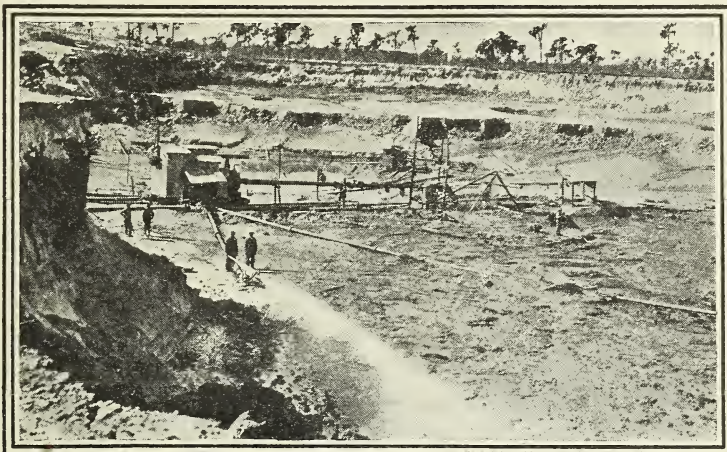


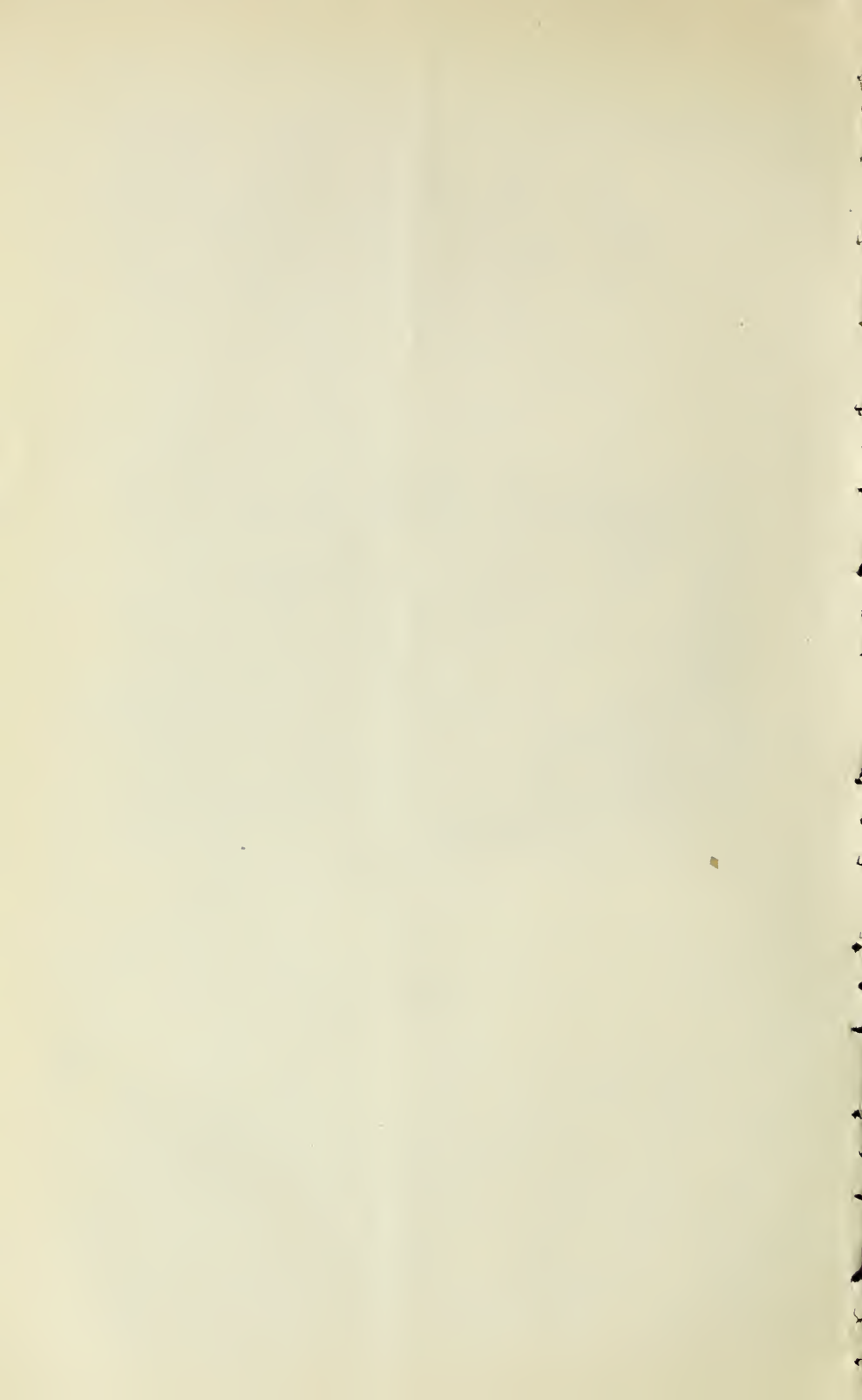
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# AMERICAN FERTILIZERS



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# AMERICAN FERTILIZERS

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## INTRODUCTION

In this publication is given a brief description of the production of commercial fertilizer. It is believed that this description, in which complex technical discussion and statistics are avoided, will be of use to students, as well as farmers and gardeners.

## SOIL EXHAUSTION

It has been known for many centuries that continued cropping reduces the ability of the soil to produce. Ordinarily, but not in all cases, virgin soil is highly productive and will produce good crops for several years after being put into cultivation, but the almost universal experience is that yields decrease with time and eventually become unsatisfactory unless some systematic plan of soil maintenance is employed. Worn-out fields have been a source of individual and national concern from the earliest times and have been the cause of the migration of people who were unable to keep their land in a state of adequate productivity. In the United States everyone is familiar with the expansion of farming westward into new and fertile areas, with the abandonment, in some cases, of eastern farms which were once thoroughly cultivated. So long as an abundance of new land made this practice possible, nonproductive land was no cause for anxiety except to the owner, but evidently the practice of continually putting new land into cultivation could not be the final answer to the problem of worn-out land.

Long before chemistry could explain the cause of soil exhaustion the farmers of olden times learned a great deal about the maintenance of soil productivity, and the simple methods employed are still used with excellent results. The use of stable manure and crop refuse, and crop rotation, in which one crop prepares the soil for another, are still the most important instruments of soil improve-

ment in spite of the increasing use of commercial fertilizer. In fact, commercial fertilizer is most profitably used as a supplement to, rather than a substitute for, other means of soil improvement. It is known that manure and all kinds of vegetable refuse, when applied to the soil, undergo chemical changes and in this way return to the soil the plant food which the growing crop has extracted, as well as certain elements which the crop has taken from the air. By adding larger amounts of plant food than have been removed, it has been found that larger crop yields may be obtained.

## PLANT FOOD

### ELEMENTS ESSENTIAL TO PLANT GROWTH

Several elements are essential for plant growth. Hydrogen and oxygen, for instance, are taken in as water, which is a compound of these two elements. Likewise, carbon is taken in as carbon dioxide, a compound of carbon and oxygen. Carbon dioxide is a gas occurring in the air and, like water, is so abundant that its importance as a plant food is almost forgotten. Of the other elements which are important as plant foods and are taken up from the soil, the most important are iron, sulphur, magnesium, calcium, nitrogen, phosphorus, and potassium. The fertilizer industry is engaged in supplying the farmers with the last three of these elements in such form that, when applied to the soil, they may be used by the growing plant. It has recently been learned that calcium, magnesium, and sulphur must be added to certain concentrated fertilizers deficient in these elements if they are to be used successfully on certain soils.

Nitrogen, phosphorus, and potassium, unless combined with other elements, are useless as plant food. Nitrogen is a gas when free from other elements, and the air which we breathe is made up of 4 parts of nitrogen gas mixed, but not combined, with 1 part of another gas, oxygen. Phosphorus is a yellow waxy substance which burns spontaneously on being exposed to the oxygen of the air. Potassium is a light metal which, when protected from the action of the air, looks somewhat like freshly cut lead. Combined with other elements, these three form many chemical compounds having properties which differ greatly from the original substances. Certain of these compounds are manufactured to make fertilizer, and the various compounds are mixed if a fertilizer containing two or three plant foods is to be made. The world is well supplied with potash and phosphate minerals, and, although the deposits of nitrates are limited, industrial processes are now in extensive use for making nitrogen fertilizer from the unlimited supply of nitrogen in the air.

