SULPHURIC ACID DURING THE WAR.*

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Sulphuric acid may be said to be the life-blood of an industrial nation in times of peace and in times of war the first essential for the manufacture of explosives. During the late Great War the manufacture of sulphuric acid in sufficient quantities and of suitable strength occupied the serious attention of every belligerent country. In the present paper an endeavour has been made to show how the problem was dealt with in this country, with the resultant effects on dependent industries; the figures given are published with the consent of the Ministry of Munitions, in whose service they were mostly compiled. In regard to many of the pre-war figures and of those of 1914 and 1915, it has only been possible to compile an estimate on the best information obtainable; these figures are given in brackets, and should be taken as approximate estimates only. The general position of the sulphuric acid and fertiliser trades has already been dealt with in the Report of the Departmental Committee published by the Board of Trade in February, 1919 (*cf.* J., 1919, 90 n).

During the winter of 1915-16 the following main lines of policy were adopted:—(1) That, wherever possible, the use of sulphuric acid should be partially or wholly replaced by suitable substitutes, such as nitre cake. (2) That sulphate of ammonia, which was being used for the manufacture of ammonium nitrate, should be replaced as far as possible by concentrated ammonia-liquor, thus reducing the amount of sulphate of ammonia manufactured and liberating a corresponding amount of sulphuric acid. (3) That recovery of waste sulphuric acid at explosives works should be insisted upon, and that as far as possible the recovered acid should be again used in the manufacture of further quantities of explosives.

(1) The substitution of nitre cake for sulphuric acid was, in itself, almost a romance of the Department, and is specially dealt with in a paper published in the *Society's Journal* (Dec. 15, 1920, 407 n). (2) There was very little plant in the country for producing a quality of concentrated ammonia-liquor of about 25% strength which was reasonably free from sulphides and carbonates, and which was suitable for use in the ammonia-soda process for the production of ammonium nitrate. Therefore new plant had to be erected for the production of such liquor at various coke ovens, gas works and chemical works. At a later date, when the Swindon factory came into operation, the crystallisation process adopted there necessitated the use of ammonium sulphate as such, and consequently the supply of concentrated ammonia-liquor which was foreshadowed in 1916 had to be curtailed and replaced by ammonium sulphate, with the result that the full saving of sulphuric acid contemplated was not attained. (3) Steps were taken to have the necessary recovery-plant erected at all explosives manufacturers' works, and during the whole of 1916 such construction was being carried out, with the result that the over-all requirements of sulphuric acid for the manufacture of explosives, including that used for the nitric acid required, were eventually reduced per lb. of explosive manufactured to less than one-half of that used during 1915.

Below is set out in tabular form the over-all figures of sulphuric-acid production, etc. during the years 1915-1918. The production of oleum is given in terms of 100% sulphuric acid produced

from the raw materials, namely, pyrites and sulphur, used on the contact plants, and does not include any acid brought in from outside sources for strengthening-up on such plants. Practically the whole of this fuming acid or oleum was used in the manufacture of explosives.

Summary of Production and Utilisation of Sulphuric Acid

(In terms of 100 per cent. H_2SO_4).

Tons.

	(1915).	1916.	1917.	1918.
Production by contact plant—				
Govt. factories ..	(—)	42,177	138,850	112,178
Trade ..	(33,445)	63,496	82,227	64,405
Total ..	(33,445)	105,673	221,080	166,643
Imports ..	(31,332)	5,716	1,790	—
Production in chamber-acid plant ..	(1,050,000)	1,208,275	1,160,789	964,158
Total available ..	(1,114,777)	1,319,664	1,383,665	1,130,801
Quantity of chamber acid used to manufacture concentrated acid (10% loss allowed in process) ..	(123,500)	371,710	375,517	204,814
Concentrated acid production (from chamber acid plant) ..	(111,150)	334,540	337,965	184,333
* Used as follows: For explosives ..	(36,150)	258,540	274,680	130,114
For trade ..	(75,000)	76,000	63,276	54,219

* A sharp division between explosives and trade is extremely difficult to make, but the figures given are substantially correct.

In the summer of 1917, the continued submarine menace made it imperative to take a careful survey of the raw materials required for the manufacture of sulphuric acid, and from that time forward the supplies of pyrites and spent oxide were brought directly under Government control. Sulphur supplies from abroad were under direct control by the Government throughout the war.

Sulphur Pyrites.

Tons.

