

Liquid Fertilizers from Wet-Process Phosphoric Acid and Superphosphoric Acid

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Wet-process phosphoric acid has not been used extensively in liquid fertilizer because it contains impurities that precipitate during ammoniation. Studies showed that the impurities could be sequestered by the addition of superphosphoric acid (76% P_2O_5) or ammoniated superphosphoric acid such as 11-33-0 during ammoniation of the wet-process acid. About half of the phosphate in superphosphoric acid, or its ammoniated product, is present in the form of pyrophosphates and polyphosphates which supply the sequestering effect. Best results were obtained when the wet-process acid and the sequestrant were added simultaneously during ammoniation. When about 30 to 40% of the total P_2O_5 in the final products was supplied as sequestrant, the maximum grades of liquid fertilizers that stored satisfactorily for 7 days at 32° F. and for 30 days at room temperature were as high as, or higher than, those made with electric furnace H_3PO_4 .

THE USE of wet-process phosphoric acid in the production of liquid fertilizers is of considerable interest to the fertilizer industry because it is cheaper than electric furnace acid at many locations. However, it has not been used extensively because it contains impurities that precipitate when the acid is ammoniated. These impurities, when precipitated, settle in storage tanks and tend to clog pipes and spray nozzles. Also, they contain a considerable amount of P_2O_5 ; therefore, from economic considerations, it is not feasible to filter out the precipitated impurities and discard them.

The Tennessee Valley Authority (TVA) has been studying methods that will permit the use of wet-process acid in the production of liquid fertilizers. These methods include the incorporation of a sequestering agent to prevent precipitation of impurities, and suspension of the impurities either by special technique or by use of a suspending agent.

Of the materials tested as sequestrants, the ones that appeared to be the most promising from the standpoint of sequestering and economics were superphosphoric acid (76% P_2O_5) and ammoniated superphosphoric acid (11% N, 33% P_2O_5). Potassium pyrophosphate was as effective as these two materials, but was relatively expensive. Potassium or sodium metaphosphate was not effective.

The present article describes small-scale and pilot-plant work carried out on the use of superphosphoric acid and ammoniated superphosphoric acid in the production of liquid fertilizers from wet-process phosphoric acid. Superphosphoric acid is a recent TVA development (4). It is made by the elec-

tric furnace process and contains about 76% of P_2O_5 (105% H_3PO_4 equivalent). About 50% of the phosphates are present as pyro and higher polyphosphates. It has been used successfully in the production of high-analysis liquid fertilizers (5) and in the production of high-analysis superphosphate of about 54% P_2O_5 content (2).

Small-Scale Tests

Raw Materials. Most of the tests were made with a supply of wet-process acid made from Florida phosphate rock. It contained less than 2% by weight of solid impurities, and was considered to be "shipping-grade" acid. A few tests were made with "production-line" acids made from Florida phosphate and from western phosphate. These acids had not been allowed to settle to separate solids; they contained 20 and 13% of solids, respectively. Analyses of these acids are shown in Table I. All tests reported were made with the shipping-grade acid produced from Florida rock, except where otherwise specifically noted. Other raw materials were aqua ammonia (23% N), superphosphoric acid (76% P_2O_5), potassium chloride (63.2% K_2O), and urea (46.6% N) or urea-ammonium nitrate solution (27.2% N), which was used as a source of supplementary nitrogen to obtain the desired N: P_2O_5 ratios.

Storage Requirements for Liquids. In laboratory tests of liquid fertilizers made from electric furnace orthophosphoric acid, it generally was considered that a satisfactory product would be one in which the fertilizer salts would remain in solution when the product was stored for 1 week at 32° F. and for 30 days at

room temperature. This criterion for determination of maximum grade also was used in the current work with impure wet-process phosphoric acid. However, since impurities in the acid tended to precipitate during ammoniation, the following additional specifications were arbitrarily established: Products that contained less than 1% of finely divided solids were considered probably satisfactory; those that contained more than 1% of solids or that contained less than 1% of solids, but in large crystal form measuring $1/8$ -inch or larger were considered to be unsatisfactory. Also considered questionable were products that formed light gels during storage. Light gels were considered to be those which, when stored in 4-ounce sample bottles, would break and pour upon tilting the bottle. Heavy gels were considered to be unsatisfactory.

