PROCEEDINGS
OF THE
20th ANNUAL MEETING
FERTILIZER INDUSTRY ROUND TABLE
1970

November 4, 5, 6, 1970
Sheraton-Peabody Hotel
Memphis, Tennessee

TABLE of CONTENTS

Wednesday, November 4th
Morning Session

Albert Spillman, Moderator
Ladd Pircon, Moderator

Wednesday, November 4th
Afternoon Session

Joseph E. Reynolds, Jr., Moderator

Thursday, November 5th
Morning Session

Harold D. Blenkhorn, Moderator

Thursday, November 5th
Afternoon Session

Albert Spillman, Moderator
Grant C. Marburger, Moderator

Friday, November 6th
Morning Session

Herman G. Powers, Jr., Moderator

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Fertilizer Industry Round Table

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Wednesday, November 4th, 1970
Morning Session
MODERATORS: ALBERT SPILLMAN AND LADD PIRCON

CHAIRMAN SPILLMAN: Ladies and Gentlemen. Welcome to our 20th annual meeting. We are happy to meet in this beautiful City of Memphis. Thanks to The Memphis Chamber of Commerce Organization for their excellent support helping us with the major arrangements necessary to take care of Our Members' needs.

We have an excellent program. Your Executive Committee worked very hard -- two special meetings held in Baltimore -- lots of correspondence-- many telephone calls -- to finally wrap up the program. We had good help from many members here. You will recognize a number of your suggestions have been included in this program. Thanks to all of you for a good job extremely well done.

Our 3 day program will be discussed thoroughly by competent and experienced people. The papers to be given by each panelist will cover up-to-date information on present practices and also gazing into what the future might bring during the 1970-80 decade. The latest technology will be covered, viz: Manufacturing, Formulation, Facilities (Building and Equipment), Ammoniation, Granulation, Raw Materials Specifications, Engineering Techniques, Bulk Blend Operations, Liquid Operations, Pollution control (In Plant and Outside of Plant), Quality Control, Marketing and other interesting comments. Sufficient time has been allowed for questions from the floor.

Our Keynote Speaker, Travis P. Hignett, really needs no introduction. Most of us know him very well. Travis is Director of Chemical Development, Tennessee Valley Authority, Muscle Shoals, Alabama. Travis and his associates have been good friends and supporters of our Round Table since its beginning two decades ago. They have contributed many valuable technical papers at our previous yearly meetings and helped to a great extent to make our organization a success.

KEYNOTE ADDRESS

Trends in Fertilizer Materials, 1970-1980

Travis P. Hignett
DIRECTOR OF CHEMICAL DEVELOPMENT
TENNESSEE VALLEY AUTHORITY
MUSCLE SHOALS, ALABAMA

It is a pleasure and an honor to present the keynote address to this 20th annual meeting of The Fertilizer Industry Round Table. My subject concerns trends in fertilizer materials for the coming decade.

In the history of the fertilizer industry, various materials have risen into prominence, flourished for a time, and then declined into unimportance. The most popular fertilizer materials today include anhydrous ammonia, nitrogen solutions, ammonium nitrate, urea, triple superphosphate, ammonium phosphate, phosphoric acid, ammonium polyphosphate solutions, and high-grade potassium chloride. Almost all of these materials achieved their popularity after 1945. In 1945, ammonium sulfate and sodium nitrate were still the most popular nitrogen materials; as late as 1950, ordinary superphosphate supplied 80% of the P2O5 for fertilizer.

If we can project our past experience into the future, we must expect that new materials will rise into popularity and that some of those now popular will become less so. Those materials that remain popular may change in form; an example is the growing demand for granular, coarse, and solution-grade potash.

The fertilizer materials that are now popular did not become so as soon as they were recognized as potential fertilizer materials. For instance, diammonium phosphate was manufactured for fertilizer use in Germany about 1930. Even earlier (probably before 1850), Sir James Murray used ammonium phosphates in fertilizer mixtures. Nevertheless, diammonium phosphate did not become popular until the 1960's. Similar histories could be related about urea, triple superphosphate, and many other materials. So we may conclude from our past experience that the "new" fertilizer materials of the near future are already here. We have only to look about us and see what materials are being used or are under experimental study and then try to decide which of these materials will be this next decade's winner.

So we come to the question of how to foretell what materials will become popular. Again, we might seek the answer in our past experience. Why was diammonium phosphate a failure in 1930 and a success in the 1960's? Why did it take so long for urea to become a popular material?

One answer is technological improvements. Gradual improvements in production processes have improved urea's economic position relative to competing nitrogen products. Likewise, improvements in phosphoric acid have strengthened the economic position in both ammonium phosphates and triple superphosphates. Increased costs of transportation have improved the relative economic positions of the higher analysis materials.

Another answer to the delayed popularity of some new materials lies in finding their place in the

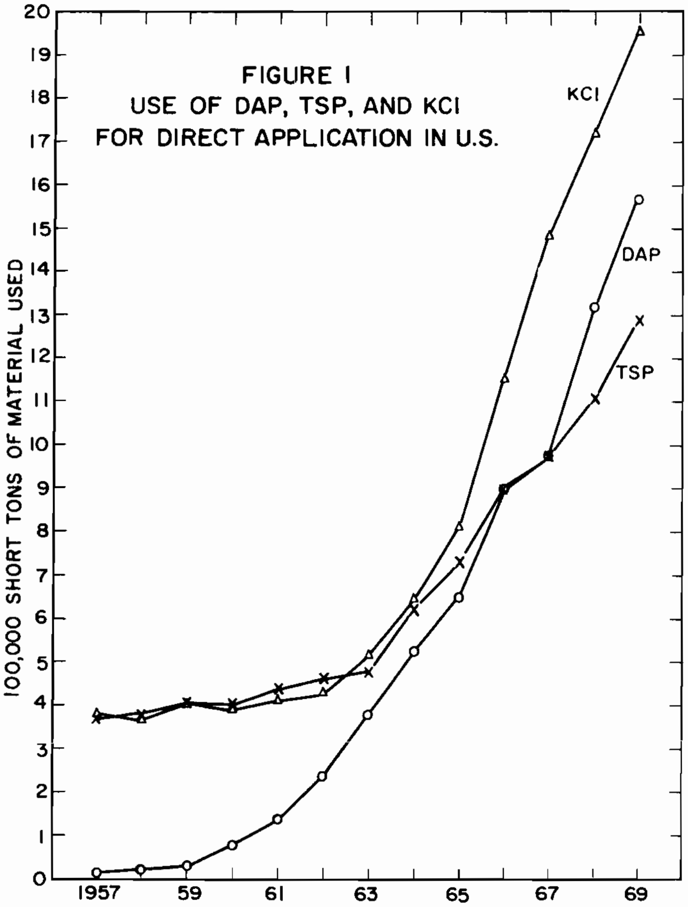


FIGURE I
USE OF DAP, TSP, AND KCl
FOR DIRECT APPLICATION IN U.S.

marketing and distribution system. Most new materials have succeeded, not because the farmers want or need them as such, but because they fit into a distribution and marketing system that gives the farmers what they need, namely, a variety of mixed fertilizers, flexibility of formulation, and convenience of application.

For example, diammonium phosphate did not fit very well into the marketing and distribution system of the 1950's. At that time, most of the fertilizer phosphorus reached the farmer in the form of granular and nongranular mixed fertilizer. Use of DAP in such mixtures seemed to promise only marginal advantages. TVA forecast a market potential of about 100,000 tons per year, mainly for direct application in certain areas. Some people in industry regarded this forecast as much too optimistic. However, when TVA produced DAP, it proved to be popular both for direct application and in mixtures.

In the 1960's, bulk blending began to be an important marketing and distribution system. DAP fitted nicely into this system; it can be said that bulk blending made DAP successful, or that DAP made bulk blending successful.

The moral of this story is that new materials, to be successful, must fit into existing marketing and distribution systems, or else new marketing and distribution systems must be devised to fit the new materials.

Figure 1 shows the abrupt rise in consumption of DAP (18-46-0 and 16-48-0) that was reported to be used for direct application. Statistics on the total amount used are not available, but no doubt the total is substantially higher, possibly double, the "direct application" use.

Figure 1 also shows a concomitant rise in direct application of triple superphosphate and potash. It seems likely that the major portion of these materials were not applied singly, but in bulk blends. Many states permit blenders to sell straight materials to farmers even though the blender mixes the materials as a service to the farmers. Also, some large farms have their own mixing equipment. These practices account in part for a decline in reported use of "mixed" fertilizer. Under present reporting systems it is impossible to determine what amounts of fertilizers actually are applied to the soil in the form of mixtures and what amounts are applied as "straight" fertilizers. In 1969, some 8 million tons of solid fertilizer materials were reported as used for direct application, not including 18-46-0 and several other ammonium phosphate grades that are classified as "mixtures." I think it possible that as much as half of these direct application materials actually were used as blended mixtures.

Indeed, the distinction between straight and mixed fertilizers is beginning to lose any meaning. For instance, 16-20-0, which can be made by a variety of formulations, is called a "straight" fertilizer, and 18-46-0, which is as near straight diammonium phosphate as can be made from most wet-process acid, is called "mixed" fertilizer.

TRENDS IN TYPES OF PHOSPHATES

Figure 2 shows trends during the last 15 years in types of phosphatic fertilizers produced in the United States. During this period, ordinary superphosphate declined from 68% of the total in 1955 to 15% in 1970. Difficulty in meeting new pollution standards may result in closure of small superphosphate plants and thereby contribute to further decrease in production of this material. Triple superphosphate increased from 28% in 1955 to a maximum of 34% in 1962, then declined to 26% in 1970. Ammonium phosphates increased from less than 4% in 1955 to 37% in 1970, and further increases seem likely. Diammonium phosphate is the most important grade in this group, but there are several other grades, both solid and liquid. Ammonium phosphates became the leading class in 1968. All other phosphates rose from 3% in 1955 to 22% in 1970. Probably the most important material in this group is merchant phosphoric acid used in granulation plants and liquid mix plants and to some extent for direct application. The group also includes nitrophosphates, NPK grades made by captive use of phosphoric acid, and miscellaneous minor materials.

Very likely this "other" group will continue to increase, primarily because of increased use of merchant phosphoric acid, including superphosphoric acid.

On a worldwide basis, straight ammonium phosphates are less popular than in the United States, but "complex" fertilizers are very popular. Many of these complex fertilizers are NPK products made directly from phosphoric acid and ammonia with addition of ammonium nitrate or urea, potash salts, and other materials, and contain high proportions of their phosphorus content in the form of ammonium phosphates.

Figure 3 shows trends in the share of the world market for phosphate products. FAO data were used through 1969 for world production (Russia and Communist Asia are not included). Projections to

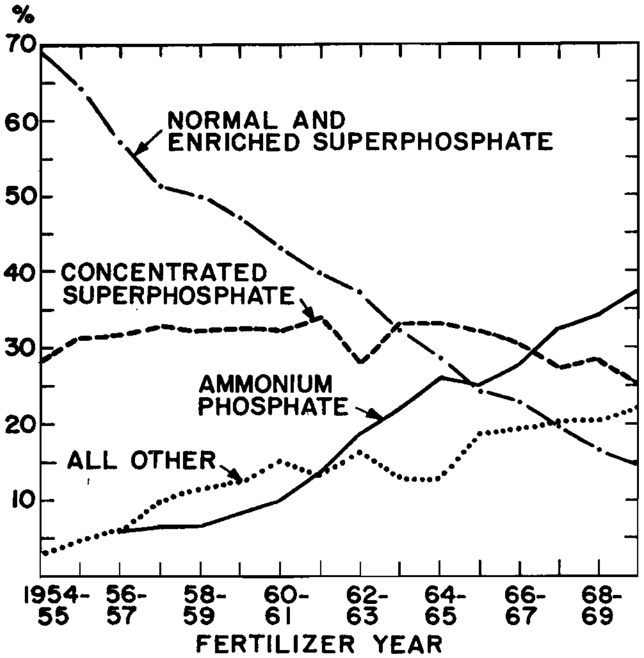


FIGURE 2
TRENDS IN TYPES OF PHOSPHATIC FERTILIZER MATERIALS PRODUCED IN U.S.

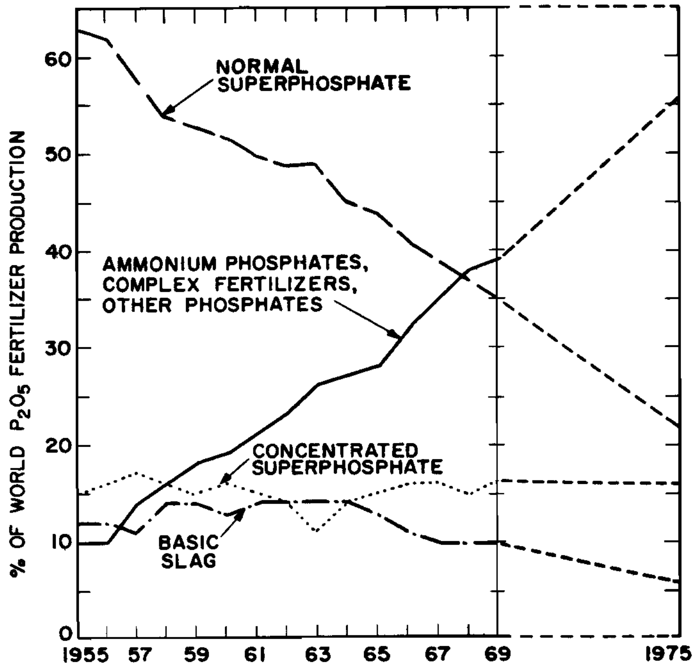


FIGURE 3
WORLD TRENDS IN TYPES OF PHOSPHATIC FERTILIZER MATERIALS

1975 are based in part on capacity. The graph shows that normal superphosphate, which has been the world's leading phosphatic material, will supply a declining share of the market, reaching 22% in 1975. Concentrated superphosphate will remain at about 16%. The main increase will be in the group -- ammonium phosphates, complex fertilizers, liquid mixed fertilizers, and others -- which will reach 56% by 1975. It seems safe to predict that well over half of this group will be ammonium phosphates or ammonium phosphate-based complex fertilizers. Other members of the group include nitrophosphate-based complex fertilizers and mixed-base complex fertilizers. Phosphate rock for direct application is not included in the above estimates.

MERCHANT PHOSPHORIC ACID

Trade in phosphoric acid for fertilizer production has increased rapidly within the last decade. Previously, wet-process acid was manufacured mainly for captive use in adjoining facilities. Merchant acid is now shipped extensively within the United States for use in liquid fertilizer or granulation plants or for direct application. More recently, overseas shipment of phosphoric acid has begun and probably will grow in the next decade. In fact, rapid growth has been predicted, with the possibility that several large plants will be built in various countries mainly or entirely for production of acid for export.

About 3.5 tons of phosphate rock and nearly 1 ton of sulfur are required to make 1 ton of P205 as phosphoric acid. Thus, the weight of the raw materials is about 4.5 tons per ton of P205, whereas the weight of the acid is 1.85 tons for acid of 54% P205 concentration, or 1.4 tons for acid of 72% concentration. So one advantage of shipment of acid rather than raw materials is the reduction in weight of material transported. Another advantage is the economy of production of the acid in large-scale plants located at the phosphate mine (or at the source of sulfuric acid). Countries whose phosphatic fertilizer requirements are too small to justify large-scale production of phosphoric acid, particularly those that have neither phosphate rock nor sulfur, may find it more economical to import phosphoric acid than to make it. The same reasoning applies to districts within a large country.

As compared with importing finished fertilizer, importation of acid has the advantage of versatility; the acid can be used to make a variety of phosphatic or mixed fertilizers or for industrial uses.

Factors that may limit international trade in phosphoric acid are the cost of specially equipped ships, cost of storage, and sludge problems. Also, scarcity of foreign exchange and nationalistic policies may be limiting factors.

If phosphoric acid becomes a major material in international trade, the United States has the outstanding advantage of plentiful supplies of low-cost phosphate rock and sulfur. It has the disadvantage that the quality of the phosphoric acid is not so good as that made from some foreign rocks. The quality can be improved by calcining the rock, which eliminates organic sludge and facilitates separation of inorganic sludge. There is considerable interest in further improvement, either by partial purification of the acid or pretreatment of the rock.

Improvement in acid quality is particularly needed for liquid fertilizer use; probably the principal factor limiting more rapid growth of the liquid fertilizer industry is the limited supply of good-quality phosphatic materials.

Use of merchant phosphoric acid probably will continue to grow both in international and domestic trade. There are various problems connected with transport and handling of the acid, but solutions are likely to be evolved. Superphosphoric acid may become a favored material in international as well as domestic trade. While savings in freight are seldom sufficient to justify the increased cost of concentration, superphosphoric acid often is more valuable to the user both for solid and liquid fertilizer production.

NONGRANULAR MONOAMMONIUM PHOSPHATE

Nongranular monoammonium phosphate (MAP) is a fertilizer intermediate of considerable interest. Two processes for producing MAP have been described at previous Round Table meetings; the process developed by Scottish Agricultural Industries Limited (SAI) was described in 1964 by Dr. Brownlie; a process developed by Fisons Fertilizers Limited was described by Mr. Hemsley in 1966 and 1968. Trade names of "PhoSAI" and "Minifos" have been applied to the SAI and Fisons products, respectively. In this meeting, Mr. Mortenson will describe a process developed by Swift Agricultural Chemicals Corporation, and I believe that Dr. Ando will touch on the use of nongranular ammonium phosphate as an intermediate in Japan.

Nongranular MAP is intended for use as an intermediate in granulation plants. The MAP intermediate may be produced in a central plant where phosphoric acid is produced and shipped to granulation plants in other locations. However, a Swift publication points out that nongranular MAP also may be a useful intermediate for production of diammonium phosphate in an adjoining plant.

Although the present discussion will be confined to MAP compositions, it should be noted that similar intermediates of other compositions are possible. SAI has developed an ammonium sulfate - MAP intermediate and a DAP intermediate. Also, nongranular or semigranular DAP may be produced by the Nissan spray tower process.

The manufacture of MAP intermediates is relatively simple. As compared with production of finished, granular ammonium phosphates, the steps of granulation, drying, screening, and recycling are eliminated. Production processes make use of phosphoric acid of such concentration that reaction with ammonia vaporizes most of the moisture. Complete drying is unnecessary and perhaps undesirable, as it might interfere with the thixotropic properties that aid granualtion.

The grade of the nongranular MAP's may vary from 10 to 12% N and from 47 to 56% P205, depending on the purity of the wet-process acid and the moisture content of the product. The moisture content usually is in the range of 4 to 8%.

The particle size of PhoSAI is said to include a range of from 5 mesh to minus 60 mesh with about half finer than 16 mesh. Minifos tends to be in small granules. According to one paper, 90% is between 0.25 and 2.5 mm. (about 8 to 60 mesh). No doubt the particle size is subject to some degree of control. Probably Mr. Mortenson will tell you about the particle size of the Swift product; a sample we have seen was 90% finer than 16 mesh.

The bulk handling properties of all products are claimed to be good by their respective companies. However, we have heard some rumors of difficulties. Very likely the products should give no more difficulty in handling than run-of-pile triple superphosphate. Shipment in bulk by rail in hopper-bottom cars or boxcars is said to be feasible, and bulk shipments in barges or ocean-going vessels have been made successfully.

In comparison with use of merchant wet-process acid, one advantage is that the acid need not be clarified for MAP production. Also, special equipment (tank cars or specially equipped ships) are not necessary. Storage buildings commonly available at granulation plants are suitable, whereas special tanks are needed for storage of acid. On the other hand, phosphoric acid is a more versatile material, and loading and unloading by pumps may be quicker and more convenient.

From the viewpoint of the user, the main advantage of nongranular MAP is that a conventional granulation plant such as is used for granulating superphosphate-based mixtures is suitable, and recycle requirements are low. MAP has been used successfully in several types of granulating equipment, including pan granulators, rotary tube granulators, and TVA ammoniator-granulators. When used in the ammoniator, the MAP will absorb ammonia from ammoniating solutions up to a NH3:PO4 ratio of about 1.5 without appreciable ammonia loss. As compared with use of phosphoric acid and ammonia, production rates of some grades of granular fertilizer are substantially higher.

Information from several sources indicates that about twenty plants have been built to produce nongranular MAP for use as an intermediate. Most of them are in European countries.

In a study by TVA of the economics of using imported intermediates in developing countries, the use of MAP resulted in a lower overall cost than any other imported phosphatic intermediate. In each case the price of the intermediate was that calculated to yield a 10% return on capital investment (plus interest, etc.), a situation that may not be realistic at present, but we hope it will be in the future.

Substantial growth of the manufacture and use of MAP intermediates seems likely in the 1970's. Possible use of granulation plants in the United States is of interest.

TRENDS IN TYPES OF NITROGEN MATERIALS

A prominent feature of the world nitrogen industry is the rapid rise in popularity of urea, as shown in Figure 4. Urea's share of the world nitrogen fertilizer market has risen from less than 5% in 1955 to 16% in 1969 and is expected to increase to about 26% by 1975. These figures are based on FAO production data through 1969 for the world (excepting Russia and Communist Asia) and projections based in part on capacity for subsequent years. These figures are for solid urea only, and do not include the urea content of solutions. In the United States, about half of the urea used for fertilizer goes into solutions.

The largest group consists of anhydrous ammonia, nitrogen solutions, the nitrogen content of ammonium phosphates and complex fertilizers, and miscellaneous other materials. Ammonium sulfate, once the most popular nitrogen material, supplied only 15% of the world market in 1969, and may decline to 8% in 1975. Other low-analysis materials include calcium nitrate, sodium nitrate, and calcium cyanamide. This group now supplies only 2% of the market. Ammonium nitrate now supplies 27% of the market; in future years the percentage may decline slightly.

UREA

The place of urea in the fertilizer industry is indicated by the fact that by 1975, nearly 40% of the fertilizer nitrogen capacity will be in the form of urea (including solutions and the urea content of complex fertilizers). In the developing countries of Africa, Asia, and Latin America, urea is expected to constitute 62% of nitrogen capacity.

The growing popularity of urea is attributed to its high analysis and improvements in technology which have lowered its cost. In comparison with

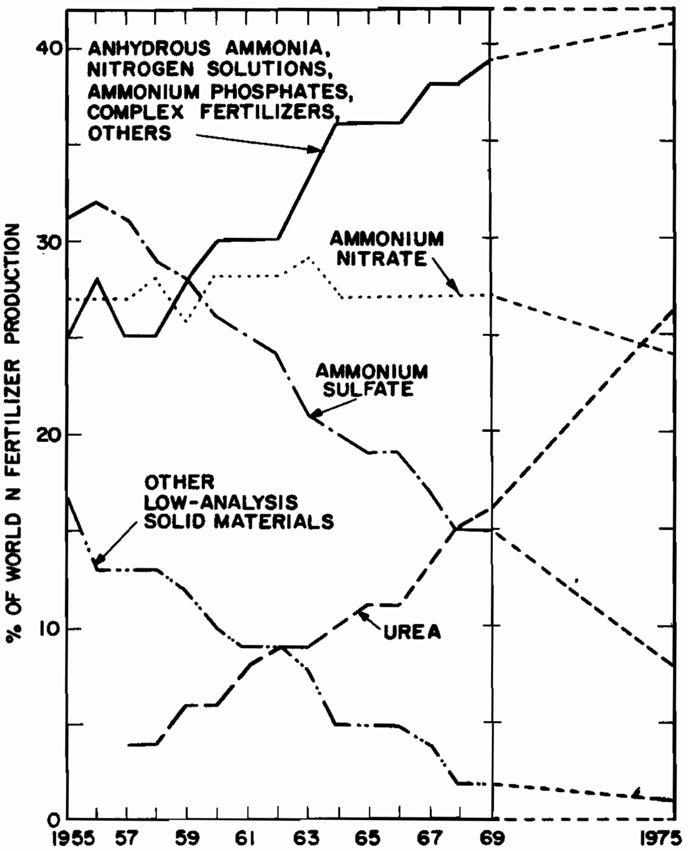


FIGURE 4
WORLD TRENDS IN TYPES OF
NITROGENOUS FERTILIZER MATERIALS

ammonium nitrate, which has been the leading form of nitrogen since about 1960, urea has advantages of freedom from fire and explosion hazards, and is agronomically preferable for rice.

In view of the plentiful supply and low cost of urea, consideration of ways of using it is appropriate. Since there is a general world trend toward farmer preference for mixed (compound) fertilizer, use of urea in granular mixtures is receiving attention in many countries. The technology is well advanced in Japan; Dr. Ando will discuss it later in the program. Urea also is used in some granulation plants in Great Britain, India, and some other countries. I think we might well consider using urea in granulation plants in the United States. The high analysis of urea permits production of a given grade while using more low - cost, low - analysis materials. For instance, a 50-50 mixture of urea and ammonium sulfate would contain 33.4% nitrogen, nearly as much as ammonium nitrate. So substitution of urea-ammonium sulfate mixtures for ammonium nitrate might be a good way to use up low-cost byproduct ammonium sulfate without lowering the grade.

Production of prilled mixtures of urea and ammonium sulfate is an interesting possibility. Promising results were obtained in a small TVA pilot plant. The prills were harder than straight urea, and the presence of ammonium sulfate seemed to inhibit biuret formation.

Use of urea in bulk blends should be attractive, but the usual prilled urea is too small in particle size to match other granular materials. The possibility of making larger prills or granules for bulk blending should be considered. Also, larger granules probably would be better for straight application, as most broadcast spreaders perform better with larger granules. One company (Cominco) in Canada has developed and is using a process for producing granular urea in sizes suitable for bulk blending (6 to 10 mesh) or for forest fertilization (4 to 6 mesh). There is a need for improved conditioning methods for urea for use in humid areas. Again, larger granules would help, as moisture pickup and caking are inversely related to particle size, and less conditioner would be needed. With increased bulk handling of urea, there is a need for a physically stronger, more durable product.

Increased use of urea in liquid mixed fertilizer is attractive, as higher solubility of most NPK grades can be obtained by substituting straight urea for urea - ammonium nitrate.

UREA - AMMONIUM PHOSPHATES

Granular urea - ammonium polyphosphate materials are a promising possibility. Such materials may be fully soluble and hence usable either for bulk blending, liquid mixing, or direct application. Processes for making urea - ammonium phosphate and polyphosphates have been studied extensively in TVA pilot-plant work. Use of nongranular MAP and urea in small conventional granulation plants may be a simple means for producing unusually high analysis products.

SUPERPHOSPHATE AND AMMONIUM SULFATE

Although these low-analysis materials will supply a declining percentage of the market, there will be substantial quantities of them used in the future. High analysis is not an end in itself, but a means for reducing the delivered cost of fertilizers. There are situations in which low-analysis materials can be obtained at low enough cost to offset increased transportation cost of the materials and products, especially in local areas.

Superphosphate and ammonium sulfate supply sulfur, a necessary element for crop production which is deficient in some areas. Perhaps more widespread areas of sulfur need can be expected in the future because of increased use of high-analysis fertilizers, decreased supply of sulfur from atmospheric sources, and increased crop yields that remove more sulfur from the soil.

When sulfur is needed, consideration must be given to the most economical means for supplying it. Quite often, superphosphate or ammonium sulfate may be the answer.

Production of superphosphate is often the most economical means for utilizing low-cost byproduct sulfuric acid when the quantity is too small for an economical scale of phosphoric acid production. Ammonium sulfate is a byproduct from various industrial processes and is often available at very low cost.

Formulations have been worked out that permit use of substantial amounts of ordinary superphosphate or ammonium sulfate or both in the production of fairly high analysis mixed fertilizer. The mixtures are upgraded by use of urea and ammonium phosphate. Grades such as 20-10-10 and 14-14-14 are being produced in Great Britain, for instance. Lower analysis grades may be economical in some cases.

AMMONIUM POLYPHOSPHATE

The advantages of ammonium polyphosphate solutions for use in liquid fertilizers are well known, and their use is increasing rapidly. As mentioned prevously, the type of wet-process acid that is available in the United States makes production of good-quality liquids difficult. Partial purification methods are being studied intensively and may provide an acceptable answer. Another possibility is the production of superphosphoric acid from a combination of elemental phosphorus and wet-process acid in which the heat of combustion of the phosphorus is utilized to evaporate water from the wet-process acid.

Solid ammonium polyphosphate would have an obvious advantage of higher analysis and lower shipping cost as compared with liquids. Liquid mixed fertilizers can be prepared by dissolving the solid ammonium polyphosphate and adding other materials as required. TVA's 15-62-0 ammonium polyphosphate made from electric-furnace superphosphoric acid has proved very popular for use in liquid mix plants. Pilot-plant studies are in progress to determine how to make a comparable product from wet-process acid. In some cases, solid ammonium polyphosphate capable of yielding clear solutions has been produced, but most acids prepared from domestic phosphate rock have yielded ammonium polyphosphate containing troublesome insoluble impurities. Also, granulation of the solid presents some difficulties when the polyphosphate content exceeds 25 to 30%. Work on these problems is continuing.

POTASSIUM PHOSPHATE AND POLYPHOSPHATE

It has long been recognized that potassium phosphates and polyphosphates are excellent, very high analysis fertilizers. Some of these products are quite soluble and therefore desirable materials for liquid fertilizers. These strong advantages have encouraged research on production processes by several organizations both in the United States and abroad. So far, no commercial production for fertilizer purposes has resulted. However, research and development are continuing, and success may be near at hand. Mr. Abell will comment further on this subject.

ELEMENTAL PHOSPHORUS

The advantages of elemental phosphorus are well known--its versatility in making high-analysis products, its very high concentration which reduces transportation costs, and the ability to use low-grade ore in its manufacture. Last year Mr. Ten Eyck reviewed these advantages and predicted that elemental phosphorus would become a major material for fertilizer production when electric power becomes available at phosphate mines at 3.0 to 3.4 mills. I agree with this conclusion. However, progress has been slower than anticipated in attaining the goal of low-cost power from atomic energy, and sulfur prices have declined. Another discouraging factor is the record-high interest rates on capital investment, as the investment cost for the thermal process is relatively high. Also, current excess capacity for phosphoric acid and consequent depressed prices tend to discourage additional phosphoric acid production by either wet or thermal processes. These factors would seem to delay the widespread use of the electric-furnace process; it seems unlikely that any substantial trend will develop within the 1970's.

CONTROLLED-RELEASE FERTILIZERS

Fertilizers that release plant nutrients slowly throughout the growing season, or even several growing seasons, continue to attract attention of technologists and agronomists. Potential advantages claimed for controlled-release fertilizers are increased efficiency of uptake by plants; minimization of losses by leaching, fixation, or decomposition; reduction in application costs through reduction in number of applications; elimination of luxury consumption; prevention of pollution of ground water, streams, and lakes; and prevention of burning of vegetation or damage to seedlings. This is an impressive list of potential advantages.

Experiments with controlled-release phosphorus and potassium materials have not been promising, and there is reason to believe that little advantage can be expected from supplying these elements in a slowly available form in most cases. However, promising results have been obtained with some controlled-release nitrogen materials.

Commercially available materials include urea-aldehyde compounds: crotonylidene-diurea, urea-formaldehyde reaction products (ureaform), and isobutylidene-diurea. These materials have found a place in specialized uses--home gardens, golf courses, and the like. They are too expensive for general farm use.

Several processes for producing coated granules of nitrogen (or compound) fertilizers have been announced. Controlled or delayed release is obtained by coating granules of soluble fertilizer with a plastic film, with sulfur plus additives, or with an asphalt-wax mixture.

In a process developed by TVA on a small pilot-plant scale, urea granules are sprayed with molten sulfur in a rotating drum to form a coating that typically ranges from 10 to 25% by weight. Then the granules receive a 3% coating of wax to seal microscopic pores or cracks in the sulfur coating. A small amount of a microbicide (such as coal tar) is incorporated in the wax to prevent soil microbe attack on the wax. Finally, about 1.5% of a conditioner (such as kieselguhr) is added to give good handling properties. Exacting control of the conditions during application of each coating is necessary for good results. It has been possible to produce coated products that release 1% or less of their nitrogen per day when immersed in water or moist soil with total coating weights of as little as 20%.