	1914.	1915.	1916.	1917.	1918.
Shipments to United Kingdom ..	781,000	1,008,000	909,000	925,000	800,000
Home-mined, including coal brassy.	(0,000)	(0,000)	(6,000)	7,000	21,000
Consumption for acid-manufacture	(800,000)	(800,000)	(922,000)	(871,000)	744,000
Stock in United Kingdom, Dec. 31 (in acid-works and stores)	(150,000)	(250,000)	(200,000)	333,000	436,000

Pyrites, the main raw material for the manufacture of sulphuric acid in the United Kingdom, represents about six-sevenths of the sulphur-material required in this industry, and prior to the war was chiefly imported in a form containing 1-3 per cent. of copper. The burnt residues from pyrites, known as "purple ore," were passed on to copper-extraction works where the copper was extracted and the resultant product rendered suitable for use in blast furnaces. This product is commonly known in the trade as "Blue Billy." It was considered necessary to build up a reserve of this essential raw material for possible use by our Allies as well as by this country, and during the years

* From a paper read before the Manchester Section on April 1, 1921.

1915—1916 shipments of pyrites were greatly increased over pre-war figures. In order to obtain these increased supplies, certain stocks of pyrites from which the copper had been extracted, commonly known as "washed pyrites," were brought into this country.

It has been impossible to obtain complete data of the quantity of sulphur pyrites actually imported during the war period for acid-manufacture alone, as considerable shipments had been arranged for on behalf of the copper-smelting industry, and consequently in the above table the shipments to the United Kingdom during the years 1915—1916 include certain quantities of pyrites of which there is no exact record of use.

Pyrites Cinders.—The pyrites, after being burnt in the sulphur-furnaces as a raw material for the manufacture of acid, gives residual pyrites cinders of about 70—72% of the original weight, and it was found that the total capacity of copper-extraction plants in the United Kingdom was sufficient to deal with 550,000 tons of pyrites cinders per annum; of this plant slightly more than one-half was located in acid manufacturers' works and the remainder at plants belonging to owners of pyrites mines. In addition to the copper-extraction works, it was found that there was crushing and briquetting plant at various blast-furnace works in the country capable of dealing with 200,000 tons per annum of pyrites cinders or iron ores, but the high sulphur content of the untreated pyrites cinders made it impossible to utilise the bulk of this plant for their treatment.

Below is briefly set out a statement for the years 1917 and 1918 of the production and use of pyrites cinders in the United Kingdom:—

	Tons.	
	1917.	1918.
Pyrites cinders produced—		
Cupreous	—	386,000
Non-cupreous	609,000	130,000
Total	609,000	516,000
Pyrites cinders delivered for use in blast furnaces—		
From copper-extraction plants—		
Briquettes	208,000	208,000
"Blue Billy"	272,000	211,000
	480,000	419,000
Non-cupreous pyrites cinders delivered direct to iron works	45,000	66,000
Total to iron works	525,000	485,000
Stocks of pyrites cinders at acid-makers' works on December 31—		
Cupreous	153,000	130,000
Non-cupreous	90,000	101,000
Total	252,000	234,000

The above figures do not include quantities delivered under contract to sintering plants, as these were not in operation.

Spent oxide is the material resulting from the purification of coal gas with hydrated oxide of iron, and after repeated use and aeration a material re-

sults containing approximately 50% of free sulphur. The country was divided into various districts and careful stock accounts were kept and particulars obtained of the receipts and use of this material; these particulars are briefly summarised in the following table:—

Area.	Stock.	(January, 1918, to May, 1919.)			Stock.
	Jan. 1, 1918.	Received.	Used.	Delivered.	May 31, 1919.
A.	676	5,328	4,905	—	1,099
B.	2,062	5,018	6,077	—	1,003
C.	5,526	18,747	17,201	307	6,585
D.	7,010	48,550	46,968	—	8,592
E.	2,250	8,383	8,733	—	1,900
F.	1,153	6,099	6,649	—	603
G.	4,711	9,829	12,343	—	2,197
H.	23,453	40,778	42,934	2,183	28,114
England Total	46,841	151,732	154,900	2,580	50,093
Scotland	287	2,372	2,250	—	409
Ireland	737	1,816	2,069	—	484
Grand total	47,865	155,920	159,219	2,580	50,986

The somewhat heavy rise in stocks during 1917 and 1918 was due to the fact that concentrated ammonia-liquor was manufactured at some of the larger gas works which normally consume spent oxide for the production of sulphuric acid required for the manufacture of sulphate of ammonia. The consequent reduction in output of sulphate of ammonia at these works considerably reduced the quantity of sulphuric acid made during these two years, and led to a decreased consumption of spent oxide.

Sulphur.—A certain amount of sulphur is produced in this country from the Chance-Claus recovery-plant, and as this supply was mainly used for industrial purposes other than acid manufacture, it was not seriously interfered with.