### TRADE DESIGNATIONS

In the language of the fertilizer trade the terms nitrogen and ammonia are used with almost the same meaning to designate nitrogen in any compound; phosphoric acid refers to phosphorus in any compound; and potash to any compound of potassium. In reporting the amount of plant food contained in a mixture the nitrogen is calculated either as nitrogen or ammonia, which is a nitrogen com-

pound containing hydrogen. Two and eight-tenths per cent of nitrogen is equivalent to 3.4 per cent of ammonia. Phosphorus and potassium are always calculated as though they were compounds of oxygen. The chemical symbols for the elements concerned are as follows: Nitrogen, N; hydrogen, H; potassium, K; phosphorus, P; and oxygen, O.

Using these symbols, the chemist writes  $\text{NH}_3$  for ammonia;  $\text{P}_2\text{O}_5$  for phosphoric acid, as this term is used in fertilizer work; and  $\text{K}_2\text{O}$  for potash. Nitrate of soda (sodium nitrate) contains no hydrogen but is a compound of sodium, nitrogen, and oxygen, which the chemist writes  $\text{NaNO}_3$ . However, a particular lot of nitrate of soda may be said to contain 16 per cent of nitrogen or 19.4 per cent of ammonia equivalent. Similarly, muriate of potash is a compound of potassium and chlorine, which contains no oxygen and has the formula  $\text{KCl}$ , in which Cl is the symbol for chlorine. Yet, as a matter of agreement for the sake of uniformity, the chemist figures his analysis as though the potassium were present as  $\text{K}_2\text{O}$ . In every case the figure below the symbol for the element indicates how many atoms of that element are present in the compound. It will be noted that all measurement of plant food is relative and simply gives a means for comparing values. There is no valid reason why P instead of  $\text{P}_2\text{O}_5$  could not be taken as the plant food in phosphate fertilizer; or K instead of  $\text{K}_2\text{O}$  as the plant food in potash fertilizer. If this were done the figures for plant food in any particular fertilizer would be much lower than with the existing system; but the value of the material would remain exactly the same. It is often said that nitrogen is the most expensive plant food, and it seems to be with prices on the basis of N,  $\text{P}_2\text{O}_5$ , and  $\text{K}_2\text{O}$ . But if we should change the system and make it  $\text{N}_2\text{O}_5$ , P, and K, which seems to be as reasonable a system, it would then appear that nitrogenous plant food is cheaper than the others. This will illustrate the fact that no true basis exists for the comparison of the cost of the three kinds of plant food, except their efficiency in increasing crop yields.

The various grades of commercial fertilizer are designated by a series of numbers, such as 7-6-5 or 2-8-10, in which the numbers indicate the percentage of the three plant foods. In most States the order is nitrogen (or ammonia), phosphoric acid, and potash. However, in a few States the order of the first two numbers is reversed and the numbers refer to phosphoric acid, nitrogen, and potash, in the order named.

The essential principles of plant feeding and plant foods were discovered by the German chemist, Liebig, and other scientists of his time, which was about 1840. On the basis of the facts which he had established, the fertilizer industry began to develop some 10 years later and has been increasing in usefulness up to the present time. In the meantime research laboratories and experiment stations, the oldest of which is the Rothamsted Experiment Station in England, have done much to improve our understanding of this subject, and are on research work on a larger scale than ever before.

## FERTILIZER PRACTICES IN THE UNITED STATES

Fertilizer practices differ somewhat in various parts of the world. Most of the farmers of the United States prefer to buy mixed fer-

tilizers containing two or three plant foods and, many of them, a number of different materials. The farmers in other countries usually buy the various fertilizer materials for separate application to the soil. However, the objective is essentially the same everywhere, that is, to make up for deficiency in the soil of one, two, or all three of the elements, nitrogen, phosphorus, and potassium.

The world production in short tons, of the more important fertilizer materials in 1928<sup>1</sup> was as follows: Bones, 330,000; basic slag, 5,700,000; superphosphate, 16,900,000; potash salts, 5,700,000; ammonium sulphate, 4,500,000; cyanamide, 1,100,000; calcium nitrate, 965,000; Chilean nitrate, 3,475,000; miscellaneous salts, 1,100,000; organic materials, 3,000,000; total, 42,770,000.

The consumption of fertilizer materials in the United States, in short tons, has been estimated for 1929, which was probably not very different from the amount produced in 1928. The figures are: Bones, 50,000; basic slag, 20,000; superphosphate, 4,400,000; potash salts, 850,000; ammonium sulphate, 550,000; cyanamide, 100,000; calcium nitrate, 35,000; nitrate of soda, 700,000; miscellaneous, 110,000; organic materials, 720,000; total, 7,535,000.

Certain materials, as basic slag and calcium nitrate, are important in world production but are only minor items in the United States. The United States, with only one-sixteenth of the world's population, uses nearly one-fifth of the world production of fertilizer. The farmers of the United States purchase annually some 8,000,000 tons of fertilizer at a cost of approximately \$250,000,000.

The manufacturer gathers the materials from many sources, assembles them at his factories, makes them into fertilizers, and distributes his product through agents, salesmen, and dealers. With the exception of the superphosphate, the materials are ordinarily purchased by the fertilizer manufacturer in condition ready for mixing. A large part of the superphosphate is produced at the factories where it is to be used in making mixed fertilizers and, as might be expected from the quantity required, the production of this material is of major importance in the industry.

## FERTILIZER MATERIALS AND THEIR PRODUCTION

### PHOSPHATES

#### BONES

Bones have always been an item of importance in the fertilizer trade. In the early years of the industry they were the main raw material for the production of phosphate fertilizer but now are of minor importance, owing to the limited supply available for such use. Several other industries are now users of bones, and the supply remaining for use as fertilizer is comparatively small in spite of the fact that the supply is utilized more thoroughly than ever before. Buffalo bones were gathered in quantities on the western plains as the railroads were extended into territory that made their shipment possible, but the supply has long been exhausted, and the present supply of bones is limited to current production of the meat-

<sup>1</sup> HOWARD, P. E. SURVEY OF THE FERTILIZER INDUSTRY. U. S. Dept. Agr. Circ. 129, 23 p. 1931.

packing and rendering establishments, those gathered by junk collectors, and to imports mainly from South America and Asia. The usual process of manufacture is simply to pulverize the bones either in the raw condition or after steaming to extract the glue. This bone meal contains from 1.6 to 4 per cent of nitrogen (N) and from 20 to 25 per cent of phosphoric acid ( $P_2O_5$ ) which is rather slowly available as plant food. Small quantities of superphosphate are made by treating bones with sulphuric acid, but phosphate rock when so treated yields a very similar and much cheaper product. Another bone product, bone black, after being used and discarded by other industries, such as sugar refining, is used as fertilizer. The phosphorus of bone is present as a calcium compound and the nitrogen as an organic material somewhat similar to the gristle of meat.

#### BASIC SLAG

Basic slag is second only to superphosphate as a phosphate fertilizer if judged on the basis of the total amount used in the world. It is produced and used extensively in Europe, owing to the character of certain iron ores used there, but has little part in the American industry. Basic slag is a by-product of the steel industry and is made as follows.

Certain iron ores contain considerable quantities of phosphorus which enters into and becomes a part, as an impurity, of the pig iron during the smelting process. The process of making steel from the pig iron is a refining process in which impurities are removed. In this process the iron is melted and the phosphorus burned out and combined with lime from the lining of the furnace. This lime phosphate floats on the molten metal as a slag in a liquid condition, is tapped off, and becomes a rocklike solid on cooling. On being pulverized, this material becomes the basic slag of the fertilizer trade, and is also known as Thomas slag or Thomas phosphate. It contains from 10 to 25 per cent of phosphoric acid ( $P_2O_5$ ) and a large quantity of lime.

Since basic slag is a by-product of one branch of the steel industry, the quantity produced is contingent on the demand for steel and can not be materially increased to meet fertilizer demands. The steel manufacturers of Germany, France, and Belgium are the leading producers of this material.

#### SUPERPHOSPHATE

Superphosphate is the leading fertilizer material, both as regards quantity and value, in the United States and in the world. In the United States this material was formerly known as acid phosphate. Superphosphate is made by mixing together about equal quantities of finely pulverized phosphate rock and sulphuric acid to render the insoluble phosphoric acid of the rock available as plant food. Each batch is stirred vigorously for a few seconds in a cast-iron mixer and then discharged through an opening in the bottom of the mixer into a "den" which is to be filled with the reacting mass. After a few minutes the fluid mixture solidifies in the den, owing to chemical reactions which use up the sulphuric acid and the water which it contained. Batch after batch is mixed and dumped until the den is full, and the mass is allowed to stand until the chemical reaction is

practically complete. The den is then opened and the superphosphate, a gray earthy product having a texture somewhat like lumpy brown sugar, is removed with pick and shovel or some mechanical device, such as an electric shovel or hoist, and an orange-peel bucket. The superphosphate is usually stored in great piles in the factory, and it improves in quality on aging, owing to the completion of the chemical reaction which increases the amount of available phosphoric acid and dries out the product, so that it can be broken up to make a drillable product. Superphosphate contains from 14 to 20 per cent of available phosphoric acid ( $P_2O_5$ ), depending on the quality of the rock used. The phosphoric acid is combined with lime in such a way that it is readily soluble and can be taken up by the plant roots. Superphosphate is a mixture of several components, part of



FIGURE 1.—Phosphate mines, pipe lines, and wet storage, Brewster, Fla.

which are useless but are necessarily present as so many different materials enter into its manufacture.