Results from some tests show that coated urea is a more effective fertilizer for some long-season crops, and is useful in areas where leaching losses are common. Further tests of the coated urea are in progress in several locations in the United States and in several other countries. Promising results have been obtained in several of these tests.

The cost of producing sulfur-coated urea on a commercial scale has been estimated at 25 to 50% higher per unit of nitrogen than uncoated product. Some farm uses may justify the differential. For example, a single application of coated material might be cheaper than two or three split applications of uncoated fertilizers. Many of the popular farm crops do not benefit from controlled-release nitrogen, however, and much work will be required to determine what place coated materials may find in the farm economy.

EXPORT OF FERTILIZER MATERIALS

As mentioned previously, the United States has some substantial advantages in raw materials, particularly for phosphatic fertilizers. Exports of phosphate rock have been growing rapidly. But export of finished fertilizers and intermediate materials has been disappointing. Market research and a marketing effort are necessary ingredients of any successful sales program, foreign or domestic. Perhaps we would have more success if we paid more attention to finding out what foreign customers want and need rather than trying to sell them whatever we have in surplus supply.

Much of our industry is geared to supplying materials for bulk blending. Bulk blending is not popular in most other countries, and there are good reasons why it isn't. So diammonium phosphate which is a fine material for bulk blending may not fit in well with the requirements of other countries.

Another factor is quality. There is a tendency to feel that whatever is good enough for American farmers should be good enough for anybody. However, European fertilizer manufacturers compete with each other more vigorously in quality and perhaps less by price cutting. As a result, European products are often more uniformly granulated or better conditioned than ours.

There are elements of quality that seem unimportant to us that foreign customers consider important. We may question whether they are right, but when we are trying to sell something, the customer is always right. Some of these factors are water solubility of phosphate, size of granules (Europeans prefer larger granules), biuret content of urea, color of liquid fertilizer, etc. In humid areas of tropical countries, conditioning and packaging requirements are much more stringent than in most of the United States.

Service is another important factor, including such small details as replying to letters in the customer's own language. If we really want an export market, we shall have to work for it. And perhaps a little more competition in quality and less in price would be good for the domestic market too.

CONCLUSIONS

It is not likely that any really new fertilizer materials will appear during the 1970's, although some materials now produced experimentally may come into commercial use.

Continued increase in popularity of DAP is expected. Use of merchant phosphoric and superphosphoric acid will increase. Nongranular MAP is a promising intermediate for use in granulation plants to replace or supplement superphosphate.

Continued growth in popularity of liquid fertilizers is expected; increased amounts of urea and ammonium polyphosphate will be used in their manufacture. Improved quality of ammonium polyphosphate in solution and solid forms can be expected. If potassium polyphosphate can be produced economically, it will be widely used.

Increased use of urea is predicted and may be accelerated by improved quality of solid urea for direct application and bulk blending. Urea - ammonium sulfate is an interesting possibility. Granulation plants may use combinations of urea, MAP, and ammonium sulfate.

Controlled-release fertilizers will receive increased attention in research and development. Commercial production and use will increase, but will remain at a small percentage level, barring unexpected breakthroughs.

Increased export of fertilizers and fertilizer materials will depend on improved quality and variety and more attention to the needs and preferences of foreign customers.

CHAIRMAN SPILLMAN: Thank you, Travis, for bringing us up - to - date on the major technical changes, 1955 - 1970, covering worldwide marketing, manufacturing of solid and liquid fertilizer materials, upgrading materials, higher analysis formulations and agronomic advantages. Your projection on "Trends 1970 - 80" is most interesting and will give us much food for thought to help us plan our operations during the 1970 - 80 decade.

Liquid Fertilizers

CHAIRMAN SPILLMAN: It is my pleasure to introduce Ladd Pircon, director of research and development, Central Farmers Industries of Chicago. Mr. Pircon is a member of our Executive Committee and has done quite a lot of work to make our program successful. He will introduce the Panel Leader, Mr. Frank Achorn, who will cover the discussion on fluid and suspended liquid fertilizers.

MR. PIRCON: I have the pleasure of bringing into our focal attention the dynamic segment of our industry under the able leadership of Panel Leader, Frank Achorn. As far as the dynamics of the industry go, liquid mixed fertilizer has had a compound growth rate of 24 percent annually. In 1959 we had 163 liquid fertilizer plants producing material, and by 1969 this had risen to 694 plants in twelve Mid - Western States. The total share of the United States market of P2O5 going this route in 1970 is 80 percent, which has almost doubled what it was in 1965. For the same period of time, potash has almost tripled, and nitrogen has increased by approximately two and one half times. Frank is a graduate in chemical engineering of the University of Louisville, and has proved many times over that he has the capability of a chemical engineer. He is an honorary member of several associations.

Status of Fluid and Suspended Liquid Fertilizers

PANEL LEADER: F. P. Achorn
HEAD, PROCESSING DEVELOPMENT TVA
MUSCLE SHOALS, ALABAMA

The fluid fertilizer industry has had a rapid growth in the past 5 years. The table at the bottom of the page shows this growth from 1965 to 1968:

In 1968 fluids accounted for about 24 percent of all forms of fertilizer; 62 percent of the straight nitrogen was applied in the fluid form. In 1968 fluid mixtures constituted about 12 percent of the total mixed fertilizer sold.

A growth-rate curve for fluid mixed fertilizers is shown in Figure 1. The growth rate of fluid mixed fertilizers has been about 35 percent per year for the past 5 years.

Much of the spectacular growth of fluid mixed fertilizers in the last 5 years was probably due to increased supplies of fluid phosphate materials such as superphosphoric acid and base solutions made from it. Also contributing to this growth were large supplies of nitrogen solutions, urea, ammonia, and liquid-grade potash.

Other reasons for the increased consumption of these fertilizers are:

1. They are easy to transport and handle
2. They provide a means for the uniform application of plant nutrients, including micronutrients.
3. Herbicides and insecticides may be uniformly mixed and applied in fluid fertilizers.
4. A fluid mixed fertilizer plant often has an investment cost less than that of a plant producing dry mixed fertilizers.
5. When a suspension fertilizer is produced, the grade is about the same in concentration as a solid fertilizer grade. However, suspensions are in the fluid form and can be transported and handled more easily than solid fertilizers.
6. Fluid mixed fertilizers can be produced with a minimum of air and stream pollution.

PANEL MEMBERS

Bob Boswell will discuss "General Practices and Trends in Fluid Fertilizers." Nelson Abell will discuss "Development in Liquid Fertilizers." Dr. John L. Strauss will discuss "Production of Suspension Fertilizers." Harold Walkup will discuss "Cost of Operating a Fluid Fertilzer Outlet."

MR. FRANK P. ACHORN: The first man we have to speak to you is Bob Boswell. Bob is the general manager of the Chemical Division of Good Pastures Incorporated, Brownsville, Texas. He worked for a long while with the Cities Service Oil Company before he came to Good Pastures. Bob is now the president of the National Fertilizer Solutions Association. He has been very active in this field in previous years and I am sure he has a lot to tell you about the status of fluid fertilizers and will give a general view of where we stand in the fertilizer industry.

Consumption of Liquid Fertilizers
in the United States
(millions of tons)

	1965	1966	1967	1968	1969	Projected 1970
Anhydrous ammonia	1.5	2.0	2.4	3.1	3.1	3.3
Aqua ammonia	0.7	0.9	0.8	0.8	0.7	0.8
Nitrogen solutions	1.9	2.3	2.5	2.7	2.8	3.0
Liquid mixed fertilizers	1.0	1.6	2.0	2.5	2.5	2.7
Total	5.1	6.8	7.7	9.1	9.1	9.8

General Practices and Trends in Fluid Fertilizers

Bob G. Boswell

GENERAL MANAGER
GOOD PASTURES, INC.
BROWNFIELD, TEXAS

In recent years the fluid mixed fertilizer industry has been divided into two segments: plants that produce only clear liquid fertilizers and those that produce both clear and suspension fertilizers. A survey for fiscal year 1968 indicates that about 12 percent of fluid mixed fertilizers was produced as suspension mixtures, but it also indicates that about twice as many companies would produce suspensions in 1969 as produced them in 1968.

Fluid mixed fertilizers, either the clear liquid or the suspension variety, are usually made in two types of processes generally known as hot-mix and cold-mix processes. The hot-mix process involves the neutralization of phosphoric acid with ammonia and the adding of supplemental materials to give the desired formula. The heat of neutralization gives a hot mix. In this process either commercial - grade orthophosphoric acid (54 percent P2O5) or superphosphoric acid (70 to 76 percent P2O5) can be used. The cold-mix process is similar to the bulk blending process. The producer stores ammonium phosphate solution, urea-ammonium nitrate solution, and potash, and he mixes these materials as needed in a simple mixing operation. Since there is no heat of reaction, the operation is a cold-mix procedure. However, most plants do not produce all their mixtures by hot mixing or cold mixing alone. They usually use both processes.

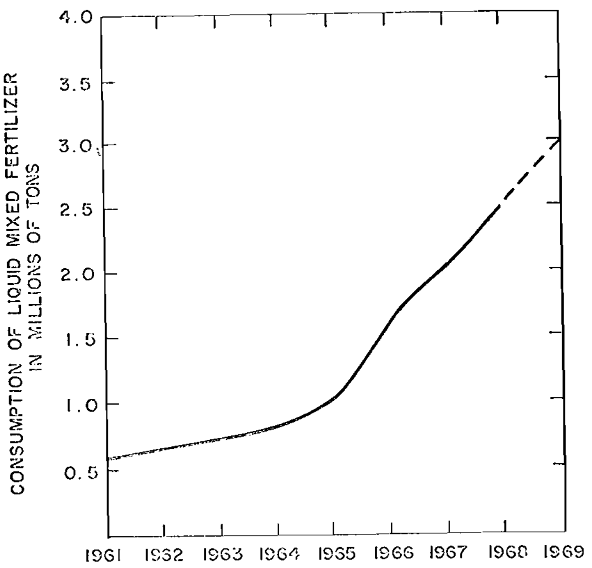


FIGURE I
APPROXIMATE ANNUAL CONSUMPTION
OF LIQUID MIXED FERTILIZER
FY 1961-1968

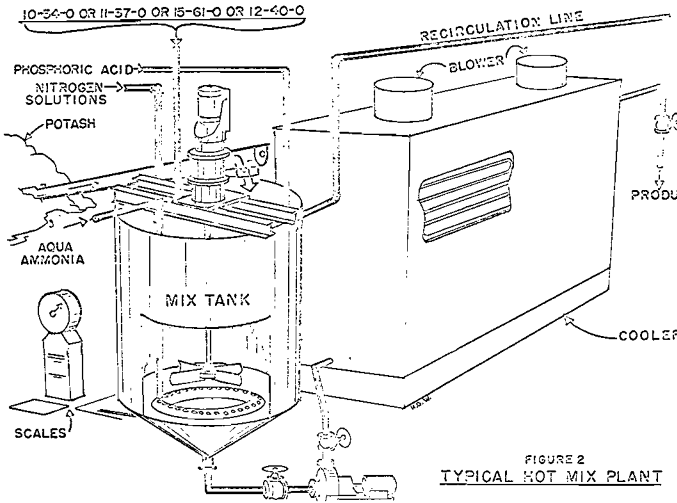


FIGURE 2
TYPICAL HOT MIX PLANT

Sometimes the two processes are combined so that a cold - mix plant is operated to produce mixtures from phosphoric acid, ammonia, and a base solution. We have arbitrarily designated this process the semihot - mix process. When it is used, the quantity of phosphoric acid which can be used is limited because the plant does not have a cooler. The quantities of phosphoric acid and ammonium polyphosphate solution (10-34-0 or 11-37-0) used in the formulation are such that excessive boiling in the mix tank is avoided. Usually between 50 and 60 percent of the product P2O5 is supplied by phosphoric acid.

HOT-MIX OPERATION

There is considerable variation in hot-mix plants, but most of them are like the one shown in Figure 2.

The mix tank, usually the batch type, has a capacity of 5 to 20 tons. It is usually equipped with an agitator, mounted on scales, and the raw materials are weighed in it. The recirculated liquor and raw materials, except aqua ammonia, are added onto the surface of the liquor in the mix tank. Aqua ammonia is added through perforated pipes mounted across the bottom of the tank. In the production of a batch of product, the liquid raw materials (aqua ammonia, phosphoric acid, and nitrogen solution) are metered simultaneously to the mix tank. At the same time the potash is conveyed to and weighed in the mix tank. During the mixing, the liquid is recirculated through a cooler to prevent excessive boiling in the mix tank.

During the early years of the fluid fertilizer industry, standard furnace acid (ortho type) was used in the small hot-mix plants. This acid causes little difficulty in storage and production; however, its price is usually above the price of wet-process orthophosphoric acid. The wet-process acid is more readily available. When wet-process phosphoric acid is ammoniated, precipitates of iron, aluminum, and some magnesium phosphate form. These precipitates cause difficulty with the application of clear liquid mixed fertilizers. They also form a thick hard sludge in the bottom of storage tanks. Superphosphoric acid or the ammonium polyphosphate solutions 11-37-0 and 10-34-0 will sequester (essentially dissolve) the impurities in wet-process phosphoric acid. Therefore, a solution free of solids can be produced from wet-process phosphoric acid and superphosphoric acid or ammonium polyphosphate solutions.

Recently the industry has developed a new solid ammonium polyphosphate. This year it is being tested in field development programs as a sequestrant for the impurities in wet-process phosphoric acid. The solid ammonium polyphosphate has a rather high pyrophosphate content (51 percent). This pyrophosphate is an excellent sequestrant of the iron and aluminum impurities introduced into the mixture by wet-process acid.

Many companies are now producing suspensions in hot-mix plants by adding a suspending clay during manufacture. The clay is usually added when the solution is still hot and before the potash has been added to the mixture. After the solution has been cooled, the undissolved potash is suspended in the fluid fertilizer. Some companies have used a clay - containing base ammonium polyphosphate suspension 12-40-0 to supply part of this clay and to supply polyphosphate for sequestering the iron and aluminum phosphate introduced by the phosphoric acid. If these iron and aluminum impurities are not sequestered, thick iron and aluminum phosphate gels usually form after the product is stored and cooled, and these gels cause difficulty in application. Some companies are producing both clear liquid and suspensions in these plants by using either wet-process or furnace superphosphoric acid as a source of P2O5.

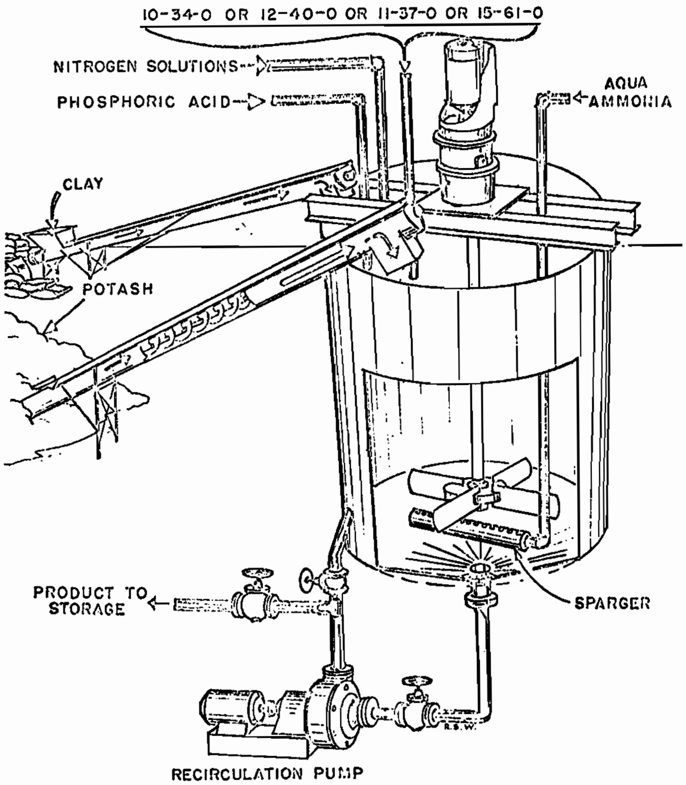


FIGURE 3
SEMI-HOT MIX PLANT FOR SUSPENSIONS

Most of the hot-mix plants in those areas which require large quantities of potash are producing, or are seriously considering the production of, suspensions because it is possible to produce a fluid fertilizer with at least twice the concentration of the clear liquid potash grade.

Some nitric phosphate suspensions have been produced from phosphate rock and nitric acid with the addition of some soluble sulfate or phosphoric acid and ammonia. These suspensions have not been very popular because of application difficulties and excessive corrosion.

SEMIHOT-MIX PLANT

Figure 3 is a sketch of a semihot-mix plant. It is similar to the hot-mix plant just shown. However, it does not require the expensive cooler which is installed in the hot-mix plant. The necessity of the cooler is eliminated by the use of the proper quantities of ammonium polyphosphate base solution, phosphoric acid, and ammonia to avoid release of enough heat to cause excessive boiling in the mix tank. Some companies with semihot-mix plants have found it particularly advantageous to use the new solid ammonium polyphosphate 15-62-0 as a partial source of P205 for their products. When solid ammonium polyphosphate is used, it is possible for a semihot-mix plant to use phosphoric acids of low concentration, such as spent phosphoric acid (24 percent P205), and still produce high-analysis clear liquids and suspensions. Tests indicate that when 50 percent of the P205 of the product is supplied by 15-62-0 and the remainder by wet-process or spent phosphoric acid, the resulting temperature of the product is less than 100 degrees F. When this procedure is followed, clear liquids produced are free of solids and have excellent storage characteristics, and suspensions produced have high analyses and can be easily applied.

COLD-MIX OPERATION

Cold-mix plants are so simple that there are few major differences among them. Storage tanks, meters, and a simple mix tank make up the equipment list. A typical unit is shown here (Fig. 4). In this plant the liquids are weighed and mixed in a batch mix tank similar to the tank used in a hot-mix plant. Cooling equipment, acid-storage tanks, and acid handling facilities are not required. Therefore, the investment cost for this plant is considerably less than that for a hot-mix plant. The plant can be used for producing suspensions or clear liquids. If clear liquids are to be produced, agitation of the product in storage is not required. Field storage tests indicate that even the best made suspensions must be periodically agitated in storage.

The product storage tank shown in Figure 4 is equipped with an air-type sparger which works well for suspensions. The type of cold-mix plant discussed works well in the production of high-analysis suspensions. It has been used to produce grades such as 27-9-0, 20-10-10, 15-15-15, 10-20-20, and 7-21-21.

SATELLITE OPERATION

A further subdivision is that of a cold-mix plant serving satellite stations. A typical station for suspension grades is shown in Figure 5. It could be used as a clear liquid or suspension satellite station. In the mixing of suspensions air spargers are required in the applicator tank; however, if clear liquids are to be used, air spargers are not necessary. In the suspension plant a 5-15-30 potash base suspension is produced in either a hot-mix or a cold-mix plant and is transported to the satellite station. The 12-40-0 base suspension is usually produced in a large regional plant designed specifically for the production of this ammonium polyphosphate base solution. The 12-40-0, 5-15-30, and urea-ammonium nitrate solutions are metered to the farmer's nurse tank and are mixed in it by an air sparger. The sparger provides enough agitation to suspend some micronutrients and herbicides in suspension mixtures.

NEW PRODUCTS

Some of the uses of new solid ammonium polyphosphate 15-62-0 have already been discussed. This material is of particular interest to bulk blenders because of its possibilities for producing both high-analysis solid grades and liquid fertilizers for the starter fertilizer market. Since the blender already has solid storage, he can install liquid mixing equipment at a fairly low cost and use the 15-62-0 to produce clear liquid grades such as 7-21-7. By using 15-62-0 the bulk blender can easily diversify his operations.

One problem that has developed in marketing clear liquid fertilizers is the formation of magnesium sludge in clear liquid fertilizers after they have been stored for several months. In the last spring season it was not uncommon to find formations of sludge 6 to 8 feet deep in the bottom of storage tanks in which 10-34-0 clear liquid was stored. Analysis of this sludge showed that it was magnesium pyrophosphate. Of course, the magnesium was introduced by the wet-process phosphoric acid used in the production of the 10-34-0. Some companies have tried to minimize this sludge formation by the installation of ion exchangers for the removal of the magnesium from their 10-34-0.

Last year in industry field programs dealers were introduced to a new 11-37-0 with a high polyphosphate content. Between 75 and 80 percent of the P205 of this material is in nonorthophosphate forms. About 60 percent of its P205 is in polyphosphate forms more condensed than pyrophosphate. The usual commercial 10-34-0 contains only 8 percent of these more condensed phosphates. Bench-scale and some plant-scale tests have shown that the more condensed phosphates are superior to pyrophosphate for sequestration of magnesium.

Plant tests have shown that no magnesium has settled in this 10-34-0 after 8 months, but a magnesium sludge formed in a 10-34-0 product made from only wet-process superphosphoric acid which had been stored for only a few weeks. These tests were made with superphosphoric acid from Florida rock. Tests made with superphosphoric acid from western rock showed that 30 percent of the product P205 must be supplied by the high-polyphosphate 11-37-0 if the product is to be stored for prolonged periods.

Next year our industry will get a look at a 12-44-0 clear liquid base solution that will have a high polyphosphate content. This material may also be used to sequester magnesium which usually precipitates in liquid fertilizers produced from wet-process phosphoric acid.

Another interesting product under study is a high-analysis urea-ammonium nitrate suspension having a nitrogen content of 37 percent. This material has been field-tested, and we have had excellent results, producing from it suspensions such as 30-10-0 and 16-16-16. However, the 37 percent nitrogen suspension does not store well during the winter. Efforts are being made to improve its winter storage characteristics.

The fluid industry also introduced into its field programs a 14-59-0-4Zn solid ammonium polyphosphate which was used as a zinc source for fluid fertilizers.

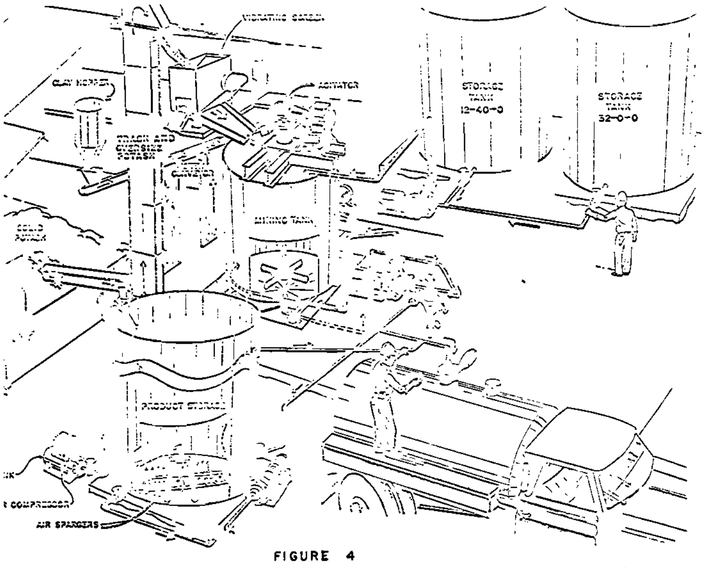


FIGURE 4

COLD-MIX PLANT FOR PRODUCTION OF CLEAR LIQUIDS OR SUSPENSIONS

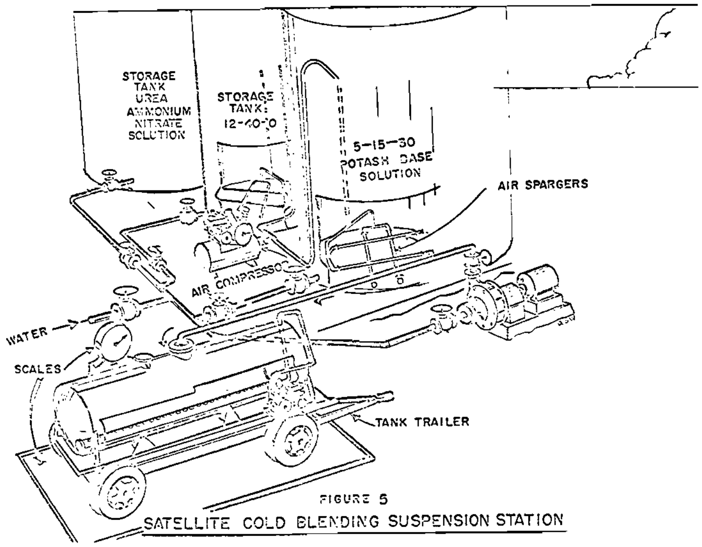


FIGURE 5

SATELLITE COLD BLENDING SUSPENSION STATION

Another factor contributing to the growth of fluid fertilizers during the past five years has been the equipment industry. Many companies have spent much time and research dollars coming up with the multitude of different types of equipment which this industry has needed.

We have come a long way since the days of aqua ammonia and clear liquid solutions. These products are still in great demand; however, with the advent of suspensions we had to have proper handling equipment.

Thanks to our equipment people ... this equipment is available to both the producer and the independent dealer.

We expect rapid growth of the fluid fertilizer industry to continue for the next few years.

PANEL LEADER ACHORN: When I came back to work with T. V. A. about ten years ago, after working in the solid business for a number of years, I got involved in the fluid business. The first man I got involved with was Nelson Abell. He was a pioneer in the fluid fertilizer business, and knows his business well. He is one man who knew how to make a profit in a depressed industry. Nelson went to Georgia Tech, graduated in 1943 and joined the Navy. He then spent some time at Ford, Baker and Davis Engineering Company. In 1955 he started his own company, the Ouachita Fertilizer and Grain Company in Monroe, and is now president of that company and also president of another company called Poly Processing Corporation, which makes molded plastic tanks and other plastic materials.

Nelson has been active in several associations. He was chairman of the Southwestern Fertilizer Conference and is now chairman of the board of the Fertilizer Institute.

Developments in Liquid Fertilizers

Nelson D. Abell
PRESIDENT
OUACHITA FERTILIZER AND GRAIN CO.
MONROE, LOUISIANA

The liquid fertilizer business has come a long way in the last fifteen years. To appreciate just how far we have come, we should recall the situation as it was in 1955.

The business belonged to entrepreneurs who had to hub it on their own without much help from the fertilizer industry. Capital was limited, equipment was inadequate, management was inexperienced, distribution costs were excessive, and the raw material position of the liquid industry was almost untenable.

Where do we stand today? Let's look.

Not all the entrepreneurs made it, but a good many of them did, and along the way they got some help, first and most from Allied and TVA, then from others. The liquid business has become a significant part of the total industry, still has an independent flavor, and may be the healthiest segment of the whole fertilizer business. Perhaps this can be explained partly by the fact that competition has been so devastating at the basic producer level that raw materials are being sold to independents at cost and below. In effect, independents are being subsidized involuntarily by basic producers.

In equipment we've had a slow evolution until we can say now we have satisfactory tanks and satisfactory metering devices. Today's equipment is far superior to what we started with, but it could stand to be engineered better.

The quality of management in the liquid fertilizer business is pretty good; the competitive aspect of the free enterprise system accounts for that. If you aren't fairly good, you can't stay.

We've studied our distribution costs and know what they are and this is a great advantage in doing business. But our costs are still high and getting higher.

The most important improvement in our situation is in the area of raw materials. Ammonia is cheap and readily available. Urea costs less than half what it cost in 1955. Urea ammonium nitrate solution is cheap and readily available. Instead of relying solely on furnace acid as a source of P2O5, liquid people can choose now from several other materials. We know how to use superacid, wet process ortho acid, and various ammonium polyphosphate solutions. The materials are readily available at a reasonable cost. As a result, the liquid fertilizer industry is no longer at a serious disadvantage when comparing our P2O5 cost to solid fertilizer P2O5 cost. Likewise, white standard potash doesn't cost any more than red standard. To sum up the raw material position of the liquid fertilizer industry, it's good, and we expect it to get even better.

For years we've recognized we need to make higher analysis liquids. We know how to do it using KOH or potassium bicarbonate as a source of K2O. But these materials are too expensive.

Through the years several fine companies and TVA have taken a look at making potassium phosphate, but the economics didn't look good. But recently an announcement has given rise to new hopes we'll get a fertilizer grade potassium phosphate.

Pennzoil United has applied for patents covering a process they developed to make potassium phosphate. In the process phosphate rock, potash, and sulfur are the raw materials. The primary products are potassium phosphates and high purity anhydrous HC1. Corrosion in the process is comparable to corrosion in a conventional wet process acid plant.

Pennzoil United has placed initial emphasis on the highly soluble potassium polyphosphates, but their process can be used to make potassium orthophosphates. Various ratios of P2O5 to K2O and varying degrees of solubility of the finished compound are attainable. Maximum concentration occurs when the P2O5 K2O ratio is 1.25, and a fertilizer grade analysis of 0-50-40 is reached.

By using potassium phosphate, Pennzoil has been able to produce grades that contain about 40% more plant food than the grades produced from KCl. Solubility studies are far from complete, so it is not known whether even higher concentrations can be attained. It appears that grades can be made almost as concentrated as with KOH, but not quite. Using small quantities of potassium phosphate produced in a pilot plant, the company has prepared liquid grades like 3-18-18, 13-13-13, and 15-10-10.

The solution of potassium phosphate is a clear amber colored liquid, having a fertilizer grade analysis of 0-21-21 and a pH of 6.7. The corresponding solid material has a fertilizer grade analysis of 0-43-43.

The question arises, is the material going to be priced low enough for the fertilizer industry to use it? The indications are that it will. Pennzoil United through its prominent subsidiary, Duval Corp., has experience and know how and market savvy in the fertilizer business. They say the economics of their process look all right, and that for a reasonable premium they expect to be able to produce potassium phosphate for the fertilizer market. How much premium is "reasonable," we won't speculate on, but it's obvious there has to be a premium because you can't start with KCl, process it, and still charge the KCl price for the K2O in the compound. It's also obvious the liquid fertilizer trade can afford to pay some premium for a product that can be used to increase plant food content forty percent or more.

The present avenue to higher analysis in fluids is through suspensions. The raw material costs are beautiful, but after that the picture isn't so beautiful. Suspensions are the subject of another paper to be presented on this program, and I'm sure the speaker will give full and excellent treatment to the subject. But since we are interested in all the possible approaches to higher analysis in fluid fertilizer, and since suspensions are presently the standard, I want to make a few observations about them.

Immediately I will disqualify myself as an expert. We have never sold suspensions commercially, but for two years we did operate a small pilot plant and we paid our tuition in the school of experience. While I'm the first to admit we don't know a lot about suspensions, I do lay claim to being objective in my analysis. In 1967, addressing a fertilizer conference, I predicted fertilizer solutions would retain their leading position in those areas where potash requirements were low, and in areas where truck spreading was not practical, but that in other areas suspensions could become the leading fluid fertilizer because of higher analysis. Suspensions got a big impetus because in certain situations higher analysis was a necessity. Also, never discount the fact that suspensions got additional impetus because of the energy, enthusiasm, optimism, and extra effort characteristic of people in the liquid fertilizer business. They made the program work because they had to make it work and because they worked exceptionally hard to make it work. Still, in my opinion, suspensions are only a qualified success. The manufacturing, transportation, shrinkage, agitation, abrasive wear, and service all cost money. To handle a ton of suspension probably costs $4.50 more than to handle a ton of solution. Furthermore, suspensions are not easy to handle, and since suspensions don't always store well it's unwise to accumulate big inventories to meet peak season demand.

Clear liquids are not the answer because of low analysis. Suspensions are not the answer because of handling problems. We think the answer is a high analysis clear liquid. At least that's what our company is shooting for.

In summary, what we've said is that the liquid fertilizer industry has made a lot of progress over the past fifteen years and today the liquid business is in pretty good shape. With respect to raw materials, our position is the best ever. Comparing our position to that of dry fertilizer people, we are no longer at a serious cost disadvantage in phosphate, and we are on equal terms in nitrogen and potash. We still don't have a satisfactory way to achieve higher analysis, but this picture could change. The most exciting thing in the fertilizer business today is the prospect of being able to produce a high analysis clear liquid fertilizer at a reasonable cost. That possibility does exist, assuming commercial production of fertilizer grade potassium phosphate is begun.