The following table shows approximate quantities of sulphur used during the five years, together with the quantities imported by the Department and stocks:—

Imported Sulphur for Acid-Manufacture.

	Tons.				
	1914.	1915.	1916.	1917.	1918.
Imports (Government)	Nil	5,700	34,200	52,600	67,800
Used for acid-manufacture	(3,000)	(4,000)	(6,400)	44,000	34,200
Stocks, Dec. 31, in Government stores and at acid works	(1,000)	6,000	29,000	20,000	51,000

Sulphuric Acid from Chamber-Acid Plant.

The pre-war production of sulphuric acid in chamber-acid plant was approximately 1 million tons per annum (calculated as 100% acid), and during the years 1915 and 1916 it was necessary to work

Spent Oxide.

	Tons.					
	1914.	1915.	1916.	1917.	1918.	1919 (Jan. to May, 5 months.)
Received at works	105,000	110,000	119,200	145,000	107,900	48,013
Consumption	108,000	111,000	127,000	119,900	106,100	45,292
Stock at works Dec. 31	31,000	80,000	22,200	47,900	40,700	50,986 (May 31)

available plant in order to obtain the maximum output. In addition, further acid-plant was arranged for by private manufacturers, and during 1916 the demands for acid were only just met by the plant then in existence. It is usual each year for acid-manufacturers to repair and renew portions of the acid-plant in the country during the summer months, when the requirements of sulphuric acid for sulphate of ammonia and superphosphate fall to a minimum.

The chamber-acid plant of the country in March, 1917, comprised 169 separate works owned by 130 different firms, and the approximate number of chambers actually in use or under construction or repair was 1081; there were 353 Glover towers and 425 Gay Lussac towers. At that time the chamber-space per lb. of sulphur consumed per 24 hours averaged 16·5 cb. ft. for the whole country. In March, 1917, when the chamber-acid plant of the country reached its highest production the output obtained during that month represented an annual production of 1,307,000 tons. The demand for sulphuric acid for the manufacture of explosives fell most heavily on the private manufacturers during the year 1916, and the chief difficulty encountered was in providing the national factories and other explosives manufacturers with sufficient concentrated acid, pending the completion of the Government and other oleum-plant then in course of erection.

Sulphuric Acid from Chamber-Plant in terms of 100% H₂SO₄.

Summary of Uses.

	Tons.			
	1916.	1917.	1918.	1919 (5 mths.).
Explosives ..	352,131	337,765	152,193	5,712
Dyes ..	17,736	9,888	9,143	5,207
Accumulators ..	2,606	3,145	3,075	822
Alum ..	24,854	24,406	26,184	11,233
Bichromates ..	8,433	5,710	5,316	1,863
Bleaching powder ..	70,413	50,302	50,694	10,471
Copper and copper pickling ..	3,360	2,702	1,339	380
Copper sulphate ..	21,705	27,032	30,424	9,540
Drugs and fine chemicals ..	3,098	4,479	4,225	1,308
General chemicals ..	9,203	9,217	9,024	3,734
Chemical warfare ..	39	1,122	1,678	93
Hydrochloric acid ..	71,872	53,510	52,227	26,105
Iron pickling ..	54,523	28,864	28,840	25,400
Metal trades, other than copper and iron ..	3,615	3,263	2,396	1,318
Mineral waters ..	2,421	490	391	1,884
Oil-refining ..	23,600	17,022	14,840	7,238
Paints and anti-mony colours ..	4,081	3,667	3,684	1,340
Sewage ..	442	307	723	1,613
Soap and glycerin ..	2,608	4,060	3,560	1,006
Sugar-refining ..	925	1,051	1,067	517
Sulphate of ammonia ..	253,340	230,145	231,092	116,144
Sulphates of magnesium and zinc ..	8,347	9,235	8,339	2,783
Sulphites and phosphates ..	10,717	11,009	12,504	5,015
Sundries ..	6,639	5,501	6,006	2,677
Superphosphates & compound manures ..	169,730	212,209	270,597	144,747
Tar ..	13,704	14,946	13,897	3,683
Textile industries ..	23,211	15,987	13,323	13,484
Totals ..	1,163,533	1,080,894	957,381	406,220

In the above table the quantities of acid used for oleum-feed, nitric acid and synthetic phenol, have been grouped together under the term "explosives" as it was found difficult to discriminate in certain factories between the quantities used for these purposes and those used directly in the manufacture of explosives.

The figures given are for deliveries and have, therefore, been influenced by action in regard to restriction of use and replacement, wherever

possible, by nitric cake. The figures given for the first five months of the year 1919 show the transition that is occurring to normal practice.