Fortunately, the United States, and in fact the whole world, is well supplied with the raw materials entering into superphosphate. There are great deposits of phosphate rock and also supplies of sulphur and sulphur-bearing ores suitable for the manufacture of sulphuric acid. At the present rate of consumption Florida and Tennessee (figs. 1 and 2) have enough phosphate rock to last the United States more than 100 years, and Idaho has enough to last more than 1,500 years. Large deposits of phosphate rock occur in northern Africa, and the European demand is supplied mainly from Tunis, Morocco, and Algeria.

It has been noted that the quantity of sulphuric acid required is approximately equal to the quantity of phosphate rock used. To make sulphuric acid, sulphur is first burned in air; the gas or



smoke so produced is caused to combine with more oxygen from the air by one of two chemical processes, either of which may be used; the product of this reaction combines with water, which is usually supplied as steam or as a very fine spray, to form sulphuric acid which condenses as a liquid. Sulphur in the form of brimstone may be used, or it may be burned from pyrites ore, in which the sulphur is combined with iron. Pyrites burns somewhat as hard coal burns but leaves a heavy cinder, an iron oxide which is sometimes smelted for the iron it contains.

Certain metallurgical operations result in great quantities of sulphur gas identical with that made as the first step in the manufacture of sulphuric acid. This gas is very destructive to plant life if discharged into the air, but it can be converted into sulphuric

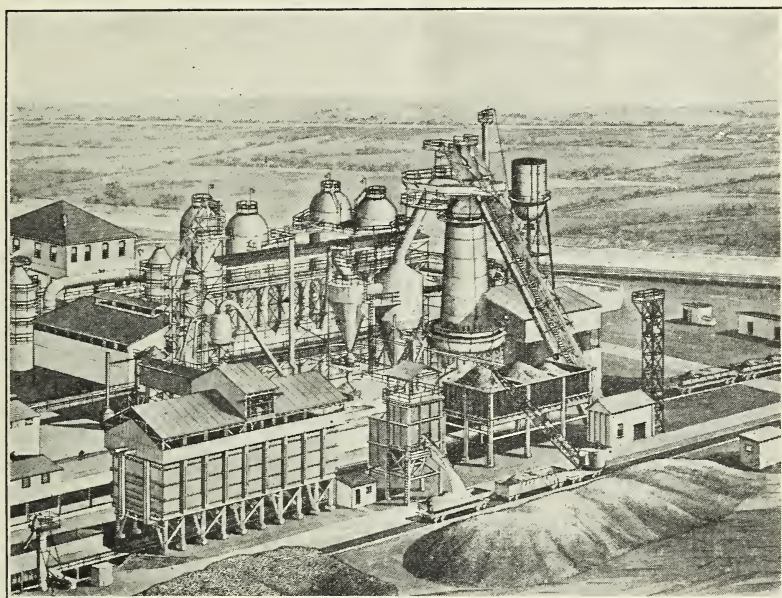


FIGURE 2.—Fuel-fired blast furnace, Nashville, Tenn. Phosphate rock is smelted to make liquid phosphoric acid which is used in the manufacture of triple-superphosphate fertilizer as well as various other products

acid by passing the smelter fumes through suitable acid production equipment. Acid so made is known as by-product sulphuric acid, and it is made in great quantities at various smelters. Thus the cost of the sulphur is eliminated, but this saving is largely offset by the extra freight expense to the points of consumption. In fact, great quantities of sulphur gas are wasted in the West, owing to the fact that the cost of shipping makes its use unprofitable, there being no adequate market for superphosphate within shipping distance of such smelters as those located at Anaconda, Mont.

#### TRIPLE, TREBLE, OR DOUBLE SUPERPHOSPHATE

Triple, treble, or double superphosphate, as it is variously designated, is made by treating pulverized rock with liquid phosphoric

acid, and it contains around 45 per cent of  $P_2O_5$ . The phosphoric acid so used may be made from the rock by extraction with dilute sulphuric acid or by smelting the rock in an electric or fuel-fired furnace, in which case the product is condensed from the gases coming from the top of the furnace. Both the electric furnace and fuel-fired blast furnace are used in the commercial production of phosphoric acid in the United States. Triple superphosphate is manufactured at several factories by the use of phosphoric acid made in various ways, but the tonnage produced is still very small as compared with that of ordinary superphosphate. Triple superphosphate has an advantage over ordinary superphosphate if long shipments are necessary or if a concentrated phosphate is required. With a reduction in the costs of producing liquid phosphoric acid, this material can be expected to occupy a correspondingly larger place in the market.

#### AMMONIATED SUPERPHOSPHATE

Ammoniated superphosphate is made by the direct addition of ammonia ( $NH_3$ ) to superphosphate. As will be noted later, there is now an abundant supply of ammonia which is at present the cheapest nitrogen carrier. Even after being thoroughly cured, superphosphate usually contains some free acid which must be neutralized in order to put the material in the best physical condition. This can be accomplished in various ways, one in common use being to add ammonia which combines with the free acid to produce desirable fertilizer salts within the mixture. Only a small amount may be added to each ton in this way, but, owing to the great quantity of superphosphate used each year, the total quantity of ammonia which can be thus added to mixed fertilizers is very large.

The materials discussed above are the principal phosphate fertilizers. Other materials containing phosphoric acid along with nitrogen will be discussed under nitrogenous materials. The amount of phosphoric acid marketed in this way is as yet small as compared with that contained in superphosphate and basic slag.

#### POTASH

##### POTASH SALTS

Practically the only source of potash used in the fertilizer industry is potash salts. These salts, which are similar to common salt in appearance, are readily soluble in water and are therefore quickly available to the growing crop. As used for fertilizer, they carry from 12.5 to 60 per cent of potash ( $K_2O$ ) and are mainly mixtures of potassium chloride (muriate) or potassium sulphate with other materials, such as common salt, with which they occur in the natural deposits and from which they have been only incompletely separated. Sometimes the salt is marketed as mined, but it is usually refined, to some extent at least, to avoid the transportation of too much worthless material.

##### FOREIGN POTASH

Five-sixths of the potash used in the United States is imported. The excellence of the potash deposits of certain foreign countries and the lack, until very recently, of any similar known deposit in

the United States, has resulted in this large proportion of imported potash. United States imports come from Germany and France, both of which have excellent deposits of potash salt. The German deposits known as the Stassfurt salts are unexcelled in quality and quantity. In these the salt strata are several hundred feet thick and contain potash-bearing strata 130 feet thick in certain places. The beds cover a large area, and the quantity of potash available is practically unlimited. The salt is mined and brought to the surface either to be crushed and marketed or refined by dissolving in water and recrystallizing in such a way that the desirable component is separated more or less completely from the worthless salts.

Potash imported for agricultural use is composed mainly of four materials. Kainit is a natural salt marketed as mined, which carries from 12.5 to 20 per cent of potash. It was formerly used more extensively than at present, as is shown by the fact that imports during 1930 were only 125,637 short tons as compared with 521,176 short tons in 1913. The trend in recent years has been toward more concentrated materials, such as the sulphate with about 50 per cent of  $K_2O$ , muriate with from 50 to 60 per cent of potash ( $K_2O$ ), or manure salts containing from 20 to 30 per cent of potash.

#### DOMESTIC POTASH

It has long been the objective of those interested in the fertilizer industry to develop a potash industry in the United States commensurate with the requirements of the country. There are many possible sources of potash such as Wyoming leucite, Utah alunite, New Jersey greensand, and Georgia shale, all of which have long been known, but these minerals are not soluble in water and require special processing to make the potash available. Potash can be recovered from cement-kiln stack fumes, sugar-factory waste, and the residue from alcohol fermentation. Certain salt lakes of the West contain potash. Kelp, a salt-water plant, which grows abundantly off the coast of California, is a source of potash. Several of these sources were developed during the World War, when potash prices were exceedingly high, owing to the impossibility of bringing the material from Europe. However, most of the producers were unable to meet the competition which came from Europe after the war, and the plants were abandoned. The recovery of potash from the insoluble minerals mentioned is still the objective of active research and may at some time become a factor in the situation, but so far no process of this kind has been demonstrated that can compete with the European supply.

