$$\frac{1}{510} = \frac{1}{h_s} + \frac{1}{53000} + \frac{1}{4.45(510)^{0.8}}$$

$$h_s = 2500$$

Table 1 gives the results of the calculation for all of the tests. Fig. I shows values of percentage of steam plotted against film coefficient— h_s .

The data include steam percentages down to 66 per cent only. The film coefficient for zero per cent, that is, all air, has been the subject of much careful work, the values of h being a function of the velocity and varying between 1 and 20. Since no information was given in Professor Kerr's experiments as to the rate of removal of the air, the writer selected a mean value of 10 for this point in order that it might be possible to derive a suitable empirical equation to fit the above calculation.

FIG. II—EFFECT OF AIR ON "L" FOR STEAM: x = PER CENT STEAM BY VOLUME, h = FILM COEFFICIENT

Inspection of the curve on Fig. I indicates that it has the form indicated by the exponential equation

$$h = ae^{\beta x},$$

where a and β are constants to be determined and x is per cent steam by volume. In order to test the applicability of this type of equation, it may be rectified as follows. Take the logarithm of both sides of the equation

$$\log_e h = \log_e a + \beta x.$$

If a plot of the data in the form of $(\log_e h - \log_e a)$ versus " x " indicates a straight line, the equation selected is satisfactory. Since when $x = 0$, $h = a$, $\therefore a = 10$, and the resulting plot is shown on Fig. II.

The proper value for β was found by averaging all of the points, the resulting equation having the form

$$\log_e h = 2.303 + 0.0566x$$

or
$$h = 2.303 e^{0.0566x}$$

a more convenient form of the equation is

$$\log_{10} h = 1 + 6.0240x.$$

A plot of this equation is represented by the curve on Fig. I.

THE PRODUCTION OF PHOSPHORIC ACID BY SMELTING PHOSPHATE ROCK IN A FUEL-FED FURNACE

By William H. Waggaman and Thomas B. Turley

BUREAU OF SOILS, U. S. DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

[PRELIMINARY REPORT]

Received March 1, 1920

Ever since the early days of the war when the high cost and scarcity of acid phosphate seemed to menace our agricultural interests, the Bureau of Soils has given

considerable attention to the production of soluble phosphates by means other than the usual method of treating phosphate rock with sulfuric acid.

Perhaps the most attractive and in many ways the most promising of these processes is that in which an intimate mixture of a natural phosphate, silica, and coke is smeltered at a high temperature, with the result that silicates of lime are formed and the phosphoric acid volatilized and subsequently collected in some suitable manner. This process is really based on the method long in use for the manufacture of phosphorus, and in order to separate completely the phosphoric acid from the lime it is apparently necessary to have a sufficient quantity of reducing agent present to produce elementary phosphorus according to the equation

The phosphorus produced is subsequently burned or oxidized within or outside of the furnace by carbon dioxide or air thus

or

It has been generally believed that the temperature and other conditions necessary to volatilize completely phosphorus and phosphoric acid from natural phosphates could be attained only in the electric furnace,¹ and the Bureau's early experiments were therefore conducted in furnaces of the arc type. As the results of these investigations have been described in previous articles, only a brief outline of the work is given in the present paper.

The first experiments were carried on in a rather crude electric furnace constructed at the Bureau's experimental laboratories at Arlington Farm, Va., and here the Cottrell method of electrical precipitation was first successfully applied to the collection of the volatilized phosphoric acid. Ross, Carothers and Merz² showed that by this means there could be obtained an acid of such high concentration that the added cost of manufacturing phosphoric acid by the volatilization process would be partly offset by the saving in transportation charges in shipping and distributing the product. Later a larger and more complete furnace with auxiliary apparatus was constructed at Hoboken, N. J.

In reporting on this work Carothers³ showed that, assuming the price of electric power at \$25 per h.-p. yr., phosphoric acid (P_2O_5) could be produced and recovered at a cost of 3.37 cents per pound exclusive of interest on investment, taxes, and royalties. By using the acid thus obtained to treat more phosphate rock, however, a double superphosphate could be produced which brought down the price of the unit of soluble phosphoric acid very appreciably. The figures indicated that under the abnormal conditions existing at that time, the cost per unit of phosphoric acid produced by the volatilization process compared favorably with the cost of this ingredient in ordinary superphosphate obtained by the sulfuric acid method.

¹ F. S. Washburn, U. S. Patents 1,044,957 (1912); 1,100,639 (1914).