The plants in use for concentration of chamber acid in the United Kingdom prior to the war were mainly of the Kessler type, with a few exceptions, where silica cascade concentrators or Gaillard towers were used. Owing to the fact that the French Government was also faced with a similar problem, viz., the necessity of producing quickly large quantities of concentrated sulphuric acid, it was found impossible to obtain the volvic stones required for building further Kessler plant in this country. It was, therefore, decided during the winter of 1915-16, and from that time onwards, to erect plant of the cascade type which could be erected in a few months and be put quickly into operation. At a later date, when experience had been gained with brick substitutes for volvic stones, erection of Kessler plant and Gaillard towers was undertaken, but during the most difficult period of 1916 the production of concentrated acid was mainly obtained from cascade concentrators, and reached the substantial figures of 334,000 tons in 1916 and 333,000 tons in 1917.

Provision had been made for further extensions of the explosives' programme and plant was in existence for producing still further quantities of concentrated sulphuric acid. During February, 1917, the output of this acid reached approximately 9,000 tons per week at acid-manufacturers' works, which represents an annual output of 460,000 tons, and had it been necessary at any time further to increase this output, plant erected after that date would probably have been capable of maintaining an annual output of 500,000 tons. In order to arrange for supplies of sulphuric acid to meet the many essential requirements in addition to those for the manufacture of explosives, it was found necessary to ascertain the exact purposes for which all sulphuric acid was used, and in the following table is set out, in a summarised form, the chief industries in which sulphuric acid was consumed during the years 1916-1918, and also during the first five months of 1919. Owing to the fact that the control of fertiliser-production did not cease until May 31, 1919, it was found essential to continue the control of sulphuric-acid manufacture and use until that date.

Fuming Acid or Oleum.

Particulars of the production and main uses are set out below, the figures given for consumption by trade being mainly of oleum used in the production of dyes, fine chemicals and in oil-refining.

Oleum (20% free SO₂).

	Tons.			
	1916.	1917.	1918.	1919 (Jan. to May incl.).
Production ..	183,000	367,000	288,000	7,500
Imports ..	6,500	1,500	—	—
Total ..	189,500	368,500	288,000	7,500
Consumption—				
For explosives ..	170,000	352,000	270,500	—
" trade ..	6,500	11,000	18,000	12,000*
" export ..	—	—	1,000	—
Total ..	186,500	363,000	295,500	12,000
Stocks on Dec. 31..	11,000	10,500	9,000	4,500 (May 31)

* No separate data available.

It should be noted that in the above table the quantities given are inclusive of feed-acid used, and therefore do not represent the acid made on contact-plant from raw materials only.

The number of contact-acid plants in the country capable of producing oleum prior to the war was extremely limited, but many plants were erected at private manufacturers' works during the war period, and, in addition, the sulphuric-acid plant erected by Government was entirely of this type. Before the war, it is estimated that the plant capacity existing in the United Kingdom for oleum containing 20% free SO_2 was about 25,000–30,000 tons per annum, whereas on December 31, 1918, it is estimated that the output capacity was 450,000 tons per annum, of which approximately 300,000 tons was represented by Government plant. Throughout the war it was found necessary to increase largely the output of this fuming acid by feeding the plant with concentrated acid made at chamber-acid works, so that the total production of this class of acid includes a certain quantity produced in the ordinary chamber-plant and concentrated for feed purposes.

CONSUMPTION OF SULPHURIC ACID FOR EXPLOSIVES MANUFACTURE.

During 1915 the demands for explosives compelled the various contractors to increase their output at almost any cost, and consequently throughout that year it was impossible to effect any great economies by recovery of waste sulphuric acid, where plant for this purpose was not already in existence. There were no exact data of the consumption of sulphuric acid for the manufacture of high explosives during 1915, but it has been estimated from such data as are available that it could not have been less than from 5–6 lb. of 100% acid per lb. of high explosive produced.

The figures given below represent the average consumption of sulphuric acid at all explosives manufacturers' works, including Government fac-

ories, during the various periods, and although it was impossible to obtain accurate data from the different contractors' works of the stocks of acid in cycle of operation, yet over the periods given, which represent practically three-monthly periods, these fluctuations in stock acids for the whole country do not appreciably affect the results. It will be seen that there was a general progress towards increased efficiency. This increased efficiency was assisted by improvements in working nitric-acid plant, as the consumption of sulphuric acid for the manufacture of the necessary nitric acid is included in the figures given in the following table, where such nitric acid is necessary in the manufacture of the particular explosive. There is no doubt that the national factories assisted greatly in effecting the economies here represented, as they were conducted from the start on the basis of full recovery of waste acid, and valuable assistance was given to the various contractors in the form of technical data which were made available for the use of the various private manufacturers.