For several years there have been two potash producers operating in this country, one using distillery waste and the other natural potash brine. (Borax brines from a lake in California.) A third producer is mining potash salt from a deposit recently discovered in New Mexico. The 1930 output of the potash industry of the United States was 105,810 net tons, containing 61,270 tons of potash ( $K_2O$ ). As might be expected, the output of the first producer is very limited, being a by-product of the crude molasses used in alcohol fermentation.

The second factory is located at Trona, Calif. (Fig. 3.) This has produced the major part of the domestic supply of potash during recent years. Borax is an important by-product of this factory. The

photograph shows this establishment as it was before beginning enlargements which were in progress early in 1931.

The nature of the third enterprise is essentially the same as that of the potash mines of Germany and France and brings an entirely new factor into the American potash situation. Mining began early in 1931, and the salt was marketed as mined. It is reported that a refinery will be constructed for the production of high-grade potash salt from the crude product which is well adapted to simple refining processes such as those used in Europe. (Fig. 4.)

It seems that the output of this mine, when well under operation, together with the output of the enlarged establishment in California, will go a long way toward bringing into operation an American potash industry commensurate with the needs of the country.

Other materials, such as castor pomace, cottonseed meal, garbage tankage, and tobacco stems, all of which carry small quantities of potash, are used as fertilizers. However, as these materials are valued mainly for the nitrogen which they contain and for the

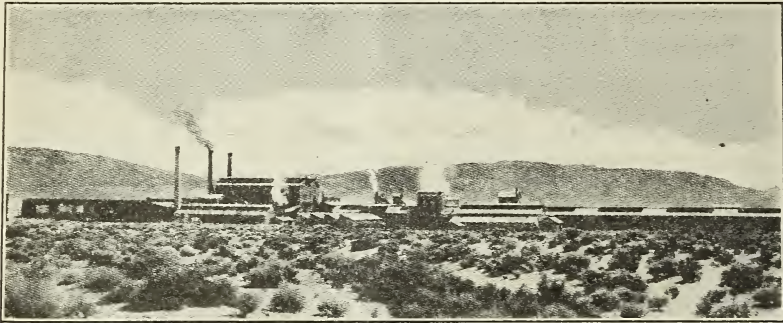


FIGURE 3.—Potash plant, Trona, Calif., as it appeared before beginning enlargements in 1931. Here potash is produced from the salt water of Searles Lake

physical properties which they give to mixtures, they are only a negligible factor in the potash supply.

## NITROGEN

According to their nature and source, the nitrogen materials of the fertilizer trade fall into four general classes, as follows: (1) Organic nitrogen carriers, (2) Chilean nitrate of soda, (3) by-product ammonia, and (4) air-nitrogen-fixation products.

### ORGANIC NITROGEN CARRIERS

All organic nitrogen carriers are of vegetable or animal origin, and most of them are by-products of some other industry. Some of them carry small quantities of phosphoric acid and potash, as well as nitrogen, and they are of value in improving the mechanical condition of mixed fertilizers. The more important organic materials used in American fertilizer manufacture are cottonseed meal, tankage, dried blood, and fish scrap. Many other materials, such as tobacco stems, castor pomace, hair, feathers, and scrap leather, are also used. With the exception of the last three, which are known as "rough ammoniates" and require special treatment, these materials

require no processing but decay promptly when applied to the soil and become available as plant food. The best of these materials are excellent livestock feed, and their demand for this purpose has reduced the quantity available for fertilizer use. However, some 700,000 tons of organic materials are still used annually in fertilizers, and they supply about one-seventh of the nitrogen used in the American fertilizer industry. The nitrogen content of the organic materials is rather low, ranging from 1.6 to 14 per cent. The nitrogen gradually becomes available as plant food as the material decays in the soil. This is considered an advantage where it is desirable to spread the effect of the fertilizer over a long growing season.

In the early years of the industry, before the other sources of nitrogen fertilizers had been developed, and before the livestock-feed market began to take so much of this product, the organic materials were the main source of fertilizer nitrogen. By 1914 the



FIGURE 4.—Typical drift in potash mine, Carlsbad, N. Mex. Entire tunnel is through potash ore. Holes in left side are experimental borings with mechanical auger

part supplied by these materials had dropped below 50 per cent, and by 1929 it was less than 16 per cent of the total quantity used.

#### CHILEAN NITRATE OF SODA

Chilean nitrate of soda is a salt, closely resembling common salt in appearance, which occurs in workable deposits only in the rainless deserts of western South America. (Fig. 5.) In these deposits it is found mixed with common salt and dirt and covered with a few feet of earth. The crude salt is dug up either by hand or by machinery, with the aid of explosives, separated as well as possible from the worthless overburden, and transported to refineries where the nitrate is separated from the common salt by dissolving in water and re-crystallizing by a process somewhat similar to that used in separating potash salts from the worthless salts with which they are found. The refined salt contains 95 per cent or more of sodium nitrate ( $\text{NaNO}_3$ ), and the nitrogen content runs from 15.6 to 16 per cent. The product is shipped by rail to the ports of Chile and then by

ocean ships to North American ports, by way of the Panama Canal, if destined to Atlantic or Gulf ports.

During 1918, when the demand for nitrate for the manufacture of explosives was at its peak, 100 vessels were engaged continually in carrying nitrate from Chile to the United States.

The nitrate deposits of Chile are very extensive, being sufficient, it is estimated, to maintain the industry for more than 100 years at the maximum rate of production ever attained. Until its hold was broken by the air-nitrogen-fixation industry, the Chilean industry held a monopoly on the available nitrogen reserves of the world, but its importance has been reduced to the point where it must now struggle to maintain its place in the markets of the world. Nitrate of soda, practically identical with Chilean nitrate, is now being pro-

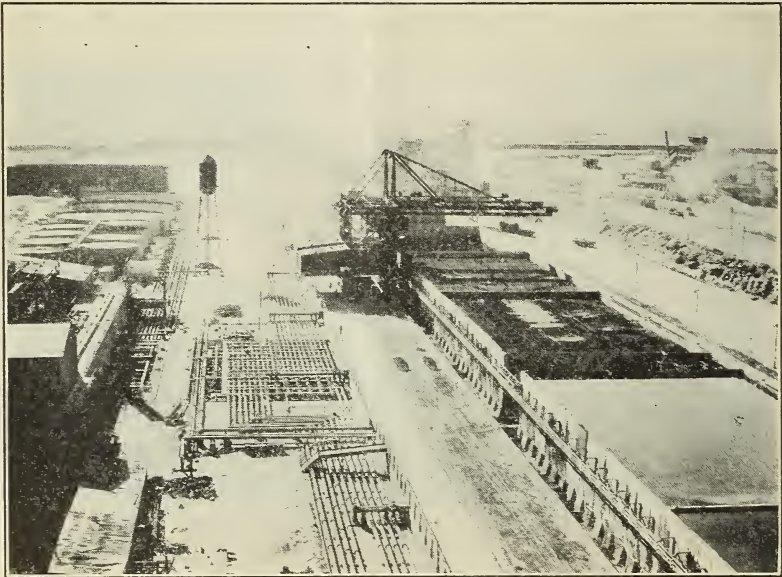


FIGURE 5.—Partial view of Chilean nitrate of soda plant (oficina) located 40 miles east of the port of Tocopilla, in the heart of the rich nitrate fields of northern Chile. The ore is mined from outlying beds and transported to refining plants, where the nitrate is extracted

duced by air-fixation processes, as will be noted later. Nitrate of soda dissolves very quickly in water and thus becomes immediately available to the plants on being put in the soil.

Figure 6 shows nitrate of soda bags being filled and sewed at a nitrogen-fixation plant at Hopewell, Va.

#### BY-PRODUCT AMMONIA

By-product ammonia, along with several other by-products, is obtained when coal is heated in closed retorts to make coke. (Fig. 7.) The ammonia comes from the hot coal with the gas which is cooled and bubbled through water or sulphuric acid to absorb the ammonia. The ammonia and sulphuric acid combine immediately on coming in contact, and this vigorous chemical reaction generates enough heat to evaporate the surplus water which has been added.