MR. ACHORN: The next speaker will discuss suspensions. As you can already sense, some folks do have independent ideas about which is the best form to use in fluid fertilizers. I think that probably Dr. Strauss is the strongest advocate I know of. Dr. Strauss attended Ohio University and Virginia Polytechnic Institute. He received his Ph.D. from Purdue University. Dr. Strauss, for a long time worked with the Brisbane Company. He was a part owner. Brisbane was sold to Armour now U. S. Steel. Dr. Strauss then went to work for American Oil Company and is active in their fluid fertilizer program. I think the first time I ever saw a suspension was back in 1959. Dr. Strauss made the 12-12-12 and my statement was, "You'll never get that stuff out." Dr. Strauss proceeded to put it out right in front of me. He has been doing it ever since."

Production of Suspension Fertilizers

John L. Strauss
CHIEF AGRONOMIST
AMERICAN OIL CO.
CHICAGO, ILLINOIS

Suspension fertilizers, the fertilizer of the future, are being produced now. These "hybrid" fertilizers, made by combining features of liquid and of dry fertilizers, are the most rapidly growing segment of the fertilizer industry. Many of the plants handling clear mixed fertilizers are converting their production and sales to the suspension type of fluid fertilizer. At the present time, it is estimated that 25% of all mixed liquids are marketed as suspensions.

Suspensions are the natural outgrowth of demands from the customers and research. Farmers wanted higher analysis fluids, and many of their soils required fertilizers that contained more than a 10% level of potash. Pioneering research by TVA indicated that added clays could be used to increase the nutrient content of fluid fertilizers and this principle was used to put tri-nutrient fluids on the market in the early sixties. The marketing of 3-10-30 in Iowa by Armour Agricultural Chemical Company led the way in demonstrating that suspensions were possible and practical.

Figure 1 is a schematic diagram which shows where suspensions fit in the family of present day fertilizers. Of the fluid fertilizers, suspensions are the most concentrated, containing 40 or more units of nutrients. The higher viscosity and the greater specific gravity of this type fluid does require more power and larger equipment than required for the clear mixed liquids.

Most suspension fertilizers are made in a manner similar to clear mixed liquids, basically by neutralizing a phosphoric acid source with ammonia and then adding the potash source. Attapulgite clay is generally added to provide a thickening and suspending action. The clay particles act as sites for cations and "cushion" the salts to prevent a cementing action while in storage. The key to suspension manufacture is to separate and hydrate each and every clay particle. This requirement necessitates a proper order of addition of ingredients, a physical shearing action, a pre-gelling, the use of a chemical catalyst and/or vigorous agitation. One or more of these steps are employed to obtain clay hydration depending upon the analysis to be made and the physical facilities of the plant.

Suspended particles in the fluid fertilizer act in accordance with the principles as presented in Stokes law:

$$V = \frac{2}{9} \frac{(d_P - d_L) g\, r^2}{N}$$

V = velocity of fall in cm/sec.
d_P = density of the particles
d_L = density of the liquid
g = acceleration due to gravity
r = radius of the particle
n = absolute viscosity of the liquid

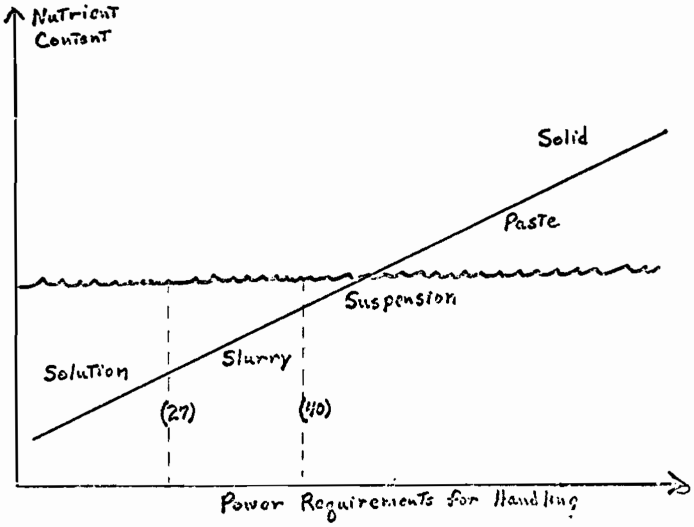
This law indicates that the fall of a particle through a liquid is dependent upon the radius of the particle and the absolute viscosity of the liquid. Man can have control over these two factors since all other factors in the law are constants. It follows that particles of smaller radii would be suspended longer, and this dictates purchasing specifications. The absolute viscosity of the liquid can be increased by adding clay or other gelling materials. The inherent ingredients of the basic mixture, such as the iron and aluminum content of the wet process phosphoric acid, can also influence the absolute viscosity. The manipulation of the pH and heat during manufacturing can be used to alter the viscosity of the final fluids. It is apparent that each analysis manufactured must be studied and a plan of manufacture established so that a standard quality product can be obtained every time.

Suspension fertilizers are not as specific in their requirements of raw materials as are clear mixed liquids. Wet process acids are commonly used in suspensions at a higher percentage rate than in clear mixed liquids. Also, the nature of suspensions allows the use of different forms of nitrogen and potash without the usual concern for salting out or for low solubility of the nutrient sources.

Suspensions can be manufactured and marketed from a central location per se, or they can be blended together to make a variety of analyses at an outlying station. Figure 2 shows a suspension satellite station where basic suspensions of high phosphorous and high potash can be blended with a nitrogen source to make different analyses. A comparison of grades of the same ratio indicates the higher analyses that can be obtained from sus-

FIGURE 1

The Family of Multinutrient Fertilizers



pension fertilizer versus clear liquid fertilizer. This type of suspension station competes favorably with a dry bulk blend operation and at a much lower initial capital outlay.

The switch from clear liquid mixed fertilizer to marketing of suspension fluids of higher analyses may cause some erroneous conclusions in examining tonnage reports. It may appear that fluid fertilizers are growing at a slower rate on a commercial ton basis, but if placed on a nutrient ton basis, the true growth of fluids can be viewed in proper perspective. Nutrient ton comparisons should be made during this transitional period of changing to suspensions.

Suspension fertilizers are extremely versatile. Additives such as secondary nutrients, micronutrients, insecticides, herbicides, fungicides, growth regulators, enzymes, chlorophyll, nitrification inhibitors, stomata regulators, seeds, conditioners, and other products can be incorporated into suspension fertilizers, lowering operating costs to the farmer. Of great importance is the fact that the additive can be homogeneously incorporated throughout the fluid by agitation. This increases the probability of proper distribution.

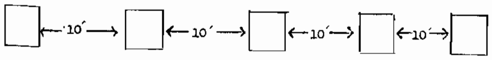
Proper distribution of fertilizer is just as important as is the analysis of the fertilizer. Fertilizer goes to work only when it is applied to the crop. Every plant should be fed the proper analysis of fertilizer, at a predetermined rate. Overfeeding or underfeeding results in inefficient use of fertilizer and a subsequent reduction in yield.

Table 1 shows the quantity variation and quality variation obtained by sampling at 10 foot intervals during application of dry bulk fertilizer and a suspension fertilizer. The data indicate the uniformity of analysis of the suspension and the wide variation in analysis of the dry blend.

TABLE 1

Spreading Data *400# per Acre Rate

Dry Bulk Blend - 400#/A Rate

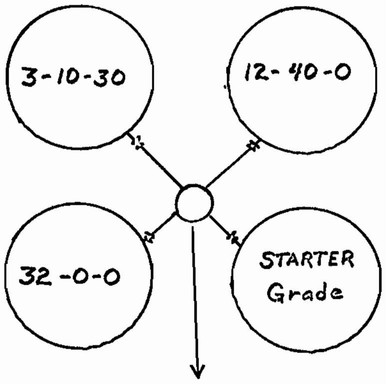


Rate/A	176	388	920	312	204	
			Analysis			Variation
N	7.9	11.5	14.4	12.0	7.7	81%
P_2O_5	7.0	4.9	7.4	5.5	8.4	71%
O	26.4	25.2	22.9	25.2	27.4	19%
			Suspension - 2 Nozzle 90°			
Rate/A	340	290	770	302	298	
			Analysis			Variation
	13.7	13.6	13.8	13.8	13.7	1.7%
	7.2	7.2	7.3	7.2	7.2	2.0%
	21.6	21.6	21.5	21.7	21.6	0.9%

*Based on U. S. Testing Laboratory Data

FIGURE 2

Typical Suspension Blending Station



Suspensions	Comparable Clear
6-18-18	3-9-9
12-12-12	9-9-9
15-15-8	10-10-5
19-10-10	14-7-7
18-12-6	12-8-4

Both fertilizers exhibited variations in the quantity applied at each 3 feet by 5 feet plastic sample. The fluid application could have been very accurate if the nozzles were at a 45 degree angle rather than at 90 degrees. A testing procedure using rain spouts as shown in Figure 3 proved that even application with up to 4 nozzles could be obtained when the nozzle angle was 45 degrees with the ground. These tests were verified by John Blue Company.

The advantage of application of suspensions can be measured in terms of yield. A comparison of 400 pounds of suspension fertilizer with 400 pounds of same analysis dry bulk blend showed over 13 bushels more corn from the suspension system. Both treatments used the same amount of added ammonia. The decrease in yield from the dry bulk blend was due to creating strips of overfeeding and underfeeding through the field because of particle size segregation and differences in specific gravity. The average of the strips did not equal the yield effects of the even application and the evenness of analysis of the suspension fertilizer. This leads to the contention that perhaps the sampling of fertilizer should be made as it is applied rather than in an applicator, bin or tank. Such a procedure would show a definite advantage for all fluid fertilizers and especially suspensions which compete against dry bulk blend fertilizers.

Research is required in handling and application equipment to obtain materials which will stand the erosive abuse of the "liquid sandpaper" action of flowing suspensions. Perhaps some of the erotic metals and synthesized compounds of the space area of operations can help in the requirement. Another piece of equipment needed is an effective metering device that will function under conditions of high salt concentration.

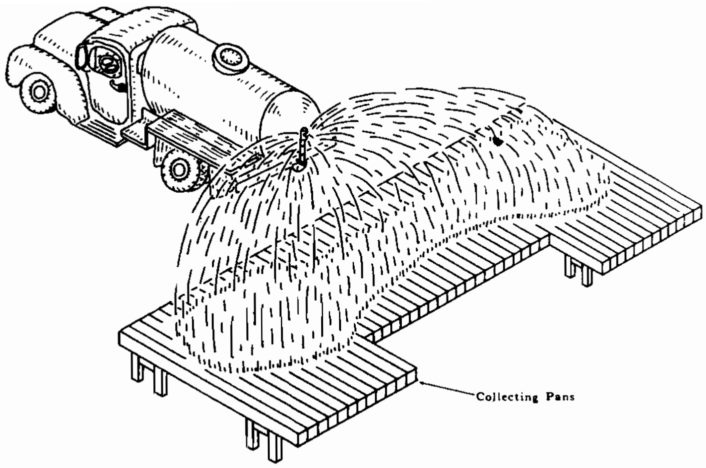


FIGURE 3

Fertilizer Application from a Fieldjet Nozzle - Test Assembly

Research on additives is necessarily a localized research project involving specific additives with specific suspension fertilizers. What works for one operator may not necessarily work for the next since his method of manufacture may differ and the characteristics of his fertilizer may vary.

Prior to the advent of suspension fertilizers, Dr. I. E. Miles compiled the thoughts of persons involved in crop production for the specifications of the ideal fertilizer. From an agronomic and versatility standpoint, the specifications more nearly fit suspension fertilizers than they do any product on the market. Precision farming requires precision methods, and versatility and suspension fertilizers best meet the precision requirements of the more progressive farmers.

MR. ACHORN: The next speaker is Harold Walkup. Harold and I have worked together very closely in the fertilizer industry for about ten years. I worried in the early days about how we were going to get the stuff out, and he has been worrying about how he's going to make a profit. That is what his talk is about today, "Cost of Operating a Fluid Fertilizer Outlet." It is an objective study, showing the entire cost breakdown in a fluid fertilizer outlet. Harold had his undergraduate work at the University of Nebraska, graduate work at Washington State and has been actively engaged in several T. V. A. Projects. Harold also is now head of the Distribution Economic Section, of the Testing Demonstration Branch of the Division of Agricultural Development at T. V. A. He has received several awards. One of the major awards is honorary membership in the National Fertilizer Solutions Association. He has done some work on the cost of marketing anhydrous ammonia, and I think if we had looked at that work a little harder in the past we would have been warned in advance of some of the pitfalls that we fell into in marketing anhydrous ammonia. I hope that he will bring out the pitfalls of marketing fluid fertilizer now so that we can avoid them.

Cost of Operating A Fluid Fertilizer Outlet

Harold G. Walkup
HEAD, DISTRIBUTION, TVA
MUSCLE SHOALS, ALABAMA

The data presented here relate only to the mixed fluid fertilizer segment of an outlet's overall business. It excludes cost data relating to nitrogen solutions and anhydrous ammonia which usually were available from the outlets interviewed. These data were obtained from a study recently completed in cooperation with the Fertilizer Solutions Association, conducted in six principal fluid fertilizer-using areas of the United States. The costs discussed pertain to an average outlet situation through which the operator plans to mix and distribute 3,000 tons of mixed fluid fertilizer of an average grade of 10-16-5.

If fluid fertilizer outlets confined themselves to the sale of fluid fertilizers, the task of determining their operating costs would be simple. Usually, however, this is not the case. The seasonality of the fluid fertilizer or any other retail fertilizer business requires the inclusion of other activities or enterprises at the outlet. As a result, many of the costs incurred by a fluid fertilizer outlet are shared by other enterprises. Shared costs are prorated on some reasonable basis to each enterprise involved, including fluid fertilizers.

Basic to the cost structure of an outlet is the initial investment in site, facilities, and equipment. Table 1 shows the average investment required for the 3,000 - ton volume. These costs are itemized and totaled and the percentage each represents is shown. Operating costs, however, are influenced only indirectly by investment costs. As a matter of fact, investment costs are a minor consideration in mixed fluid fertilizer outlets as compared with some other costs -- particularly raw materials costs.

Fluid fertilizer outlets incur costs of three general types which we call (1) capital associated, (2) administrative, and (3) operating. These costs, when developed, usually pertain to one year of operation and often are shown on a per-ton - of - throughput basis. They arise from the investment in facilities and equipment; the administrative and sales efforts involved; and from production, distribution, and application -- all relating to volume or throughput.

Capital associated costs consist of depreciation, interest on average investment, insurance, maintenance, and property taxes. These costs are nearly constant in total for an outlet, but decline per ton as throughput increases.

Table 1. Original Investment in Site, Equipment, and Facilities for Average Mixed Fluid Fertilizer Outlet for 3,000-Ton Volume

Item	Investment Cost	% of Total Investment
Site & improvements	$ 4,083	5.4
Office & other buildings	6,516	8.7
Office equipment	654	0.9
Radio equipment	1,083	1.4
Shop equipment	651	0.9
Scales	1,359	1.8
Mixing plant	8,070	10.7
Storage tanks	22,101	29.4
Nurse tanks*	12,405	16.5
Applicators*	12,402	16.5
Pickups & cars	3,375	4.5
Miscellaneous equipment	2,499	3.3
Total	$75,198	100.0

*Includes nurse tanks and applicators owned by farmer customers.

Administrative costs consist of management salaries, office employee wages, and sales staff costs of a noncommission nature. These, too, are nearly constant for an expected volume of sales, but also decline per ton of throughput.

Operating costs, on the other hand, vary more or less in total in direct proportion to volume of sales. They consist of raw materials used to make the fluid fertilizer, repairs to equipment and facilities arising from wear and tear, petroleum products, interest on working capital, sales commissions, operating labor, and numerous administrative-type costs which vary more or less directly with volume of sales. These costs tend to be rather constant per ton of throughput.

Table 2. Categories and Amount of Costs Per Ton of Product Incurred at a Mixed Fluid Fertilizer Outlet

Capital Associated	Costs in $/Ton	% of Total
Depreciation	2.22	3.8
Interest on average investment	1.06	1.8
Insurance	0.33	0.6
Maintenance	0.15	0.2
Property Taxes	0.42	0.7
Subtotal	4.18	7.1
Administrative		
Salaries and wages	3.17	5.3
Miscellaneous	1.36	2.3
Subtotal	4.53	7.6
Operating		
Materials	45.54	76.7
Repairs	1.24	2.1
Petroleum products	0.55	0.9
Interest on working capital	1.28	2.2
Losses (materials and credit)	0.44	0.7
Wages and commissions	1.59	2.7
Subtotal	50.64	85.3
Total	59.35	100.0

An itemization of the three types of costs is presented in table 2. These cost figures are averages for all types of outlets represented in the sample of 27 firms that were visited. The sample included outlets having mixing facilities for hot mixed and clear and suspension mixes and cold mixed clear and suspension mixtures. These data can be used to determine the approximate cost of operating fluid fertilizer outlets of different volumes. The impact of these costs on operating an outlet can easily be seen in a break-even diagram.

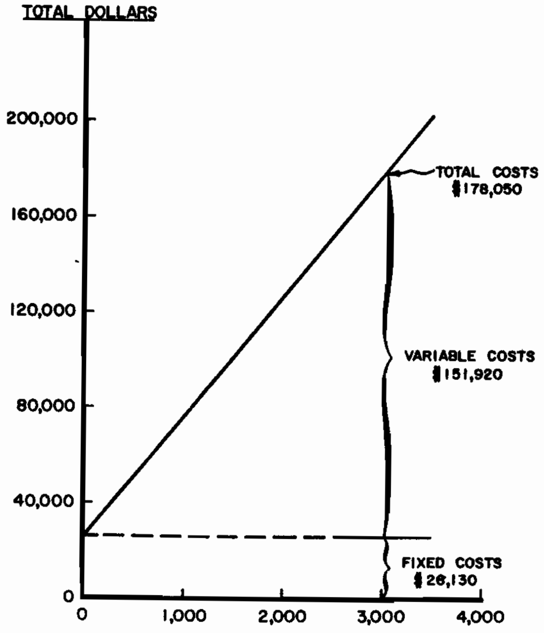


Figure 1

Fixed, Variable, and Total Costs for a 3,000-Ton Fluid Fertilizer Outlet

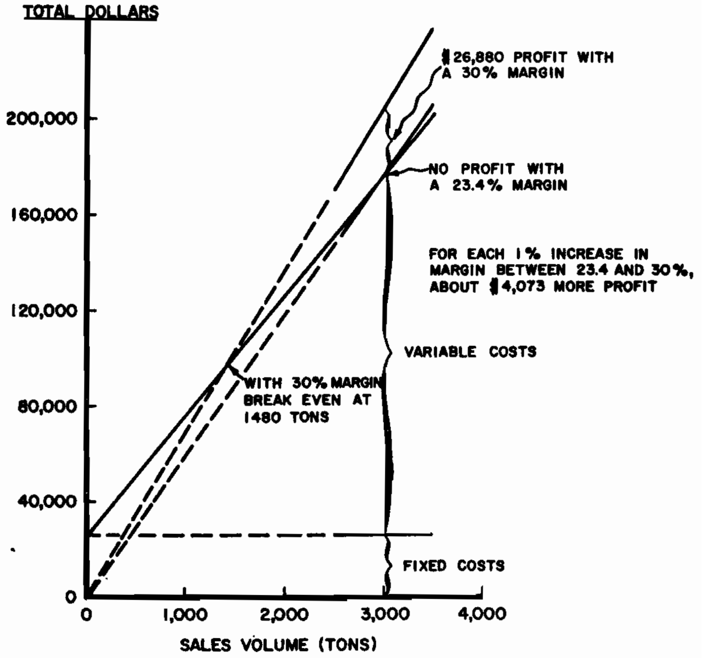


Figure 2

Break-Even Diagram for a 3,000-Ton Fluid Fertilizer Outlet

The first step is to allocate the costs shown in the following table to those we call fixed and those we call variable, depending on how they vary relative to volume or through-put. These are shown in figure 1, which was constructed to show the cost situation for an anticipated 3,000 tons of product, plus or minus about 500 tons because an operator cannot estimate his volume exactly prior to the year's business.

Since the fixed costs do not change with volume, in this case 3,000 tons of product, a horizontal line is drawn to represent $26,130.(1) Variable costs of $50.64 per ton are shown by a line originating at the $26,130 level and sloping upward to account for the additional costs incurred for each additional ton up to 3,500 tons.

This line is extended to include the 500 tons above 3,000 that could be handled if the season and other conditions worked out to the outlet's advantage. So, the variable cost line, in addition to showing how the variable costs increase, actually represents the total costs incurred at all volumes up to 3,500 tons of product.

To cover these costs, the outlet manager or operator usually thinks in terms of charging for his products and services based on a margin on his raw materials costs. Since raw materials represent about three-fourths of all costs, they provide a good reference point from which to satisfactorily gauge product prices needed to cover all costs and, hopefully, make a profit.

The fixed and variable cost information is shown in figure 2 along with income from product sales based on margins at two levels. Given a certain set of prices for products, based on a specific margin, income from product sales increases in direct proportion to sales. In the cost situation posed, a margin of 23.4 percent would cover all costs of the fluid fertilizer outlet at the 3,000-ton level of product sales, but would leave no profit. If sales exceeded 3,000 tons, a slight profit would accrue; but, with sales less than 3,000 tons, losses would result, and would increase with reduced volume.

An important fact for the manager of a new outlet to remember is that conventional cost accounting will usually underestimate the margins needed to meet amortization requirements because the depreciation figures included as costs usually are lower than the amortization requirements. This is true also when new equipment and facilities are added to the outlet because the useful life of an asset is longer than the time allowed by a lender to repay the loan set up to buy the equipment and facilities; and replacements usually cost more than original equipment and facilities. In the situation posed in this analysis, the annual depreciation is $2.22 per ton reflecting an average 11-year useful-life depreciation for all facilities and equipment, or $23.71 per annual ton over the lives of the capital assets. It is very likely that loans obtained to buy these assets must be paid off by the outlet in, say, only four years. If so, then the proper "depreciation (amortization) figure to show the income flow required to meet these obligations during the first four years is $5.93 per ton of product instead of $2.22. To meet this cash - flow requirement, the margin relative to materials cost would have to be increased from 23.4 to 27.8 percent just to break even at the 3,000 tons of product volume -- an increase of over 4 percent margin. This disadvantage may be offset slightly by decreased maintenance and repairs required during the first few years of operation. However, gaining experience, enduring low sales volume relative to the capabilities of the manpower, and investment in the fluid fertilizer outlet may cancel out the advantage of low maintenance and repairs. Of course, the financial picture for the outlet should improve following the capital payout period which occurs mainly during the first few years of operation.

MR. ACHORN: Now, if the speakers will come and sit around the table, we will entertain some questions.

MR. ROBERT GRISSO: I have a question that I would like to address to Dr. Strauss. You talked in your presentation about incorporating sulfur in suspension and that in various areas around the country, there are considerable by - products of ammonium sulfate. I understand these materials are available at low cost, and I would like to hear your comments on the possible use of such material in the suspension for sulfur and also for nitrogen?

DR. STRAUSS: We haven't tried to use any ammonium sulfate. I see no reason why it could not be used. I think we would have to work it out. You might change your balance in the mixture and might change a few properties. I think it might be a good possible source.

MR. ACHORN: I would like to add one thing that we did last week, or week before last, at the Lyon Spock Fertilizer Company in Virginia, mainly 11 - 11 - 11 and 12 - 6 - 6 suspension for ammonium sulfate and ammonium polyphosphate suspension. It was applied immediately and wasn't stored. The main reason it wasn't stored was that the ammonium sulfate was quite large, larger than we hoped to have, but it did look real successful to us, and we didn't have too much trouble applying it. In fact, we didn't have any trouble.

DR. STRAUSS: I might add this. People liked the product better with the sulfur in it than they did without it. It seemed to make it just a little better for handling purposes, and the potash seemed to be a little smoother. You can actually make the product, analysis 4 - 12 - 24, without sulfur. When you put sulfur in it and put it in your hands, you can tell right away that it is a much better handling product. The reason I like it better, and the reason I knew it would work, was because the 4 - 12 - 24 is at the lower end of these suspension ranges, and when you put that sulfur in and reduce the water and make it just a little bit thicker, I think that is the better effect you are getting.

MR. ACHORN: Does that answer your question?

MR. SPILLMAN: On a delivered basis, is the 10 - 20 - 20 delivered and spread on the farm, dry materials, competitive with 10 - 20 - 20 liquid fertilizer spread on the farm?

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1. ($4.18 plus $4.53) 3,000 tons equals $26,130.

MR. WALKUP: A comparison was not made in this study between the liquid and solids. This was just a study of the cost of mixing and distributing liquid fertilizer, and also we didn't study the cost of it, but handling and distributing items of solutions. I didn't include that in the cost computations I gave this morning.

MR. SPILLMAN: Can we have that answer from any of the panelists?

MR. BOSWELL: I would hesitate to answer that question, but in my opinion, the cost would be comparable. The price of the liquid is almost always higher than the dry material.

MR. JOHN L. BUCY: I would like to ask Mr. Walkup to comment on the effect of costs on the break-even point in operating a liquid fertilizer outlet.

MR. WALKUP: As I indicated, the fixed cost did not loom as large as many of the other variable costs, particularly the cost of material. The cost of raw materials was 75 per cent of the total cost, probably. I don't mean to imply by that that fixed costs aren't important. Obviously, they are, but I think the important point to make is that outlets should give more thought to maintaining satisfactory margins rather than trying to make profits through high volume and give way on the margin. If they do this, they end up with high through-put, but not enough margin to cover their costs.

MR. WILLIAM WEBER: Referring back to Mr. Hignett's talk, he mentioned the various ammonium phosphate processes for making semi - granular material for mixing purposes. I would like to add that Rikkihappo Oy in Finland has developed a process, since they have been operating in Siilinjarvi, for making a semi - granular product which they claim is very suitable for mixed fertilizer. They use 43 per cent of phosphoric acid, which is one reason that they put in the HYS Plant which produces 43 - 45 per cent acid directly for this plant. It makes all the steam available from the sulfuric acid plant, providing enough power to run the whole complex.

MR. ACHORN: I have an additional question for Mr. Hignett about this 11 - 55 - 0 that we have been talking about, which is a fine fertilizer material. We know it works well in granulation plants. I was just wondering if it would also be a good product for the fluid fertilizer industry, either to make suspensions or probably clear liquids?

MR. HIGNETT: I think that is a good subject for experimentation.

MR. LOREN E. HOPWOOD: (MAPCO, Inc., Athens, Illinois) Mr. Hignett you made the remark that "In the decade to come we will see more competition in quality and less in price;" are you referring to dealers and manufacturers or the retail level?

MR. HIGNETT: I think perhaps both. In the international trade, some of our products do not have as high quality as competing products available from, let's say, the European sources. That may be partly due to the fact that some product characteristics, which we consider in the United States to be unimportant, are considered to be important by the foreign customer. There are, for example, such details as size of granules. Certain foreign buyers prefer larger granules than we produce in the United States. Another factor is excellence of conditioning. A good deal of thought and effort goes into coating of granules, and many European operations turn out products with excellent physical condition, often better than ours. We may think the customer is wrong in attaching importance to elements in quality, but when we are trying to sell something, the customer is always right and you can't argue with him. Likewise, in the domestic trade, I think there is room for improvement of some products.

MR. BUCY: I would like to ask (Question inaudible).

MR. ABELL: If I understand the question, you are interested in knowing how far you can go in the finished product, considering the effect of iron and aluminum phosphate in the finished product. If that is the question, your potassium phosphate compound will carry you as far as you can go, whether in potassium bicarbonate, without consideration of the iron and aluminum phosphate, and probably the limitation in that compound, the presence of sulfate iron in the solution.

A MEMBER: I wold like to address my question to Mr. Abell also. I would like to know whether you can market solid fertilizer and clear liquid fertilizer together and have them complement each other, and how would you do it?

MR. ABELL: You asked a question that should be asked more frequently of people in the business. While we have difference of opinion about liquid fertilizer, I think we all agree if you are a dyed-in - the - wool liquid man you will succeed better than if you are undecided. Some of our friends and colleagues who started in the liquid business about the same time and have for one reason or another moved into the dry business along with the liquid fertilizer business concur with the opinion that I am expressing that you should either give the liquid business a good ride and stay out of the dry, or give the dry business emphasis and stay out of the liquid. That is something you can hang your hat on.

Wednesday, November 4th, 1970
Afternoon Session
MODERATOR: JOSEPH E. REYNOLDS, JR.

New Technology, Developments and Trends

PANEL LEADER: William C. Weber

DORR-OLIVER, INC.
STAMFORD, CONN.

MODERATOR REYNOLDS: Our program this afternoon has been very well highlighted in the outline of the program. The session this afternoon is directed to "New Technology, Developments and Trends." The Panel that has been assembled is under the direction of Panel Leader Mr. William Weber of Dorr - Oliver, Inc. The subjects that will be discussed are "Third Generation Phosphoric Acid Processes," "Developments in Granulation Techniques," "New Developments in Nitrogen Technology," "Eutrophication Impact on The Fertilizer Industry," and "Worldwide Trade in Phosphoric Acid, Phosphorus and Ammonia."

PANEL LEADER WILLIAM C. WEBER: The Executive Committee felt that at least one session during the meeting should be devoted to discussion of a broad series of topics -- that would be of more direct interest to planning and management executives at a fertilizer plant, than to the plant operator. I am sure, however, that everyone has a general interest in the topics to be discussed. I felt that we should take a look at the future, where the industry is going, what new developments are in the offing, and what the impact on the industry may be.

The first statement will cover "Third Generation Phosphoric Acid Processes." Phosphoric acid is a key material in the fertilizer industry at this time. There have been some developments in phosphoric acid and there have been tremendous plants built. New processors are looking for a more economical basis for materials and the production of stronger acids.

We have Mr. R. L. Kulp, here to tell us about new developments in the industry. Mr. Kulp, has been with Dorr-Oliver for about twenty years and has a great deal of experience in the design, engineering and operation of phosphoric acid plants. He has been very active in the development of processes. Dick will try to review for us new developments in phosphoric acid, not only at Dorr-Oliver but elsewhere.

Third Generation Phosphoric Acid Processes

Richard L. Kulp
MANAGER, PROCESS TECHNOLOGY
DORR-OLIVER, INC.
STAMFORD, CONN.

Over the past several years a great deal of interest has been generated in the development of new and improved schemes for the manufacture of wet process phosphoric acid. Thus in spite of the overcapacity in many of the major producing areas of the world it is apparent that a number of companies are now giving serious thought to the type of process they will favor to meet their future needs.

How large the P2O5 market is likely to be over the next few years is difficult to predict. However, we will be brave and guesstimate that, in the next five years, the USA will add a total of 1,200,000 tons per year capacity to the 1970 figure of around 5,000,000 tons. The rest of the world, excluding the USSR and China, will add at the end of the next five years approximately 4,000,000 tons P2O5 to the 1970 capacity of close to 7,000,000 tons.

These forecasts reflect the opinion that the wet process phosphoric acid industry will continue to be big business. We believe though that competition will force producers to pay increased attention to technology and to be more selective in their choice of process in order to minimize costs.

Over the last decade a major contributing factor to lower production costs has been the construction of large single train plants. This concept developed from the nonlinear effect of plant size on battery limits plant cost and the relationship between capital investment and the fixed costs of production. However, in the phosphoric acid industry, where raw material costs still represent over 75% of the manufacturing cost, the non-linear scale-up exponent has a decreased influence on overall manufacturing costs.

Our feeling is that certain segments of the market are demanding processes that reduce the consumption of raw materials by increasing yields to 98% and beyond, and preferably produce a stronger acid, thereby minimizing or eliminating evaporation. The market also, in many cases, wants a gypsum that is sufficiently pure to be discharged into waterways or that is suitable for making wall board or a setting retarder in cement.