² THIS JOURNAL, 9 (1917), 26.

³ *Ibid.*, 10 (1918), 35.

TABLE I—VOLATILIZATION OF PHOSPHORIC ACID FROM MIXTURES OF TRICALCIUM PHOSPHATE, SILICA, COKE AND ALUMINA BY SMELTING IN OPEN AND CLOSED CRUCIBLES IN A DENTAL FURNACE BY MEANS OF ILLUMINATING GAS AND AN AIR BLAST

Sample No.	Crucible	PROPORTIONS OF MATERIALS USED IN CHARGE				PERCENTAGE COMPOSITION					Temperature Attained °C.	Length of Time Heated Hrs.	P ₂ O ₅ in Slag Per cent	P ₂ O ₅ Volatilized Per cent of Total	Character of Slag
		Ca ₃ (PO ₄) ₂ Grams	SiO ₂ Grams	Al ₂ O ₃ Grams	Coke Grams	SiO ₂	CaO	Al ₂ O ₃	P ₂ O ₅	C					
12 A.....	Closed (Clay)	20.0	16.6	...	5.2	40.7	25.9	0.7	21.9	10.8	Above 1400	0.75	3.24	89.8	Fluid, grayish black
12 G.....	Open (Clay)	20.0	16.6	...	5.2	40.7	25.9	0.7	21.9	10.8	Above 1400	1	7.20	76.2	Viscous gray. White bloom on surface ¹
12 N ₁	Open (Graphite)	20.0	16.6	6.6	5.2	35.1	22.4	14.3	18.9	9.3	1200	1	4.92	80.4	Viscous black
12 N ₂	Open (Graphite)	20.0	16.6	6.6	5.2	35.1	22.4	14.3	18.9	9.3	Above 1400	2	None	100.0	Fluid, black
12 O.....	Open (Clay)	20.0	16.6	...	4.8	41.1	26.2	0.7	22.1	9.9	Above 1400	1	3.36	89.3	Fluid, light gray
12 P.....	Open (Clay)	20.0	16.6	6.6	5.0	40.9	26.1	0.7	22.0	10.3	Above 1400	1	2.22	93.0	Fluid, light gray; bloom on surface ¹
12 Q.....	Open (Clay)	20.0	16.6	6.6	5.4	40.7	25.8	0.7	21.8	11.0	Above 1400	0.75	4.65	84.9	Fluid, light gray; bloom on surface ¹
12 R.....	Open (Clay)	20.0	16.6	6.6	5.6	40.5	25.7	0.7	21.7	11.4	Above 1400	0.75	2.45	92.2	Fluid, light gray; bloom on surface ¹
12i.....	Open (Clay)	20.0	16.6	6.6	5.2	40.7	25.9	0.7	21.9	10.4	1300	1	Trace	100.0	Fluid, light gray; large bloom ¹
12j.....	Closed (Clay)	20.0	16.6	6.6	5.2	40.7	25.9	0.7	21.9	10.4	1300	1	Trace	100.0	Fluid, all slag
12i ₁	Open (Clay)	20.0	16.6	2.0	5.6	38.7	24.5	5.2	20.7	10.9	1300	1	5.28	81.3	Viscous light gray; bloom on surface ¹
12i ₂	Closed (Clay)	20.0	16.6	2.0	5.6	38.7	24.5	5.2	20.7	10.9	1300	1	1.91	93.6	Viscous dark; no bloom
12i ₃	Open (Clay)	20.0	20.0	2.0	4.8	43.6	23.2	4.9	19.6	8.7	1300	1	4.26	83.7	Viscous gray; large bloom ¹
12i ₄	Closed (Clay)	20.0	20.0	2.0	4.8	43.6	23.2	4.9	19.6	8.7	1300	1	3.52	86.6	Viscous gray; no bloom
12i ₇	Open (Clay)	20.0	22.0	2.0	4.8	45.9	22.2	4.7	18.8	8.4	1300	1	3.90	84.3	Viscous gray; large bloom ¹
12i ₈	Closed (Clay)	20.0	22.0	2.0	4.8	45.9	22.2	4.7	18.8	8.4	1300	1	3.75	84.8	Viscous gray; no bloom

¹ An analysis of the bloom or white crust on the surface of slags obtained in open crucibles shows a considerably higher percentage of phosphoric acid than in the original mixture. The proportion of lime to phosphoric acid coincided very closely with that in calcium pyrophosphate (Ca₂P₂O₇).