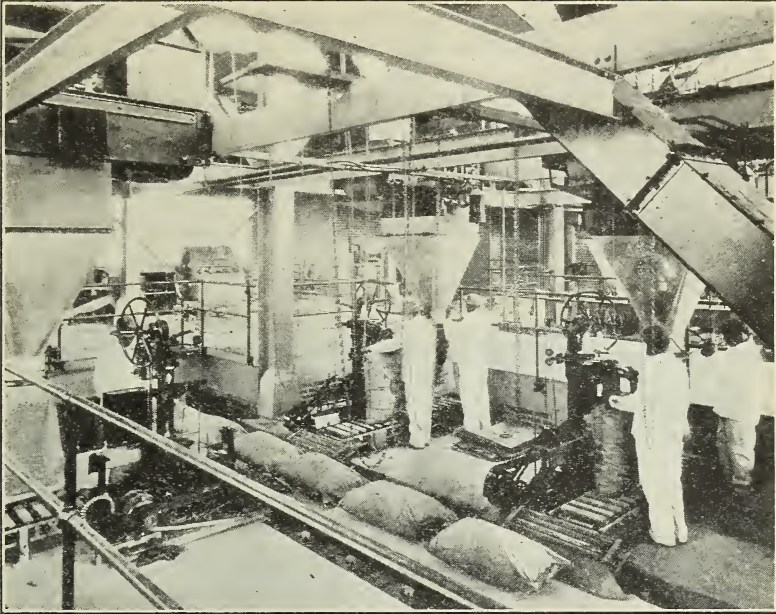


FIGURE 6.—Nitrate of soda bags being filled and sewed at nitrogen-fixation plant, Hopewell, Va. The nitrogen of the nitrate of soda was first taken from the air and made into ammonia which was then converted into nitric acid and finally into the nitrate in the bags

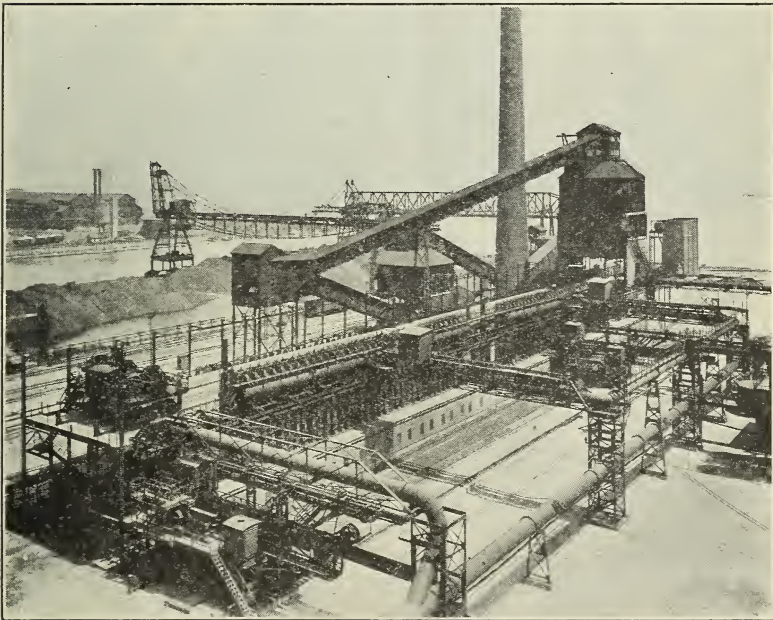


FIGURE 7.—Coke ovens, South Chicago, Ill. Coal is coked and ammonia recovered from the gas and made into sulphate of ammonia. This type of plant supplies most of the sulphate of ammonia used as fertilizer in the United States

The ammonium sulphate (sulphate of ammonia) crystallizes as a white or slightly colored salt which is drawn from the bottom of the container, separated from the liquid, washed free of acid, and dried. (Fig. 8.) The acid, drawn off with the crystals, and the wash water, which contains some acid and ammonium sulphate, are returned to the container. Ammonium sulphate contains from 20.6 to 21 per cent of nitrogen and is readily soluble in water. About 25 pounds of ammonium sulphate is recovered from each ton of coal coked.

This ammonia, coming from the by-product coke ovens and gas works is used for various purposes other than ammonium sulphate production, but the major part is used for this purpose, and production is often figured as "sulphate equivalent" which is merely the

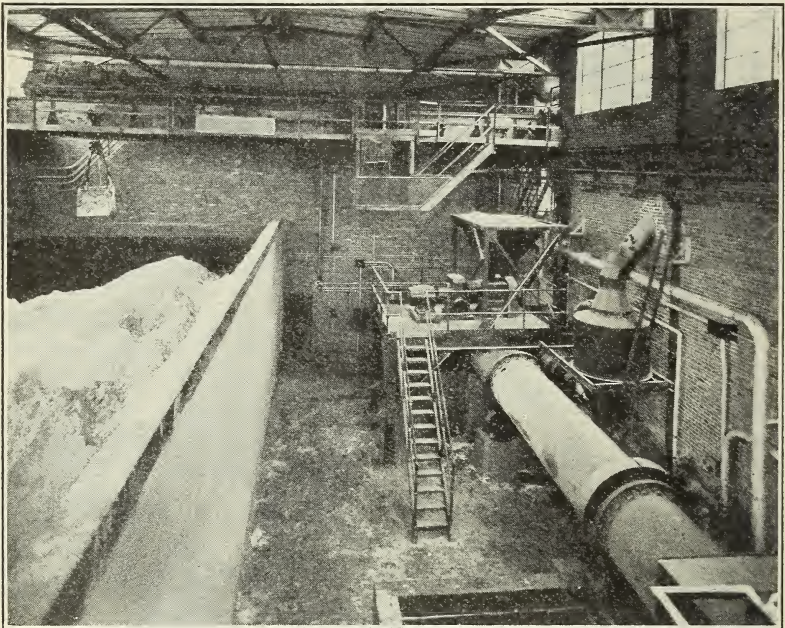


FIGURE 8.—Ammonium sulphate drier and storage, South Chicago, Ill. The ammonium sulphate made by passing ammonia, from the by-product coke ovens, into sulphuric acid has been separated from the liquid, but it is moist. A crane with grab bucket is provided to take the product from storage

amount of sulphate that could have been produced had all the ammonia been so used. It is produced at about 100 coke works in 21 States and also in a large number of gas works and bone-charring establishments. During 1929 about 900,000 tons of sulphate equivalent was produced, containing about 188,000 tons of nitrogen. Production from this source has increased rapidly during the last 15 years, owing largely to the substitution of by-product coke ovens for the old beehive ovens which wasted all the by-products. This program of change is nearly complete, and future growth in by-product ammonia production will be mainly dependent on increases in the consumption of coke. Apparently this will be very limited unless some unlooked-for circumstance brings about a great increase in the consumption of coke.



Practically all the sulphate of ammonia produced in this country is made from by-product ammonia and sulphuric acid. In Europe ammonia made from the nitrogen of the air is converted into sulphate of ammonia by using gypsum instead of sulphuric acid.

#### AIR-NITROGEN-FIXATION PRODUCTS

Air-nitrogen-fixation products have in very recent years become the world's main source of nitrogen for fertilizer use.

By nitrogen fixation is meant any chemical process by which the free nitrogen gas of the air is combined with some other element, to make compounds useful in agriculture or industry. Nitrogen is very abundant, the air containing 80 per cent of this element, but it is an element which does not combine easily with other elements and which tends to break away and leave its compounds after they have been formed. For this reason fixed nitrogen is not abundant in nature. The intricate chemical processes which have been invented for forcing the free nitrogen of the air to combine with some other element are known as nitrogen-fixation processes.

In 1909 only 1 per cent of the world's supply of nitrogen came from the air; by 1913 this had increased to 10 per cent; by 1917 to 33 per cent; by 1921 to 42 per cent; and in 1930 it was approximately 60 per cent of the total. The world used about four times as much nitrogen in 1930 as in 1909, and the increase was mainly in the quantity obtained from the air. This is the one unlimited supply, since the nitrogen of the atmosphere over every square mile of the earth amounts to about 20,000,000 tons—enough to last the whole world for 10 years at the present rate of consumption. In the United States progress has not been quite so fast, but great strides were made during 1929 and 1930.

#### THE ARC PROCESS

The arc process of nitrogen fixation, which has been largely displaced by more economical methods, produces nitric acid as its first product. This acid can be neutralized with lime to make calcium nitrate, with ammonia to make ammonium nitrate, or with soda ash to make sodium nitrate. These products are now made in larger quantities by another method and will be discussed later. The arc process was never used to a great extent outside of Norway, where the cheapest hydroelectric power is available.

#### THE CYANAMIDE PROCESS

The cyanamide process of nitrogen fixation produces calcium cyanamide ( $\text{CaCN}_2$ ) as its first product. This can be used directly as a fertilizer, and the main part of the world output is so used. Cyanamide is a heavy powder, similar to Portland cement in appearance, but it is darker. A part of the cyanamide is converted into other products, including ammonia, which can be used in the same way as ammonia from the coke ovens or other sources in making ammonium sulphate, ammonium phosphate, or similar materials. There is no cyanamide factory in operation in the United States. The largest plant of this kind in the world is located at Niagara Falls, Canada.