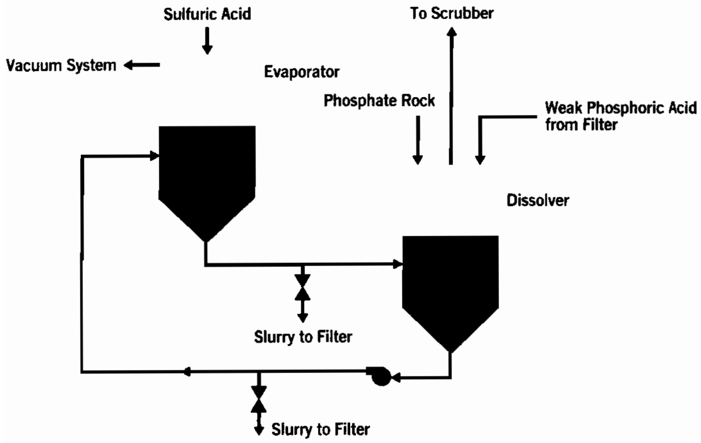

Fig. 1-The Kellogg - Lopker Reaction System

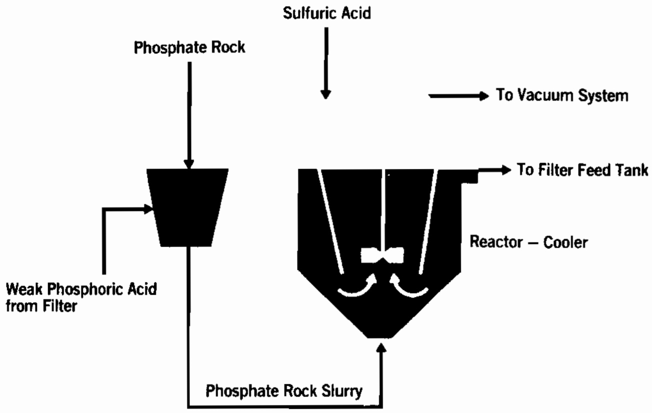

Fig. 2-The Gulf Design - Swenson Reaction System

We have chosen to call processes that fulfill these specifications "third generation," although we recognize that the principles for many of them were developed decades ago. First generation was the old Dorr Process using continuous counter current decantation and producing 20% P2O5 acid with about 90% yield. Second generation covers the present conventional dihydrate plants that produce 30% P2O5 acid with a 95-96% yield.

The development of the second generation plants began in 1931 at the Trail, B. C. factory of the Consolidated Mining and Smelting Company where the Dorrco strong acid process was introduced. Over the years there have, of course, been many changes in the hardware of the feeders, digesters, filters and evaporators. A brief look at the digestion system indicates that whereas the reaction was originally performed in cascading multiple tanks, most designers now use single tank reactors -- either cylindrical or rectangular multi compartmented.

NEW REACTORS FOR DIHYDRATE PROCESS

The market is currently studying two new approaches to reactor layout that have been demonstrated commercially in the dihydrate process. These are the Lopker design offered by the M. W. Kellogg Company and the Swenson design offered by Gulf Design Company of Lakeland, Florida. Both systems claim significant reductions over conventional processes in capital investment and operating costs per ton of P2O5 produced. Yields are reported to be in the 96% range when producing 30-32% P2O5 acid.

The Kellogg-Lopker (1) design substitutes high capacity pump recirculation for mechanical agitators. Figure 1 shows the arrangement. Two interconnected vessels are positioned offset at different levels to provide a recirculating flow of slurry. The upper vessel, maintained under vacuum to remove the heats of dilution and reaction, is called the evaporator. Sulfuric acid is distributed over the boiling surface. The lower vessel, designated as the dissolver, receives the return acid from the filter and the phosphate rock. Magma from the dissolver is delivered to the evaporator by a high capacity low head pump. Introduction of the slurry is tangential, to give a swirling motion to the vessel contents. The slurry then flows downward to the dissolver where the inlet is also arranged to impart a swirling motion. The system is arranged so that product slurry can be withdrawn from either vessel, and this flow is delivered to a surge tank ahead of the filter.

The process has been running for more than a year in a 240 LTPD P2O5 plant operated by the Marchon Division of Albright and Wilson at Whitehaven, England.

Claims are made that the process can handle a rock feed of the following size:

% Minus 20 mesh - 90
% Minus 100 mesh - 20
% Minus 200 mesh - 2

Operating requirements are submitted as follows:

Operators per shift: - 3

Maintenance - 5% of capital investment

Utilities per long ton of P2O5

Power: - 53 KW Hrs.
Process Water: - 1000 Gallons
Cooling Water: - 12,000 Gallons
Steam: - 1800 Lbs.

The capital investment is said to be 20% less than for conventional designs.

Claims are also made that the process can accommodate the manufacture of greater than 40% P2O5 acid by changing parameters and operating in the hemihydrate region.

The Gulf Design-Swenson (2) unit is an isothermal single reactor system invented by H. B. Caldwell. Figure 2 serves us with an illustration. The reactor is a cylindrical vessel maintained under vacuum and equipped with a propeller positioned within a draft tube to pump a high volume against a low head. Phosphate rock is conveyed to a premix tank where it is slurried with recycle weak filter liquor before it is added to the reactor. Sulfuric acid is sprayed over the surface of the turbulent boiling slurry so that it mixes rapidly with the tank contents. Reports indicate that the high internal recirculation rate limits the temperature variation of the slurry mass to about 0.5 degrees Fahrenheit and eliminates local concentrations of sulfuric acid.

This promotes the formation of large gypsum crystals which are fast filtering and suitable for efficient washing.

The system has been tested since 1966 in the 25 TPD P2O5 plant of AFC Inc. at Edison, California.

FUNDAMENTAL PRINCIPLES

Unlike the dihyhdrate flowsheets we have just described, the Third Generation processes involve the formation of hemihydrate. To understand the difference in principles it is necessary to be familiar with the conditions under which these two forms of calcium sulfate crystallize. Figure 3 (3) shows the approximate parameters. Note that when acid concentrations (sum of P2O5 and H2SO4) and temperatures plot above the boundary line, hemihydrate forms; and when they plot below the boundary, gypsum precipitates. Of course, the exact location of this dividing line will be modified by a number of factors, such as the presence of impurities originating with the rock.

The driving forces behind the development of Third Generation processes were the reduction of P2O5 losses and the production of high strength phosphoric acid from the filters. However it should not be construed that hemihydrate operation is inherently associated with low P2O5 losses. As a matter of fact, hemihydrate processes are subject to the same losses as gypsum processes: -citrate insoluble P2O5 or unattacked rock; citrate soluble P2O5 (lattice losses); and water soluble losses at the filter. The citrate soluble loss is a function of the P2O5 and sulfuric acid concentrations and the relationship is as follows:

$$\%\ P_2O_5 \text{ in hemihydrate} = K\,\frac{(\%\ P_2O_5 \text{in Acid})}{(\%\ SO4 = \text{in Acid})}\ (\%\ SO_4\ =\ \text{in hemihydrate})$$

Incidentally this same relationship holds for lattice P2O5 losses in gypsum except for a modified constant and the obvious changes in the formula.

In both cases crystal lattice losses are related to the level of supersaturation during crystallization. Low degrees of supersaturation and reduced rates of precipitation promote low P2O5 deposition in the crystals. The new processes achieve their high yields by optimizing the conditions for rock attack and careful control of crystallization techniques.

While hemihydrate operation is not inherently associated with low P2O5 losses, it is closely allied with high acid strengths; and we believe that it is significant that many of the high yield or third generation processes produce phosphoric acid with P2O5 concentrations considerably in excess of 32%. Included in this group are the following processes: - Fisons, Dorr-Oliver HYS, Al-Batros, Singmaster and Breyer, Nippon Kokan (double filtration), and Prayon-Central Glass.

PROCESSES WITH ONE STAGE OF FILTRATION AND ACID PRODUCTION AT 30% P2O5

On the other hand the commercialization of the third generation processes with acid production at 30% P2O5 has been far more extensive. In these processes ground phosphate rock is reacted with dilute sulfuric acid at high temperature to produce hemihydrate. The slurry is then cooled ahead of filtration to convert the hemihydrate to gypsum. P2O5 recoveries are of the order of 97.% to 98.5%.

Perhaps the best known in this classification is the Nissan process which was developed about 1954 in Japan by Nissan Chemical Industries, Ltd. This company has designed about fourteen plants: -four in Western Europe; two in East Pakistan; five in Japan; and three in Australia. Their overseas licensing agents are International Ore and Fertilizer.

Other prominent designers with similar processes are Mitsubishi with five plants in Japan; and Nippon Kokan with eight plants in Japan and one in Taiwan.

In Japan these high yield plants have gained wide acceptance practically to the exclusion of the conventional dihydrate. There have been two reasons for this development. Japan imports all of its phosphate rock and therefore the high yield obtained is important. Also, Japan has no natural gypsum and gypsum commands a high price (about $10 per ton) for making plaster, wallboard, and as a setting retarder in cement.

We will now take a closer look at the Nissan (4) process. Figure 4 shows it diagramtically. The phosphate rock is ground to 90% minus 100 mesh, 70% minus 200; and sulfuric acid is diluted to about 74%. The digestion and precipitation of the hemihydrate is achieved in one premix tank and one or two reactors in series at around 95 degrees C. Part of the return acid from the filter is introduced here and the remainder into the recrystallization. By controlling the temperature of the diluted sulfuric acid no cooling is required.

The slurry passes to three recrystallization reactors in series where the hemihydrate is converted to gypsum. In this circuit the temperature is reduced in stages to less than 50 degrees C. by air cooling; and the sulfuric acid concentration controlled at 3 to 5% to obtain a minimum lattice loss of P2O5. Slurry is recycled from the last reactor to the first to act as seed.

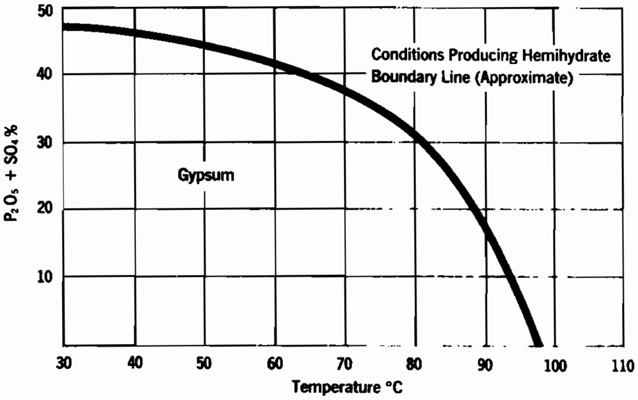

Fig. 3–Conditions Producing Gypsum and Hemihydrate

These conditions promote the formation of an easily washed gypsum which filters at a rate considerably higher than from a conventional dihydrate plant.

The Nippon KoKan (5) process is similar in basic principles to the Nissan. The most significant point of difference is that a separately prepared gypsum seed is added to the recrystallization. Also about 1 to 2% on rock of active silica is added in the form of diatomaceous earth or silica gel. This is said to improve crystal growth and increase the rate of recrystallization by absorbing organic matter and neutralizing free fluorine. Vacuum cooling is used to control the temperature in the conversion section.

The Mitsubishi (6) is similar to the other two Japanese processes. The necessary seed for recrystallization is obtained through the discharge of supersaturation during cooling. Active silica is introduced to the extent of 1.3% to 2.0% on rock.

PROCESSES WITH ONE STAGE OF FILTRATION AND ACID PRODUCTION IN EXCESS OF 30% P2O5

Let us now turn to the processes that produce acid at relatively high strength. In this category there are those with a single reaction stage and those with two stages. As far as we know, the only single stage process that is being promoted is that of Fisons Ltd.(7) For some years Forenade Superfosfat at Landskrona, Sweden operated a single stage hemihydrate process to produce 42% P2O5 acid, but they changed to a gypsum process because the strong acid did not justify their high operating costs.

TVA developed and demonstrated a variation of the hemihydrate process involving a technique of adding the sulfuric acid to a maintained foam blanket to obtain filterable hemihydrate. It has been demonstrated only on a small pilot scale and is not completely developed. Moreover there are some doubts as to the practical extrapolation of the technique to large capacities; and to our knowledge, no organization is proposing to commercialize it.

Fisons developed their process in a laboratory pilot plant at their Levington research center and then, in 1967, demonstrated it at a nominal production rate of 40 LTPD P2O5 in a converted gypsum plant at King's Lynn, England. This plant operated on Morocco rock only and produced acid up to a strength of 50% P2O5.

Eerste Nederlandische Cooperative Kunstmes of Holland decided on the Fisons design for their 200 MTPD P2O5 plant which was scheduled for completion in the middle of 1970. This plant is to produce 45% to 50% P2O5 acid from Togo or Morocco rocks. The hemihydrate is converted to gypsum before disposal.

A simplified flowsheet of the Fisons process is shown in Figure 5. Relatively coarse phosphate rock is reacted with 93% or higher sulfuric acid to produce 40 to 54% P2O5 acid. The rock is approximately 50% minus 60 mesh Tyler and 10% minus 100 mesh. Only material that is coarser than 1/16 inches is subjected to grinding.

In the two tank reaction system, rock is added to the first vessel, sulfuric acid to the second, and slurry is recycled from the second to the first. The temperature of reaction is controlled in the range of 85 degrees C. to 110 degrees C. by air impingement. This system is designed to produce a high sulfate swing in order to produce agglomerated hemihydrate that is suitable for filtering and washing. By controlled recirculation the concentration of sulfate in the liquid phase is low in the initial reactor and high in the second. The second reactor tank overflows to a filter feed tank from where it is pumped to a tilting pan filter. The cake is washed three or four times, depending on the required strength of the product acid.

The following recoveries - based on total P2O5 losses in the discharged hemihydrate are claimed by Fisons:

Product Acid - % P2O5	Recovery Based On Total Losses in Discharged Hemihydrate
40	97.0
45	96.4
50	94.0
54	88.6

PROCESSES WITH TWO STAGES OF FILTRATION AND ACID PRODUCTION IN EXCESS OF 30% P2O5

Our attention now will be directed toward two step processes (i.e. two reaction stages and two separations of calcium sulfate) that produce relatively strong acids. Included in this group are the following: Dorr-Oliver HYS, Albatros, Singmaster and Breyer, Nippon Kokan (double filtration), and Prayon-Central Glass. With the exception of Prayon-Central Glass all of the above operate with hemihydrate in the first stage and

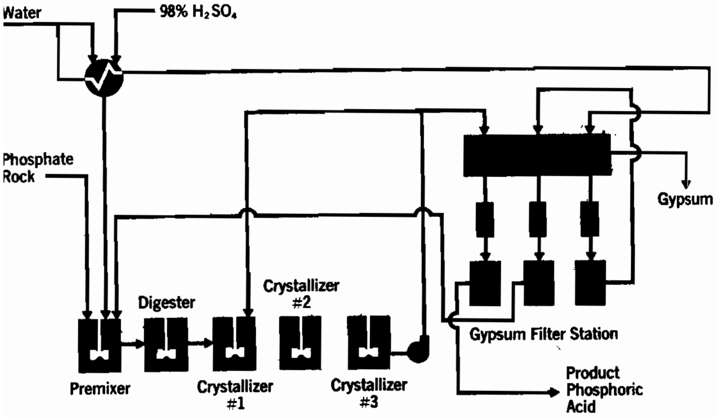

Fig. 4-Simplified Flowsheet of the Nissan Phosphoric Acid Process

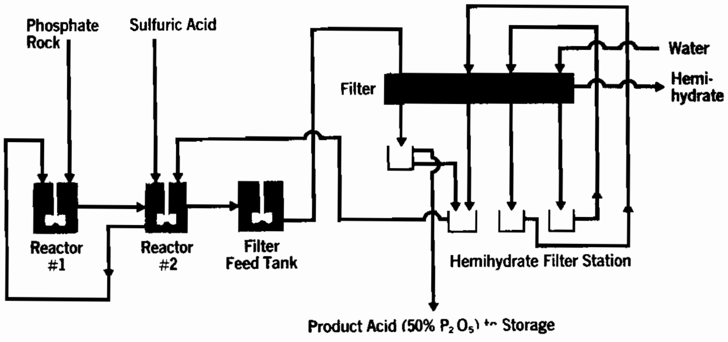

Fig. 5-Simplified Flowsheet of the Fisons Phosphoric Acid Process

gypsum in the second. The Prayon-Central Glass reverses the pattern, i.e. gypsum is the first stage product and hemihydrate the second.

Two step processes are more complex than others we have considered, but their advantage is that when producing relatively strong acid they provide two opportunities to extract the P2O5 and two chances to remove dissolved P2O5. Any P2O5 remaining in the calcium sulfate from the first reaction stage due to incomplete attack or as coprecipitated P2O5 in the crystal lattice is released when the calcium sulfate goes into solution in the second stage and is reprecipitated. This statement is true, provided, of course, that sufficient sulfuric acid is present to effect the dissolution and to provide the high SO4 environment that depresses the tendency to coprecipitation.

Dorr-Oliver's HYS (8) process was developed from laboratory piloting and data that were obtained in the initial operation of the Trail, B. C. plant of Consolidated Mining and Smelting Co. The first commercial installation was designed for Rikkihappo Oy at Siilinjarvi, Finland; and it was commissioned in the summer of 1969. This plant uses Kola apatite and has a designed capacity of 242 MTPD of P2O5 as 43% P2O5 acid.

A diagrammatic flowsheet of the HYS process is illustrated in Figure 6. The temperature in the hemihydrate circuit is between 80 degrees C. and 85 degrees C.; and in the gypsum circuit between 60 degrees C. and 65 degrees C. where the phosphoric acid concentration lies in the range of 8% to 12% P2O5.

One of the features of the process is the shared time tipping pan filter. It has two cake dumping points and goes through two complete and separate filter cycles per revolution. Hemihydrate is filtered in one of the cycles and gypsum in the other. Thus, any individual pan is first used to filter hemihydrate and wash it with weak acid. At the first dump point hemihydrate is discharged and thoroughly removed from the filter cloth with a spray of weak acid. The pan is then used to filter gypsum, the cake being washed with water. At the end of the gypsum cycle, essentially all the P2O5 has been washed from the cake, pans, and filter cloth. After the filter cake has been dumped, the empty pan is thoroughly washed with high pressure water to clean the cloth and remove any scale. The filter medium is thus thoroughly cleaned once per revolution.

The provision of a desulfation reactor makes it possible to produce a high strength acid with a minimum of excess sulfuric acid. This step represents a savings in sulfuric acid consumption and makes possible the production of higher analyses fertilizer products. Phosphate rock is added to the No. 1 filtrate at 43% P2O5 -- 45% P2O5; and after reaction the slurry is settled to give a clarified product acid. The sludge from the clarification is returned to the first stage of the hemihydrate reaction system where any excess rock is dissolved. The coprecipitated P2O5 is recovered in the recrystallization.

Based on the results of pilot plant tests, P2O5 recovery for Florida and Morocco rocks should be above 98% P2O5 when producing 45% P2O5 acid. The amount of insoluble P2O5 which remains in the recrystallized gypsum on a dry basis is about 0.18 to 0.22% for both rock sources. With Kola rock, the strength of the product acid is also 45% P2O5, but recoveries are somewhat lower because the hemihydrate tends to recrystallize slowly or incompletely. Plant scale operation and laboratory testing give results that are in close agreement. Slow recrystallization or incomplete recrystallization is attributed to inhibiting impurities in the Kola rock.

The Albatros process (9) is a product of VKF Mekog - Albatros N. V. of the Netherlands. It has been investigated over a number of years in several different sizes of pilot plants. Claims are made for a phosphoric acid of up to 52% P2O5 with 1-2% free sulfuric acid. Test runs in a two-ton-per-hour pilot plant indicated a P2O5 content in recrystallized gypsum of less than 0.1% and P2O5 recovery in excess of 99.5%.

Figure 7 represents a simplified flowsheet. In the first of the two reactors of the hemihydrate circuit, phosphate rock is dissolved in a recycled slurry of phosphoric acid and hemihydrate. Overflow from the reactor contains a dissolved CaO of almost 4% in excess of the corresponding SO4 content and gravitates to the hemihydrate crystallizer where the remaining calcium sulfate is precipitated. The crystallizer is called a Rotating Disc Reactor and is designed to permit the introduction of sulfuric acid over several injection points and to promote gentle but thorough agitation. Temperature in this circuit is held above 100 degrees C.

In the recrystallization section, the acid is controlled at 10% P2O5 and 15% SO4, with temperature maintained around 65 degrees C.

Two filters are used in this scheme: one for handling the hemihydrate and one for the gypsum. Provisions are made for washing the gypsum with

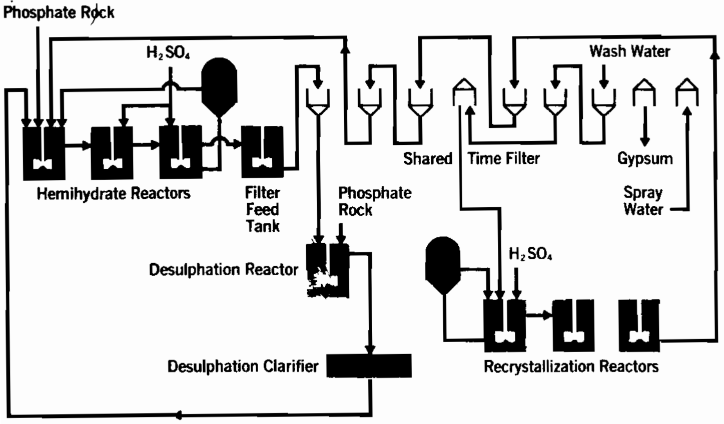

Fig. 6–Simplified Flowsheet of The Dorr-Oliver HYS Process

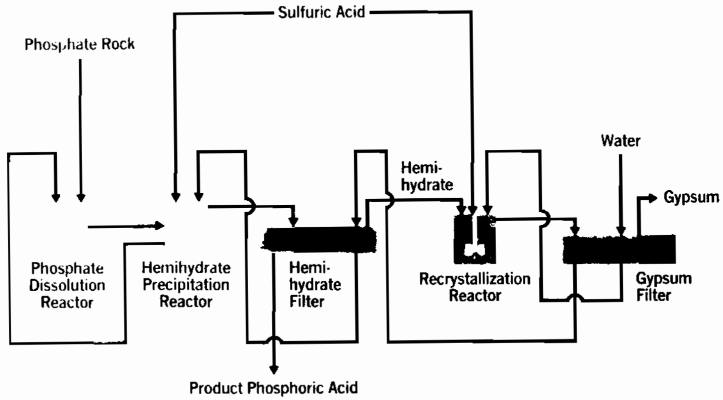

Fig. 7–Simplified Flowsheet of the Albatros Phosphoric Acid Process

water and for washing the hemihydrate with the 10% P2O5 acid from the gypsum section. Tests have demonstrated that the hemihydrate - gypsum combination has a much higher filtration rate than gypsum produced in a conventional dihydrate process.

The Singmaster Breyer process is based on principles similar to the two stage schemes already discussed. A presentation was given by Chelminski and Somerville in the May, 1966 edition of Chemical Engineering Progress (Vol. 62, No. 5).

Nippon Kokan, whom we mentioned earlier as a designer of 30% P2O5 plants with 98% recovery, is currently working on a two stage filtration process for high strength acid. We have no information on the status of their work.

The Prayon-Central Glass process, as we stated earlier, is a reverse crystallization process whereby gypsum from the first stage is converted to hemihydrate in the second stage. The process was independently developed and patented by Prayon of Belgium and Central Glass of Japan, whom we believe have made a cross licensing arrangement. Prayon (10) (11) began the development of their scheme about 1963 and have been operating it on a small industrial scale in a converted dihydrate plant for more than two years. Central Glass may also be operating the process on a small scale.

For a product acid of 35 to 38% P2O5 and an SO3 content of 2.0 to 2.5% of the P2O5, Prayon claims a P2O5 recovery in excess of 99%.

It has been reported that Prayon has sold at least one commercial plant.

Figure 8 represents a simplified flowsheet of the Prayon process. Gypsum is produced in a conventional dihydrate reaction system using vacuum cooling. The gypsum slurry, or part of it, then passes to a centrifuge for removal of the production acid; and the sludge plus any uncentrifuged slurry goes to the hemihydrate reaction system. The centrifuge effluent carrying several percent suspended solids is clarified by sedimentation, the underflow being returned to the gypsum reaction.

A significant part of the sulfuric acid requirement is added to the hemihydrate reaction. The acid, along with steam, provide the necessary conditions to convert the gypsum to hemihydrate: temperature, about 80 degrees C.; and acid concentration, 20% to 30% P2O5 and 10% to 20% H2SO4 (11).

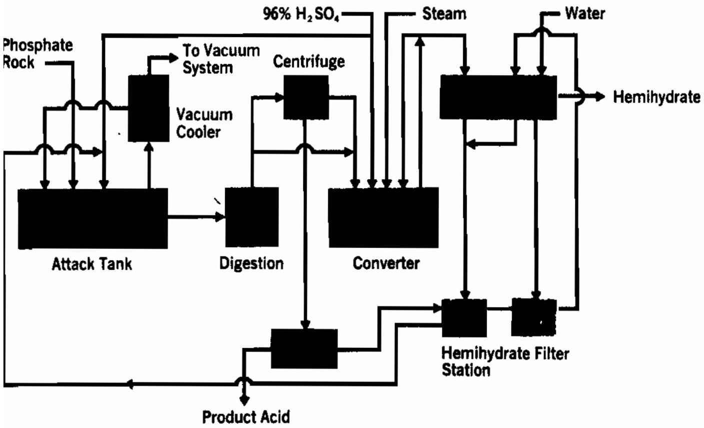

Fig. 8-Simplified Flowsheet of Prayon Process

The hemihydrate slurry is filtered on a Prayon filter and given two washes before being discharged as a cake with 20% total water or about 15% free moisture. Filtration capacities are reportedly higher than with conventional dihydrate.

Claims are made that the hemihydrate is not only low in P2O5 and moisture but also in fluorine. With Kola rock, the fluorine is said to be 0.07%. The purity of the calcium sulfate makes it suitable for by-product use.

We have tried to cover our subject broadly and objectively. We recognize that we may be guilty of one or several important omissions. If so, we apologize to those concerned and assure them that we did not do so intentionally.

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PANEL LEADER WEBER: A very important subject to all fertilizer men is granulation techniques. Our next paper concerns this area of fertilizer production, and will be presented by W. A. Lutz.

Bill Lutz has been with Dorr - Oliver for twenty two years. During this period, I have worked very closely with him. More recently, however, during the last six years, Bill has been on his own as a consultant, operating as "Weston Process Design." He specializes in fertilizers of all kinds, phosphates and phosphoric acid in particular.

Developments in Granulation Techniques

W. A. Lutz
WESTON PROCESS DESIGN
WESTON, CONN.

Today, most fertilizers are being utilized in granular form. While particle sizes of the products are reasonably consistent, the composition of the materials varies widely. Granular fertilizers include such materials as ammonium nitrate, urea, ammonium phosphates, potassium chloride and superphosphates, as well as a broad range of combinations utilizing these materials. Both the materials used, and their products, differ widely in their physical and chemical characteristics.

It is not surprising that a variety of methods of granulation exist, since no single process can operate efficiently and economically over the wide range of materials and conditions encountered in the various plants. Some plants are essentially one product plants, producing such fertilizers as granular triple superphosphate, diammonium phosphate, ammonium nitrate or urea. Other plants may be called upon to manufacture as many as twenty grades or compounds, and special considerations are involved in the design and operation of such a plant.

Granulation processes have been broadly classified (1) into the following categories:

(1) Granulation, followed by water removal. Granulators are drum, pugmill or pan granulators.
(2) Water removal during granulation. The spray drum has been commonly used and there has been some limited use of double drums or fluid bed machines.
(3) Water removal ahead of granulation. A prill tower is the most familiar means of granulation, but spray drums, pugmills, pan granulators and flakers may also be utilized.

GRANULATION FOLLOWED BY WATER REMOVAL

These plants are the familiar types which produce the bulk of today's granular fertilizers. There are a considerable number of propriety processes available, many of which are basically similar with respect to process considerations, but differing primarily in the equipment supplied and the arrangement employed. Drum granulators and pugmills are used somewhat interchangeably, although there is a general tendency to use drums when the percentage of solids in the feeds is high, or when substantial quantities of reactants are to be added during granulation. Ammoniation is now being carried out successfully in pug mills. Selection of the granulator is in part a matter of preference of the owners or contractors. Pan granulators have not yet gained wide acceptance.

Single train plants can now produce as much as 75 tons per hour when granulating ROP triple, and in excess of 50 tons per hour of diammonium phosphate.

Plant costs will, of course, be somewhat a function of local circumstances and products to be made. Published figures (2) would indicate the investment of a 1000 tons per day diammonium phosphate plant to be about $4.50 per yearly ton of capacity for the battery limits production unit. Operating costs are reported to be $2.40 per ton, excluding raw materials costs. This, of course, does not include auxiliary facilities such as storage and bagging. However, the cost of production of the granular fertilizer in this case represents only about three percent of the selling price. It is difficult to see how improvements in the granulation operation could have a major effect on the ultimate cost of fertilizer delivered to the farmers.

One relatively new development which may allow some capital and operating cost reduction, is the pressure ammoniation system (3) for ammonium phosphate production which can replace the familiar preneutralizer.

Pressure ammoniation permits the production of mono-ammonium phosphate as a powder containing 6-10% moisture. This solid material can be fed either directly or transported to a remote granulator, ammoniated to DAP and granulated by substantially conventional means, either alone or mixed with other ingredients. The reduction in water content of the feed permits substantial increases in plant capacity by reducing circulating load and dryer loading.

A number of plants are now producing granular ammonium nitrate in substantially conventional systems, using 95 - 97% solutions as a plant feed. Some safety precautions are required, such as indirect fired air heaters, and conditioned air is sometimes desirable for cooling the ammonium nitrate below its transition point of approximately 90 degrees F. The granules are of excellent quality and can be produced in a somewhat larger particle size range than is commonly done in prill towers. Production costs, particularly for large plants, appear to be somewhat higher than for conventional prilling operations, but the arrangement does permit a variety of products including ammonium nitrate, calcium ammonium nitrate and N-P-K grades to be made in the same plant.

Urea - ammonium phosphate fertilizers having analyses as high as 28-28-0 are being made in plants of this type.

WATER REMOVAL DURING GRANULATION

This system has been carried out largely by the spraying of a solution or slurry directly into a specially designed drying drum. The Spheroidizer (4) which utilizes this system, has been installed in 22 plants throughout the world. The same type of system has also been used for the granulation of anhydrous melts.

Recent improvements have made it possible to produce granular ammonium nitrate, urea, and NP or NPK compounds in the same plant. The plant and operating costs appear to be competitive with other systems, although detailed cost analyses with reference to the specific circumstances involved are necessary to firmly establish relative costs.

Plants of this type are best suited to materials which can be produced in the form of high concentration solutions or slurries or melts ahead of the granulation step. They do not appear to be broadly competitive for the granulation of fertilizers containing high percentages of superphosphates, or where substantial chemical reactions are to be carried out as a part of the granulation step.

Some development has been done on simultaneous granulation and drying in fluid bed units. Machines of this type have not yet gained wide commercial acceptance in the fertilizer industry.

WATER REMOVAL AHEAD OF GRANULATION OR MELT GRANULATION

This procedure includes the familiar prill towers that have been widely used for the production of ammonium nitrate and urea. In recent years prilling has been extended into the production of NP and NPK compounds and one plant is understood to be prilling potassium nitrate. Melt granulation can also be done in other equipment arrangements such as flakers, drum and pugmill granulators, spray drums and pans. While these latter methods are being used commercially only to a limited extent, their use may be expected to increase as further research and development work is done.

Prilling is considerably less flexible (5) than conventional granulation systems in regards to the range of compounds that can be produced. The melt must be low enough in viscosity to flow through the prilling head or bucket. This places limitations on the percentage of materials such as calcium phosphates and potassium chloride that can be included in a formulation. Impurities present in phosphoric acid can also affect melt viscosities. Additionally, the melt must be stable at melt temperatures, and the compounds must have characteristics which permit freezing during their fall through a prill tower.