In a later investigation, Waggaman and Wagner¹ pointed out that by using the "mine-run" phosphates of Florida, which in their natural state contain impurities which preclude their treatment with sulfuric acid until they have been put through an elaborate washing and screening process, a great saving in phosphate could be effected and the cost of the soluble phosphoric acid produced therefrom very materially reduced.

The high cost of electric power in this country, however, made it appear very desirable to test out the commercial possibilities of producing phosphoric acid for fertilizer purposes in a fuel-fed furnace, and, since crude oil is the cheapest and most accessible fuel for the phosphate regions of Florida, it was decided to undertake experiments with a view to producing phosphoric acid by this means.

LABORATORY EXPERIMENTS

Preliminary work in the laboratory, where various mixtures were heated in a dental furnace by means of gas and an air blast, showed that contrary to general opinion the nearly complete evolution of phosphoric acid from a charge of calcium phosphate, carbon and quartz flour was perfectly feasible provided that reducing conditions were maintained until a fusible slag was produced, and a temperature of approximately 1500° C. was continued throughout the operation.

Table I shows in part the results obtained by heating such mixtures, with and without the addition of small amounts of aluminum oxide, in both open and closed fire-clay crucibles.

An inspection of Table I will show that as a rule considerably better results were obtained where the crucibles were kept covered so that the oxidizing gases were not allowed to come into contact with the charge. When the crucibles were left open, it was noticed that a white crust or "bloom" almost invariably formed over the slag and no matter how long the high temperature was maintained this crust gave no sign of melting. The quantity of this crust in a number of

instances was equal to that of the underlying slag. It is assumed that the phosphoric acid distilling from the lower part of the mass recombined with or was fixed by the lime at the surface where oxidizing conditions prevailed, forming calcium pyrophosphate according to the following equation:

It was found, however, that when the fusion of the charge was well under way and the carbon or coke thus protected in the mass of molten slag, the covers of the crucibles could be removed without the formation of this crust and that the reaction continued in spite of the oxidizing conditions at the surface of the slag. The addition of small amounts of alumina to the charge seemed to aid the fusion somewhat, it being a well-known fact that the presence of this substance in limited amounts lowers the melting point of both acid and basic slags.

In most of these mixtures the ratio of silica to lime was approximately 39 to 61 per cent, but it was found later, in dealing with the natural phosphates of Florida, that better results could be obtained by varying these proportions according to the composition of the mineral used.

These laboratory experiments pointed almost conclusively to the necessity of maintaining reducing conditions in the phosphatic charge until fusion has begun, and it appeared at first sight that the most practical method of doing so in a mass containing much finely divided material, such as the pebble phosphates and the mine-run phosphates of Florida, was to heat the mixture in a separate chamber so that the oxidizing gases from the burning fuel would not come into contact with the charge until the latter had been brought to a state of incipient fusion.

LARGER SCALE EXPERIMENTS

Accordingly in order to test this process on a semi-commercial scale, a fire-brick furnace of the type shown in Fig. 1, described by the senior author and

¹ THIS JOURNAL, 10 (1918), 353.

others in U. S. Patent 1,282,994, was constructed at Arlington Farm, Va. This furnace comprised a central or inner chamber (holding about 150 lbs. of charge) open both at the top and bottom but constricted somewhat at its lower end to prevent the charge from working through too rapidly. This chamber was supported on arches of carborundum brick above a hollow hearth intended to receive the molten silicate. The whole was surrounded by an outer chamber into the opposite walls of which were set two oil burners so placed that their flames played upon and around the lower part of the inner chamber, heating the charge by radiation through the 4-in. walls. Any fumes which were evolved from the smelting of the mass were to be drawn down through the charge chamber and passed together with the gases of combustion onto the Cottrell precipitator in order to collect the phosphoric acid.

FIG. 1—FURNACE USED IN FIRST EXPERIMENTS

This indirect method of heating the charge proved so inefficient and entailed such a loss of heat that after several trials lasting from 18 to 24 hrs. it was abandoned as impractical, and no molten slag was obtained, although a certain amount of phosphoric acid was driven off, and a sintered product obtained in the charge chamber. The experiments showed quite clearly that in order to make the process economically practicable the full calorific power of the fuel must be utilized, which can be done only by heating the charge directly in the flame. This conclusion only served to emphasize the problem of how to maintain the reducing conditions necessary for the volatilization of the phosphoric acid, when the maximum efficiency of the crude oil flame, or that of any other fuel, can only be obtained under oxidizing conditions. Moreover, the phosphates with which the experiments were being conducted are of such a character that it is impossible to handle them in a plant of the blast furnace type, as a flame cannot be forced through a mass of such finely divided material.

