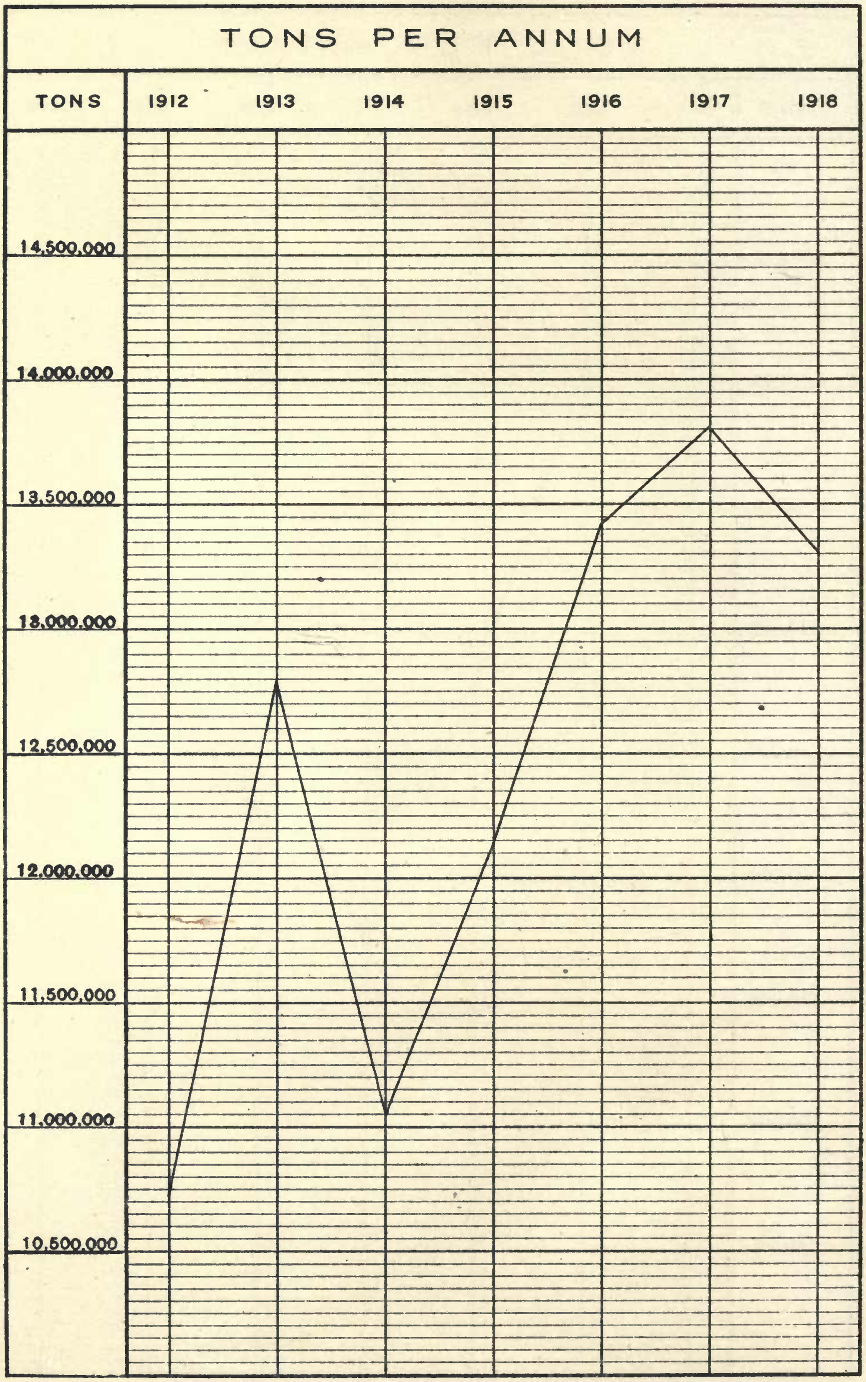
METALLURGICAL COKE

Production in the United Kingdom



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