Generally, prilled fertilizers have excellent physical characteristics and appearance, (6) but are frequently smaller in particle size than conventionally granulated materials, since large prills may not freeze during their fall. Oil prilling may help in this respect, but oil prilling cannot be safely applied to ammonium nitrate grades.

Prilling appears to be most effective with compounds containing in excess of perhaps 30% ammonium nitrate or urea, and becomes increasingly easy as the percentage of ammonium nitrate is increased.

Costs of granulation in prill plants, including evaporation, appear to be competitive with other means of granulation, particularly in the larger plants having capacities of the order of 1000 tons per day. However, in any case, a study reflecting individual circumstances would be required.

OTHER MEANS

Compression rolls have been used for granulation of KCl. They have not been extensively used in other applications.

There have been a limited number of commercial fluid bed granulation units installed in the United States and abroad. These units are not yet developed to the point where they have wide commercial acceptance.

SUMMARY

It would appear, at present, that the majority of future granulation plants will be similar to existing units, with a granulator followed by a dryer. Developments in this type of process may involve further reductions in the water content of the granulator feed, so as to optimize capacity of these systems. The primary advantages of plants of this type are their extreme versatility and reasonable cost.

In future plants, where the compositions of the compounds permit, melt granulation procedures warrant serious consideration. These processes are still in the relatively early stages of development, and future improvements may be expected. The application of melt process will probably be in the grades containing ammonium phosphates, plus ammonium nitrate or urea.

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MR. WEBER: We have heard what developments there are going to be and the sources of phosphates in the production of mixed compound granulated fertilizers. Our next speaker will take a look at what is going on in the nitrogen sphere and the new processes there. Our speaker is Russell James. Mr. James has had very extensive experience with ammonia and nitrogen, generally. He was associated with the Chemical Construction Company for fourteen years and is now a consultant operating under the name of James Chemical Engineering Company.

New Developments in Nitrogen Technology

Russell James

JAMES CHEMICAL ENGINEERING
ARMONK, NEW YORK

The area of nitrogen technology is so broad and contains so many disciplines that it is necessary for this paper to restrict itself to some of the areas of basic nitrogen chemical manufacture.

Briefly then I will discuss present developments and future possibilities in the areas of ammonia (the basis of nitrogen products), nitric acid, ammonium nitrate and urea. Construction of new facilities in all these areas is depressed because of the high rate of construction in the mid sixties. Thus there is quite a bit of engineering talent that can be devoted to developments for the '70s.

AMMONIA

Ammonia manufacturing is considered by many to be pretty "old hat." Perhaps few are devoting much time to development. However, it was considered "old hat" forty years ago, yet just in the past ten years manufacturing process costs have dropped from approximately forty dollars per ton to perhaps twenty dollars per ton. Roughly half of the cost reduction is due to increased plant size, the balance attributable to technological improvements in reform pressure, heat recovery and CO2 removal efficiency.

What is happening today in ammonia and may happen in the future will probably not have as much to do with size as with added technical development in process and equipment.

Breaking an ammonia plant into four sections plus storage and shipping provides a convenient basis from which to discuss technical development which is bound to come as more plants are built.

GAS PREPARATION is the first section in the normal ammonia process (see Fig. 1). Reforming accounts for the major tonnage, with partial oxidation next in line.

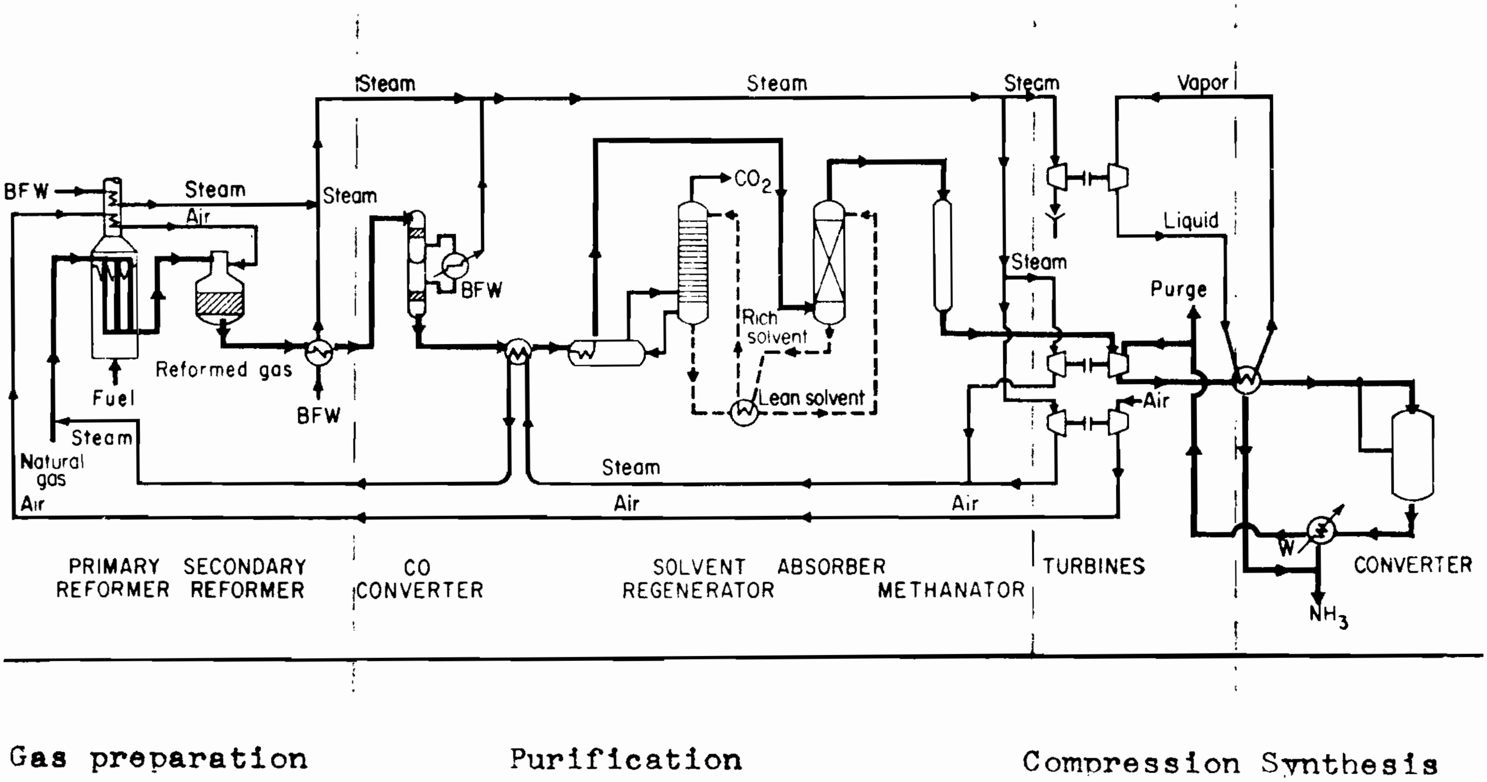
REFORMING of hydrocarbons with steam has been accomplished at higher and higher pressures. Pressure has now leveled out at 450 to 550 psig, balancing equipment costs and operating costs although some saving can still be realized by going higher.

There are several problems in the present systems which will lead to further development:

1) Reformer catalyst life in gas reforming is not what it might be. "Hot bands" or areas in which carbon has deposited have mystified designers, although there is some feeling that the bands are due to carbon formed from higher hydrocarbons in the feed.

In any event, development of newer or "different" catalysts may be expected to offset the problem, or it may be necessary to remove sulfur and higher hydrocarbons to lower levels.

FIGURE 1. Typical Ammonia Process Flow Sheet for a Gas Reforming Unit



2) Piping in the convection section, in the reformer itself, and to and from the secondary reformer is a major contributor to down time. It is to be expected that designers will come up with systems which integrate primary and secondary reformers to decrease the amount of high temperature, high pressure piping.

   The main reason for the difficulty is that the increase in pressure required for saving compression has resulted in higher process temperature requirements. Temperatures are now as high as 1800 degrees F. at 500 psig.

3) A recent attempt to alleviate this problem is the so-called "Purifier Process" by C. F. Braun, a system which assists in reducing reformer temperature by introducing more than the required amount of air into the secondary, thus allowing reactions to take place inside a brick lined vessel which otherwise would require heat input through a high pressure, high temperature furnace tube.

   While the process has its advantages, it does have the disadvantage of requiring a low temperature system to remove excess nitrogen later in the process.

PARTIAL OXIDATION was a coming process for ammonia syngas preparation in the fifties. Relatively few partial oxidation plants have been built in the 1960s because of the advent of high pressure reforming and naphtha reforming. There are now, however, plants producing synthesis gas via partial oxidation which operate in the range of 1200 psig vs. the previous operating pressure of approximately 500 psig.

Savings at 1200 psig in heat and compression energy are considerable. At 2500 psig, analysis indicates that partial oxidation is quite competitive with reforming. A 2500 psig pilot plant and associated purification equipment has been operated successfully for some time by Texaco Development Corporation in Montabello, California.

Depending on the relative cost of feed stocks or the desirability of being able to use both gas or heavy oil as feed, it may be expected that partial oxidation will make a comeback in the next ten years.

ELECTROLYSIS as a means of supplying raw hydrogen is relatively dormant. There are no new plants which depend on electrolysis as a source of hydrogen for ammonia fixation. A small possibility exists that large nuclear power stations might furnish power to a large ammonia plant at 1-2 mills in the future. If that were the case then ammonia might be made from electrolysis and compete with a large gas-based plant operating on moderate priced gas.

PURIFICATION is the second section of the ammonia plant. As in the flowsheet in fig. 1 the first step is CO Conversion. This process step has been improved and simplified in the past six years with the use of low temperature catalyst, however, many plants are now plagued with difficulty due to rapid catalyst poisoning from what has been attributed to sulfur or to chlorine in minute amounts.

New and better low temperature catalysts will be available in the future, and also improved methods for limiting the amounts of sulfur and chlorine which might reach the catalyst.

A development of several years ago which seemed to offer promise of success was that of low temperature selective oxidation of CO. In this process a small amount of air is introduced after initial CO conversion, the balance of CO was then selectively oxidized over a catalyst to additional CO2 which was removed in the normal CO2 removal step. Although this method did result in loss of hydrogen potential, and an added step for oxygen removal, it resulted in a purer gas to snythesis because the methanation step was omitted. Further development of this process step may be expected.

CO2 removal is the next step in syngas purification. The type and efficiency of CO2 removal processes have been an area of major advance in the last ten years. Further advances may be expected soon since this process is still a major heat consumer in the ammonia process.

There are now at least fifteen different processes available to ammonia plant designers. Only those which use a "physical" absorbing medium, such as water or methanol are low in heat requirements. Heat at even the low level used in a CO2 removal plant can be used for power. Designers therefore may be expected to find ways to recover this heat, which amounts to perhaps 4,000,000 BTU/ton of ammonia.

Evaluation of a particular physical solvent, methanol absorbtion, for both gas reform at 400 psig and partial oxidation at 500 psig indicates a substantial saving through use of this absorbent. There are other physical absorbents which give a similar result.

The process using methanol is known as Rectisol (available under license from Linde). Others are Purisol (available under license from LURGI) and the Fluor solvent process.

In some cases it is economical to compress before CO2 removal via physical solvent. In any event, with the current trend to high pressure synthesis gas production physical solvents will become more and more attractive.

Compression of the purified gas used to be done by lumbering reciprocating compressors. As plant size increased centrifugal machines, because of their low unit costs, and their adaptability to turbine drive have become standard. Low capital cost and turbine drive with process steam have reduced costs of ammonia in present large size plants.

Smaller, higher speed machines may be expected in order to accommodate higher pressure processes or smaller capacity plants.

Synthesis is the area in which designers have dreamed of a "low pressure" process.

Although several pressure levels of synthesis are available, they have never really become lower than approximately 1800 psig. There is little reason to prefer one over another except for the experience that a particular designer may be able to muster for his own selection. It may be said that lower pressure synthesis designs should give somewhat lower overall power consumption. Equipment, however, gets larger, and refrigeration levels lower. Initial large plant designs using centrifugals were for relatively low pressures. As size and experience have increased, pressure level in synthesis has also increased.

Still, for many years there has been an attempt to develop a "low pressure" ammonia catalyst. What is really meant by this is a "low temperature" catalyst, since for a catalyst to produce ammonia satisfactorily at low pressure it must operate at low temperature.

This type of development will probably continue, although there is not much chance of success based on past performance.

Shipping and Storage of NH_3 has recently changed considerably. Perhaps the most interesting development in recent years is that of direct pipeline transfer of ammonia. One complex of pipeline and storage system, installed for ammonia transfer, ties the Gulf Coast producers direct to the "corn belt." Another goes from the Texas panhandle to roughly the same destination, covering different territory en route. Feeding ammonia in at one point and out at another, participants are able to increase their flexibility considerably and to extend the area to which they can ship cheaply now only by barge.

UREA

Urea has developed rapidly over the past 20 years from an insignificant member of the fertilizer family to a major part of production. Processes have changed from the early, once-through systems to sophisticated operations which recover each BTU that can be found.

The most recent occurrence is the advent of the "stripping" process whereby either ammonia feed or CO_2 feed is used to strip the reactor products, thereby reducing the recycle to the reactor and eliminating much of the pumping problem present with older systems which require a high pressure "carbamate" pump.

This type process has also the advantage of lower utility consumption overall since it does not require as much steam as do the "conventional" or non-stripping processes.

Comparing the two processes:

	Units per Short Ton	
	Conventional	CO_2 Stripping
NH_3, tons	.58	.58
CO_2, tons	.77	.77
KWh	140	114
C.W.-Gals.	24000	14000
Steam - lbs.	3200	1200
150 psig —	--	1400
150 psig	3200	600
50 psig (credit)	--	800

As can be seen, there is an appreciable difference in steam consumption. This can be an important economic factor if the export 50 psig steam can be used when a stripping process is integrated into the complex.

Other areas of development in urea relate to lowering of biuret in solid product and improving the operation of prilling systems.

Biuret, a degradation product of urea, which has caused much consternation can be reduced in prilled product by decreasing the time at which the melt is held at high temperature. The current method is to concentrate via crystallization rather than evaporation.

"Crystallization" prilling is considerably more expensive than evaporative prilling and, additionally, more difficult to operate. Therefore, unless there is a strong case for a low biuret product, it makes sense to stick with the normal product of approximately 1% biuret.

Biuret developed into somewhat of a bogeyman in the early days of urea manufacture and many plants were built or "sold" on the basis of low biuret product although they (or their clients) did not really need such low biuret.

It is true that citrus crops may be damaged by biuret contents above 0.3% but 1% maximum will not hurt the majority of other crops, and contents as high as 10% have been used on corn, cotton, tomatoes and oats with no significant effect.

Ammonia & Urea Plants are closely related. Consideration may be given to mechanical integration of the two:

Refrigeration in urea plant and ammonia plant may have a common temperature level. Refrigeration thus may be furnished by the ammonia plant refrigeration compressor for the urea plant ammonia storage tank vent condenser, to minimize loss of NH_3 on purging insert gases.

Engineering companies have been looking for years at the possibility of feeding NH_3 liquid from the NH_3 plant at synthesis pressure, thus avoiding use of a liquid ammonia pump in the urea plant. It has been generally concluded that the increased $H_2 + N_2$ inerts that would be introduced into the urea plant along with the NH_3 would result in 1) increased NH_3 losses, 2) reduced conversion of urea and 3) cause possible metallurgy problems in the urea reactor. As a result this idea as far as is known has never been used.

The CO_2 booster compressor may be steam-turbine driven and thus be integrated into steam balance of overall plant. Usually let-down steam at 50 - 150 psig can be used for the MEA or CO_2 removal reboiler or purifier in the ammonia plant. Power requirement for the CO_2 booster in a 1200 T/D urea plant might typically be 3500 HP using 90,000 pounds of 600 psig steam at 750 degrees F. and throttling to 160 psig at discharge of the turbine.

Centrifugal Compressors in Urea Plants would be used for this duty. Centrifugal compression in urea plants, however, is limited to CO_2 service and in larger plants of say 1200 T/D is limited to a range of 225-250 psig. At higher pressures the necessary flow of gas to meet requirements of centrifugal compressor head-capacity curves is not available. The savings in replacing two stages of reciprocating compressor by using the centrifugal machines is significant. Usually a single centrifugal machine is followed by two recipricators of 55-60 per cent of capacity.

Ammonia & Urea Plants may be integrated process-wise too. A step in ammonia manufacture discussed above is the removal of CO_2 from the gas stream on the way to the synthesis step. Since ammonia is re-combined with CO_2 in urea plants in any event, it makes considerable sense to combine the two.

		Separate Units			Combined Units			Saving
	Item	NH3	Urea	Total	NH3	Urea	Total	Ton Urea
10^6 Kcal	Natural gas	5.53	.69	6.22	5.80	-	5.80	.420,000 Kca
kwh	Electricity	5.0	160	165	5.0	60	65	100 KWH
Tons	Cooling water	116	110	226	67	120	187	39 Tons of

One manufacturer and plant designer has done just that by scrubbing CO2 from synthesis gas with carbamate solution and ammonia. The result is an overall saving in the cost of manufacture both from equipment and from operating standpoints. (see figure 2).

Mitsui Teatsu, the integrated process supplier, summarizes utility requirements for combined vs. separate units in the accompanying table.

In addition approximately a 7 per cent capital investment saving is expected. Although to date no plant of this integrated type has been erected, it is expected that as fertilizer markets improve such an installation will be built.

There are of course disadvantages to the system. Unless a CO2 removal system is installed, for example, the urea plant must be operated at least at 50% rate in order to make ammonia at full rate.

NITRIC ACID

Manufacturers of nitric acid have two particular problems which have recently been attacked by industry designers and manufacturers. The problems are high catalyst cost and pollution from nitrogen oxides in absorber tail gases.

Catalyst, normally platinum, is an expensive part of nitric acid cost. C & I Girdler announced about a year ago a new catalyst which is not of the conventional platinum-rhodium type.

Others had used such catalysts years ago, notably cobalt by Allied before 1920. It is claimed, that with the C & I catalyst, however, results are obtained similar to the overall performance of pt-Rh. In fact, because of longer periods on stream and elimination of the catalyst recovery system, the new catalyst is said to reduce acid cost considerably.

The new process has considerable experience in revamped and new plants.

Not to be outdone by the non-noble metal process of C & I Girdler, Englehard Industries has recently come up with a new platinum system which can be installed in present plants. The new system includes its own pd - Au "getter" which captures volatized platinum directly after the new platinum installation called "Random Pack." The new system uses some 60% less platinum than current installation.

Both of these developments can be important to nitric acid manufacturing cost, since periodic shutdowns are costly and catalyst cost itself might vary between 75¢ and $2.00 per ton of 100% product.

Tail Gas Clean up is necessary to be a good neighbor. It is becoming less possible to continue putting brown fumes into the air. At conventional absorber pressures tail gases contain nitrogen oxides at concentrations of approximately 3000 ppm. Because of the current pollution control concern there has been an effort over recent years to reduce this level of nitric oxides, at least to reduce the color of the tail gas.

Initial efforts used a catalyst at approximately 900 degrees F. and natural gas which reacted with O2 in the tail gases, at the same time decomposing nitrogen oxides.

As time passes in this process the catalyst becomes deactivated and will not perform with natural gas. The next step is propane which acts more readily, and finally, hydrogen, which will react at much lower temperatures.

Three solutions are known to this problem of catalyst deterioration. The first is the recently announced "dual combustor" system announced by Chemico which overcomes the reaction initiation problem by using more than one catalyst bed and controlling inlet temperatures to get complete reaction.

Among others are the patent taken out by Englehard Industries which uses converter heat to reform natural gas, thus providing a hydrogen steam which reacts more easily over the catalyst. A similar system has been developed by our company. This system, instead of using converter heat, uses the heat from gases out of the catalytic oxidizer itself. The result is a simplified plant heat balance and reduction of temperatures before gases leave the equipment.

AMMONIUM NITRATE

There is only one point that will be treated here. That is solidification of nitrate in equipment other than prilling towers.

Where manufacturers are set up to make solutions using nitrate, they may have no provisions for making solid nitrate. When the market conditions are such that nitrate solutions are not selling, a simple method of making solid nitrate might be economical.

Such a method might be the TVA pan granulator. Preliminary discussions with TVA engineers indicate that a simple system might granulate 98% nitrate and provide an acceptable solid product at a minimum cost. Such a system would bear further investigation.

There are many other developments in nitrate manufacture. Additions for improving storage of solid nitrate have been developed by Coastal Chemical Corporation and C & I Girdler which promise savings in clay and decreased caking. These and other developments in nitrate, urea, ammonia and solid mixed fertilizer use of nitrogen are the topic of a great deal of effort, but unfortunately cannot even be mentioned in this brief presentation.

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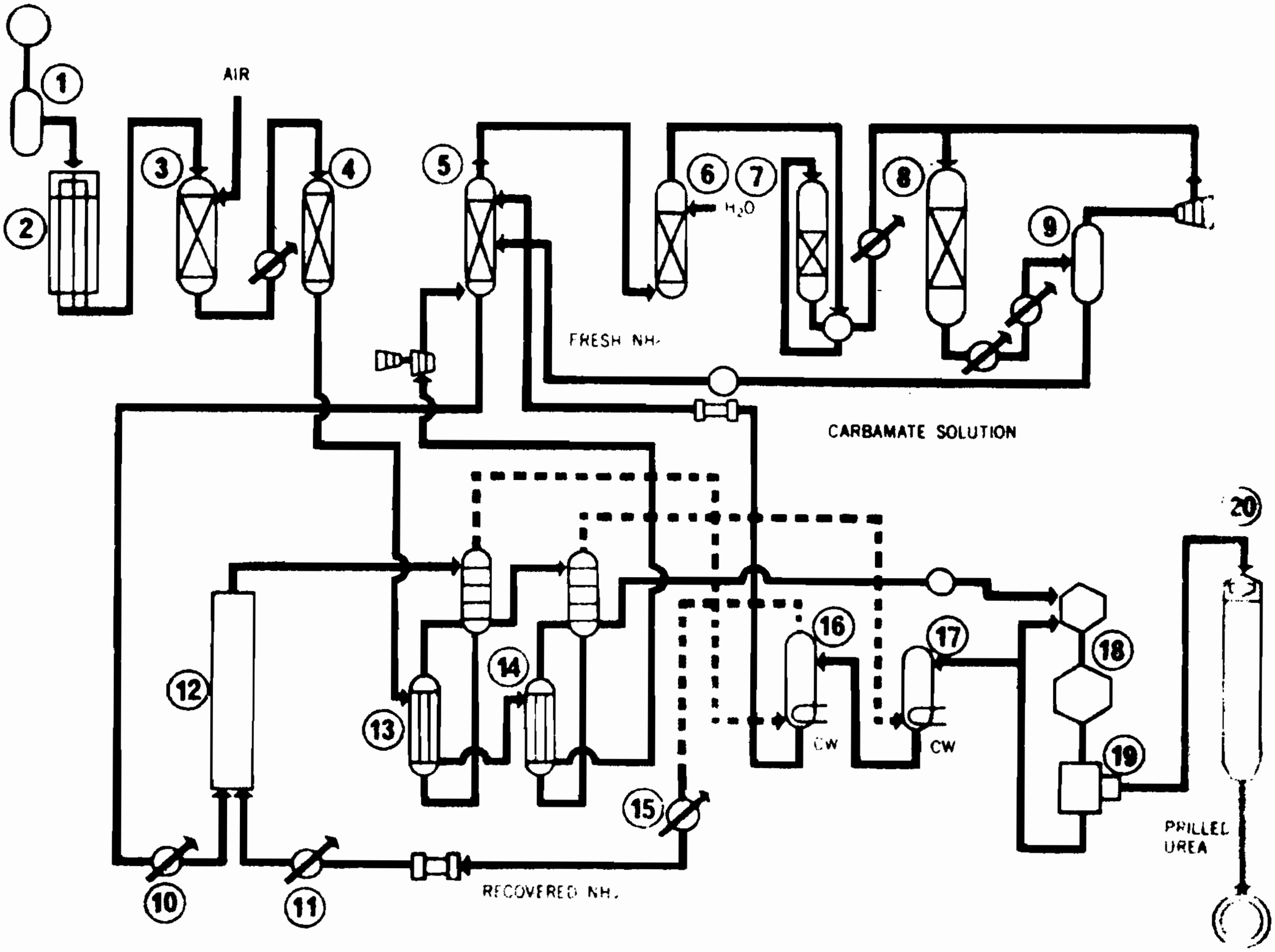
MR. WEBER: The next paper will deal with "Eutrophication and its effect on the Fertilizer Industry." This is something that you are going to hear a lot about in years to come. Eutrophication deals with the pollution of waters, by phosphorus and nitrogen, to the extent that it impedes the growth of algae and aquatic plants, especially in waters such as lakes and reservoirs.

Dr. Raistrick, who will discuss the subject, is with Albright and Wilson in the United Kingdom. He started in the fertilizer industry with Albright and Wilson. From Albright and Wilson he went to the Scottish Agriculture Division of Scotland and then with Associated Chemicals, which was later taken over by Albright and Wilson; so he went back to where he started. Dr. Raistrick is manager of the phosphorus and phosphate facets of Albright and Wilson.



1 Sulphur removal
2 First reformer
3 Second reformer
4 CO Shift converter
5 CO_2absorber
6 NH_3scrubber
7 Methanator
8 NH_3 converter
9 NH_3 separator
10 Solution preheater
11 NH_3 preheater
12 Urea reactor
13 HP decomposer system
14 LP decomposer system
15 NH_3 condenser
16 HP absorber
17 LP absorber
18 Crystallizers
19 Centrifuge
20 Prill tower

Figure 2. Mitsui-Toatsu combined ammonia-urea process

Eutrophication
and its Impact on the Fertilizer Industry

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INTRODUCTION

The enrichment of natural waters by plant nutrients is known as eutrophication, and as a result of it, algae and other aquatic plants grow in exceptional profusion. The phenomenon is at its worst in relatively static waters such as lakes and reservoirs. The aquatic plants sometimes choke waterways and pumping equipment and after they have died back the decaying vegetable matter absorbs oxygen, kills fish and creates other undesirable effects which detract from the value of the lake or other water. In bad cases the water and shore look unsightly and smell, and if the water is to be used for drinking purposes, problems of taste and odor also arise. The main nutrients involved in eutrophication are carbon, nitrogen and phosphorus, although inputs of others such as silicon and iron occasionally cause excessive growth of certain plants.

Since the fertilizer industry is selling phosphorus and nitrogen in enormous quantities annually, it must always be reviewing the possible contribution of its products to contamination of natural waters. In my view, if our products are significant contributors, we are automatically involved in any problems which arise. In addition to eutrophication we must also remember that high levels of nitrate in drinking water can be damaging to the health of babies (methaemoglobinaemia). It is for this reason that the World Health Organization has set a limit for drinking water of 10.2 mg./litre of nitrate-nitrogen, although I believe that a higher maximum, of 22.6 mg./litre, is likely to be recommended in future for countries with temperate climates, because less water is consumed there than in warmer countries.

NITROGEN

There is considerable evidence that plentiful supplies of nitrogen for aquatic plants arise from the constant decomposition of organic matter which is present in soil of all kinds, and this quantity is not very significantly altered when nitrogen fertilizers are used in an efficient way. There have been instances, however, of fertilizer nitrate getting directly into natural waters, when it has been used without commonsense -- for example by application on top of frozen or waterlogged land. In such cases quantities of the nitrogen and other nutrients are carried into lakes and rivers by run-off.

The forms of nitrogen commonly used as chemical fertilizers are urea, anhydrous ammonia, ammonium nitrate and other ammonium salts. Plants absorb nitrogen mainly in the nitrate form and the fertilizers mentioned are quite quickly converted to nitrate by bacterial action. Nitrate is readily leached from soils (especially from sandy ones, which drain the most rapidly) unless quickly used by crops; therefore with present nitrogen forms there will invariably be some loss to natural waters by leaching, which will be largest in wet weather. However, other sources of nitrogen entering natural waters are so large - they include rainfall, sewage, biological fixation of atmospheric nitrogen and especially the nitrate released by the decay of organic matter - that the contribution from properly applied fertilizers is relatively small. Nevertheless, slow-release, less leachable N products will continue to be sought, hopefully to minimize the fertilizer contribution to eutrophication and, more importantly, to maximize the efficiency of nitrogen use and avoid the need for multiple dressings. N.B. The bulk of the 0.1 - 0.3% total N found in agricultural soils is present in organic matter.

There is another aspect of nitrogen in natural waters which could become of far greater importance than eutrophication. Nitrate is easily reduced to nitrite in biological systems and nitrite reacts with amines to form nitrosamines. Most nitrosamines are carcinogenic to animals, and work at very low concentrations. Moreover, nitrites and certain secondary amines have been shown to cause cancer when fed together to rats and there is also evidence of nitrosamine formation. According to one U. S. cancer specialist, nitrates in water may be of greater relevance for nitrosamine formation than nitrates or nitrites in meat, because the availability of the latter may be limited by chemical binding to meat constituents.

Research work on nitrosamine formation and problems of human safety is proceeding quickly, but until it is complete there will be resistance to introducing additional nitrates or amine products into uses which will result in them entering the environment. One of the amine products being considered for widespread sale to the public is SNTA (sodium nitrilotriacetate), paradoxically a possible substitute for phosphate in detergent powders. The relevant department of at least one European Government is seriously concerned about the question of nitrosamine formation in the human stomach from amines and nitrate, and certainly SNTA or any other amine carboxylic acid must be cleared of the possibility of nitrosamine or carcinogen biosynthesis in vivo before it is accepted as a safe material for detergent use, or indeed any other major application which results in its entering natural waters. It is hard to see how the alternative approach to the avoidance of nitrosamines -- i. e., elimination of nitrate from drinking water -- can be achieved and so until the toxicological evidence is available, secondary amines or their precursors should not be introduced gratuitously into the environment.

PHOSPHORUS

In the case of phosphorus, the largest contributions to natural waters are made by untreated or treated sewage which particularly contains phosphate from human wastes and synthetic detergents. The phosphate contribution from fertilizers is normally smaller than from sewage and arises mainly from top run-off of agricultural land. This carries soil particles containing fertilizer phosphate into natural waters.

At the present time, considerable efforts are being made in some countries to reduce substantially the phosphate loading of sewage discharges. The two main tactics are (a) to cut down or eliminate completely the use of phosphates in synthetic detergents, and (b) to remove phosphate at sewage works by precipitation, using lime or aluminum or ferric salts. If this chemical precipitation technique is used, orthophosphate is reduced by more than 90%. Orthophosphates from different sources are indistinguishable, and, when chemical precipitation is used, there is little or nothing to be gained by reducing or removing phosphates from synthetic detergents: if chemical treatment of sewage is not used, there is little or no hope for the improvement of lakes eutrophied by phosphorus. I am convinced that even chemical treatment of sewage for phosphate removal will not of itself lead to a significant improvement in the condition of most affected lakes. To stand a chance of being effective, it must be part of a complete system-design - see later.

It will be realized that the phosphate contribution to natural waters from agriculture is always from diffuse sources, excepting where housed cattle are concerned. On the other hand, the contribution from human wastes and detergent phosphates is largely collected at point sources -- i.e., sewage works -- and therefore can be treated relatively easily. I am sure that in those locations where eutrophication is a serious problem, more and more sewage works will go over to phosphate removal, and as fertilizer manufacturers we must note that in these locations agriculture will be left as the major phosphate contributor. For example, by 1972, Sweden, the country doing most in respect of phosphate removal from sewage, will have 60% of its population connected to phosphate removal plants. There is no possibility of banning phosphate from fertilizers and using a substitute, as in the case of detergents. There is simply no substitute for phosphate in fertilizers, and in my view the best approach will be to ensure that fertilizers are used in a responsible way to avoid loss into natural waters. It should not be difficult to ensure this, because farmers, like everyone else, have a special interest in using the products they pay for in the most efficient manner possible.