At the suggestion of Professor Whitney, chief of this Bureau, the plan of spraying the phosphatic charge

into the furnace along with the fuel was then tried; one oil burner was entirely cut off and a concave baffle of carborundum brick built opposite the other burner. The charge was placed in a hopper from which it was mechanically fed through a screw conveyor and blown into the furnace against the baffle in a spray under an air pressure of 30 lbs. to the square inch. It was found that if the charge was fed into the furnace very slowly a certain amount of slag low in phosphoric acid formed upon and ran down the wall of the baffle, but the vast bulk of the material, owing to its finely divided condition, was carried out of the furnace along with the gases of combustion and lost. After several trials with material of various degrees of fineness this method was also abandoned.

BRIQUETTING THE PHOSPHATE CHARGE

It was then thought that perhaps the nodulizing or briquetting of the phosphate charge might present a solution of the problem, and experiments were begun on the briquetting of mixtures of finely ground pebble phosphate, sand and coke, using various binders such as solutions of magnesium chloride, calcium chloride, calcium sulfate, sodium chloride, sodium silicate, phosphoric acid, and an acid sludge from the refining of petroleum. Short cylindrical briquettes 1 in. thick and 1 in. in diameter were made in a mold under a pressure of about 1 ton, but none of the binders employed proved satisfactory since the briquettes (either air dried or oven dried) shattered when dropped upon a stone table from a height of 1 to 3 ft. In the Florida hard-rock regions, however, the phosphate deposits in their natural state contain much soft phosphate and clay-like material of considerable plasticity, and it was thought that possibly the binding qualities of this mine-run phosphate might prove sufficiently effective without the addition of any other ingredient.

TABLE II—MECHANICAL ANALYSIS OF FINELY GROUND FLORIDA PEBBLE PHOSPHATE, MINE-RUN PHOSPHATE, AND FURNACE CHARGES MADE UP FROM THESE PHOSPHATES

MATERIALS ANALYZED	PERCENTAGE OF VARIOUS SIZED PARTICLES IN SAMPLES					
	Fine Gravel and Coarse Sand Diam. 2-0.5 Mm.	Medium Sand Diam. 0.25 Mm.	Fine Sand Diam. 0.5-1.1 Mm.	Very Fine Sand Diam. 1-0.05 Mm.	Silt Diam. 0.05-0.005 Mm.	Clay Diam. 0.005-0.000 Mm.
1—Florida pebble phosphate (finely ground).....	0.0	0.0	20.4	24.8	36.0	18.8
2—Mine-run phosphate from hard rock regions.....	0.0	0.2	30.2	14.6	21.0	34.0
3—Sample 1 mixed with finely ground silica and coke....	3.2	6.4	36.6	20.2	27.6	6.2
4—Sample 2 mixed with finely ground silica and coke....	0.4	0.6	35.0	18.9	19.5	25.5

In order to compare the fineness of the washed and ground pebble phosphate with that of the mine-run phosphate, samples of each were ground in a ball mill and then submitted to the mechanical analysis employed in this Bureau in connection with the classification of soil types. Samples of these two phosphates mixed with the proper proportions of finely ground sand and coke to produce a charge suitable for furnace treatment were also analyzed in the same way. For results of these mechanical analyses see Table II.

This table will show that the percentage of clay particles present (upon which the plasticity of the material largely depends) was nearly twice as great in the mine-run phosphate as in the sample of pebble phosphate, even after the two materials had been ground for several hours in a ball mill and passed through a 60-mesh sieve.

Experiments were then undertaken in briquetting samples of the original mixture except that the finely ground pebble phosphate was replaced in part and finally wholly by the mine-run phosphate. These charges in each case were mixed with 10 per cent of water and made into short cylindrical briquettes (1 in. in diameter) under a pressure of one ton.

The results of these tests¹ are given in Table III.

