Mit den veränderten Anwendungsformen des Mineraldüngers dürften sich auch die Relationen zwischen den beiden Düngungsarten verschieben. So wird etwa bei der Stickstoffzufuhr die Verbesserung der Stickstoffdüngung durch Bewässerung oder verbesserte Zeitfolge der Aufbringung die Bedeutung der organischen Bodensubstanz als Träger mineralischen Stickstoffs zurückgehen. Mit anderen Worten, bestimmte Humusfunktionen werden unter Umständen nicht mehr dieselbe Bedeutung haben wie zu der Zeit, als die Mineraldüngung noch in den Anfängen stand.

Ist ein organischer Dünger imstande, den mit Mineraldünger erzielten Ertrag zu steigern, so bedeutet dies, dass beide Düngerarten kombiniert werden müssen. Dabei werden örtliche wirtschaftliche Erwägungen ins Spiel kommen, deren Erforschung nunmehr mit Nachdruck vertieft werden sollte.

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than water unless the pressure is very low or the orifice very small.

Some of the experimental suspensions showed a high degree of thixotropy, especially after extended storage. In extreme cases, the suspension thickened during storage to the extent that it would not flow from the container; however, mild agitation was adequate to restore fluidity practically equivalent to that before storage.

Although clay was an effective inhibitor for crystal growth, it was also helpful to cool the ammonium phosphate solution before addition of potassium chloride crystals. The reason for this appears to be associated with the rate of formation of potassium nitrate, the most troublesome crystal form in salt suspensions because of its long, needlelike shape and consequent tendency to clog spray nozzles. Potassium chloride must dissolve before any potassium nitrate can form; therefore, anything that delays dissolution of potassium chloride is helpful.

Some work has been done on a method which avoids the need for clay as a suspending agent. This is an adaptation of the high-pH technique discussed earlier for suspending impurities precipitated from wet-process acid. When these impurities are precipitated in such a way as to develop adequate viscosity, they act as an effective suspending agent. In addition to ammoniating the acid at a relatively high pH (7.5 to 8.0) it is necessary to keep the temperature during neutralization at 70° to 77° C. or below. At higher temperatures an adequate suspending effect often is not obtained even at high neutralization pH.

The high-pH, low-temperature neutralization technique has given good results but the products, on the average, have not been quite as stable as those made from clay. However, the stability obtained probably is adequate for most use situations. The main drawback to use of the method is the necessity for cooling during neutralization; few liquid fertilizer plants are equipped with coolers large enough to give the degree of cooling required.

In current research at TVA, the use of superphosphate as the source of phosphate in suspensions is being studied. In many areas, superphosphate can be obtained at lower cost than phosphoric acid. Use of the material, however, introduces some new problems. For one, a solution of superphosphate is quite acidic (pH about 3.2) and therefore likely to be corrosive to equipment. The pH can be raised by ammoniation but this converts part of the phosphate to insoluble dicalcium phosphate, thereby increasing the quantity of solids in suspension and reducing the allowable concentration as compared with suspensions made from phosphoric acid. Suspensions made from superphosphate are also generally more thixotropic. However, if the products are not stored for long periods, it appears feasible to use concentrations high enough to give a significant reduction in handling costs as compared with clear liquids.

Another departure being studied is production and use of high-analysis base suspension. The suspension is made by ammoniating superphosphoric acid as in production of the clear base solutions 10-34-0 and 11-37-0, but the amount of water in the formulation is reduced to give a concentration of 13-43-0, and 1 to 2 % clay is used as a suspending agent. The resulting suspension of ammonium phosphate crystals has a relatively high viscosity, on the order of 500 to 700 centipoises. However, the product has been shipped successfully in tests and used in making blends as high in concentration as 15-15-15.

The use of fertilizer in suspension or slurry form avoids many of the difficulties associated with either clear liquid or solid fertilizers. Much higher concentrations can be obtained than with solution fertilizers and the raw materials cost can be lower. If solids such as superphosphate prove to be feasible on a large scale, suspensions then will have the advantage that the lowest cost raw materials available can be used, thereby giving a raw materials cost lower even than for solid mixes. The main problems associated with suspensions are settling — which eventually takes place in extended storage — and difficulty in handling products that are thick and viscous. These problems do not appear insurmountable; they are generally similar to the problems that have been encountered in the many applications of slurry handling found in the chemical and fuels industries.

Handling and application

Procedures used in handling and applying liquid mixed fertilizer are much like those used with nonpressure nitrogen solutions. One difference is that many of the liquid mixes are corrosive to aluminum, the material mainly used in storage and handling of nitrogen solutions. Tests reported by HATFIELD et al. **(10)** showed that liquid mixed fertilizer high in phosphate, such as 8-24-0 and 6-18-6, is very corrosive to aluminum. In tests with carbon steel, corrosion of submerged surfaces was found to be quite low. In other tests, however, corrosion of metal surfaces in the vapor space above the liquid has been noted. The most severe corrosion of this type is associated with solutions containing potash; a heavy scale of corrosion product builds up on unsubmerged surfaces and gives trouble by flaking off and clogging equipment. Notwithstanding this, most producers consider carbon steel preferable to aluminum and use it in storage and handling equipment.

Since many liquid mixed fertilizer producers also handle nitrogen solutions, provision of two different types of storage tanks is an inconvenience. If phosphoric acid is stored, a third type of tank is necessary. There is a need in the liquid fertilizer industry for a construction material resistant to all type of liquids handled, so that tanks can be used interchangeably and the number of tanks kept to a minimum. Stainless steel is such a material and its use in handling equipment and in smaller tanks, such as those used on application equipment, appears to be growing. However, the cost of stainless steel for storage tanks may be prohibitive. There has been a considerable amount of experimentation in recent years on use of plastic materials, either as linings for carbon steel or as the sole construction material. These have been used in delivery and applicator tanks as well as in storage tanks, and some appear to give acceptable service life.

Application equipment and methods vary widely, depending on type of crop and the period of the farming cycle in which the fertilizer is applied. Application to the soil surface before plowing is a major practice in the central region of the country. For this, a tank truck equipped with a spray boom is most often used, with the pressure for spraying provided by a gasoline engine-pump combination. Sometimes the boom is omitted and a single spray nozzle of special type, designed to throw out a fan spray over a wide swath, is used.

The very fast application rate obtained by truck spraying is one of the advantages of liquid mixed fertilizer. Moreover, as compared with truck application of solid fertilizers, the liquids can be metered more accurately. The boom-type applicator, with several small nozzles located along its length, also gives good uniformity of application, whereas the usual fan-type solids applicator requires accurate overlapping of swaths to give adequate uniformity.

The second major application period for liquid mixed fertilizer is at planting time. Ordinarily this is done by the farmer, with an attachment mounted on the planter. Most of the planter attachments incorporate gravity flow of the liquid, and various devices have been developed to give uniform flow with varying level in the supply tank. Convenience is a major factor in the popularity of liquid fertilizers for use at planting time. The planter tanks can be filled quickly and the labor required in handling is less than for either bulk or bagged solid fertilizer.

Another type of applicator used to some extent is the «squeeze» pump. This is a metering-type pump consisting of a series of flexible hoses and a set of rollers which press against the hoses to squeeze out successive portions of liquid. The pump usually is wheel-driven; thus, the rate of application (per acre) does not vary with change in rate of travel