Nitric Acid.—During the war the quantity of nitric acid used for general trade—other than for the manufacture of explosives—did not change materially, and during 1917 and 1918 the requirements for this purpose remained steady at about 1000 tons per month, of which rather more than one-half was used in the manufacture of dyestuffs.

During 1917 efforts were made to increase efficiency in the use of nitrate of soda and nitric acid in the manufacture of sulphuric acid. It was found during 1918, for which year alone complete data are available, that 15,800 tons of nitrate of soda and nitric acid expressed in terms of 95% nitrate of soda was used in the production of 961,000 tons of 100% sulphuric acid, or approximately 36·7 lb. of nitrate per ton of 100% acid made.

100% Sulphuric Acid Consumption per lb. of Explosives made 1916, 1917, 1918.

	1916.			1917.				1918.		
	March to June.	July to Sept.	Oct. to Dec.	Jan. to March.	April to June.	July to Sept.	Oct. to Dec.	Jan. to March.	April to June.	July to Nov.
All acid expressed as 100% H_2SO_4 .										
TNT— Sulphuric acid, including oleum and that used for nitric acid expressed as 100% H_2SO_4 , deducting acid re-concentrated	4·36	3·13	3·04	2·75	2·23	2·24	2·08	2·20	1·96	1·78
Picric acid from phenol— Sulphuric acid for sulphonation, deducting acid re-concentrated	1·93	1·81	1·79	1·50	1·46	1·34	1·26	0·78	0·58	0·57
Sulphuric acid, including that for sulphonation and nitric acid, and deducting quantity re-concentrated	4·75	4·44	4·39	4·18	4·01	3·66	3·66	3·10	2·64	2·66
Picric acid from DNP— Sulphuric acid, including that for nitration and nitric acid and deducting acid re-concentrated	2·90	2·40	2·07	2·58	2·00	2·14	1·90	2·44	1·85	—
Synthetic phenol— Sulphuric acid consumption, including oleum	4·55	3·90	3·49	3·35	3·21	3·08	3·12	2·86	2·30	2·42
Propellants (nitro-glycerin, gun-cotton, etc.) Sulphuric acid, including oleum and that used for nitric acid, deducting quantity re-concentrated	No data	2·20	2·14	1·94	1·71	1·70	1·64	1·51	1·45	1·55

Nitric Acid (as 100% HNO_3).

	Tons.					
	1914.	1915.	1916.	1917.	1918.	1919 (Jan. to May incl.).
Production	16800	85,000	172,500	237,000	158,000	5,000
Factor—Sulphuric acid used	(1·5)	(1·5)	1·50	1·47	1·42	1·40
Nitric acid made						
Nitric acid made						
Factor Nitrate of soda (95%) used	No data	No data	No data	0·07	0·06	0·04

Nitre Cake.

Tons.

	1914.	1915.	1916.	1917.	1918.	1919 (Jan. to May incl.).
Total production	(32,000)	(16,000)	304,271	431,122	280,608	11,211
Total sold and used	(20,000)	(50,000)	155,360	252,857	230,810	10,500
Percentage of production used	(62.2)	(31.3)	51.1	58.7	82.8	94.5

Hydrochloric Acid.

Tons.

	1916.	1917.	1918.
Production 30% HCl	272,633	288,001	263,580
Nitre cake used	48,085	55,031	47,460
H ₂ SO ₄ consumed (100%)	111,120	107,431	101,707

Consumption of Hydrochloric Acid (30%).

Tons.

	1917.	1918.
Ammonium chloride	7,421	9,572
Aniline	814	1,083
Barium salts	2,440	2,444
Bleaching liquor, powder and chlorine	134,453	125,139
Carbonising	2,520	3,071
Drugs and fine chemicals	3,574	3,950
Dyeing and bleaching	18,148	14,577
Dyes	10,380	14,080
Extraction of metals such as gold, platinum, etc.	3,062	5,285
Foodstuffs and preservatives	1,854	1,743
General chemicals	2,598	1,807
Glue, size and gelatin	4,261	3,295
Leather	1,060	982
Metal-pickling	58,038	53,314
Paint, varnishes, colours, ink, etc.	3,270	2,135
Soap and glycerin	9,973	8,128
Metallic chlorides	20,103	12,145
Chemical warfare and explosives	450	1,836
Sundry purposes	3,257	2,063
Totals	288,015	266,709

allowed to a very limited extent. From the tabular statement set out below, it will be seen that the phosphatic manures (made from phosphate rock) available in the United Kingdom during 1916 had reached the very low figure of 460,000 tons in terms of superphosphate, and as the supplies of potash from the Continent were practically cut off and as the use of sulphate of ammonia for agriculture had not greatly increased, there was, therefore, a serious dearth of fertilisers. This state of affairs presented a very serious problem, in view of the necessity of increasing the production of home-grown foodstuffs.