(Fig. 9.) The product of this factory is imported into the United States, and a large part of it is used in making a fertilizer containing both nitrogen and phosphoric acid. The phosphoric acid used in this factory is made by treating phosphate rock with dilute sulphuric acid, then separating the liquid phosphoric acid from the insoluble residue. Two grades of ammonium phosphate fertilizer are produced at a plant at Warners, N. J., in New York harbor. (Fig. 10.) One of these fertilizers carries 11 per cent of nitrogen and 46 per cent of phosphoric acid ( $P_2O_5$ ), and the other carries 16½ per cent of nitrogen and 20 per cent of phosphoric acid ( $P_2O_5$ ).

The United States Government owns a cyanamide factory, known as United States Nitrate Plant No. 2, at Muscle Shoals, Ala. (Figs. 11 and 12.) It was built in 1918 to produce ammonium nitrate for munitions purposes, and when so used the cyanamide is converted into ammonia, one-half of which is in turn converted into nitric acid, which is then neutralized with the remaining ammonia to make ammonium nitrate. The ammonium nitrate was made for use in the manufacture of high explosives for artillery ammunition. The equipment was given a test run early in 1919, but since then it has been idle. In the meantime a great dam and hydroelectric power plant have been constructed, by the Government, on Tennessee River in the immediate vicinity of the Muscle Shoals plant, but they have never been used in connection with the cyanamide works. Many plans have been suggested for putting United States Nitrate Plant No. 2 into operation as a fertilizer producer, but none of these has become a law. The estimated annual capacity of the equipment is 40,000 tons of nitrogen in the form of approximately 200,000 tons of cyanamide, or 110,000 tons of ammonium nitrate, which is a little more than one-tenth of the annual nitrogen fertilizer demand of the United States. It has been suggested that ammonium sulphate and ammonium phosphate be produced, as well as cyanamide and ammonium nitrate. However, additional equipment would be required to produce these additional products. The whole question of fertilizer production at Muscle Shoals is one on which there is wide difference of opinion among those well informed on the subject.

#### THE DIRECT SYNTHETIC AMMONIA PROCESS

The direct synthetic ammonia process, sometimes called the Haber process, is the leading producer of air-nitrogen-fixation products. There are about 75 manufacturing establishments of this type in the world, 8 of which are in the United States. From 1917 to 1929 the inorganic-nitrogen production of the world from all sources increased from 1,205,600 tons to 2,324,300 tons, which is equivalent to 14,500,000 tons of nitrate of soda, and the increase was due mainly to growth in production by the direct synthetic ammonia process. However, the 1929 production included many products containing different percentages of nitrogen. In the United States production by the direct synthetic ammonia process alone increased from 26,000 tons of nitrogen in 1928 to approximately 140,000 tons in 1930, which was equivalent to approximately 875,000 tons of nitrate of soda.

Figures 13, 14, and 15 are views of a synthetic ammonia factory at Belle, W. Va.

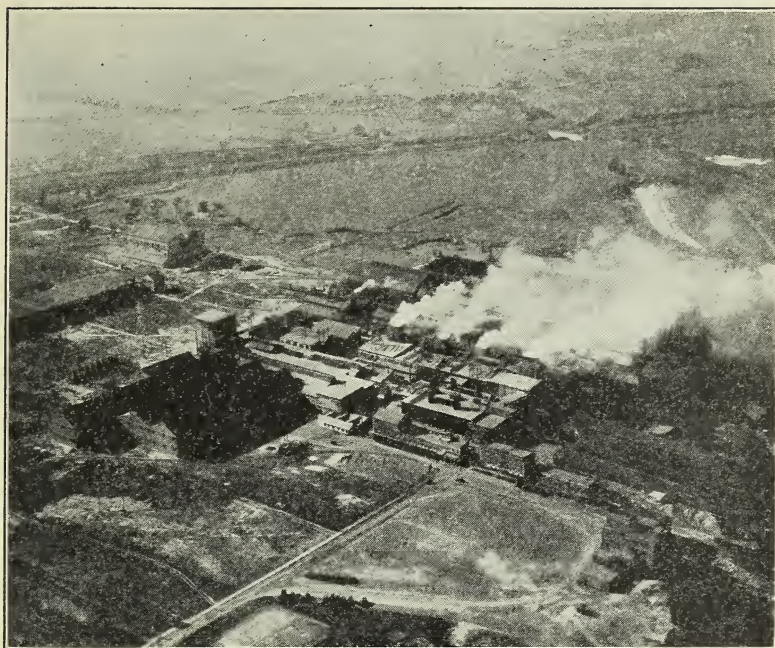


FIGURE 9.—Airplane view of air-nitrogen-fixation plant, Niagara Falls, Canada. Annual capacity, 350,000 tons cyanamide containing from 80,000 to 90,000 tons of nitrogen

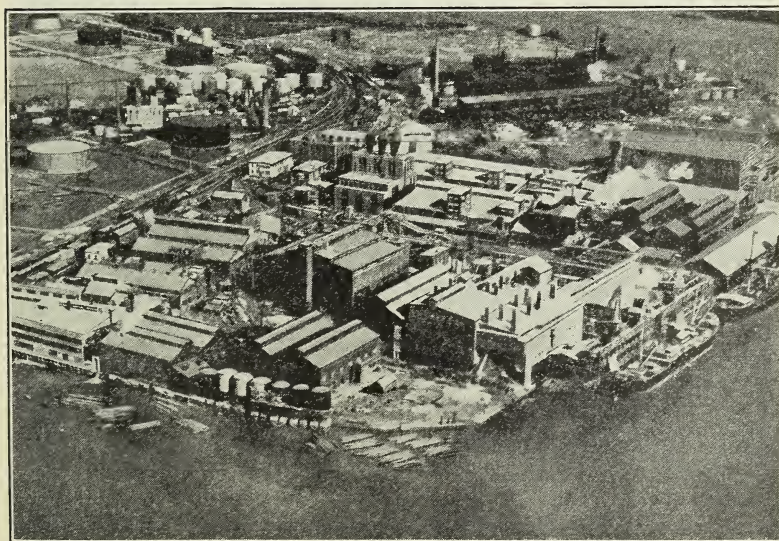


FIGURE 10.—Airplane view of an ammonium-phosphate plant, Warners, N. J., in New York Harbor

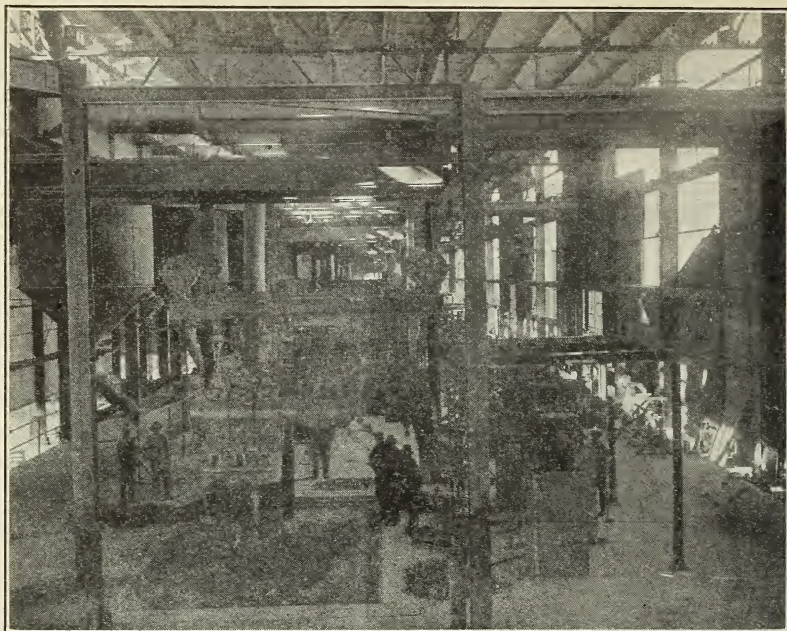


FIGURE 11.—Carbide furnace, United States Nitrate Plant No. 2, Muscle Shoals, Ala. Coke and burned lime are melted together to make calcium carbide which is cooled, pulverized, and treated with nitrogen gas in other parts of the plant to make cyanamide. In the picture the electrodes have been lifted out of the charge