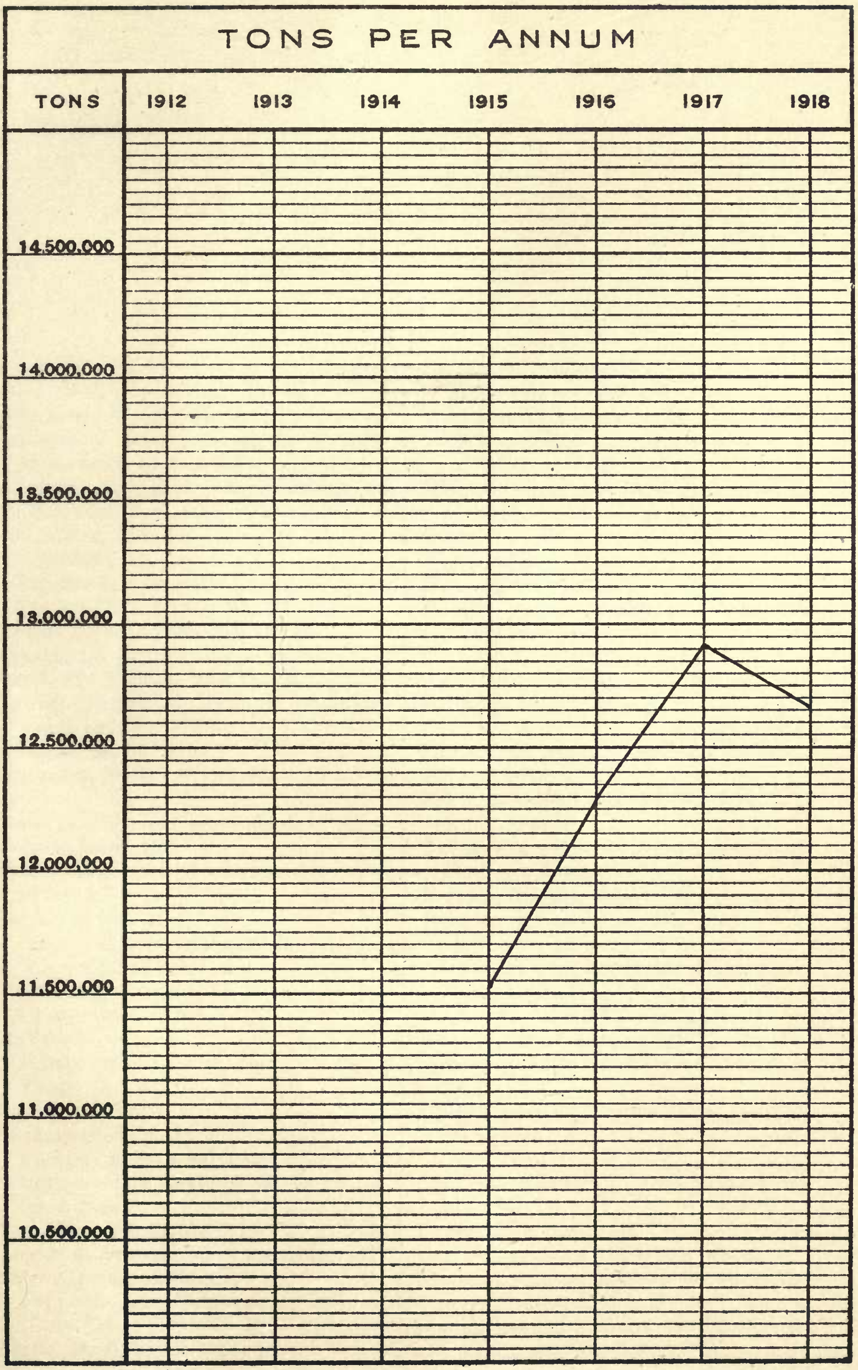
METALLURGICAL COKE

Consumption in the United Kingdom



Iron and Steel Industry: F. H. Hatch.