In actual practice the requirements for storage need not be as rigorous as those stated above. Most liquid fertilizers probably are distributed within 1 or 2 days after production.

Procedures for Adding Sequestrant. Ammoniation of orthophosphoric acid to approximately neutral pH (pH 6.6) gives a solution having an N: P_2O_5 weight ratio of 1:3. The highest grade that will store at 32° F. without salting out is 8-24-0. Two procedures (3) are commonly used in the production of liquid fertilizers: a batch procedure consisting of the stepwise addition of raw materials in which the usual order of addition is water, acid, aqua ammonia, and then supplemental materials as necessary to produce the desired grade product; and a batch procedure in which aqua ammonia and phosphoric acid are fed simultaneously to a neu-

tralization vessel so as to maintain an approximately neutral solution (pH about 6.6) of nominal 8-24-0 grade; supplemental materials may then be added as necessary to produce the desired grade. The current work was limited to batch procedures that could be adopted easily in existing plants. Continuous procedures are only in limited use in industry and, therefore, were not studied in the current work.

Exploratory tests were made of the production of an 8-24-0 grade liquid in which 5 and 10% of the P_2O_5 were supplied as superphosphoric acid or ammoniated superphosphoric acid. The neutralizing vessel was a 250-ml. beaker and the raw materials were measured into the system by means of burets. No difference appeared in the sequestering effect of these materials when they were added to the neutralization vessel simultaneously with the wet-process phosphoric acid and aqua ammonia so as to maintain an approximately neutral solution (pH about 6.6). The products usually contained less than 1% of solids as produced, but further precipitation or gelling occurred on standing at room temperature for several days.

When the sequestrants were added to solutions that were acidic until near the end of the ammoniation step, however, they appeared to be less effective and there was much more precipitate present especially when the temperature was maintained during ammoniation at 180° F. Pyrophosphates and higher polyphosphates probably hydrolyzed to orthophosphate, which has no value as a sequesterant. Superphosphoric acid was less effective when added to water and allowed to stand for several minutes before ammoniation; hydrolysis of the polyphosphates occurred again. Upon dilution, the rate of hydrolysis of superphosphoric acid is rapid (7). How-

ever, ammoniated superphosphoric acid (11-30-0) was added to water without apparent loss in sequestering effect. The 11-33-0 grade was found also to be relatively stable during storage at moderate temperatures. Only about 5% of polyphosphates hydrolyzed in 4 months at 80° F.

Although it was possible to obtain sequestration by stepwise addition of water, acid, sequesterant, and aqua ammonia when the materials were added in rapid succession and the temperature was held at a low level (120° F.), it appeared likely that this procedure would cause excessive hydrolysis of the sequesterant in plant practice because a longer time would be required for addition of each material. Further consideration, therefore, was given only to procedures in which the sequesterant was added to a neutral solution. Ammoniated superphosphoric acid (11-33-0) was used as the sequesterant in most tests because, with the exception noted, it gave the same results, was neutral, and therefore easier to handle. About 47% of the total phosphate in the 11-33-0 sequesterant was in the nonortho form.

Procedures and results of tests of these procedures in which the amount of

sequesterant was varied are shown in Table II. The tests were made with the temperature during ammoniation held at a maximum of 120° F. However, in other laboratory tests of procedure 1 and in several tests in commercial plants of procedures 1 and 3, it was found that no appreciable hydrolysis of the sequesterant occurred when ammoniation was carried out at 180° F.; the temperature had little effect on the efficiency of the sequesterant provided it was added to a neutral solution.

The data show that when the wet-process acid and ammonia were added simultaneously to a mixture of water and sequesterant (11-33-0) or simultaneously with the sequesterant to water (procedures 1 and 2), it was necessary to supply about 20% of the P_2O_5 as sequesterant to obtain a product that remained essentially free of solids during standard storage tests (7 days at 32° F. and 30 days at room temperature). When the wet-process acid, water, aqua ammonia, and sequesterant were added stepwise in the order named (procedure 3), about 25% of the P_2O_5 had to be supplied as sequesterant.