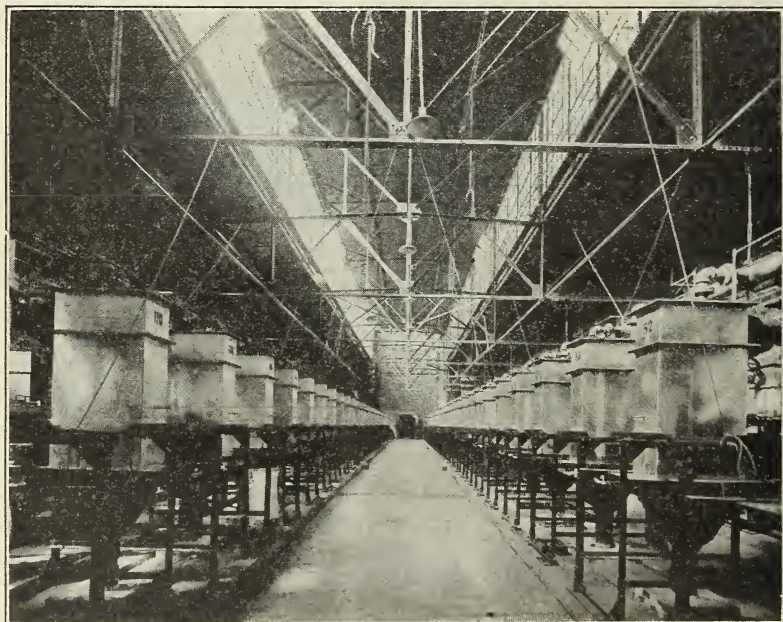


FIGURE 12.—Nitric-acid plant, United States Nitrate Plant No. 2, Muscle Shoals, Ala. A mixture of ammonia and air is passed over heated platinum gauze as the first step in the conversion of ammonia into nitric acid

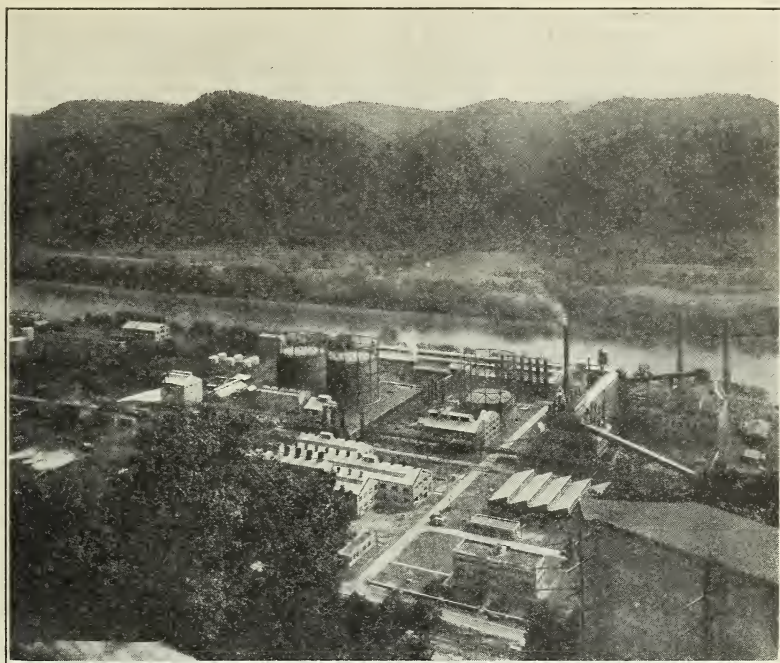


FIGURE 13.—Partial view of synthetic ammonia plant, Belle, W. Va.

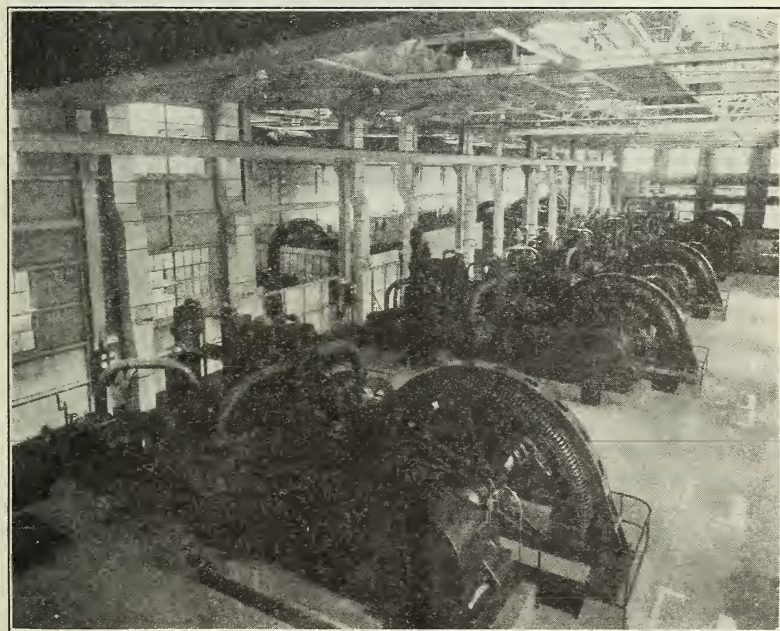


FIGURE 14.—Gas compressors, Belle, W. Va. Here the gas mixture is subjected to several stages of compression, resulting in the high pressure required for ammonia synthesis

The direct synthetic ammonia process fixes nitrogen by the direct union of nitrogen and hydrogen to form ammonia. Three parts by volume of hydrogen gas combine with one part of nitrogen to make two parts of ammonia. The product, ammonia, is a gas under ordinary conditions, but under pressure it becomes a liquid which can be shipped in cylinders or tank cars as liquid or anhydrous ammonia. The ammonia gas can be dissolved in water to make aqua ammonia, which can be shipped and handled without difficulty. In this country anhydrous ammonia is being shipped extensively in tank cars, built especially for the purpose, thus avoiding transporta-

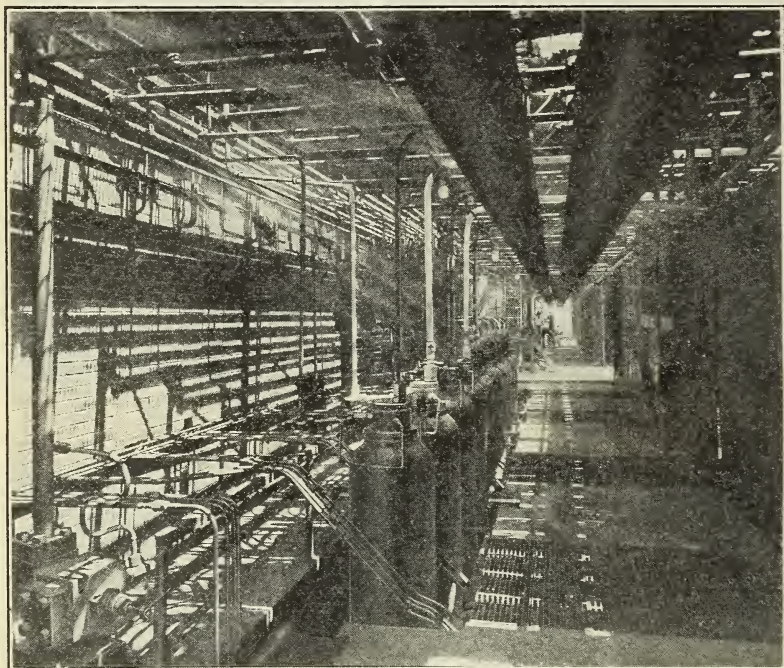


FIGURE 15.—Synthesis building, showing high-pressure receivers and piping, Belle, W. Va. Here ammonia is made by passing a mixture of nitrogen and hydrogen, under high pressure, through a bed of catalyst, maintained at an elevated temperature.

tion of water, which, if required, can be easily added at the point of consumption.

The ammonia produced by the American nitrogen-fixation industry is used for many purposes, such as ice manufacture, explosives, chemical products, and fertilizer. The main product of the largest American nitrogen-fixation plant, located at Hopewell, Va. (fig. 16), is nitrate of soda, which is made by converting ammonia into nitric acid; this, in turn, is neutralized with soda ash (sodium carbonate) and evaporated to give a solid salt which is practically identical with Chilean nitrate. Ammonia is shipped as such to the superphosphate and fertilizer mixing establishments of the country and is there added to the superphosphate to neutralize excess acid. This procedure has the double advantage of improving the mechanical

condition of the goods, and at the same time producing desirable fertilizer salts in the mixture without extra expense for acid.