Canada has recently adopted legislation which already limits the P2O5 content of laundry detergents to 20% and at least one manufacturer in the United States has now stated his intention of limiting to a content of 20% P2O5, with steps towards further reductions by 1972 and with the aim of complete removal. In Europe, production of low- and zero-phosphate-content detergents has also begun and may be expected to increase, particularly in those countries such as Sweden, where eutrophication is a major problem and public opinion is very strong. Since detergent phosphates in North America are made mainly from elemental phosphorus, it is certain that increasing efforts will be made to sell surplus thermal phosphoric acid into the fertilizer market, because this is the only market large enough to consume the quantities involved. The alternative is to shut down plants producing elemental phosphorus and in the case of older high cost plants this will happen. In those countries which produce their detergent phosphate from wet process phosphoric acid, the same will happen, and it is quite certain that in Europe there will be less need for phosphoric acid plant construction in the next few years than would have been the case if there were to be no likelihood of a reduction in the detergent phosphate usage.

I think it will be worth while to compare the phosphate contribution to natural waters from agriculture with the contributions from other sources, and I will quote some data from my own country. In the United Kingdom the quantity of P2O5 finding its way into sewage works is about 100,000 t.p.a. P2O5, and of this, roughly 50,000 t.p.a. enters rivers or lakes as effluent from sewage treatment. Of the 100,000 t.p.a., less than half is detergent phosphate and rather more than half is human waste. The quantity of soluble P2O5 used as chemical fertilizer is about 400,000 t.p.a. Relatively little of this is leached or is in run-off or dust loss. In the U. K., therefore, the quantity of P2O5 entering natural waters from fertilizers is probably only about one-tenth of that coming through sewage works. However, it is important for our industry to note that if phosphate treatment were applied to all sewage works, the contribution of fertilizer phosphate would be of the same order of magnitude as that from sewage disposal in those countires where soil erosion into water is relatively minor. In those countries such as the United States, where erosion due to wind and water is more serious, the fertilizer contribution would become the largest single one. In all this I am assuming that effective steps to deal with nutrient disposal on to the land, rather than into water, are taken by the intensive animal - rearing industry; other wise the distinction of being the largest contributor to phosphate in waters will pass to it. This is because in most countries animal excreta accounts for much more phosphate than does human waste -- e.g., in the U.K. it is about tenfold greater.

In passing, I may say that in the United Kingdom our water engineers have learned to live with such eutrophication problems as exist, and we do not expect to install any significant number of phosphate removal plants at sewage works in this decade. At present the cost of dealing with eutrophication in the United Kingdom is no more than 1-2% of what would be the cost of operating nationwide phosphate removal from sewage. It is perhaps too much to hope that those who are intent on banning phosphorus detergents and embarking on widespread removal of phosphate from sewage will be made to pay the taxes involved whenever these expedients are shown to be ineffective in causing a substantial reduction in algal productivity: as they certainly often will be unless considerable amounts of additional money are spent on installing the complete system-design mentioned later.

IMPACT ON THE INDUSTRY

Eutrophication is already a serious problem in many parts of the world, especially those with a large number of lakes or with landlocked seas. There have always been natural nutrient inputs to lakes and rivers, but the recent growth of urbanization and water-borne sewage disposal have led to quickly-mounting quantities of plant nutrients reaching these natural waters and causing extra algal growth. We have seen that the most effective practical way of reducing nutrient input to these lakes is by chemical treatment of sewage. The use of this technique will increase steadily in the years to come, especially for phosphate removal, because it is easily applied to point discharges and phosphate from all sources -- e.g. human wastes, detergents, industrial discharges and animal sewage, is removed by this treatment.

Fertilizer and other agricultural discharges are, however, mainly from diffuse sources and, as we have seen, it is hard to see that treatment of these sources can ever be practicable. But there are no substitutes for nitrogen and phosphorus in plant growth and ever-increasing usage of fertilizers is essential if the world need for food is to be met. There is no evidence that inputs of potassium contribute significantly to eutrophication.

The situation in regard to fertilizers can best be handled therefore by a combination of several procedures, including the following:-

(i) Avoidance of fertilizer application at a time when the prospect of usage by a crop is relatively low. This usually means avoidance of application at times outside the growing season.

(ii) Avoidance of surface application of fertilizer when the nutrients are likely to be washed off the top of the soil: for example in the case of frozen or waterlogged land.

(iii) Avoidance of excessive rates of fertilizer application; for example because of a badly calibrated spreading machine.

(iv) A careful choice of fertilizer composition must be made to best suit the crop, soil and climatic conditions and avoid a wastage of plant nutrients.

(v) Large quantities of nutrients are often carried into natural waters adsorbed on or mixed with soil. Good conservation methods are required to keep soil in place.

(vi) More trials need to be conducted to examine slowly-soluble or slowly-available fertilizers which might provide more nutrients to the plant and less to leaching.

(vii) More trials need to be conducted comparing the behavior of split fertilizer applications versus single large application. These trials should be made with a variety of crops and conditions, studying nutrient efficiencies and leaching losses, especially of nitrogen. Even though the direct fertilizer nitrogen contribution to natural waters is relatively minor, every small loss should be identified and eliminated if possible, not only to minimize nutrient input to natural waters but also to maximize efficiency of fertilizer utilization.

(viii) Research workers should be encouraged to dream up and test out unconventional methods of minimizing nutrient loss from agricultural land. Who knows what might be done, with ingenuity, determination and plastic sheeting and similar modern materials?

When considering these procedures, we must remember that soils, crops, climates, etc., vary from place to place, and no single solution will apply everywhere -- but the basic principles will be applicable to almost all locations suitable for agriculture.

In (vi) above we have mentioned the possibility of new fertilizer forms which hopefully will be discovered and give higher efficiency of nutrient usage and/or a lower contribution to eutrophication. But as with all new products coming into widespread use, the question of safety is paramount, and caution must be used. As just one example we might mention the use of metaphosphates and polyphosphates in fertilizers. These materials have been tried widely as fertilizers, particularly in the last two decades. However, they are powerful complexing agents for metal ions, and it is possible that toxic metals (e.g., mercury) can be mobilized from lake and river sediments and cause harm to fish, animals or human beings. Similarly a modification in the availability of trace elements may upset natural ecosystems by altering equilibria involving them.

CONCLUSION

The basic principles indicated in (i) to (viii) above are important for minimizing the contribution of our industry to eutrophication. However, they must form just one part of a complete system-design to protect our natural waters. This system will include many other procedures, such as nutrient removal from sewage, water treatment to remove aquatic plants, good reservoir design and operation, and the blending of waters from different sources.

The fast deterioration of many of the world's waters will permit of no delay, and procedures which are based on adequate evidence rather than on fully-verified fact, and which above all are safe, should be adopted as soon as possible.

MR. WEBER: Our next speakers are also from the United Kingdom. They will discuss the worldwide trade in ammonia, phosphorous and phosphoric acid which is becoming of considerable significance. One of the speakers is Miss Daphine L. Mermikides. She is with the British Sulphur Corporation, Limited, of London. The British Sulphur Corporation manages a consulting operation, which Miss Mermikides, directs.

Mr. Ivan T. Elek is research manager of the British Sulphur Corporation, Fertilizer Division. He is engaged in specialized market research and allied fields. They will divide this presentation.

World Trade in Phosphoric Acid, Phosphorus and Ammonia

Daphine L. Mermikides and Ivan T. Elek
THE BRITISH SULPHUR CORP.
LONDON, ENGLAND

As we stand at the threshold of the 70's it is of inordinate interest, indeed, of dramatic interest, to consider the changes that have been wrought world wide in raw materials for the fertilizer industry. Of the three materials which we shall be discussing here - ammonia, phosphorus and phosphoric acid -- only ammonia was moving over ocean routes in the early 1960's, and it is in the latter half of the decade that the other two materials have been shipped long distances. Even now world trading is confined to ammonia and phosphoric acid, since phosphorus is being shipped in commercial tonnages only from Canada to Britain and Japan. I refer, of course, to the Erco Newfoundland operations.

AMMONIA

The world's synthetic ammonia industry has undergone the most dramatic changes of its 50 odd years, when in 1963 the technological breakthroughs - of steam reforming and the centrifugal compressor - heralded the much larger capacity plants, and the means to produce ammonia at greatly reduced cost. World ammonia production has tripled to 37.8 million tonnes while the average size of new plants has not only tripled but quadrupled in capacity. Indeed, in the period 1967 to 1969, there was a 12 million tons increase in world ammonia capacity.

Hand in hand with these changes have been the no less remarkable changes in feedstocks used, the location of large centres of production, in the U.S. Gulf, the Middle East, North Africa and soon South American States, and in the transportation and storage of the finished product.

Of the total world synthetic ammonia production capacity of 45 million tones N, just under 50% is located in the highly industrialized countries.

(Europe 14.0 million tonnes, Eastern Europe 6.2 million tonnes, the USSR 5.8 million tonnes, Japan 3.0 million tonnes and Canada 1.5 million tonnes.)

The remaining production is found in non-communist Asia (excluding Japan) (3 million tonnes) mainly in India, Pakistan South Korea and Taiwan (4.3 million tonnes N). Communist world ammonia capacity is an estimated 11 1/2 million tonnes; while Africa, limited to South Africa, Algeria and Egypt, has 1.1 million tonnes, Latin America 1.6 million tonnes with Mexico and Trinidad accounting for 70% of this total.

By 1975, British Sulphur Corporation estimates that world ammonia production will approach 71 million tonnes N, always providing, of course, that new construction already in hand proceeds according to schedule, unannounced shutdowns of older plants do not occur and that estimates for Communist Asia and the USSR are reasonably correct. Of the new projected capacity, from 6.8 million tonnes N to over 23 million tonnes N by 1975/76, the developing nations are seen as almost tripling with the greater tonnage arising in non-communist Asia and India, presently 4.3 million tonnes N and increasing by 1975/76 to 14.5 million tonnes N.

It is the countries such as Kuwait, Quatar, Saudi Arabia and Iran in the Middle East and possibly Duai and the countries of Latin America which will have the most noticeable increases in ammonia production capacity in the next few years.

AMMONIA TRANSPORT AND STORAGE

The changes in ammonia transport and storage have been as dramatic as those of capacity in the last few years. Small storage facilities, and the conventional rail, truck, barge and ship are no longer able to accommodate the high tonnages of ammonia being produced, particularly from the 1,000 tonne per day plant upwards that are often located great distances from the point of use. With freight and storage costs increasing all possible means are continually being sought to reduce those to the minimum. Shipment of large tonnages of ammonia within the last few years has now become akin to that of liquified petroleum gas (LPG); in fact, much of the equipment and containers, be it rail, wagon or ship, is interchangeable.

Today, 30,000 - 33,000 (80 s tons) gallon capacity jumbo railway tank cars are rapidly becoming commonplace in the U.S.A., while in the U.K. within the last year 46-ton rail containers have come into being. Refrigerated barges of 2000-ton capacity or over, designed exclusively for ammonia service, are plying the Mississippi and in Europe, of 800-tons on the River Rhine.

Sea-going, refrigerated ammonia tankers have been in use for almost a decade. The first of these was the W.R. Grace which has been transporting anhydrous ammonia from Trinidad to England and

WORLD AMMONIA CAPACITY
(millions tons N)

	1961/62	1966/67	1971/72	1975/76
Europe	7.6	15.7	26.3	30.7
America	5.2	10.7	14.8	17.6
Africa	0.3	0.3	1.0	3.4
Asia & Oceania	2.4	4.8	10.3	19.0
World	15.5	31.5	52.4	70.7

Western Europe since 1966. In the States, there is the 850-mile, still to be completed, pipeline running from Borger, Texas to the Midwest and another from the Gulf Coast to Midwest. A 200-odd mile pipeline in Mexico and a smaller-25-mile pipeline in the Saarland running into France. It seems quite within the realms of possibility, always providing there is stability of Government and friendly accord, for pipelines carrying ammonia from North Africa to traverse the Mediterranean to those countries bordering that sea.

Where ammonia is transported large distances, terminalling points require adequate storage. Atmospheric pressure, refrigerated storage vessels of large capacity have become almost standard, replacing the small (up to 1000 - 1500 tons) thick-walled pressure spheres at considerable saving in investment and operating costs.

TRADE

The influence of the large capacity ammonia plants is already being felt, to such an extent that it is now believed that very careful consideration is being given to weighing up the pros and cons of going ahead with a new large capacity ammonia unit or purchasing under favourable contracts.

We can say that an increasingly larger share of the world's ammonia production capacity will be centered in very large - 1000 t to 1500 t.p.d. if not larger - single train plants sited at sources of low-cost natural gas, and transported to user markets either overland or by ocean and, certainly more often than now, at great distances. Nevertheless the small plants are not going to vanish entirely since these have their place in supplying local markets and using locally available feedstocks. These will be careful evaluations, however, against pipeline transportation. Foreseeing even further into the future, as natural gas reserves become depleted, new technology will come to the fore; making electrolytic hydrogen and coal gasification attractive as feedstock and in this event the locations now in the forefront for ammonia supply will give way to others with the most suitable feedstock.

World Exports of Anhydrous Ammonia
(1000 tonnes N)

	1968	1969*
West Europe	405	592
East Europe	60	35
North America	677	1007
Central America	329	363
South America	26	23
Asia	10	10
World	1,507	2,030

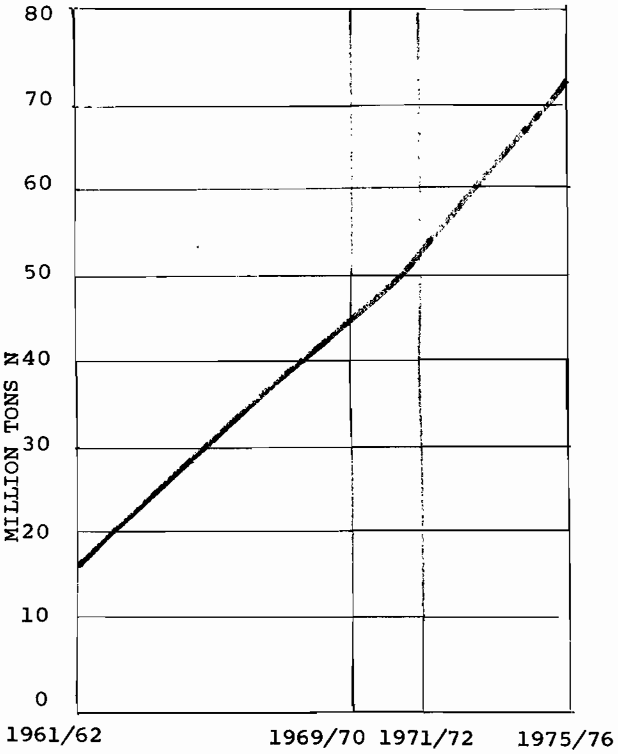
*provisional

WORLD EXPORTS

World exports of ammonia in 1969, including intra-regional deliveries reached the massive total of 2.2 million tonnes N 35% higher than the level of trade during 1968. This exceptional growth in trade does not lie solely in the expansion of export deliveries from the U.S. to North West Europe and other areas of the world, but also the significant increase of shipments from one European country to another - intra-regional trade.

Today the U.S. is the largest supplier of ammonia to the world market, 1968-69 export shipments reaching a level of just over 1 million tonnes N, almost 56% greater than during 1968. Prior to this U.S. exports were mainly oriented to over the border trading with Canada and Mexico. But the increase in trade has been over the Atlantic in North West Europe and Scandinavia, and we estimate

PROJECTED INCREASE IN WORLD AMMONIA CAPACITY



that just over 75% of U.S. ammonia exports were destined for this area. The intake by West Europe of U.S. ammonia was just about half of the total U.S. exports in 1968/69. (1969 1st half 1970).

Outside of West Europe, ammonia exports have been effected shipments to Poland, Algeria, Iran and Mozambique. Admittedly Algeria and Iran may sound strange as these are designated ammonia producing countries, but as is more generally the case these two countries' own ammonia facilities have not come along as fast as had been expected.

In the case of Mozambique, the probability is that the final destination was, in fact, Rhodesia. Other countries where U.S. ammonia has been shipped latterly have been Senegal, Australia and Morocco.

The other major source of ammonia on the west side of the Atlantic - W.R. Grace and Co.'s Trinidad operation, which started in 1964 and has been a major supplier to North West Europe, notably the U.K., and Scandinavia, has apparently changed its pattern of sales to accommodate demands on the U.S. East coast, as well as the U.K. and North Africa.

In so far as ammonia exports in West Europe are concerned, the pattern is one of satisfying demand within Europe and of almost 88% of the 492,000 tonnes N crossing the borders of countries in the continent in 1969, the greater part was retained in the region (we must admit to this figure probably containing some double counting, of material imported from the U.S. to the Netherlands and subsequently re-exported to West Germany.)

NH3 TANKER FLEET

It is only since 1964 that there has been effective and economically viable transport for anhydrous ammonia - the refrigerated LPG/ammonia tanker. In 1969 of the 2.2 million tonnes of N exported, almost 1.6 million tonnes N, or 72% was moved in pressurized refrigerated LPG/ tankers - the remainder being moved by other forms of chemical tanker -rail or road.

During 1969, the world LPG/ammonia fleet increased, in terms of volume of liquefied gas by just over 28%, equivalent to almost 182,000 tonnes ammonia, the bulk of this expansion due to eight new refrigerated tankers in 1969 principally for employment on transatlantic voyages and journeys of similar length.

Refrigerated tanker capacity increased by nearly 34% to an overall ammonia equivalent of over 637,000 tonnes. In Western Europe there are now numerous refrigerated LPG/ammonia vessels, well-suited to coastal and navigable waterway traffic.

The new vessels ordered would appear to confirm the growth of world ammonia exports. 1973 should see an additional 558,194 ton capacity in the form of refrigerated tankers operating with about 90% in the fully refrigerated class. All of which suggests further growth of LPG/ammonia trade, particularly on the transatlantic route.

OUTLETS FOR AMMONIA

Ammonia trade up to now could be said to have relied substantially on the failure, either sporadic or in start-up, of ammonia plants throughout the world, but mainly in West Europe.

Europe could be regarded as a long-term outlet for U.S. ammonia; although other than W.R. Grace & Co., there is apparently no other U.S. company linked with Europe through special terminal facilities. This is not the case, however, with the other countries which have large ammonia capacity-i.e. Kuwait, Iran, Saudi Arabia, Libya etc. In the case of Kuwait and Iran these countries have tied their respective outputs to medium-to-long-term contracts with consumer industries in other areas e.g. Turkey and India.

With regard to U.S. ammonia, its competitiveness, at least for the time being, appears to have made European fertilizer producers more receptive to basing their production on imported ammonia.

AMMONIA TRADE

Why should ammonia trade be successful or continue to be? Examination of the economics reveals that LPG tankers are substantially more costly than ammonia tankers since the lower temperature (255 degrees F. vs. 28 degrees F.) and the lower density (26 pounds per cubic foot vs. 42 pounds per cubic foot) of the cargo are required. Nevertheless the price of gas available to an ammonia plant is an all important factor in determining whether anhydrous ammonia or natural gas is to be transported.

The only areas in the world where gas is liable to stay in the 5¢ area are those places where gas is abundant, wasted, and there is no industrial or population growth in the near future that could give rise to a local demand for the gas. Where gas goes almost 20¢ and the reserves are not as large, the gas converted into chemicals other than ammonia will show a much higher return to the manufacturers than will the production and sale of ammonia. If the price of natural gas went as high as 40¢ this makes a differential of $12.74 in production costs, or enough freight equivalent to carry gas from the Middle East to Australia or the Philippines or the West coast of Africa and, if Suez was opened, into the Mediterranean. In fact, it would mean that Dutch or British natural gas would be better used for other chemical manufacture, and hence the European market would become a purchaser of ammonia rather than producing it.

Now, where there seems to be a surplus of ammonia in the Arabian Gulf, it is foreseen that the price of gas in Europe and the United States would change the supply situation markedly and this would result in a rearrangement of ammonia markets.

It could be considered that the U.S. Gulf area will not be competitive in the world ammonia market in 1975. Venezuela with its cheap gas is expected to be competitive in the world market, but the possibility of inefficient operation may prejudice it as a satisfactory source of supply. Because of high cost and low volume Trinidad and Aruba will lose their importance.

Algeria is seen as being a useful source of supply, but a high cost of carrying the product to port could be an adverse factor.

Mozambique could be an interesting possibility, as also Alaska. However, with regard to the latter, heavy capital expense will be required as well as high delivery costs.

SUPPLYING DEVELOPING COUNTRIES

There are now 77 developing countries in the world and while a considerable part, if not most, of the increased availability of nutrients in these countries, will have to be supplied from indigenous works, this will not mean that each of them will or should seek to be self-sufficient in production of all fertilizer requirements. Where feedstock sources are minimal or expensive that country will be better off purchasing its nitrogen requirements elsewhere than producing ammonia based on costly raw materials. These countries would import urea or other nitrogenous materials such as monoammonium phosphate or ammonium polyphosphate in finished form and mix and blend within the countries, or equally, if economic, import anhydrous ammonia and produce complex fertilizer from these imports.

ELEMENTAL PHOSPHOROUS PRODUCTION TONS

United States	550,000	Netherlands
U.S.S.R.	160,000	France
West Germany	70,000	Italy
Newfoundland	75,000	Japan
Canada	75,000	

World production of elemental phosphorus is about 800,000 tonnes. Whereas in 1962 about two-thirds of production was in the United States, it now has over one-half 530,000 tonnes, since several large furnaces have been built or are under construction in Canada, U.S.S.R. and West Europe. Most of the phosphorus is used for production of industrial chemicals or animal feed supplements. However, some of the new projects have been indicated as being intended largely for fertilizers.

Elemental phosphorus is a material equivalent to 229% P205. One tonne of phosphorus is equivalent in phosphorus content to 5 tonnes of triple superphosphate or diammonium phosphate made from wet-process phosphoric acid which is equivalent to 7 tonnes of high grade phosphate rock. So substantial savings in transportation, storage and handling are possible with this highly concentrated material.

Another advantage of the furnace process is its ability to utilize low-grade phosphate rock. Rock containing 24% P205 (about 52% BPL) can be used economically if the principal impurity is silica. Moderate amounts of iron and aluminum oxides are not objectionable and even lower grade rock can be used without serious economic penalty. The other major advantage of the furnace process is that a variety of high-analysis fertilizer products and liquid mixes can be produced as well as industrial and feed grade phosphates.

Superphosphoric acid containing 80% or more P205 can be produced economically from elemental phosphorus and used to make fertilizer products such as ammonium polyphosphate (15-60-0) or high-analysis liquid fertilizer (11-37-0) Processes for conversion of phosphorus to these products are not complicated and they can be carried out in relatively small-scale plants located in fertilizer market areas.

DISADVANTAGES

A disadvantage of the furnace process is the high investment cost. The estimated investment for an electric furnace plant to produce 600 s tons of P205 per day, including facilities to convert phosphorus to phosphoric acid, is $35.1 million, as compared with $16.5 million for the wet process. Capital charges (20% return on investment, 6.7% depreciation, 2% taxes and insurance) amount to nearly $50 per ton of P205 for the furnace process, compared with about $24 for the wet process.

It is considered that the investment cost for the furnace process could be reduced substantially by development of larger units. A 70,000 kw furnace is said to be in operation in the U.S.S.R. and a 150,000 kw furnace is thought to be feasible by some constructors. Such developments would tend to decrease the gap in investment cost between the furnace and wet processes.

Although a cost-analysis may show an advantage (or a disadvantage) for electric furnace or wet process acid under certain price situations for raw materials and energy input, where only one of the products can be used in industrial and some other processes, then furnace acid will most likely continue to be used and only limited amounts will be available for fertilizer use. This latter use is most likely to be directed principally into such areas as sequestration in liquid fertilizers, for which it has unique qualities that justify a premium price; although work by your T.V.A. shows that up-graded wet phosphoric acid can be used as well.

In the future much will rest on whether the fertilizer industry will produce large quantities of (15-62-0) ammonium polyphosphate from furnace acid or 12-58-0 ammonium polyphosphate from wet process acid.

The versatility of elemental phosphorus can be seen as having a particular advantage in developing countries since it could be used to make phosphatic animal feed supplement and industrial chemicals as well as fertilizers. It does, however, require costly storage facilities and expert knowlege in handling.

SHIPMENT

Overseas shipment of phosphorus to developing countries and other markets has been seen as a promising means for saving transport costs in comparison with shipment of phosphate rock or finished fertilizer or even phosphoric acid or ordinary of super grade. The reasons that can be advanced are that shipment of phosphorus to developing countries and other markets where one raw material and most probably two raw materials i.e. phosphate rock and sulphur would have to be ordered to produce phosphoric acid e.g. Japan, India, has been considered a promising means of saving transportation costs.

Unloading costs would be lower since the phosphorus can be pumped to storage tanks in ports, whereas unloading of solids is often expensive and time consuming in ports of developing countries. Whereas shipment of superphosphoric acid requires relatively expensive tank cars (stainless steel or rubber-lined and insulated), phosphorus is shipped in plain steel tank cars.

The most important event in shipment of elemental phosphorus has been the decision by Albright and Wilson Ltd. to transport the product from the phosphorus furnaces the company has established in Newfoundland, Canada through its subsidiary, Electric Reduction Company of Canada Ltd. (ERCO) by sea in specially designed tanker vessels to the United Kingdom (Port Maitland, Canada to Portishead, England) and more recently in April this year to Japan to Nippon Chemical Industrial Co.

Transport is effected in two 5,000 ton ships, one of which was launched in 1968 with the first delivery being made in late 1969. The second vessel is just coming into service.

PHOSPHORIC ACID TRADE

1970 is a notable year in the history of phosphoric acid for it celebrates the centenary of commercial production by the wet process. It was in 1870 that a German company began production of wet process phosphoric acid.

By 1900 about a dozen companies entered this industry, chiefly in the U.S., and among the early names we find Davison, Kettlewell & Co., and Stauffer Chemical Co., followed by the American Agricultural Co. and Virginia-Carolina Chemical Co.

It is of interest to mention that the production centre for phosphoric acid was Baltimore. In the early part of this century plant sizes were in the range of 8 - 40 t.p.d. P205 and it was not until a major technical breakthrough in 1932 that 100 t.p.d. and larger plants were built. By the early 1960's the maximum size reached was 800 t.p.d. and approached the 1000 t.p.d. towards the end of the decade. Historically Europe lagged behind the U.S. in constructing the larger plants.

U.S. output was about 1000 t.p.d. in 1900, but it was not until about 20 years ago, with the advent of ammonium phosphates in the U.S., that phosphoric acid began to be produced on a really large scale.

PRODUCTION CENTRES

There are now many countries which have production facilities for phosphoric acid; two years ago there were 38; two years hence there will be 50, and this number may increase further. Analysis of the location of plants reveals that most plants are situated in the highly industrialized regions of the world. A breakdown of wet process acid capacities by region shows a spectacular growth in the five years since 1963/64. The largest expansions in this period took place in the U.S.

In contrast, little new capacity is expected to be added in the U.S. or Canada up to 1973; although the worst may be over there is still a considerable degree of overcapacity in North America. Elsewhere the rate of expansion in Eastern Europe is rather faster than in Western Europe although here, too, several new plants have been and are scheduled to be constructed in the next two to three years. Potential output of phosphoric acid in Africa and Asia will be doubled following the present round of expansions.

It is of interest to note that since 1969 the major increments to capacities have been made in the developing countries.

WET PROCESS PHOSPHORIC ACID CAPACITY

	1963/4	1968/9	1973/4
Europe	1.4	3.6	6.4
America	2.8	6.2	6.9
Africa	0.1	0.5	1.0
Asia & Oceania	0.3	1.4	2.7
Total	4.6	11.7	17.0

Many of the larger plants are located near the source of phosphate rock and/or sulphur. Alternatively where such materials are not indigenous, plants are found near convenient supplies of sulphuric acid and located suitably for receiving shipments of phosphate rock. The major phosphoric acid producers today are the U.S.A., Japan, U.S.S.R., Canada, U.K., France and Italy.

END-USE

The principal outlet for phosphoric acid is the fertilizer industry. Production for phosphatic and complex fertilizers requires about eight million tonnes P205 as phosphoric acid and technical requirements in the production of DCP and STPP amount to another one million tonnes P205.

Until the mid-1960's phosphoric acid trade was largely confined to producers within the U.S. and on a smaller scale between producers in Belgium, France, Netherlands, and West Germany. By 1967, however, trade in Europe increased to some 50,000 t.p.a. P205 as a result of the changes instituted in the production programmes of Continental producers.

A trend towards higher concentration became evident and demand from the marketing people for higher analysis NPK fertilizers (of which the 1:1:1 ratio was the most popular) could not be satisfied by the traditional nitro-phosphate producers without the additional use of phosphoric acid. As the quantity required was in most cases supplementary P205, purchase of acid domestically or from neighbouring countries was the most economical short term solution.

Long-distance ocean shipping did not make much progress until the end of the 1960's. Mention should be made of small shipments from the United States to Italy some years ago. Experience with these shipments, however, proved somewhat troublesome, and they highlighted problems associated with long-distance shipping. On shorter distances regular deliveries have been established from the U.S. to Colombia and from Lebanon to Turkey, in each case to one particular company.

MERCHANT ACID

In the period 1968 - 1970 large phosphoric acid plants came on stream whose output was primarily designed for sale to domestic and overseas customers. The first and largest of these was Freeport's Uncle Sam plant in Louisiana with a total capacity of 550,000 t.p.a. P205. This was followed by Fertilizantes Fosfatados Mexicanos' (FFM) plant in Mexico in March 1969. Other potential large merchant acid suppliers are Israel Chemical Industries, Produits Chemiques et Metallurgiques du Rupel in Belgium, and Shahpur Chemical Company in Iran.

Aggregate capacity for merchant acid in 1971 will be more than 1.2 million t.p.a. P205, illustrating the scale of development in the space of three years. Furthermore there are projects for largely export orientated installations in Tunisia, Morocco, Algeria and elsewhere.

Companies for whom merchant acid is of particular interest fall into three main categories; those whose requirement is not large enough to justify construction of a phosphoric acid plant; those which need acid additionally to their own production; and those which have seasonal shortages.

Phosphoric acid is moved by road, rail and water. Whereas in the U.S. road transport is employed only for short journeys, in Europe this mode of transport is the one most frequently used.

The first transatlantic shipment of phosphoric acid was delivered by FFM in September 1969 to its storage terminal in Rotterdam. FFM's fleet of vessels currently comprises two vessels of 23,000 tons each, capable of carrying 200,000 tons of acid a year with a 32 day turn-around. It has been announced that by the end of 1970 another vessel will be built for FFM.

Now under construction, too, is a 5,000-tons acid carrying vessel for Industries Chemiques Maghrebines of Tunisia, which will transport phosphoric acid from Gabes to Southern Europe; and Arad Chemicals Ltd. has also ordered some specially built ships.

It should be noted that in the case of phosphoric acid it is the producing companies which have made themselves responsible for the provision of suitable vessels.

From the purchaser's point of view, phosphoric acid can be considered a substitute raw material for phosphate rock or merely another source of P205 intermediate, just like triple superphosphate or diammonium phosphate. Economical considerations dictate that in terms of unit cost, the cheapest source be selected giving maximum advantage in terms of overall manufacturing and operating costs.

OCEAN TRADE

Why has ocean trade not developed more rapidly then? Mainly because there are no striking cost advantages and also because of the reluctance to rely on a distant supplier coupled with the disinclination to narrow purchasing options from two products (phosphate rock and sulphur) to one product.

Phosphoric acid is now available for sale in large quantities. Among the advantages of phosphoric acid are high concentration of P205, a reduction in the bulk moved and the flexibility it affords in formulating the final product. Of the disadvantages, foreign exchange requirements are very high for a developing country; while a major disadvantage is that phosphoric acid contains impurities which vary with the type of phosphate rock used; also receiving liquids of this nature is more troublesome than solids, although some producers have come to prefer working with materials in the liquid phase.