As found in exploratory tests, addition of only 10% of P_2O_5 as sequesterant by the three procedures gave products that con-

Table I. Chemical Analyses of Wet-Process Phosphoric Acids

Source of Rock for Acid	Per Cent by Weight										Solids Content, ^a % of Total Acid Weight
	P_2O_5	Fe	Al	Ca	SO_3	F	Cr	V	Mg	SiO_2	
Florida ^b	54.3	1.0	0.6	0.04	2.6	0.5	0.01	0.01	0.2	0.2	1.9
Florida ^c	51.5	1.5	0.6	0.7	2.1	1.8	..	..	0.4	0.6	20.3
Western ^c	53.5	0.5	1.0	0.9	1.0	1.1	0.1	0.09	0.3	0.6	13.4

^a Obtained by filtration through a coarse fritted glass Büchner funnel.

^b Shipping grade.

^c Production line (not settled to remove solids).

Table II. Storage Tests on 8-24-0 Liquid Fertilizers from Wet-Process Phosphoric Acid and a Sequestering Agent^a

Procedure	P_2O_5 as Sequesterant, % by Wt.	Product				Storage Tests, Condition ^c				
		Chemical Analysis, % by Wt.			Solids content, % by wt. ^b	Room Temperature, Days				
		Total N	Total P_2O_5	Ortho P_2O_5		7 Days, 28°-32° F.	7	14	21	30
1. Acid and aqua ammonia added simultaneously to water-11-33-0 mixture	5	7.9	23.7	23.1	0.1	U	Q	U		
	10	8.1	23.7	22.4	0.02	Q	Q	U		
	15	8.1	23.7	22.0	0.02	S	S	Q	Q	U
	20	8.0	23.8	21.3	0	S	S	S	S	S
2. Acid, aqua ammonia, and superphosphoric acid or 11-33-0 added simultaneously to water	5	8.0	23.3	22.9	^d	U	Q	U		
	10	8.1	23.9	22.8	0.09	Q	Q	Q	U	
	15	8.3	24.5	22.8	0.06	S	S	S	Q	Q
	20	7.7	24.0	21.6	0.02	S	S	S	S	S
3. Stepwise: acid, water, aqua ammonia, superphosphoric acid, or 11-33-0	5	..	..	..	6.0	U	U			
	10	8.2	24.1	22.8	0.2	Q	Q	U		
	15	8.2	24.2	22.3	0.1	Q	S	Q	U	
	20	8.3	24.0	21.8	0.03	S	S	S	Q	U
	25	8.0	24.4	21.4	0.03	S	S	S	S	S

^a Ammoniated superphosphoric acid; chemical analysis, % by wt.: total N, 11.0; total P_2O_5 , 33.9; and ortho P_2O_5 , 17.9.

^b Determined by filtration of portions after only 1 or 2 days of standing at room temperature.

^c S = satisfactory, essentially free of solids; Q = questionable, contains small amounts of fine crystalline material identified as $MgNH_4PO_4 \cdot 6H_2O$; and U = unsatisfactory, formed heavy gels or contained large size crystals.

^d Heavy gel formation not filtrable.

tained small amounts of precipitates and crystals of struvite ($MgNH_4PO \cdot 6H_2O$) after a few days of storage at room temperature. The solids were finely divided and could be dispersed easily with light agitation. Products of this nature can be handled satisfactorily in most types of application equipment if used within 1 day of production. Longer storage resulted in continued growth of struvite crystals to such size that they probably would cause trouble by clogging the spray-type equipment used.

A few tests were made to show the effect of large quantities of solid impurities with acid produced from Florida rock. This acid was taken directly from the production line and contained about 20% of solids. It was necessary to supply about 35% of P_2O_5 as 11-33-0 to obtain a product with less than 1% of solids. With an acid containing about 13% of solids which was produced from western rock, it was necessary to supply 20% of P_2O_5 as 11-33-0 to obtain a product containing less than 1% of solids. The acid made from western phosphate contained more Cr, V, and Ca than acids made from Florida phosphate.

Tests were not made with acids from the two sources containing the same total amount of solids to see whether the type of impurities would have a significant effect on the requirement of sequestrant.