#### CALCIUM NITRATE

Calcium nitrate, known also as nitrate of lime, is a material of increasing importance in the agriculture of the United States. It is imported from Germany and Norway, where it is made by neutralizing nitric acid with limestone (calcium carbonate). Calcium nitrate dissolves in the moisture of the soil and becomes immediately available as plant food. Formerly the tendency of this material to become wet from moisture taken up from the air made its shipment and use

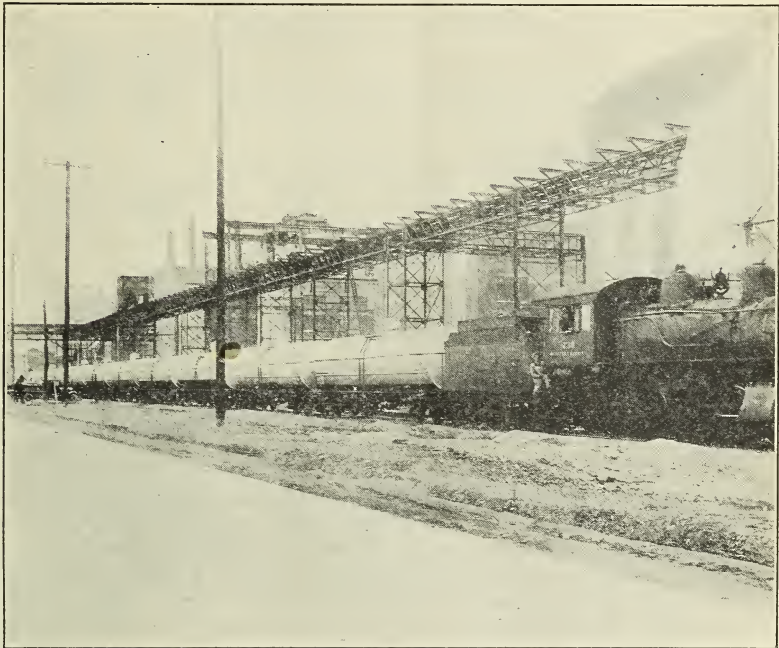


FIGURE 16.—Tank cars loaded with anhydrous ammonia leaving synthetic ammonia plant, Hopewell, Va. Ammonia is shipped to fertilizer plants for addition to superphosphate

rather difficult, but this undesirable characteristic has been reduced by improvements in the method of manufacture.

A number of materials enter into the fertilizer trade in smaller quantities. In the figures of production (p. 4) these were grouped together as miscellaneous. Since some of these materials have come into use only in recent years they probably deserve more attention than their small tonnage might indicate, and some of them may fill more important places in the future. This miscellaneous item includes urea, calurea, ammonium sulphate-nitrate, nitrophoska, ammo-phos, nitrolime, cal-nitro, ammonium chloride, potassium nitrate, and other materials which have been introduced during recent years to meet special conditions of the market and to create new outlets for the increasing production of fixed atmospheric nitrogen.

## PERCENTAGE OF PLANT FOOD IN FERTILIZERS

In Table 1 the leading fertilizer materials are listed, together with the approximate amount of plant food they contain. These materials when mixed in the proper proportions make up, largely, the many grades and brands of mixed fertilizer which are now available on the market.

TABLE 1.—*Plant-food content of fertilizer materials*

| Material                                     | Nitrogen<br>(N) | Phos-<br>phoric<br>acid<br>(P <sub>2</sub> O <sub>5</sub> ) | Potash<br>(K <sub>2</sub> O) |
|--|-----------------|---|------------------------------|
|  | <i>Per cent</i> | <i>Per cent</i>   | <i>Per cent</i>              |
| Pone.....                                    | 1.6-4           | 20-25   | 0                            |
| Basic slag.....                              | 0               | 10-25   | 0                            |
| Superphosphate.....                          | 0               | 14-20   | 0                            |
| Triple superphosphate.....                   | 0               | 40-50   | 0                            |
| Kaifit.....                                  | 0               | 0   | 12.4-16                      |
| Manure salts.....                            | 0               | 0   | 20-30                        |
| Muriate of potash (potassium chloride).....  | 0               | 0   | 50-60                        |
| Sulphate of potash (potassium sulphate)..... | 0               | 0   | 48-50                        |
| Ammonia.....                                 | 82.2            | 0   | 0                            |
| Sulphate of ammonia (ammonia sulphate).....  | 20-21           | 0   | 0                            |
| Ammonium sulphate-nitrate.....               | 26              | 0   | 0                            |
| Nitrate of soda (sodium nitrate).....        | 15.6-16         | 0   | 0                            |
| Nitrate of lime (calcium nitrate).....       | 15.5            | 0   | 0                            |
| Nitrate of ammonia (ammonium nitrate).....   | 34.5            | 0   | 0                            |
| Cyanamide.....                               | 20-25           | 0   | 0                            |
| Urea.....                                    | 46              | 0   | 0                            |
| Calurea.....                                 | 34              | 0   | 0                            |
| Cottonseed meal.....                         | 5-7             | 2-3   | 1.5-2                        |
| Dried blood.....                             | 9-14            |   | 0                            |
| Tankage.....                                 | 5-10            | 3.5-14  | 0                            |
| Garbage tankage.....                         | 2.5-3.3         | 2-5   | 0.5-1                        |
| Fish scrap.....                              | 6.6-10          | 4-8   | 0                            |
| Ammo-phos.....                               | 11-16.5         | 20-46   | 0                            |
| Nitrophoska.....                             | 15-16.5         | 11-30   | 15-26                        |

Since bags, freight, hauling, and handling are important items of expense in the cost of fertilizer, high-analysis fertilizers are economical to the farmer and manufacturer alike. Sand or some other useless filler is sometimes added in order to meet the demand for low-analysis fertilizer at low prices per ton. This practice always results in increased cost of the plant food to the buyer, who should be guided by the price of the plant food rather than by the price per ton. If by mixing certain quantities of materials a fertilizer containing 20 per cent of plant food is produced, there is no good reason for adding sand to reduce the percentage of plant food to 18 or 16 per cent, although this will naturally result in a lower price per ton. The buyer who insists on its addition must pay for the filler, the extra bags required, and also the freight. In addition he must haul and handle the useless weight.

The percentage of plant food contained in the various materials listed ranges from approximately 6 to 82.2 per cent. In none of them has the plant-food content been reduced by the addition of filler. Such useless substances as they contain are present because of the nature of the product and the process of manufacture, and because the advantage to be gained by their removal does not justify the expense involved.



It will be noted that the list includes several highly concentrated materials manufactured for use where a high percentage of plant food is desirable. Since 666 pounds of fertilizer containing 54 per cent of plant food contains as much plant food as 2,000 pounds containing 18 per cent, the saving on bags, freight, hauling, and handling is evident. However, the cost of manufacture is a determining factor, also, and the difficulty of distributing such small quantities of fertilizer uniformly in the soil has been considered a disadvantage by the users. As yet the consumption of concentrated fertilizer has been a very small part of the whole, the average plant-food content of all the fertilizer used in the United States being about 18 per cent.

### FERTILIZER FACTORIES

In the foregoing discussion much has been said about the materials which enter into fertilizer and about the establishments for their production. Although essential to, and really a part of, the fertilizer industry, these works are usually called chemical plants. The typical plant ordinarily referred to as a fertilizer factory is one engaged principally in making up and shipping fertilizer ready for use by the farmers. All have storage for raw materials and the finished product, dry-mixing equipment, and packing and shipping facilities. Some producers buy all the ingredients, whereas others have rock-grinding and acidulating equipment for making superphosphate, using either purchased sulphuric acid or acid made in their own acid plants. Others manufacture organic nitrogenous materials for mixing with purchased ingredients. There are some 800 fertilizer factories in the United States with capacities ranging from a few tons to about 450,000 tons a year.

Since the fertilizer market is highly seasonal, each factory requires ample storage space, where great piles of their product may be prepared ready for the rush shipping season. The storage piles serve the additional purpose of allowing mixtures, which require time for seasoning, a chance to cure thoroughly before being placed in bags for shipment. Certain materials when freshly mixed have a tendency to cake and become lumpy. By allowing this action to take place in the stock pile and then disintegrating and screening the material immediately before bagging, the likelihood of the fertilizer becoming lumpy in the bags is reduced.

The fertilizer factories are well distributed throughout the consuming area, which is mainly in the South and East. The five States, North Carolina, South Carolina, Georgia, Florida, and Alabama, use more than half the fertilizer consumed in the United States. Many of the larger works are located at seaports in order to take advantage of cheap water transportation in bringing in the raw materials, and also, to less extent, in sending out the finished product.

Every modern fertilizer factory must have its chemical laboratory. Materials must be sampled and analyzed by the factory chemists in order that the right quantity of each ingredient may be used in making fertilizers of any given analysis. After the fertilizer

has been mixed, it is analyzed to make sure that it is up to the guarantee. Almost every State has a fertilizer-control law and a system of inspection and analysis. These furnish protection both to the farmer and to the honest fertilizer manufacturer, and, as a result, the fertilizers sold are usually equal to or better than the guarantee.