To a large extent the lack of large scale ocean movement of phosphoric acid is due to difficulties in shipping, after shipping storage and handling.

Phosphoric acid is a corrosive product and for this reason a specially constructed or modified ship must be used, of stainless steel construction. The cost of building a terminal to act as buffer storage is considerable (over one million dollars for the storage of 30,000 tonnes) and this too would have to have specialized construction.

There are also problems with sludge formation; these, however, can be overcome by clarification at the producing plant and by agitation with air streams or circulation pumps in transport and storage at additional cost.

At one time it was thought that superphosphoric acid might enter world trade; however, while corrosion problems are seemingly less severe with superphosphoric acid, the corresponding increase in viscosity leads to handling difficulties as well.

PHOSPHORIC ACID

Rate of Import Duty*
Selected Countries

Belgium, France, W. Germany, Luxembourg, Netherlands, Italy		13.2%
United Kingdom		17.5%
Yugoslavia		6%
Greece	max.	20%
Turkey		15%
India		27.5%
Thailand		30%
Japan	max.	15%
Australia	max.	25%

(*based on the c.i.f. value of goods)

A particularly pertinent factor which may not have received adequate attention in the past is the high duty rate on phosphoric acid levied by some of the countries which may be potential purchasers. In the case of producer countries, the high duty is of protective nature.

Some of the problems mentioned above will of course be ironed out as experience is gained in shipping phosphoric acid. There certainly is a growing demand for P205 world wide and phosphoric acid is the most recent intermediate to enter world trade.

PERTINENT STATISTICS

Trade, as between producers within countries, is particularly highly developed in the U.S. We estimate trade of this kind to be in the order of 1.3 million tonnes P205 world wide.

Trade between countries has increased one hundred times from some 2,000 t.p.a. P205 ten years ago to almost 200,000 t.p.a. P205. This is a very dramatic rise, but it represents only 2 1/2% of the present use of phosphoric acid. In the context of phosphate fertilizer trade which is over three million t.p.a. P205 and phosphate rock trade which is about 12 million t.p.a., the trade volume recorded for phosphoric acid is admittedly not very high. The comparative proportion for ammonia is about 8%.

Provisional statistics of the British Sulphur Corporation in respect of 1969/70 indicate that world consumption of P205 exceeded the 20 million tonne mark for the first time at 20.3 million t.p.a. Phosphoric acid P205 supplied 40% of this quantity as enriched superphosphate, triple superphosphate, ammonium phosphates and other multinutrient fertilizers.

According to our estimates, world fertilizer P205 consumption in the period up to 1975/76 will grow by an average of 1 1/4 million tonnes to reach 27.8 million tonnes P205. If the present extent of phosphoric acid use continues, there will be a need for about 11 million tonnes P205 in this form. While there are ample supplies of phosphate rock and a buyers market prevails, the production of merchant phosphoric acid is an obvious alternative.

QUESTIONS AND ANSWERS

MR. WEBER: We are now ready for questions from the membership.

MR. JOHN G. KNONSEDER (Fluor Corp.) Dr. Raistrick, you mentioned that the requirements of eutrophication are nitrogen, phosphorus and carbon. A recent article discusses these and says that nitrogen and phosphorus are present in the mud in the water, or underneath the water, in any case, and that the real control of eutrophication has to begin with the raw sewage.

DR. RAISTRICK: I said that the main elements in eutrophication are carbon, nitrogen and phosphorus, although sometimes it is silicon and iron that cause the excessive growth of certain plants. This is just like agriculture. Sometimes it is one element that is limiting, and sometimes it is another. You talked about nutrients at the bottoms of lakes. Yes, they are present. The eutrophied lakes usually have enough phosphorus at the bottom to feed the algae. If you want to convert a eutrophied lake, one that is overgrown with algae, such as Lake Erie, or possibly Lake Geneva, you have to do a lot of things. One thing that can be done is to dig out the bottom. There is a lake in Denmark where this is being done, but this would obviously be impossible in a lake the size of Lake Erie.

MR. CHACAM ARUNA (Madras Fertilizers Limited): I have a question I would like to ask the lady from England. What are the significant advantages of adding polyphosphate to urea - based NPK formulations?

MISS DAPHINE L. MERMIKIDES: The significant advantages would be a highly concentrated product which would cut down on shipping costs.

MR. CHACAM ARUNA: Are there any shipments in the world trade?

MISS DAPHINE L. MERMIKIDIES: Not as yet.

MR. WEBER: Would you like to answer that question, Mr. Hignett?

MR. HIGNETT: We are shipping substantial amounts to Hawaii, thousands of tons. This is not exactly world trade, but I think that's a good possibility for the future.

MR. CHACAM ARUNA: I have a question to address to Mr. Lutz. It is said that the blunger performs well for certain NPK formulations and T.V.A. granulators / perform well for certain NPK formulations. Any comments about that?

MR. LUTZ: The two machines seem to be used interchangeably on almost any formulation. Granulation is still an art and not a highly developed science.

MR. HAMMOND (Chemical Construction Co.): You mentioned, Dr. Raistrick, that in the United Kingdom you were relying on the more specialized engineering devices to regulate pollution in water. Have you had any success, and why have you not considered or why are you not considering larger schemes like we have in the United States?

DR. RAISTRICK: The United Kingdom has had good, comprehensive sewerage treatment for many, many years. We don't have the problems of gross pollution, which are common in North America and many other countries. We have plenty of eutrophication problems in the sense that many of our waters are above the critical levels, but we, shall I say, have had the problem for so long that our engineers have learned to live with it, and reservoirs have been designed for take-off in specialized places. For example, in most of our reservoirs, water can be taken off at different levels, and we always have take-offs on two opposite sides of the reservoirs; so if the wind is blowing the algae up to the west bank, you might say, we take-off on the east bank. It is by employing techniques of this kind that our engineers have learned to live with the problem of eutrophication -- and its cost -- in the United Kingdom.

MR. UDAY HATTIANGADI (Continental Oil Co.): I have a fairly loaded question for Mr. Kulp: How would he rank the several two - stage, high - recovery phosphoric acid processes that he has discussed, leaving out the Dorr-Oliver "HYS" process for the moment?

MR. KULP: I will answer it this way: The two-stage filtration process, I think, has a better chance of higher recovery.

Thursday, November 5th, 1970
Morning Session
MODERATOR: HAROLD D. BLENKHORN

MODERATOR BLENKHORN: Many of you in this room will recall that the keynote speaker, at last year's meeting in Washington, was Mr. H. S. Ten Eyck. On that occasion, Mr. Ten Eyck made reference to the hazards of making predictions, particularly if one is attempting to predict future happenings in the fertilizer industry.

Sometimes, however, with the advantage of hindsight, it is interesting to recall predictions which have been made in the past. A few years ago -- around 1964, I believe, a prediction appeared on the editorial page of Farm Chemicals. As nearly as I recall, it went something like this: --

"Within the next five years, two things will happen: (a) -- you will be working for a different company, and (b) -- most of the mixed fertilizer going to the market in the U. S. A. will be bulk blended."

It is fair to say that we have seen these predictions come to pass. Old companies have been dissolved or are now known by another name. Even though some of us are still with the same company, in most cases its organization bears little resemblance to that of five years ago. Also, the decentralized bulk handling system which, for the want of a better term, we call "bulk blending," has become the predominant method of putting fertilizer on the market place.

To bring us up - to - date information on various aspects of bulk blending, we are fortunate to have with us a panel of four men, all of whom are employed by Canadian Industries Limited. The leader of this panel is Mr. John H. Johnston, marketing manager, Agricultural Chemicals Division. Mr. Johnston's background is business and finance, and prior to his present appointment, has held management posts in administration and credit management. His formal training in economics and finance has been extensive, and includes attendance at the Dartmouth Graduate School of Credit and Financial Management.

Bulk Blend Plant Operations

PANEL LEADER: J. H. Johnston

MARKETING MANAGER, AGRICULTURAL CHEMICALS DIVISION
CANADIAN INDUSTRIES, LTD.
MONTREAL, CANADA

It is a distinct pleasure to represent CIL at this conference. I will try to provide you with some background information on our company, and my confreres will provide additional detail on our operations.

Canadian Industries Limited is best described as a chemical industry and is presently Canada's largest producer of chemicals and allied products. Imperial Chemical Industries Limited of London, England, the largest chemical group in Europe and one of the largest industrial organizations in the world, owns 74% of CIL.

CIL's history goes back to 1862, and the formation of the Hamilton Powder Company. Since then it has grown by acquisition, amalgamation and expansion, along much the same lines as several of the chemical companies in the U. S.

Products include ammunition, sporting goods, explosives, agricultural and industrial chemicals, paints, plastics and textile fibres.

In addition to hundreds of products manufactured in our own plants, many others, from water treatment chemicals to golf equipment, are manufactured by subsidiary and associated companies.

CIL entered the fertilizer business in the late 20's and early 30's with the manufacture of single super-phosphate. It was based on the availability of spent sulphuric acid from the manufacture of explosives. Thus the Agricultural Chemicals Division has the humble lineage of being the "disposal unit" for the company's spent acid.

The super-phosphate was marketed through the manufacture of mixed fertilizers and the normal distribution organization of feed mills and other farm supply dealers. It was also sold to co-manufacturers of mixed fertilizers.

CIL's experience in the fertilizer business, before the building of its 1,000 ton per day ammonia plant at Courtright, Ontario, in 1965, paralleled what could be expressed as the normal pattern for the major portion of the industry in the eastern half of the North American continent. The production of ammonia led to planned expansion into the derivative products of ammonia and phosphoric acid being produced on the site. These are nitric acid, ammonium nitrate, urea, nitrogen solutions, diammonium phosphate and monammonium phosphate.

Lambton Works, as this plant is known, is situated at Courtright, Ontario, about 25 miles south of Sarnia, on the St. Clair River. Sarnia is directly across the St. Clair from Port Huron, Michigan.

As mentioned earlier, CIL's marketing and distribution of fertilizer products followed the normal pattern for relatively large centralized granulation plants. As late as 1967, when Lambton Works was completely "on stream," and CIL's position was firmly established as a basic manufacturer of nitrogen phosphates, the company's domestic marketing program was basically oriented to homogeneous granulator fertilizers, and its historical distribution channels, because it still had a vested interest in four granulation plants, and a firm conviction about the product's superiority. The advantages, published by T. V. A. and others, of switching to the blending route still had to be demonstrated against the quality control and the specific economies to CIL of continuing to use the granulation plants on a completely "written off" basis.

Early in 1968, CIL completed a thorough review of the needs of the market and agreed:

1) The least cost marketing arrangement was a series of small blending plants combining the economics of warehousing, mixing, and the retail sales function at a local service centre.
2) Progressive merchant dealers were recognizing that increased fertilizer penetration and profit could be obtained by acquiring blending facilities rather than by continuing in the conventional dealer role. It was obvious also, that unless CIL assisted these dealers to become blenders, it would lose many effective outlets and a substantial share of the market.
3) Increased penetration could be achieved only by following the trend to a blending system of manufacturing and marketing in areas of high fertilizer demand.
4) The typical future farmer would expect to buy "packages of farm in-puts and services," sold on the farm.
5) Further investigation confirmed that with the proper choice of materials and with careful selection of equipment all quality requirements could be met. These conclusions shaped one of the biggest, most ambitious marketing ventures in our company's history.

We call it our "Agromart" program, and in Quebec it is known as "Agrocentre." It calls for a network of franchised retail outlets, each servicing its area with its own salesmen. These are usually established dealers. The "Agromart" outlets sell a full range of CIL fertilizers, blended on the site in most instances, plus such products as: seeds, farm chemicals, feed pre-mixes, animal health products, and farm supplies. The diversity of products offers an excellent opportunity for various divisions to join in a company wide marketing scheme.

The new marketing plan is being offered to selected well - established farm merchant retailers who will maintain their own local identity in the operation of an "Agromart" as a joint venture with CIL. Where CIL cannot initially obtain a suitable franchisee, the company will operate a wholly CIL owned "Agromart" which will be sold to an independent businessman as soon as a suitable one is found.

CIL provides training for all "Agromart" managers and their staffs in production, product and business management, and technical services. Additional specialized services are provided as required.

We foresee our strength as lying in the quality of the "Agromart" managers selected. They will be men who have "dollar signs for eyeballs." They are interested, and involved with their farmer customers in the successful planning of their cropping and nutritional programs. They promote soil fertility, provide quality in-puts, planned profit farming programs such as on-the-farm feeding, and such other products as seed fertilizer, pesticides, animal health products, propionic acid to preserve feed grain, pre-mixes, portable mixing machines, in short, they provide a total program to maximize the farmer's profit, from soil fertility to finished beef, hogs or milk.

During the transition from the traditional dealer organization to the "Agromart" program, both channels of distribution are functioning in parallel with some minor conflicts. In a short time the dealer organization will virtually disappear, with a corresponding reduction in divisional marketing and distribution costs.

As the conversion to bulk blending is completed, operation of the fertilizer granulation plants is being systematically phased out. Two have been closed and a third is scheduled for shut down in 1971.

That concludes my introduction of CIL, its Agricultural Chemicals Division, and the "Agromart" marketing concept with blended fertilizers as the logical base of its product package. My colleagues will take over and discuss in more detail the economics of "Agromart": "Agromart" building specifications, equipment and ancillaries; fertilizer control and the agronomic acceptance of blended products.

PANEL LEADER, JOHN H. JOHNSTON: Several of my associates at Canadian Industries are participating in this discussion on "Bulk Blend Plant Operations."

The first speaker on the panel is James Sinclair. Jim was born on a farm and has a formal agricultural education. He received his degree in chemistry at the Ontario Agricultural University of Toronto. He began his career as a chemist and from there moved on to technical sales. He became plant foreman and then superintendent of a variety of operations, including blending of homogeneous units, super units and acid plants. Jim is now working in Montreal as Plant Operations Manager. He will discuss "Facilities for Blending."

Facilities for Blending

J. W. Sinclair
PLANT OPERATING MANAGER
CANADIAN INDUSTRIES, LTD.
MONTREAL, CANADA

Almost everyone knows how to blend raw materials and make bulk blended fertilizer. Just ask your local blacksmith, your nearest equipment representative, or your director of research. We in CIL have been mixing chemicals for generations and, of course, consider ourselves real experts in the field.

Therefore, when we decided to blend fertilizers we approached the problem straight from the market place and asked ourselves, "What do our customers think they need? and what do our customers actually need?" We recognized that there is a difference. We presumed the real need of the farmer was to make profits from farming and we recognized that we needed his inputs as our sales. Therefore, we needed to blend fertilizers efficiently so that we would not increase his cost and thereby reduce his profits. Our blend plants were therefore designed to be as efficient as possible and stay within the quality requirements of our customers and the Federal Control Officials. Howard Horton will explain in his address more of the Federal Control guide lines and our approach to quality control.

With these considerations we proceeded to design and build customer oriented facilities and so designed our plants that they would be easily acceptable to our customers, preferably on the edge of a farm shopping centre, and so located that farmers would be inclined to drop in and pick-up even their smallest incidental requirements.

Our actual manufacturing of bulk blends is accomplished by handling-in raw materials into the back of the building, using a combination under-car and truck-receiving conveyor, and an elevator discharging onto a shuttle belt across the top of the bins. Our raw material storage is normally 6 bins of 150 ton each, with the building being constructed of 8x8 B.C. Fir treated posts with plywood roof, asphalt shingles, and the pretreated plywood sides.

The bin dividers are affixed to the posts by using 4 inch wide flanged channels and 2x4 on the side for the first 10 ft. and 2x3 on up. The raw material is removed from the bin front using front end loaders to a 2 ton weigh hopper with a hinged scalping screen on the top of the hopper using a number 2 mesh. From the weigh hopper the material is carried by a screw conveyor into a 2 ton rotary mixer.

When we came to choosing the mixing equipment, we recognized that a wide variety of equipment was available for blending the ingredients in compound fertilizers. The units available varied radically in concept, size, complexity and cost. It was also suspected that the degree of mixing achieved by the various alternatives varied appreciably.

If our company was to become more active in the blending of compound fertilizer it was essential that the equipment used in our plants be capable of producing materials of adequate chemical quality. This meant that at least 90% of the official samples taken by the Department of Agriculture inspectors from the plant's output must prove satisfactory under Canada Fertilizer Act.

Unfortunately most of the units available for blending were manufactured in the United States. Therefore, the performance claimed by manufacturers or divulged by fertilizer producers was difficult to relate back to our Canadian Act. It was, therefore, necessary to devise a simple test procedure to measure the comparative mixing efficiency of a number of types of units. Using this information about mixers, together with other important characteristics such as cost, operating performance and mechanical reliability, it was then possible logically to select the best unit evaluation.

The grade chosen for the test was 12-24-24 since it had given a great deal of analytical problems in the past and therefore was known to be difficult to blend. The formula employed was as follows:

Ammonium Nitrate	150 lbs.
Diammonium Phosphate	1050 lbs.
Muriate of Potash	800 lbs.
Total	2000 lbs.

To reduce variation caused by raw material variability and weighing errors, all material was pre-assembled in bags at our Beloeil Works. The stocks of test material were sampled to establish their average chemical analysis. From this stock sufficient bags for each test were chosen at random and dispatched to the various test sites. At the test site attempts were made to simulate as closely as possible actual plant operating conditions. Materials were dumped from bags to tractor buckets and then moved to weigh hoppers. The order of addition of materials to the weigh hopper adhered to the local plant practices. In the case of retention type mixers the mixing times recommended by the manufacturers were employed. Samples were obtained with a standard bulk stream sampler. The normal discharge time of the mixer was determined and divided equally so that between 10 and 20 samples were obtained. All samples were taken as close to the mixer discharge as possible to reduce the effects of post mixer segregation.

In order to reduce the chances of sampling and analytical variation, the same person took all the samples and the same laboratory did all the analysis. The analytical results obtained for nitrogen, total P205, and K20 on each series of samples were listed and averaged. The standard deviation was calculated for each plant food in each series. Using the calculated standard deviation and the tolerance as a basis, the mixing efficiency index for each mixer was calculated.

This index indicates the chance of a 10 grab composite sample, taken from the discharge of the mixer, meeting the requirements of the Fertilizer Act if the grade was formulated to exact strength, that is, no overage allowance made. The mixers tested in descending order of mixing efficiency were as follows:

Mixer Type	M.E.I.
Retention - Rotary Drum	100
Type A - Screw in Centre	
Volumetric - Variable Speed Auger	100
Retention - Rotary Drum	100
Type B - Large Heavy	
Retention - Horizontal	69
Retention - Rotary Drum	63
Type C - Cement Mixer	
Retention - Horizontal Auger	44
Mixer Type	
Gravity	38
Transblender	38

OUR CONCLUSIONS:

1. Well-designed Retention and Volumetric Type mixers achieve better mixing than the Gravity and Transblender Types tested.
2. The Mixing Efficiency Index offers a useful statistical tool for forecasting mixer performance capabilities and for estimating the overage levels required in formulation to meet the requirements of the Fertilizer Act.
3. Future plants should be designed only around mixers of known performance capabilities. Any mixing device, employed in the future in a Company or Company-sponsored plant, should score an M.E.I. of 100 on a 12-24-24 mixer trial. Although this requirement may appear stringent, it is considered practical for the following reasons:
   - (a) Mixers with capabilities of this order are commercially available, and in some cases are less expensive than less efficient types.
   - (b) The average strength of fertilizers is steadily increasing, so that an ability to mix high strength grades effectively will be of ever-increasing importance.
   - (c) It should be recognized that mixing efficiency is only one factor affecting plant performance. Other factors such as misweighing of input, contamination of materials, operator errors and post-mixer segregation may all tend to degrade the material. It is, therefore, essential that an efficient mixing device be employed so that even with the possibility of degradation, an acceptable record can be achieved.

From the mixer we then go to an elevator for shipment in bulk or to the bagging unit.

In most of our plants we are using our own plastic valve bags, this being a pillow type bag with the valve on the side. However at some of our locations, particularly the units servicing the tobacco farms, we use open top polythene bags which are best sealed at the blend plant.

All Agromart sites are equipped with small offices and display rooms showing the farm products we are merchandising. Each Agromart also has areas for heated and unheated pesticide storage, feed pre-mixes, and farm supplies such as bailer twine and plastic.

The handling of anhydrous ammonia in eastern Canada requires that you own your own siding which is then referred to as a private siding, or if you are using Department of Transport Control sidings you must obtain a permit for the temporary transfer of anhydrous ammonia from railway cars to nurse tanks.

Therefore, in order to have complete control of the unloading of anhydrous ammonia it has been our practice to build and operate private sidings wherever possible. The use of Propionic acid for the storage of corn will be increasing and we will be ready.

OPERATIONS

From a production standpoint the major items controlled by the operation group are as follows:

SAFETY

Our safety policy in the blend plants is as follows:

1. The safety of employees is a matter of the greatest importance to the management of CIL, ranking equally with production, sales, quality of product and cost.
2. The Company's goal is the prevention of all accidents in its plants, laboratories, warehouses, and other places of work, since only by achieving this goal can all personal injuries be prevented.
3. In pursuit of this objective each member of management and supervision is held accountable for the safety of employees within his jurisdiction.
4. The company has an obligation to take all reasonable measures to provide safe working conditions and to assure safe work practices.
5. The company expects every employee to recognize that he has a vital part to play in preventing accidents, and an obligation to work and act safely at all times for his own welfare and that of his fellow employees.

In our blend plant operations we have a zero frequency rate for our to-date position in 1970.

In all the C-I-L operations we employ 7,800 employees, and our frequency rate to-date stands at 1.81 injuries per million man hours worked.

We plan to do even better.

HANDLING LOSSES

We have established handling loss guide lines for all operating units and the provision for handling loss is incorporated in our forward plan as follows:

On all goods received in bulk and shipped in bulk 3/4 of 1%.

All goods received in bulk and shipped in bags 1-1/2%.

Any plant that is operating within these guide lines is considered to be under control, and any unit beyond 2% is considered to be out of control, requiring remedial action.

As could be expected, the major contributing factor has usually been overall carelessness in the handling of raw materials and the housekeeping levels on the site itself.

The calibration of scales is frequently a contributing factor.

However, one of the major items that causes excessive handling losses has been found to be bag weights. While using commercially available baggers that we can economically justify for a relatively small annual bag tonnage, the operator must constantly check and re-calibrate in order to walk the narrow line between light weight bags and excessive handling losses. It is virtually impossible to split up 2,000 lbs. into 40 bags of 50 lb. each and have the bags all meet the rules of the Department of Weights and Measures (which allow us only 2 oz. of tolerance) and still not give away excessive amounts of product.

In our plants the foreman operator has the responsibility for inventory control and is held accountable for handling losses. We find this an area that requires considerable training, as the normal new employee has difficulty understanding the significance of these handling losses.

ENGINEERING AND MAINTENANCE

One of the first requisites of the foreman operator is that he have a good local image and be able to meet and talk with the customers that come to the plant for service.

This has given us a group of foremen who are sales oriented and sometimes, therefore, may lack maintenance skills. This has been a problem in a couple of locations, and will become significant as our plants become older and require more maintenance.

Our plant operators group supplies staff assistance to the fine organization in Engineering and Maintenance.

FORMULATIONS

All formulations for our company-owned joint ventures and franchised locations are run on the computor.

We are using a system whereby we run 20 formulae for each grade that the site expects to sell, and the sheets are printed so that the least cost formula shows as No: 1 and the penalty in dollars per ton is calculated for each variation from least cost.

We have found this system a tremendous advantage during times of raw material shortage. We are able to quickly evaluate the cost of changing our formulation policy. Once we have decided to make a change, the plants are notified immediately to change from say No: 1 formula to No: 6 formula. Therefore, within a very short time, all locations can be alerted to fit the new raw material situation.

RAW MATERIALS AND POLY BAGS

The Plant Operations Section co - operates with our Purchasing Dept. in the setting of raw materials specs for the blending operation.

We have very tight manufacturing and sales specifications on our raw materials coming out of our company-owned plants, particularly our Lambton works, and we have found other manufacturers, particularly the potash industry, have difficulty meeting our specs.

We also work closely with our Plastics Division on improvements in our poly bags and have developed a side valve poly bag that is being used in many of our company locations.

STAFF AND LABOR

In our rapidly expanding situation the Plant Operations Group becomes continually involved in the choosing of foremen and the training of operational people at the various Agromarts.

QUALITY CONTROL

We have completely automated the mixing timing cycle so that the operator is not able to rush the raw materials through the equipment without being properly mixed. The driver on the front end loader pushes one button to start the sequence and gets a green light when the weigh hopper is ready to receive the next batch.

Mr. Horton will detail some of our quality control systems for analytical works.

MODERATOR JOHNSTON: Our next panel member, Howard A. Horton, has a background in the technical field as well as the commercial aspects of the business. Howard has a masters degree in Agricultural Science from the Agricultural College, University of Toronto. His first job, after leaving the University, was with the Canadian Government in Soil Research and one of the research stations that devoted its attentions to tobacco crops. After leaving the Federal Government he joined C. I. L. He has filled positions as agronomist, field salesman, sales supervisor, district sales manager, and is now in Montreal filling the role of technical sales manager at C.I.L. Howard will talk to us about "Quality Control and Agronomic Aspects."

Quality Control and Agronomic Aspects

H. A. Horton

TECHNICAL SERVICE MANAGER
CANADIAN INDUSTRIES, INC.
MONTREAL, CANADA

FERTILIZER REGULATIONS

A few years ago the industry record in producing fertilizers which conformed to the analytical standards of the Canada Fertilizers Act was far from good. It became evident that action was required and in addition to stringent measures taken within the Industry a Technical and Federal Affairs Committee of the Canadian Fertilizer Association worked closely with regulatory officials of the Canada Department of Agriculture on this problem. The conclusion was reached that wider tolerances were required to avoid a significant increase in cost of fertilizer carrying no increase in value to the farmer. The economic state of the North American fertilizer industry gave cause for very serious concern both within and outside the industry. It was therefore important that money not be wasted in trying to achieve a level of uniformity in mixed fertilizers which would not show a return to the farmer for the increase in cost which must eventually be passed on to him.

The recommendations of the committee were acted upon. There was need also for more flexibility in the preparation of formulae for customer-formula fertilizers. Accordingly, in February 1969 the Regulations pertaining to the Canada Fertilizers Act were amended extensively, the main changes pertinent to this paper being:

1. Registration of all mixed fertilizers other than fertilizer - pesticide mixtures was discontinued, although these fertilizers still remained subject to the standards, guaranteed analysis and labeling requirements of the Regulations.

2. Guaranteed Analysis. Provision was made for expressing guarantees for nitrogen, phosphoric acid and potash in custom-formula fertilizers in less than whole numbers. Particularly with customer-formula fertilizers containing pesticides, it was difficult to formulate with whole number guarantees for N,P2O5 and K2O, hence this exemption. All other mixed fertilizers are still required to state these guarantees in whole numbers only. Guarantees for the secondary major elements -- magnesium, calcium and sulfur, are expressed as the minimum percentage of the element rather than in the oxide form in pounds per ton. This change was made to achieve uniformity in the methods of expressing guarantees.
Guarantees for the minor elements or micro nutrients are expressed as the actual percentage of the element present, since most of these nutrients can be detrimental to crops when present in excessive amounts.

3. Labeling. The cautionary statement required on the labeling of fertilizers containing micro nutrients with toxic properties (zinc, copper, boron or molybdenum) has been simplified to read as follows:

"Caution -- This fertilizer contains (name of micro - nutrient(s)) and should be used only as recommended. It may prove harmful when misused." The new Regulations exempt specialty fertilizers from this labeling requirement.

For customer - formula fertilizers not containing a pesticide or micro nutrient with toxic properties, the requirements are that at least one package in each lot or shipment, or the shipping bill in the case of a bulk shipment, show the name of the person requesting the fertilizer, the number of packages in the lot, the grade of the fertilizer and the net weight of the shipment.

However, for customer - formula fertilizers that do contain a pesticide or micro nutrient with toxic properties, the labeling requirements are more involved and, we think, are rather cumbersome. Each label or shipping bill must show the grade of the fertilizer for the total mixture, the cautions to be observed, the name and amount of each micro nutrient, the name and amount of the active ingredient of the pesticide, the directions for use where the fertilizer contains a pesticide, the name and address of the customer requesting the fertilizer and the net weight of the shipment.

The former Regulations did not permit names of crops other than tobacco to be shown as part of the name of a fertilizer. The new Regulations do permit the showing of crop names as part of the fertilizer name. This change was made since many fertilizer recommendations make reference to a specific grade or ratio for each crop.

4. Standards. Now I shall discuss some features of the new Regulations which are probably of more direct concern to the bulk blender in Canada than those previously discussed.

In addition to the requirements of minimum guarantees for total nitrogen, available phosphoric acid and soluble potash, every mixed fertilizer containing two or more major plant nutrients must have a combined nutrient level determined on the basis of an analysis equal to or greater than the combined nutrient level determined by calculation from the guaranteed analysis. In other words, the mixed fertilizer must meet the requirements of the combined nutrient level and also the individual tolerances as set out under the Regulations. The tolerances of the major plant nutrients are as follows:

N tolerance equals 0.3% plus 1/10 of guarantee
(total not to exceed 1.0%)

P2O5 tolerance equals 0.3% plus 1/10 of guarantee
(total not to exceed 2.0%)

K2O tolerance equals 0.3% plus 1/10 of guarantee
(total not to exceed 2.0%)

The combined nutrient level (C. N. L.) is calculated by adding the amount of total nitrogen multiplied by 2.5, the amount of phosphoric acid multiplied by 2.0, and the amount of soluble potash or

$$C.N.L. = (N \times 2.5) + (P_2O_5 \times 2) + K_2O$$

Although the Regulations state that C. N. L. as calculated from the found analysis must be at least equal to the C. N. L. as calculated from the guarantee, it is recognized that the analyst's findings are subject to analytical variation and sampling error, so administratively the C. N. L. for the found analysis is considered satisfactory if it is at least 98% of the C. N. L. for the guarantee.

The following examples illustrate the application of these Regulations:

Example No.1	N	P_2O_5	K_2O
Guaranteed Analysis	15	15	15
Found Analysis	14.4	13.6	16.7

(a) Individual nutrient tolerances -not in violation (see above)

(b) C.N.L. of guarantee = (15 x 2.5) + (15 x 2) + 15 x .98 = 80.85

C.N.L. of found analysis= (14.4 x 2.5) + (13.6 x 2) + 16.7 = 79.9

Although the found analysis is within the individual nutrient tolerances, the sample is not acceptable, as C. N. L. of found analysis is deficient.

Example No. 2	N	P_2O_5	K_2O
Guaranteed Analysis	6	24	24
Found Analysis	6.6	22.1	25.9

(a) Individual nutrient tolerances - not in violation

(b) C.N.L. of guarantee = (6 x 2.5) + (24 x 2) + 24 x .98 = 85.3

C.N.L. of found analysis = (6.6 x 2.5) + 22.1 x 2) + 25.9 = 86.6

Sample is acceptable. In this case the C. N. L. of the found analysis is sufficiently high to compensate for the variation in P2O of 1.9%.

The new Regulations provide for greater deviation from the guarantees than did the previous administrative tolerances. However, the overall effect of the individual tolerances when coupled with the combined nutrient level requirement is to insure that in terms of total plant food, full value is received, while permitting a degree of variation which is feasible in terms of present day manufacturing capabilities. The degree of variation permitted does not reduce the overall utility value of the fertilizer.

Summarizing the regulations, the new revisions (1) provide labeling requirements which make it possible for farmers to establish whether they have been delivered the grade of fertilizer ordered and (2) permit the fertilizer trade to develop economies in scale of operation that result in a lower net cost of the fertilizer without any loss in essential fertilizer value to the farmer.

SAMPLING

Under the new regulations the number of deficient samples was reduced by about 50%, but there still remains much room for improvement. The Technical Committee study referred to earlier emphasized that one of the problems is in proper sampling, and bulk sampling methods in particular present concern to the industry. It was noted that the percentage of deficient samples increased markedly in May and June when a high proportion of the samples were taken from bulk shipments.