Requirements for Various N-P₂O₅-K₂O Ratios. Tests were made of the production of liquid fertilizers of various N:P₂O₅:K₂O ratios by adding potassium chloride and supplemental nitrogen as urea or urea-ammonium nitrate solution to sequestered 8-24-0 solution made from shipping-grade, Florida wet-process acid. As stated earlier, 8-24-0 solution containing 10% of its P₂O₅ as sequestrant (superphosphoric acid or ammoniated superphosphoric acid 11-33-0) contained less than 1% by weight of solids after storage for a few days. However, addition of supplemental nitrogen as urea or urea-ammonium nitrate solution to increase the N:P₂O₅ weight ratio to 1:2 or 1:1 or the addition of potash as potassium chloride caused increased precipitation. These liquids probably could be handled in common types of application equipment immediately after production. However, on standing overnight, they formed heavy gels or

separated into two layers; the upper layer was clear and the lower layer contained settled solids.

Proportions of sequestrant required to obtain liquids of various N:P₂O₅:K₂O ratios that remained essentially free of precipitates, during storage, are shown in Table III together with chemical analyses, salting-out temperatures, and pH's.

The use of urea-ammonium nitrate solution instead of urea as supplemental nitrogen did not appear to have any effect on the amount of sequestrant required to prevent precipitation of impurities. With 8-24-0 solution containing 20% of its P₂O₅ as 11-33-0, only 1:2:0 ratio products were free of solids after the standard storage period at room temperature. It was necessary to supply 30% of the P₂O₅ as sequestrant to obtain 1:1:0, 1:2:1, and 1:3:1 ratios that remained clear during storage tests, and to supply about 40% of P₂O₅ as sequestrant for products of 1:1:1 ratio. Grades of liquid fertilizers produced from wet-process acid and 11-33-0 sequestrant and urea as supplemental nitrogen that had satisfactory properties and did not salt out during storage included 10-20-0, 16-16-0, 8-16-8, and 9-9-9. Those produced with urea-ammonium nitrate solution as supplemental nitrogen included 10-20-0, 15-15-0, 8-16-8, and 7-7-7. Also, a 7-21-7 grade, which required no supplemental nitrogen, withstood the standard storage test.

The data indicate that the amounts of P₂O₅ in the nonortho form required to obtain products that withstood storage tests ranged from 6.3 to 8.5% of the total plant food.

The salting-out temperatures of the fertilizer solutions made from wet-process acid and 11-33-0 generally were lower than those of the same grades produced from electric furnace orthophosphoric acid as shown in Table IV. These lower salting-out temperatures probably result from the presence of polyphosphates which were shown in earlier work to be more soluble than orthophosphates (5).

In most cases, in the production of an 8-24-0 grade liquid, the change from products that were satisfactory as produced to products that were unsatisfactory during storage was the result of formation of struvite ($MgNH_4PO_4 \cdot 6H_2O$) crystals. The crystals continued to grow in size and formed into clusters during storage. Struvite also was found in some of the three-component liquids in which 20% or less of P₂O₅ was supplied as sequestrant. Also, struvite was found in all products in which 50% of P₂O₅ was supplied as sequestrant. However, no struvite was present in any products containing 30 to 40% of P₂O₅ as sequestrant. Since formation of struvite crystals large enough to clog spray

Table III. Proportions of Sequestrant Required to Produce Satisfactory Liquids of Various Grades

Grade	% of Total P ₂ O ₅ as 11-33-0 Sequestrant	P ₂ O ₅ in Nonortho Form, ^a % of Total		Chemical Analysis, % by Wt.			Salting-Out Temperature, ° F. ^b	Solution pH
		P ₂ O ₅	Plant Food	Total N	Total P ₂ O ₅	K ₂ O		
Urea for Supplemental Nitrogen								
8-24-0 ^c	20	9.4	7.04	8.5	24.5	..	8	6.7
10-20-0	20	9.4	6.27	10.6	20.4	..	4	6.8
16-16-0	30	14.2	7.10	15.8	15.6	..	24	7.0
8-16-8	30	14.2	7.10	8.2	15.4	8.0	18	6.7
7-21-7 ^c	30	14.2	8.54	7.2	21.2	7.2	24	6.6
9-9-9	40	18.9	6.29	9.5	9.0	9.3	11	7.1
Urea-Ammonium Nitrate as Supplemental Nitrogen								
10-20-0	20	9.4	6.27	10.5	20.3	..	+2	6.7
15-15-0	30	14.2	7.10	14.9	15.4	..	-10	6.6
8-16-8	30	14.2	7.10	8.1	16.3	8.1	29	6.6
7-7-7	40	18.9	6.30	7.3	7.3	7.0	27	6.7