The manufacture of compound manures is carried out by a variety of processes, as the term "compound manures" covers numerous fertilisers which are mixed at manufacturers' works for use for special purposes. In some cases compound manures are manufactured by mixing the ingredients in the usual superphosphate "den," and in other cases by mixing superphosphate already manufactured with various other nitrogenous materials. The position, therefore, in regard to information as to available supplies and requirements was difficult in the first instance, and the fact that many works were engaged in manufacturing on a small scale to meet local requirements also added to the difficulty of obtaining exact data.

The table at the base of the page shows the position in the years 1913—1918 inclusive, from which it will be seen that during the calendar year 1918 the available supplies of fertilisers made from phosphate rock reverted to those of 1913.

For ordinary trade purposes the fertiliser year is taken as from June 1 to May 31, and the figures set out below give a comparative summary of the results obtained during the two years in which the explosives department had to deal with the output of fertilisers.

During the year 1918 labour problems became more acute, and had it not been for the fact that many of the manufacturers were able to utilise female labour in their works it would have been impossible to attain the results set out.

One of the chief difficulties encountered in endeavouring to increase the production of superphosphate and compound manures was that the consumption of these materials is confined to a comparatively short period of the year, and the storage capacity of the manufacturing works is soon filled during those months when consumers are not in a

Superphosphates and Compound Manures.—Prior to the war there was a considerable export in superphosphates and compound manures, and although the "Fertilisers and Feeding Stuffs Act" provided for a proper analysis of manures to be available for the farmers' information, it was decided that in fixing prices for fertilisers under the Ministry Orders regard should only be given to those contents which were considered, in the view of the Board of Agriculture, to be of definite manurial value. In consequence of this the Superphosphate Order of August 20, 1917, the Compound Fertilisers Order of October 13, 1917, and subsequent Orders were issued, under which the prices to be charged for superphosphates or compound manures were fixed on the basis of the contents of nitrogen, potash and phosphoric acid, and exports under licence were

Superphosphates and Compound Manures.

Tons.

	1913.	1914.	1915.	1916.	1917.	1918.
Imports of phosphate rock, less re-exports	471,000	450,000	374,000	323,000	262,000	404,000
Phosphate rock used in manufacture of fertilisers (1)	450,000	425,000	350,000	280,000	310,000	415,000
Superphosphate (as such) manufactured	No data	No data	No data	No data	440,000	584,000
Imported	50,000	50,000	1,000	8,000	15,000	—
Phosphate rock used in manufacture of compound manures in terms of superphosphate (4)	No data	No data	No data	No data	118,000	156,000
Acid (70%) used in manufacture of fertilisers	420,000	400,000	330,000	242,470	303,160	380,570
Total superphosphate equivalent of phosphate rock used for fertilisers (taken from 1, 2, 3 and 4)	800,000	815,000	631,000	500,000	573,000	740,000
Superphosphate exported (a)	64,000	66,000	69,000	14,000	3,000	—
Compound manures exported (b)	152,000	127,000	61,000	51,000	27,000	—
Approximate total quantity of superphosphate exported in (a) and (b)	140,000	130,000	100,000	40,000	17,000	—
Superphosphate equivalent available for consumption in U.K.	720,000	685,000	531,000	460,000	556,000	740,000

*Superphosphate and Compound Manures.
Fertiliser years June 1 to May 31, inclusive.*

	Tons.	
	1917-18.	1918-19.
Phosphate rock—		
Stocks at works on June 1	70,000	90,000
Imports of rock during year	447,000	438,000
Home-mined production	—	3,000
Total available	517,000	531,000
Phosphate rock used for fertilisers ..	400,000	430,000
Issued for trench warfare and trade purposes	27,000	13,000
Stock of rock on May 31	90,000	88,000
Total		
Superphosphate equivalent value of phosphate rock used for fertilisers	710,000	760,000
Superphosphate—		
Production of straight superphosphate	500,000	602,000
Of which was used in the manufacture of compound manures ..	180,000	193,000
And sold direct to consumers ..	380,000	409,000
Compound manures—		
Production of compound manures ..	472,000	495,000
In the production of the above compound manures the following materials were used:—		
Superphosphates	180,000	193,000
Phosphate rock dissolved in compounds or used in mixing ..	80,000	87,000
Ground basic slag	4,000	—
Sulphate of ammonia	58,000	67,000
Nitrate of soda	3,000	1,000
Other nitrogenous materials ..	33,000	41,000
Bones and bone-meal	32,000	13,000
Potash materials	6,000	5,000
Total	390,000	407,000
Balance including acid and filling materials such as lime, gypsum, etc.	70,000	88,000
Sulphuric acid used for fertiliser-manufacture in terms of 70% or chamber acid	300,000	374,000