TABLE III—SHATTER TESTS ON BRIQUETTES			
Ratio between the Two Phosphates in Charge, Per Cent		Height at Which the Briquette Shattered, Feet	
Pebble Phosphate	Mine-Run Phosphate	Air Dried Briquette	Oven Dried Briquette
100.0	0.0	3	3
90.0	10.0	3	3
75.0	25.0	4	4
50.0	50.0	4	6
25.0	75.0	6	7
0.0	100.0	9	10

It is evident that a charge containing from 20 to 25 per cent of finely divided material classed as clay can be formed into very satisfactory briquettes, but it was decided that the size of those used in the first tests was somewhat small for furnace treatment, so a larger mold was made and a round briquette 2 in. in diameter used in the next furnace experiment. The tediousness of preparing a sufficient number for a protracted run, coupled with a desire to test thoroughly the efficiency of the natural binder, prompted the writers to make arrangements with the Lehigh Coal and Navigation Co., of Lansford, Pa., to use their coal briquetting machinery on this phosphate mixture. This company kindly consented to turn over their briquetting plant for the experiment, and accordingly a half ton of the mixture was crushed to pass a 10-mesh screen, thoroughly mixed with 10 per cent of water and shipped to Lansford in air-tight barrels. Without any further treatment it was charged into a screw conveyor and fed directly to the hopper above a press of the Belgian Roll type. Very satisfactory briquettes in the shape of eggets (2.25 x 2' x 1.5) were produced which on drying withstood a drop of 6 ft. upon a cement floor without shattering.²

DIRECT HEATING OF BRIQUETTED CHARGE

The furnace was then so modified that a portion of the flames and hot gases of combustion from the oil burners would play up through the central shaft and thus heat the charge of briquettes directly. The burners were lighted at 8 A. M. and run steadily until 6 P. M., when a reading with an optical pyrometer was made which showed a temperature of over 1300° C. on the hearth. A few lumps of coke were then dumped into the shaft followed by 32 lbs. of briquettes. Within 10 min. fumes of phosphoric acid began to be evolved,

¹ These early briquetting experiments were made by Mr. L. A. Steinkoenig, who has since resigned from the Department of Agriculture.

² The writers wish also to express their appreciation of the courtesy extended by the General Briquetting Co., of New York City. This company not only made a number of experiments in briquetting the phosphate charge but also briquetted a ton of material used in later experiments.

and this continued for over an hour. At 7.45 P. M. a few more lumps of coke were added followed by 32 lbs. of briquettes. Copious fumes were evolved about 15 min. later which gradually grew less dense until at 8.50 P. M. (one hour later) another charge of 34 lbs. was added. This was followed by a fourth charge of 33 lbs. at 9.03 P. M. The heat was continued until 12:00 midnight when the optical pyrometer gave a reading of 1470° C. on the hearth. The burners were then shut off and an attempt made to tap the furnace, without success, due to the viscous nature of the slag produced.

After the furnace had cooled down, the slag was dug out and its phosphoric acid content determined. An average sample of the slag showed 11.52 per cent P_2O_5 while that which was more glassy and better fused contained only 3.53 per cent of P_2O_5 . It was found that some of the briquettes which had not been fused were covered with a thin white glaze. This glaze evidently protects the carbon in the mass from the oxidizing gases until fusion takes place, for upon breaking the briquettes the coke was found unaltered, although they had been in the furnace several hours.

FIG. 2—EFFECT OF THE DIRECT OIL FLAME UPON PHOSPHATIC BRIQUETTES JUST BEFORE FUSION TAKES PLACE. NOTE THE UNALTERED COKE CONTAINED WITHIN THE MASS

The effect of this direct heating on the briquettes before they are actually fused can be seen in Fig. 2. On the right are the briquettes as they appear before being charged to the furnace, and at the left of the picture are shown those which have been exposed to a high temperature for several hours but not sufficiently high to cause them to melt. In the center are shown some of these latter briquettes broken open. It will be noted that there is a sharp line of demarkation between the thin glaze of the oxidized exterior of the briquettes and the interior containing the unaltered coke.

It was unfortunate that the furnace used was of such a type as to be ill adapted to the change from the indirect to the direct method of heating the charge. This fact accounts in part for the long time required in attaining a smelting temperature. With a view to overcoming this difficulty, firebrick "annexes" were built on each end of the furnace and the burners thus placed further from the charge chamber so that the

oil would have a better chance for combustion. The iron plates holding the burners were replaced by cast iron water jackets to avoid the danger of injuring the burners, and a coil of pipe imbedded in a coke fire was also placed between the blower or fan and the furnace so that the air required for the combustion of the oil could be preheated before it was delivered to the burners.