^a Calculated values, assuming hydrolysis was not significant during production, which was the usual case.

^b Determined by cooling 4° F./hour in critical range until crystals appeared. On warming at same rate, crystals dissolved from 3° to 6° F. higher.

^c Required no supplemental nitrogen.

Table IV. Salting-Out Temperatures of Fertilizer Solutions Made from Sequestered Wet-Process Phosphoric Acid and Electric Furnace Phosphoric Acid

Grade	Additional Nitrogen Supplied as	Liquid Produced from Wet-Process Phosphoric Acid and Sequestrant		Liquid Produced from Furnace Orthophosphoric Acid,
		Salting-out ^a temp., ° F.	Saturation ^b temp., ° F.	Saturation ^c Temp., ° F.
16-16-0	Urea	24	27	76
9-9-9	Urea	11	18	25
8-16-8	Urea	18	25	43
7-21-7	None	24	28	74

^b Determined by cooling 4° F./hour in critical range until crystals appeared.

^c Determined, after crystals had formed, by warming solution at 4° F./hour until crystals dissolved.

^d Based on data of Slack (3).

nozzles usually did not occur until after about 2 weeks of storage, the problem was not investigated in detail.

Most of the work on three-component liquid fertilizer was done with shipping-grade, wet-process acid described earlier (2% solids). However, limited tests made with four other wet-process acids which contained about 50% P_2O_5 and that were reported by the suppliers to contain less than 2% of solids gave about the same results. In general, essentially clear liquids that withstood the standard storage tests were obtained from these acids when 35% of P_2O_5 was supplied as sequestrant either as 11-33-0 or superphosphoric acid.

Pilot-Plant and Large-Scale Tests

Pilot-plant tests were made to demonstrate the use of superphosphoric acid and ammoniated products of this acid as sequestrants in the production of liquid fertilizers from wet-process acid that contained about 3% of solids. Pilot-plant equipment (Figure 1) consisted essentially of a 12-inch diameter, 22-inch high stainless steel cone-bottomed tank (reactor) which was equipped with an agitator and with internal cooling coils arranged to serve as baffles. The reactor had an effective capacity of about 0.8 cu. foot of solution. Equipment was operated at a rate to produce about 10 to 12 gallons per hour of nominal 8-24-0 liquid fertilizer. Sufficient sequestrant was supplied to furnish 25% of P_2O_5 in the product. In the first of these tests, water was placed in the neutralization vessel to provide initial agitation. The wet-process acid, 76% P_2O_5 superphosphoric acid, and gaseous ammonia were added simultaneously at rates to maintain a nearly neutral solution. No cooling water was used; the maximum temperature was 215° F. Boiling occurred, and water was added to compensate for evaporation. In later tests, water and 11-33-0 as sequestrant were placed in the neutralization vessel. The wet-process acid and gaseous ammonia were added simultaneously at rates to maintain a neutral solution. Sufficient cooling water was used to keep the temperature at a maximum of 180° F. Chemical analyses and storage tests of these products indicated no significant difference obtained by either process. The products remained clear throughout standard storage tests.

The use of wet-process acid and a sequestering agent was successfully demonstrated in a commercial plant. The commercial plant had a design capacity of 10 tons of 8-24-0 solution per hour when electric furnace orthophosphoric acid and aqua ammonia were reacted at a temperature of 180° F. Sufficient 11-33-0 ammoniated superphosphoric acid was used to supply 10% of P_2O_5 in the product. The sequestrant was

weighed into the reaction vessel, since no meter was available for its simultaneous addition. The wet-process acid (53.8 P_2O_5), aqua ammonia (19.5% N), and water were added simultaneously. The product contained only a trace of settled solids; no further settling or salting out occurred either at room temperature for 30 days or at 28° to 32° F. for 7 days.