position to accept delivery and utilise the material. During the season 1918-19 it is interesting to notice that the production and deliveries of these fertilisers were mainly confined to the months December to May, in spite of the fact that under the Ministry Orders attempts had been made by the adjustment of prices to induce consumers to buy during the summer months. Of deliveries of superphosphate to consumers, three-quarters of the annual total was delivered during these months, and of compound manures practically four-fifths. It will be seen, therefore, that in order to increase considerably the production of these fertilisers, it is necessary to have works' capacity largely in excess of the annual requirements, as otherwise during the busy months of the season it is impossible to complete the orders. During the two years of control the works' capacity of the country was increased by erecting new plant and effecting repairs and improvements in existing plant in order to deal with a further 100,000 tons of phosphate rock per annum (if the works could be kept going during the twelve months of the year on full output), and of this

quantity about one-half was provided by new construction; in actual practice this meant only an approximate annual increase of dissolving capacity for 50,000-60,000 tons of phosphate rock. In the production of some 355,000 tons of compound manures, it was found that about 33,000 tons of nitrogenous materials was used (other than sulphate of ammonia and nitrate of soda) and that this quantity was made up as follows:—

Nitrogenous materials used.	Tons.
Fish waste, meal and guano	6,000
Leather wastes	700
Dried blood	1,000
Meat and meat meal	1,200
Horns and hoofs	200
Oil-seed, cake and meal	1,400
Slaughterhouse refuse	2,100
Wool waste and shoddy	2,800
Sugar acum	300
Sud cake	6,700
Dried sewage sludge, etc.	2,000
Other nitrogenous materials	8,600
Total	33,000

In the production of this quantity of compound manures, about 20,000 tons of filling materials was used, composed of gypsum, lime, etc.

Basic Slag.—Before the war considerable quantities of basic slag were exported from the United Kingdom and also imported from the Continent, and from the information obtained from the Board of Trade and the various manufacturers grinding basic slag, the following table has been drawn up to show approximately the quantities of basic slag which were available for consumption in the United Kingdom.

In the spring of 1917 arrangements were made for increasing outputs from the existing grinding plant in the country and also for installing further grinding plant, with the result that during the two fertiliser years (June 1 to May 31) the following results were obtained:—

	Tons.	
	1917-18.	1918-19.
Production of ground basic slag—		
High grade (over 10% P ₂ O ₅)	357,000	402,000
Low grade (under 10% P ₂ O ₅)	130,000	162,000
Total	400,000	504,000

From the above it will be seen that the amount of phosphatic fertilisers available was considerably increased during the two years of control. The total quantities of phosphatic fertilisers available were as follows:—

Summary of Phosphatic Fertilisers Available.

	Tons.	
	1917-18.	1918-19.
Superphosphates	380,000	400,000
Compound manures	472,000	495,000
Basic slag	400,000	504,000
Total	1,348,000	1,408,000

Basic Slag.

Tons.

	1913.	1914.	1915.	1916.	1917.	1918.
Production	147,300	455,000	430,000	434,000	447,000	545,000*
Net exports (allowance made for imports)	118,000	117,000	117,000	39,000	2,000	—
Available for consumption in U.K.	355,000	338,000	322,000	395,000	445,000	545,000

* Of this figure about 70% was high-grade and about 30% low-grade slag.

Ammonia Production and Uses in the United Kingdom in terms of Sulphate of Ammonia.

Tons.

	1913.	1914.	1915.	1916.	1917.	1918.
*Total production of ammonia compounds	433,000	426,000	426,000	434,000	450,000	432,500
Exports of sulphate of ammonia	323,000	313,000	294,000	250,000	63,000	20,000
Exports of other products	14,000	12,000	14,000	15,000	12,000	8,000
Ammonia products used for munitions purposes (ammonium nitrate)	—	—	8,000	—	125,000	120,000
Sulphate of ammonia used for agriculture	(60,000)	(60,000)	(60,000)	(80,000)	230,000	240,000
Balance of ammonia products available for use in U.K. for other trade purposes	36,000	41,000	50,000	30,000	20,000	38,500

Figures to nearest thousand.

* Figures taken from the Chief Alkali Inspector's Reports and representing about 24½% ammonia content.

Sulphate of Ammonia and Concentrated Liquor.—The demands for ammonium sulphate for the manufacture of ammonium nitrate began to assume fairly large dimensions in 1915, and when the shortage of sulphuric acid became acute towards the end of that year, it was decided to replace sulphate of ammonia by concentrated liquor in the ammonia-soda process for the manufacture of ammonium nitrate. The maximum output of concentrated liquor was attained in January, 1918, when an output was reached corresponding to 148,000 tons of 25% ammonia-liquor per annum.