The first test (No. 2, Table IV) made with these changes in the furnace was unsuccessful due to the cracking of the cast iron water jacket around one of the burners which made it necessary to close down after a few hours' run. But the second run (No. 3, Table IV) was very encouraging, since phosphoric acid was copiously evolved but the temperature attained was not quite high enough. The third test (No. 4, Table IV) was more successful while it lasted, but during the last hour of the experiment the charge chamber collapsed and the burners had to be shut off before the last of the charge was fully smelted.

TABLE IV—RESULTS OBTAINED IN SMELTING BRIQUETTES MADE OF MINE-RUN PHOSPHATE, SAND AND COKE IN A SHAFT FURNACE HEATED BY CRUDE OIL

Test	Briquettes Charged, Lbs.	Time after First Charge, Hrs.	Temp. Air to Oil Burner, ° C.	Temp. Attained in Furnace, ° C.	P ₂ O ₅ in briquettes, Per Cent	P ₂ O ₅ in Slag, Per Cent	P ₂ O ₅ Volatilized, Per Cent of Total
1	153	6.5	15	Over 1400	20.46	{ 11.52 ¹ 3.53 ²	{ 49.12 85.82
2	97	1	100 to 150	Approx. 1400	20.46	{ 11.36 ¹ 11.09 ¹	{ 50.19 51.51
3	110	6	200 to 270	1500	20.46	{ 10.66 ² 8.64 ¹	{ 53.56 63.24
4	105	3.5	250 to 300	1500	20.46	{ 1.63 ³	{ 93.55

¹ Bulk of slag.

² Evidently better fused slag.

³ Part of this slag was left in the furnace from the previous test and its phosphoric acid content further reduced by the last heating of the furnace.

While it was only in the last run of the furnace that a slag was obtained nearly free from phosphoric acid, it appeared evident that by exposing the charge to a high temperature for a sufficient length of time nearly complete evolution of phosphoric acid could be brought about.

FIG. 3—NEW OIL BURNING FURNACE WITH AUXILIARY APPARATUS

The erection of a furnace better adapted for the treatment of the material and for the more efficient utilization of the heat of the burners was then begun. Auxiliary apparatus for burning of any combustible gas evolved and heating of the air to the burners by waste gases was constructed, and the whole system

connected with a Cottrell precipitator for the collection of the volatilized phosphoric acid. This furnace (shown in Fig. 3) holding 700 lbs. of charge was completed early in January 1920, but adverse weather conditions and certain necessary changes in the equipment have delayed its running. Only one short test has been made so far, and the breaking of the belt to one of the motors made it necessary to cut off the burners before the experiment was completed. The results obtained in this short run, however, have convinced the workers that the form of the furnace is well adapted for the purpose and the principle used apparently sound. It is expected that interesting and valuable data will be obtained within the next few months which will show the commercial practicability of this process.

ECONOMIC CONSIDERATIONS

It is too early yet to prophesy the cost of producing phosphoric acid from mine-run phosphates by this new process, or to compare this method with that long in use for manufacturing soluble phosphates for fertilizer purposes. Certain advantages of this new process over the old sulfuric acid method, however, are so evident that they hardly need pointing out. For example, only high-grade phosphate rock containing a maximum of 4 or 5 per cent iron and aluminum oxides are at present used by the fertilizer manufacturers in producing acid phosphate. In order to obtain rock of this grade in Florida an elaborate washing and screening process is employed. This combined washing and screening process entails great losses of finely divided phosphate material which is discharged along with the impurities contained in the phosphate beds. The losses of phosphate thus entailed are fully twice as great as the quantity marketed and although much work and considerable money has been spent upon the problem, no mechanical or chemical method has yet been devised which will separate the phosphate from these impurities. It appears peculiarly fortunate that much of the material in the hard rock regions of Florida as it occurs in the mines has a composition almost ideally fitted for this furnace treatment. Instead of requiring reinforcement or enrichment by the addition of higher grade phosphate much of it must be brought to the desired composition by the addition of silica or sand, of which there is an unlimited supply at hand throughout the phosphate area. It will be seen, therefore, that the saving which can be effected by cutting out the expensive washing and screening plants, coupled with the advantage of prolonging the life of the phosphate deposits, will go far towards offsetting the additional expense, if any, involved in the preparation of the briquettes and the use of oil fuel rather than sulfuric acid as a reagent to convert the phosphoric acid into a soluble or available condition. Moreover, the product obtained is so concentrated that it can stand the expense of much longer shipments than the ordinary acid phosphate (which contains at best only from 16 to 18 per cent of soluble phosphoric acid) and by combining this concentrated phosphoric acid with ammonia and potash, fertilizers of the highest grade can be produced.