Several commercial liquid fertilizer producers are using this process at present. Wet-process acid from different sources is being used. Grades such as 8-8-8, 8-16-8, 4-11-11, and 7-10-10 are reported to be produced with 25 to 50% of P_2O_5 in the products supplied as superphosphoric acid or 11-33-0 ammoniated acid.

Conclusions and Discussion

In the production of liquid fertilizers from wet-process acid, precipitation of impurities during ammoniation was prevented by addition of a sequestrant such as superphosphoric acid or ammoniated superphosphoric acid. The amount of sequestrant needed to prevent precipitation depended on the grade of the product and on the impurities content of the acid. Satisfactory 8-24-0 and 10-20-0 grade solutions with respect to storage properties were made with about 20% of P_2O_5 supplied as superphosphoric acid of 11-33-0 ammoniated acid. For other grades, such as 16-16-0, 8-16-8, 7-21-7, and 9-9-9, it was necessary to supply 30 to 40% of P_2O_5 as superphosphoric acid or ammoniated superphosphoric acid.

For best results in the production of an 8-24-0 grade liquid from wet-process phosphoric acid when using superphosphoric acid as the sequestrant, a heel of previously prepared 8-24-0 liquid first should be charged to the reaction vessel so that circulation or agitation can be established. The formulated amounts of ammonia, superphosphoric acid, wet-process acid, and water then should be added simultaneously so as to maintain an approximately neutral solution (pH about 6.6). If there is inconvenience in using a heel of previously prepared 8-24-0 liquid, the formulated amount of water may be added to the reaction vessel and then superphosphoric acid, wet-process acid, and ammonia are simultaneously added so as to maintain an approximately neutral solution. Superphosphoric acid should not come in contact with water before ammoniation, since pyrophosphates and higher polyphosphates will hydrolyze to orthophosphate, and the sequestering effect of superphosphoric acid will be lost.

When ammoniated superphosphoric acid (11-33-0) is used as sequestrant, the formulated amount of water may be placed in the reaction vessel and the ammonia, wet-process acid, and 11-33-0 added simultaneously so as to maintain an approximately neutral solution (pH about 6.6). Also, another procedure, and probably a more convenient one for most plants when using 11-33-0 as sequestrant, is the addition of formulated amounts of water and 11-33-0 to the reaction vessel first; then, ammonia and wet-process acid should be added simultaneously so as to maintain an approxi-

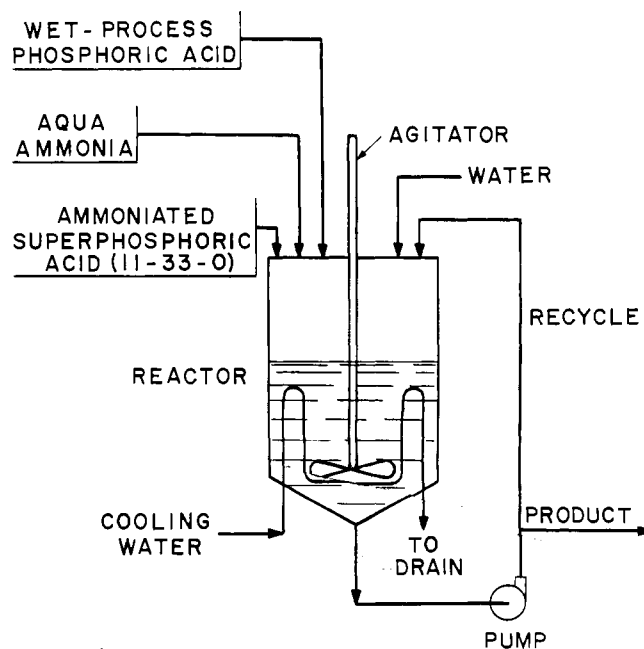


Figure 1. Unit for production of clear liquid fertilizer from wet-process phosphoric acid by sequestration of impurities

mately neutral solution (pH about 6.6). The ammoniated superphosphoric acid (11-33-0) may be added to water without danger of hydrolysis, whereas superphosphoric acid cannot. Adding sequestrant after ammoniation of the wet-process acid is feasible, but somewhat less effective than adding it during or before ammoniation.