The two years 1917 and 1918 also included the period when increasing demands were made for sulphate of ammonia for agricultural purposes in this country, and in the table given below is shown in approximate over-all figures the position with regard to ammonia products for the years 1913 to 1918 inclusive.

The figures given for ammonia products for other trade purposes include ammonia-liquor used in the ammonia-soda process, ammonium chloride and ammonium carbonates, and also certain quantities of ammonia products used for other purposes. From the data available, it appears that the requirements for these trade purposes in the United Kingdom are approximately 30,000–35,000 tons per annum, but these requirements, of course, vary somewhat from year to year.

It is interesting to note the increased use of ammonium sulphate for agricultural purposes:—

	1917-18. June 1 to May 31. Tons	1918-19. to May 31. Tons
Sulphate of ammonia used for agriculture	234,000	270,000
Of which was used in compound manures	58,000	67,000

The quantity of concentrated ammonia-liquor made during these two periods in terms of 25% ammonia was as follows:—

As ammonia liquor—June, 1917, to May, 1918 ..	121,763 tons
June, 1918, to May, 1919 ..	58,970 "

DYESTUFFS INDUSTRY DEVELOPMENT COMMITTEE.—

In accordance with the provisions of the Dyestuffs (Import Regulation) Act, 1920, the President of the Board of Trade has appointed the following to be a committee to advise the Board of Trade with respect to the efficient and economical development of the industry:—

Mr. W. J. U. Woolcock (chairman), Mr. Percy Ashley (Board of Trade), Sir Henry Birchenough, Mr. W. H. Dawson, Mr. George Douglas, Mr. E. V. Evans, Dr. M. O. Forster, Mr. L. B. Holliday, Dr. Herbert Levinstein, Prof. G. T. Morgan, Mr. James Morton, Mr. Max Muspratt, Mr. Thomas Taylor, Mr. Norman Thomas (Admiralty), Mr. G. S. Witham (War Office).

Another representative of dye-using interests will be appointed shortly.

MEETINGS OF OTHER SOCIETIES

INSTITUTION OF CIVIL ENGINEERS.

A conference was held at the Institution, Westminster, on June 29, 30, and July 1. The president, Mr. J. A. Brodie, was in the chair, and extended a hearty welcome to the deputation of American engineers which had come over to express appreciation of the work done by British engineers in the war. Dr. I. N. Hollis, of Worcester, U.S.A., presented a message from the engineers of America, and in his address stated that a few years ago the American engineering societies did nothing more than hold educational meetings for the discussion of engineering papers, in fact, American engineers treated themselves as men educated and trained to occupy routine, subordinate positions; but they were now climbing out of the rut; they had their own Federation of American Engineering Societies and a central headquarters, the gift of Andrew Carnegie. After Dr. W. C. Unwin had replied on behalf of British engineers, Mr. Ambrose Swasey, the chairman of the deputation, presented the John Fritz medal of the American Engineering Federation to Sir Robert Hadfield, in recognition of his distinguished services to metallurgical science, and in particular for his invention and perfection of manganese steel.

The conference was divided into seven sections, that on Waterworks, Sewerage, and Gasworks being presided over by Dr. Charles C. Carpenter. In a paper on "The Utilisation of Waste Heat in Gasworks," Mr. E. G. Stewart dealt more especially with heat recovery by means of waste-heat boilers. Utilising the flue gases of the carbonisation process, from 500–900 lb. of steam per ton of coal carbonised is at present being generated by means of such boilers. In the "blue water gas" process an economy of 0·66d. per therm may be effected by such recovery. In America, waste-heat recovery in the "carburetted water gas" process is responsible for the production of 80 lb. of high-pressure steam per 1000 cb. ft. of gas.

Dr. J. S. G. Thomas contributed a paper on "Desiderata in the Qualities of Town's Gas," in which he urged that the constituents of town's gas should be such that their combustion yielded only carbon dioxide and water, and that the minimum needless expenditure of energy should be incurred in the distribution of the gas. Sulphur compounds, naphthalene, and cyanogen should be eliminated as completely as possible. For the present no legal restriction should be placed upon the permissible proportions of inert or combustible constituents that may be present.

Messrs. E. H. Richards and M. G. Weeks read a paper on "Straw Filters for Sewage Purification." Laboratory experiments have shown that about 72 per cent. of the nitrogen content of sewage can be recovered by filtration through wheat straw at the rate of 250 galls. per cb. yd. of straw per day.