Liquid fertilizers of other N:P₂O₅:K₂O ratios may be made from sequestered 8-24-0 solution by adding urea, nitrogen solutions, or potash salts. These supplemental materials may be added simultaneously to the reaction vessel during the ammoniation process. For commercial plants that are not equipped with heat exchangers, the simultaneous addition of the ingredients is desirable in the production of a three-component liquid, since the negative heat of solution of potassium chloride will help keep temperature down during ammoniation.

In any of the recommended procedures described above, it is advisable, if practical, to maintain the liquid in the

reaction vessel below 190° F. At temperatures above 190° F., the amount of vapor from the reaction vessel becomes appreciable, and the water must be added back to the product at the end of the test or the calculated loss added in excess before or during ammoniation; however, reaction temperatures as high as 215° F. had no detrimental effect on the salting-out properties of the products.

Studies of the use of wet-process acid in the production of liquid fertilizers are continuing. Promising results are being obtained by use of special ammoniating techniques. Interesting results have been obtained also with wet-process phosphoric acid that has been concentrated to about 70% of P₂O₅ content. A process for concentrating wet acid is being studied.

Acknowledgment

The authors acknowledge the assistance of T. P. Hignett, Chief of the Applied Research Branch, and of others

who made important contributions to the work including M. M. Striplin, Jr., D. McKnight, J. P. Harris, and S. C. Blalock. A major part of the analytical work was done by H. E. Mills and L. A. Riedel.

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Received for review March 31, 1960. Accepted December 19, 1960. Fertilizer and Soil Chemistry Division, 136th Meeting, ACS, Atlantic City, N. J., September 1959.

FERTILIZER TECHNOLOGY

Liquid Fertilizers from Superphosphoric Acid and Potassium Hydroxide

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Formulations, salting-out temperatures, and storage properties of liquid fertilizers based on superphosphoric acid and potassium hydroxide are presented. The use of potassium hydroxide permitted the production of high-analysis liquid fertilizers of low-chlorine content, which is desirable for some crops, and the production of neutral solutions of 1:4:4 and 0:1:1 ratios, which could not be made with potassium chloride as the only source of potash. The grades that did not salt out on storage for 1 week at 32° F. were considerably higher than can be made with potassium chloride as the source of potash. Some of the grades were 11-11-11, 7-14-14, 6-18-18, 5-20-20, 10-20-10, 8-24-8, 6-12-18, and 0-25-25.

IN EARLIER reports, information was presented on the production of high-analysis liquid fertilizers from superphosphoric acid (76% P₂O₅) (1, 2) and on the use of this acid as a sequestrant to prevent the precipitation of impurities from wet-process phosphoric acid when it is ammoniated (3). The potash in the liquid fertilizers was supplied as potassium chloride, which is relatively inexpensive and commonly used in liquid and solid fertilizers.

With a view toward expanding the available information relative to liquid fertilizers and potential raw materials,

an experimental study was made of liquid fertilizers based on superphosphoric acid and potassium hydroxide. A recognized drawback to the use of potassium hydroxide in liquid fertilizers is its relatively high cost. However, there may be special situations, especially for crops which need low chlorine fertilizers, where the use of potassium hydroxide or mixtures of potassium hydroxide and potassium chloride may be justified economically. Potassium sulfate, which commonly is used in low-chlorine solid fertilizers, is not sufficiently soluble for use in liquid fertilizers.

Use of potassium hydroxide also would permit production of neutral liquids of no- and low-nitrogen grades. Liquids of this type made with potassium chloride would not contain enough ammonia to neutralize the acid and therefore would be highly acidic. Exploratory tests indicated that the use of potassium hydroxide would result in liquids of exceptionally high plant food concentration. Formulations, salting-out and saturation temperatures, and results of storage tests of liquid fertilizers made in the laboratory based on superphosphoric acid and potassium hydroxide are presented.