In an attempt to improve sampling techniques, the Canada Department of Agriculture has recently issued a directive to the inspection staff providing new instructions for sampling using the Missouri D-probe trier for sampling bulk fertilizers. This trier, 54 inches long, is used in the vertical plane, and is inserted in the open position to its full effective length where possible, then closed and withdrawn. An official sample is composed of 10 cores from the bin or pile taken in a predetermined sampling pattern. Bulk fertilizer may also be sampled from the stream as the fertilizer is being transferred or loaded into or out of a bulk container such as a truck body, bulk spreader or tote box. The sampling cup should be at least 3/4" in width and at least as long as the width of the stream. The cup is passed across the stream at least 10 times at the same rate of speed to collect the official sample.

Bagged fertilizer is sampled with a trier in the length range of 26" to 36" and is used in the horizontal plane. It is inserted to its full effective length diagonally through the container, rotated and withdrawn so that it will remove fertilizer from each part through which the trier travelled. When a single tube trier is used, it is inserted with the openings down and withdrawn with the openings up. For lots or shipments of eleven bags or more, equal portions are drawn from any ten bags. For ten bags or less, each bag is sampled to make up the official sample.

It is too early to assess fully the effectiveness of the new sampling procedures, but we are convinced that a real progressive step has been taken.

SEGREGATION

It is recognized that segregation is one of the main problems in quality control of blended fertilizers. Handling procedures which allow the mixed product to drop and form a cone lead to an undesirable degree of segregation. Studies by T. V. A. and others have shown that segregation is controlled mainly by the size characteristics of the granules. It has been concluded also that a prill - granular blend is more prone to segregation than a granule - granule blend.

In order to determine the magnitude of the segregation effect on large quantities of bulk blends when using normal solids handling procedures, Canadian Industries Limited conducted some large scale plant tests on two high-strength blends, 15-15-15 and 6-24-24. All raw materials were 90% or more in the 8-14 mesh (Tyler) size range. One hundred tons of each grade were blended batchwise in a 1-ton rotary mixer at Chatham, Ontario and transferred to storage bins to form a cone-shaped pile. Each of the 100-ton piles was then transported by truck to Ingersoll, Ontario, 90 miles distant, and again poured into storage bins. Thirty tons of each grade were removed from the piles at Ingersoll to simulate normal distribution methods (tote-box, bulk truck and bagging). The fertilizers were sampled extensively at the key stages of these tests, both by CIL and by inspectors of the Canada Department of Agriculture. The Department cooperated fully in the tests, being largely interested in establishing the accuracy of sampling large quantities of blended fertilizer.

The results showed that both grades suffered serious segregation after a single coning, although 6-24-24, a granule-granule blend, was not as severe as 15-15-15 which was a prill-granule blend. The standard deviations for the plant food concentrations increased by a factor of three for the latter product, compared with an increase of about two for 6-24-24.

The second coning of these products after transportation to Ingersoll appears to have caused little change in analysis. For each of the 30-ton lots sampled, the results indicate a similar occurrence of deficient material in each 100-ton pile, as was indicated by the results after the grades has been coned only once. Therefore, further handling did not appear to significantly increase segregation, or result in re-mixing.

These tests show that large-scale blending and storage of high-strength fertilizer is impracticable if the fertilizer is "coned," even using closely size-matched raw materials.

STORAGE PROPERTIES

To gain more information on the storage properties of blended fertilizer, CIL selected for testing a series of seven blends ranging in content of ammonium nitrate from 1.9% to 41.3%. The tests were designed to evaluate storage properties in bags only. Burning tests were carried out on some of the grades which have potential "cigar-burning" properties. The grades tested, together with formulations are listed in the table below.

The formulation selected to represent each grade is based on the maximized use of M. A. P. and ammonium nitrate consistent with a maximum filler content of 700 lb. per ton of blend. Where necessary, granular superphosphate was used to hold the filler content to this value. Ammonium nitrate prills containing the C and I additive (a special grade of finely divided clay) were used in the test as a main nitrogen source. The size range of the raw materials was restricted to 8-14 mesh. The batches were bagged and stacked and weight placed on top of the blends to give a stack equivalent to 20 bags high.

After nine weeks of storage, one bag of each grade was removed carefully from the pile before inspection for caking, and the remaining bags were each dropped once from waist height before examination. Examination of the undropped bags showed that some degree of caking had occurred in all blends, and in general the amount of caked material increased with the ammonium nitrate content. The cakes in all cases were very soft and could not be moved from the uncaked material without extensive breakdown. The material in the dropped bags was found to be completely uncaked for all grades, giving confirmation of the lightness of caking under the test conditions.

Each of the blends was subjected to thermal cycling of twelve 4-hour cycles between 60 degrees and 120 degrees F. under a moderate pressure of 2.5 pounds per square inch. These tests showed caking in the high nitrate blends only, and again these cakes were very soft and were restored to granules by application of light finger pressure.

The three high nitrate blends, 10-10-10, 15-15-15 and 16-8-8 fall in the marginal burning zone of the ternary diagram used in estimating cigar-burning potential of blends. Therefore, these three blends were tested, and the results showed these to be safe at temperatures below 175 degrees F., thus being safe under all normal storage conditions.

AGRONOMIC ASPECTS

Very little doubt remains regarding the agronomic value of blended fertilizers. When properly made, they are equal in quality and performance

SUPER	MURIATE OF POTASH	FILLER	GRADE	A. N.	M.A.P.
0-20-0	0-0-60			34-0-0	11-48-0
	533	96	8-32-16	38	1333
293	400	700	6-12-12	229	378
156	267	700	8-16-8	275	602
	667	184	10-20-20	316	833
139	333	700	10-10-10	469	359
	500	200	15-15-15	675	625
	267	573	16-8-8	827	333

to homogeneous granulated fertilizers. Even should there be some slight segregation, the agronomic performance is quite satisfactory because the requirements of crops for the major plant nutrients are not all that precise. We now have sufficient evidence from use by research stations and by practical farmers that blended fertilizers and homogeneous granulated fertilizers are quite comparable in producing yield and quality of crops.

Modern fertilizer technology has shown how to produce dry materials of such a size and shape that they tend to cling together once they are properly mixed. The chief variation in flow characteristics is between prills and granules. Correct and uniform sizing of particles is very important, and we prefer 7 to 12 mesh (Tyler) which are the specifications for our own production at our Lambton Works. For example it was not possible to prepare suitable blended tobacco fertilizers until the potash producers developed properly sized granular sulfate of potash. Now the tobacco crop, which is an excellent indicator crop in that it readily shows deficiencies and excesses of plant food, can be and is being produced quite satisfactorily with blended fertilizers.

Customer acceptance of blends is now fairly general in eastern Canada, but the transition from homogeneous granulated has not been immediate. After all, most of the industry, ourselves included, exerted much effort a few short years ago in extolling the superiority of granulated fertilizers, and farmers were persuaded of this. Little wonder, because the free flowing granulated was a far cry from the traditionally "cured" fertilizer that all too frequently assumed tombstone - like hardness by the time the farmer was ready to use it. However, the natural reluctance to change from a product satisfactory in quality was for the most part overcome by the convenience and economy offered by the local blend plant in meeting individual requirements. It remains for the blend plant operator, on his part, to be continually vigilant in continuing to provide a quality product which conforms to the standards established.

I feel this paper should not be completed without some mention of formulations that have been found to be unsatisfactory from an agronomic viewpoint. For some time now various authorities in agronomy have indicated that caution should be exercised in the use of diammonium phosphate in starter fertilizers for corn and cereal grains. Researchers at the Department of Soil Science, University of Guelph, and at the Ridgetown College of Agricultural Technology have done work which supports this position. When urea is combined with D.A.P., yields are further depressed, and this fact resulted in a resolution being made by the Eastern Ontario Soil and Crop Improvement Association some time ago to the effect that manufacturers of blended fertilizers should be required to state on the label if urea was contained in the mixture.

Further evidence of the effect of urea and/or D. A. P. on the growth of corn was presented last year at an American Society of Agronomy meeting at Cornell University by Dr. W. S. Reid in a paper entitled "Methods of Application of Phosphorus and Potassium Fertilizers for Corn in New York: A Summary of Recent Research." One paragraph follows:

"Compounds of mixed fertilizers differ considerably in their tendency to produce unfavorable conditions. Some of the more recently introduced components of fertilizer with high potentials for forming unfavorable conditions are urea and diammonium phosphate. Both of these compounds either together or alone have a high potential for producing unfavorable conditions, yet they are used extensively as a source of nitrogen and/or phosphorus. The older fertilizer sources such as ammonium nitrate and concentrated superphosphate are much less likely to be harmful. Thus, in the last few years the probability of adding harmful quantities of fertilizer in band placements at seeding have increased greatly, because of the introduction of urea and diammonium phosphate and because the quantity of fertilizer added at planting time has increased."

The problem is obviously too high a concentration of ammonia in proximity to the seed causing germination injury. Authorities agree that a much more desirable source of nitrogen and phosphorus for starter fertilizers is mono ammonium phosphate, in which there is less concentration of ammonia, and our starter fertilizers (those having a N:P2O5 ratio of 1:4 or wider) are formulated with M. A. P.

It should be emphasized, however, that these remarks concerning urea and D. A. P. have validity only with starter fertilizers placed in proximity to the seed. Fertilizers containing urea and D. A. P. are not harmful when broadcast, plowed down or other wise placed farther away from the seed.

MODERATOR JOHNSTON: Our third and final panel member is Don P. Brady, who will review the C. I. L. Agromart Program.

Don is a graduate of Mc Donald College. He has a bachelor's degree in economics. He has been in industrial sales and market research. Don is a member of our Task Force. He handled the C.I.L. ammonia plant in Ontario and various other positions viz: product manager, district sales manager, and now merchandising development manager.

Implementing the Agromart Concept

D. P. Brady
AGROMART DEVELOPMENT
CANADIAN INDUSTRIES, LTD.
MONTREAL, CANADA

The objective of the "agromart" program is a chain of blending plants in relatively high consuming areas to blend and distribute fertilizer and sell a group of complementary products and services such as seeds, pest control products, feed concentrates, custom application and other inputs that the farmer purchases.

This objective developed from the conclusion that under eastern Canadian conditions, (1) blending, distribution and marketing of fertilizer products is more economically achieved from decentralized locations, combining the economics of warehousing, mixing and dealer functions. (2) the combining of other product lines in the merchandising package assists in absorbing fixed costs, which, as is well known, are proportionately large in the highly seasonal fertilizer industry; and (3) the total marketing effort would be more successful and profitable if fertilizers were promoted and sold as part of a package of retailed farm inputs and services fulfilling an economic service to farmers.

MARKET IDENTIFICATION

The first step in implementing the program is to identify localized market areas where the intensity of agriculture will provide a market of sufficient size to support the investment required in blending and other facilities.

Although considerable knowledge of various areas is obtainable from the experience developed by the sales staff over the years, this is confirmed with more detailed statistical research and surveys against the background of an increasing rate of farm consolidation and of improvement in the technological and management ability of the farm operator.

For example it is predicted that the farmers of tomorrow will be only 20 percent in number of those statistically classed as farmers today, and will purchase annual inputs for their operation averaging in the order of $25,000 each.

Trends in cropping and marketing of crops: i.e., cash cropping or conversion of crop through livestock, poultry and hogs, is also an important factor in assessing the market potential. Sources of information include government and trade association statistics and interviews with personnel of departments of agriculture, agricultural faculties of colleges and universities, agricultural research farms and stations, and prominent farmers.

Once this information has been collected and digested, market projections are made for the area, and the share of the market that the "agromart" should reasonably obtain is predicted. In projecting the proposed "agromart" sales, consideration is given to the type and aggressiveness of competitive outlets in the area.

Based on the projections, a decision is made on the type and magnitude of blending capability best suited for market conditions of the area. That is, should the unit be built to handle, mix and ship bulk fertilizers only, or do the conditions warrant the provision of bagging facilities. Generally, it is found that this is a function of (a) the intensity of agriculture in the area, or (b) the types of crops grown in the area.

In areas of high intensity, with corn and potatoes the predominate crops, a bulk only unit provides the best return on the investment required. This is because the cropping practices in the area are adapted to utilize bulk fertilizers economically. Also, in such a high intensity area, the market area of the "agromart" is relatively small geographically so that it can achieve a high and economical utilization of its distribution equipment.

Other areas of relatively high intensity may exist, with crops such as tobacco and/or fresh fruits and vegetables the predominate crops. In these areas, the cropping practices are such that bagged fertilizer is the market preference. Bagging facilities are thus required.

In areas of lower intensity, the demand for bagged fertilizer in proportion to bulk fertilizers is high, and the size of market area the "agromart" services is of necessity larger in order to achieve a profitable sales volume. In these areas, therefore, bagging capability is provided.

In addition to "sizing" the blending facility, information is developed to assist those responsible for design in the development of other facilities required for the handling of other product lines.

TYPES OF "AGROMARTS"

a) JOINT-VENTURES

Studies and consultations indicated that the success of a local agro-business, including the blending of fertilizer, depended heavily upon the initiative, resourcefulness, and the marketing and managerial ability of the operator. The success is a function of the operator's commitment to the business. Based on the observed experience of other businesses, it was concluded that a manager is most committed when he has a financial interest in the business he is operating. Indications are that in the majority of cases, superior performance is achieved with an owner-manager operation compared with a unit operated by corporate personnel. Thus a joint-venture scheme was conceived whereby C-I-L and an agribusiness merchant would become partners in an "agromart" operation.

In essence, C-I-L brings technology and financial assistance to the partnership, and the agribusiness merchant contributes local marketing and managerial know-how.

The advantages of such a partnership to C-I-L are:

1) It achieves the objective of having the business managed by a committed manager.

2) It provides detailed marketing know-how for the specific area;
3) It minimizes the company's direct investment in new fixed capital;
4) Although, C-I-L shares in only half the profits, present Canadian tax law enables the company to realize a greater return on equity because of a lower tax base.

The advantages of the partnership to the agribusiness merchant are:

1) It allows him to achieve increased market participation and profit by acquiring blending facilities with the sponsorship of a basic manufacturer.
2) It provides him with resources that only a large basic manufacturer can provide in the form of technology, up-dated product information, and managerial and financial assistance.
3) As there is no capital gains tax in Canada, as yet, it presents the opportunity for a tax-free recapture in cash of part of his equity built-up over the years.
4) It provides an opportunity to leave a viable and growing business for his heirs.

Once the market area has been defined and evaluated, a survey of agribusiness merchants operating in the area is undertaken to identify those with the desired characteristics.

The method used to form the joint-venture is for C-I-L and the joint-venture partner to incorporate a new company of which C-I-L and the partner hold equal shares, that is the interest in the business is on a 50/50 basis. A shareholder's agreement is drawn up which specifies the number and nomination of directors. It empowers the joint-venture partner to appoint or elect the president (usually the partner) and vice-president, defines the limits of the authority of officers, and sets out the conditions and terms whereby either partner may sell or acquire shares in the company.

The new company is formed with a minimum amount of equity which varies according to the volume of business anticipated. Fixed capital requirement, mainly for the blending facilities, is financed with a term loan from a chartered bank, and operating capital is also financed from the bank, utilizing inventories and accounts receivable as collateral.

The new company purchases the assets and goodwill of the partner's former business, and constructs the blending facilities to C-I-L's specifications.

The new company enters a franchise agreement with C-I-L which defines the market area in which the new company will operate, specifies that the franchisee shall purchase fertilizer ingredients and other farm input products that C-I-L presently sells or expects to sell in the future, and permits the franchisee to use the C-I-L "agromart" word mark. The agreement also defines C-I-L's obligations to train the franchisee's personnel in product knowledge, sales techniques, management techniques and plant operations. C-I-L also is obliged to provide least cost formulations for the blend plant operation.

Prior to completing the agreements and incorporating the new company, C-I-L projects the sales, costs, and expenses of the proposed new company for a five year period to ensure that the operation can reasonably be expected to earn a return on the investment that is satisfactory to C-I-L and will be attractive to the proposed joint-venture candidate.

Although association with a satisfied progressive agribusiness merchant is the preferred joint-venture arrangement, it is recognized that there are areas where this could not be achieved. In these cases new joint-ventures are sought with suitable individuals such as with sales representatives with established positions in the agricultural community and with a strong entrepreneurial background.

COMPANY-OWNED UNITS:

In areas where a suitable partner can not be found, the choice would be to provide a wholly-owned C-I-L outlet with its attendant captive market and with a growing access to the market for other product lines as C-I-L's position becomes established. Some units would be on "green-field sites", while others would involve conversion of existing warehouses. It is foreseen that this type of operation might eventually evolve into a joint-venture arrangement if a qualified partner should be found.

Company-owned "agromarts" are managed by company personnel who are frequently the sole representation in the area. The operation is a profit-centre, and its results can be measured comparably against those of joint-venture.

INDEPENDENT FRANCHISE

In areas where large blocks of existing business are firmly controlled by dealers who are either uninterested or unsuitable for joint-ventures, or where the potential market is insufficient to justify a C-I-L owned outlet, it is sometimes necessary to come to a franchise agreement with an independent dealer. A franchise agreement is negotiated where, in return for assistance in such areas as access to capital, assistance with construction and operation of blending plants, use of C-I-L identification, participation in marketing programs and staff training, the franchisee would agree to give C-I-L first refusal on all requirements for materials and other "agromart" products.

COMPARATIVE ECONOMICS OF MARKETING FERTILIZERS

a) Joint-venture "agromart" agribusiness
b) Company-owned "agromart" abribusiness
c) Granulation/Dealer system

Table 1 indicates the comparative profitability of fertilizer marketing and distribution through the blending route combined with agribusiness, through a company-owned blending unit, and through the granulation dealer route, in a hypothetical area.

In all cases, it is assumed that 7,000 tons of fertilizer is marketed in the area, although experience indicates that the local service provided by blending units attracts more business than a dealer system. Net value of fertilizer sales would-be identical for the two blending outlets, but the granulation/dealer system would have a lower sales realization because of dealer discounts.

Gross profit on fertilizer sales would be the same for the two blending units, as inbound fertilizer materials are charged in at the same cost level.

Although granulation fertilizer materials costs are lower than blending materials costs, they are not sufficiently lower to offset the lower realizations.

Gross profit earnings on the other product lines are larger with the joint-venture operation, reflecting the attraction of the partnership with a viable agribusiness.

Production and delivery expenses are higher than those of a company-owned unit with the joint-venture operation because of the non-fertilizer operations. Production and delivery expense of the granulation route are double those of the company-owned blending unit, largely because of outbound freight costs to the point of consumption and warehousing costs in the market area.

Marketing and administration costs for the joint-venture operations are higher, because of a wider range of products and operations. Depreciation costs for the joint-venture operations are higher than the company-owned unit, which reflects the additional capital in grain and feed handling facilities. Hower, depreciation cost for the granulation unit and warehouses is a third greater than for the company-owned blender.

TABLE 1

	Blending Joint-Venture	Blending Co-Owned	Granulation Dealer
Sales-tons of Fertilizer	7,000	7,000	7,000
	$ '000	'000	'000
Value Fertilizer	450	450	414
- Grain	250	-	-
- Feed	200	20	-
- Other	100	60	-
	1,000	530	414
Gross profit -			
- Fertilizer	100	100	92
- Grain	30	-	-
- Feed	40	4	-
- Other	15	9	-
	185	113	92
Operating Expenses			
- Production & Delivery	65	35	70
- Marketing & Administration	35	30	30
- Depreciation	24	15	20
- Interest	10	-	-
	134	80	120
Profit before Tax:	51	33	(28)
Tax	17	17	(--)
Net	34	16	(28)
Partner's Share	17	16	(28)
Partner's Investment	50	150	200
Return on Investment (%)	34	11	-

The profit earned before tax reflects the benefits to be derived from considering fertilizers as part of a farm supply package. The granulation route, handling fertilizers only, is out of the race under the conditions hypothesized.

I am unfamiliar with the U.S. corporate income tax structure, but under Canadian regulations the tax rate on taxable income on the first $35,000.00 is less than half that on the excess over $35,000.00. This, of course, provides a distinct advantage over a company-owned operation where the earnings would incur a higher tax rate when the profits are accumulated prior to taxation.

QUESTIONS AND ANSWERS

MODERATOR JOHNSTON: That concludes our speakers on the panel, we look forward to an animated dialogue with the members of the Fertilizer Industry Round Table.

MR. SPILLMAN: Approximately what is the percentage dollar volume broken down: (1) Fertilizer sales and (2) Miscellaneous other items per average unit at one of your locations.

MR. JOHNSTON: I don't think I could give you a percentage figure at this stage in our development. I can say quite honestly, however, that predominantly in the area of fertilizers, as we project ourselves five years away, we feel the lines of the retail products, other than fertilizer products are rising very much more sharply than fertilizer.

MR. SPILLMAN: Can you give us the average breakdown facility cost, building and equipment for fertilizer use and miscellaneous facility costs for items other than fertilizer?

MR. SINCLAIR: I would say 75 to 80 per cent for fertilizer facilities, including the building.

MR. SPILLMAN: That brings me to my final question. For an economical operation, and I am assuming that facility costs are comparatively equal at a number of your locations, what is approximately the minimum tonnage of fertilizer put through needed to operate in the black?

MR. BRADY: I was hoping this question would not be asked. The addition of other product lines would assist in absorbing overhead of an operation such as this and sort of cloud over the break even point. I am sorry I don't have a reference with me so that I can give you an accurate figure.

MR. UDAY HATTIANGADI (Continental Oil Co.): Mr. Hornton discussed the problem of post-blending segregation. I was wondering why it is not possible to bulk blend and follow the blending operation with granulation so that segregation will not result. Is it not practical, or simply not economical?

MR. HORTON: It would be prohibitive to have granulation facilities at the local level or ship raw materials to a large granulation plant and back again. There is too much expense involved, principally transportation costs.

MR. HATTIANGADI: The next question I have is what percentage of the total fertilizer produced is consumed by the tobacco industry in Canada, in the United States, and in the world as a whole?

MR. BRADY: In the Province of Ontario Canada, 80,000 tons of tobacco is grown. I do not have figures here for tonnage in the U. S. and in the World.

MR. JOHNSTON: Don made reference to the fact that tobacco is grown only in Ontario, and predominantly that is correct. I think there has been some grown in the Prince Edward Islands.

MR. RICHARD L. GILBERT (American Cyanamid Company): I believe Mr. Sinclair made the statement that 90 percent of all samples taken actually meet his objective?

MR. JOHNSTON: The question is, do we meet our objectives?

MR. SINCLAIR: Before answering this, I should mention the 90 per cent. You people have all dealt, I presume, with government officials. Of course, we must be realistic and realize that you can't be perfect. We feel that 90 per cent is really what officials are looking for. We may be wrong, it may be 95% they are looking for. However, we have set 90 per cent, allowing for the errors we might run into. Your specific question is, how well are we doing? As far as my records are concerned, on the units that we have designed as outlined in my paper and the statistical results that we have back, I show 88 percent of the fertilizer going through these units in the past year has met government requirements. I should really round that off to the nearest 5 percent and just answer you with a flat "yes." We are meeting the 90% objective.

MR. GILBERT: You talked about specifications on your raw materials, and how tight they are. You talked 90 per cent particle size minus 8 mesh plus 14 mesh. Are you worried about interim sizes?

MR. SINCLAIR: Yes, we are. As you can appreciate, this is a complicated question. I frequently have discussions with potash producers. Generally, they are impressed or even amazed with the tightness of our specifications. We have our own products very closely matched and we use this as a guideline in the buying of our other raw materials, primarily potash and fillers. We have not been able to get potash that matches as closely as we would like. We have a grading system we use on suppliers and we certainly buy where we can get the product we want. We are a little disappointed that the potash industry has not moved up quite as fast as we have. We are moving into an area of quality, and as the people yesterday pointed out, this is one area where I hope some further improvement will be made.

As to fillers, many of these are supplied by local industries that are anxious to meet our specifications. We are large buyers of fillers because of our MAP - DAP base formulations. We have found these people very cooperative, and we are moving toward a very close screen analysis range. We hope the potash industry will move along with us.

MR. GILBERT: What do you do when one of your units is out of potash and you cannot use the close specifications?

MR. SINCLAIR: We mix it, we sell it, and we try to make a profit.

DR. RAISTRICK (Albright and Wilson): In locations where bulk blends are competing with a good class homogeneous granular, do you sell at equal prices, do you get a premium, or do you sell at a discount?

MR. BRADY: At the retail level, there is no premium for either product.

MR. LARRY LORTSCHER (Cities Service Co.): You pointed out that through bulk formulations at your various plants, you could easily make rapid shifts through your system if one of your products was short or long. I was wondering how does this square with the joint venture partner and franchise dealer insofar as they are taking a higher cost?

MR. SINCLAIR: This really breaks down into two parts. First of all, in company owned locations where we have complete control it is very obvious that we just make the switch. Because of our complexities and various types of outlets we can anticipate the raw material problem. If we come to a joint venture and can't get MAP, -- the same thing applies here as anywhere else. The operator looks at the penalties on formulation sheets and decides whether he is going to pay an extra dollar or two for raw materials. Frequently, because of the flexibility of these units and the fact that they are right at the point of consumption, the operator says to his customer, "I am sorry, I don't have any MAP and I can't make you the analysis you want, but I can give you a close ratio with my raw materials presently at hand." He has the other alternative of saying "My raw materials are higher cost on this formulation," as part of his cost.

MR. DON WARREN (W. R. Grace): We still use paper bags. I would like to ask you your bagging rate on plastic bags.

MR. SINCLAIR: So far as the plastic bags are concerned, I will divide this into two portions because we do use two different types, valve as well as open top. On the open top units, we normally operate, (I am referring to 50 - pound bags) at 20 bags a minute. At some plants we operate at a lower rate than that. On the valve units we have operated up to 20 - 22 per minute. These are twin units and we are talking about eleven bags, per minute, per spout. This is too fast as far as we are concerned, therefore, we arbitrarily set a limit of 16 bags per minute coming off two spouts. This is fast enough and fits in with our process equipment. The other thing is we are a little bit concerned about segregation in the valve bags, if we blow it in too fast.

MR. WARREN: How many people do you ordinarily have employed in one of your agri-marts. I am especially interested in those involved with fertilizer?

MR. SINCLAIR: We have varying sizes of agri-marts. First of all, we have a highly seasonable type of operation. We had one firm using a full-time employee, the only man on the site. He goes out and does quite a bit of selling. He will respond to our sales manager or district sales manager who may have one or two plants under him. Going into some of the other units, our plants are designed to be very flexible. Taking a typical agri-mart, I will refer to our operation in Quebec. This particular plant has a joint-venture manager. He has one regular employee in the plant most of the time. When this unit starts to bag they hire another man. Much of the year this plant operates with three men. They bag up the fertilizer and load it on trucks, get in to the trucks and go out and deliver. I don't need to tell you this is very efficient. The unit runs with three men and will move up to four as the season comes in. At the height of the season, this plant will have five men. One agri-mart in particular, in Ontario, now operates the bagging unit with one man. He is a pretty versatile type fellow. He weighs material out, puts two tons in the mixer, two tons in the weigh hopper and two tons in the bagging hopper giving him six tons. He bags it off, jumps onto the lift truck and delivers it to the customer's truck.

MR. WARREN: I have one more question. In your presentation, you said you hold the manager responsible for the safety of the employees under his supervision. In what manner and to what degree do you hold the manager responsible?

MR. SINCLAIR: The manager has his responsibility like anyone else to the Board of Directors. We hold men responsible and the ability of our manager to operate a plant safely is a very important part of his progression through our organization.

MR. HAMMOND: (Chemical Construction Co.:) I gather from what was said this morning that this agri-mart concept was used officially in Canada. Does any one of the Panel Members foresee this marketing concept being used in the United States in the near future. Is it actually used to any extent now?

MR. BRADY: I am not too familiar with American producers. I think there have been joint venture arrangements in the blending aspects. I don't know whether we will bring the total package approach in the agri-mart concept to the United States?

MR. HAMMOND: Can you foresee its use?

MR. BRADY: I trust it is creating an interest.

MR. SPILLMAN: Our final speaker on this morning session is W. W. McGillivray, general marketing manager at Albright and Wilson, Yorkshire, England.

A Successful Marketing Program for Fertilizers in the United Kingdom

W. W. McGillivray
GENERAL MARKETING MANAGER
ALBRIGHT AND WILSON
YORKSHIRE, ENGLAND

What is success in a marketing venture?
It seems to me to be:--

1. Producing a product which fits the customers' needs.
2. Carrying out the sales, distribution and payment for the product in the most economical manner so that the optimum margin of profitability is obtained.

In order to do this one must

a) know the users' requirements.
b) learn the extent in volume and kind of the total present market and the potential for growth within that market, taking into consideration the trends of usage development.
c) balance the size of the production unit to the possible shape of the market (observing growth) and balance the selling strength to the market uptake possible from the production resources.
d) decide the optimum selling method for the size of the enterprise in the market place.

BRITISH MARKET

British farming is mixed farming, i. e., cereals, roots (these being mostly potatoes and sugar beet) and grassland. The fertilizer requirement for optimum yield is for: --

(i) a High Nitrogen fertilizer of a 2:1:1 ratio for cereals, i.e. wheat, barley and a much smaller acreage of oats, and grass.
(ii) a High Potash ratio fertilizer for the root crops (1:1:1 1/2, or similar).

Although the soil conditions vary from extremely light sands to very heavy clays in Britain, 72% of the total sales of compound fertilizers fall roughly into these two ratios.

TOTAL VOLUME:

In the year 1968/69 U. K. usage of N. P. K. compound fertilizers was 3.08 million long tons distributed as follows: --

England and Wales	2.45
Scotland	0.47
N. Ireland	0.16

The average concentration was: --

N.	15.61
P2O5 Water Soluble	11.31
P2O5 Water Insoluble	1.04
K2O	13.75
Total	41.71

As stated above, 72% of the total volume was distributed as follows: --

High Nitrogen	49.3
High Potash	22.8
	72.1

A. C. C. Division of Albright and Wilson Ltd. holds between 6% - 7% of the England and Wales market. We are, therefore, a small company but are fourth in size behind Fisons, I. C. I. and Shellstar who hold approximately 80% of the total market in the U. K. between them.

SUCCESS

This depends upon the capacity of the company to obtain the best balance or mixture of various factors and I propose to deal with these varying factors as they apply in this market to our own company.

1. Raw Material Costs.
2. Process Efficiencies.
3. Market acceptability of the product, both for quality and presentation, i.e. packaging.
4. The Company's market impact and coverage.
5. Closeness of contact with user and diversification.
6. Competitive Pricing.
7. Field Technical back-up.
8. Effective Publicity.
9. Accounting and Credit Control Systems, including the provision of credit.

1. RAW MATERIALS

Our raw materials are as follows: --

a) Nitrogen is provided in the cheapest form available as ammonia.
b) Phosphoric acid (Wet Process acid).
c) Potash, either as chloride or sulfate is imported: the bulk of the usage, however, is chloride.

As can be seen in the foregoing, where the concentration level generally throughout the country is over 40 units per cwt., concentration is essential in order to provide the lowest transportation costs of finished product and reduce labor costs on the farm. Traditional types of plants in the U. K. employed sulfate of ammonia and superphosphate, but these did not provide the highest concentration. Our new plant provides the concentration as well as considerable price advantages through the use of ammonia as a raw material.

Prilling was selected as the preferred manufacturing method because of the low initial capital cost and the low running cost. This process provides a final product of high yield from input raw materials, avoids the various disabilities of the large recycling units and has no gaseous exit problems.

THE PLANT:

(i) Ammonia is received by rail tankers and is stored in a refrigerated sphere.
(ii) Phosphoric acid is available at a concentration equivalent to 50% P_2O_5.
(iii) Potash, the bulk of which is chloride, is received by coasters to our own jetty.

2. PROCESS EFFICIENCIES

Initially ammonia is converted to nitric acid by a high pressure process yielding a rated 200 tons per day. The 58% nitric acid is neutralized with ammonia in a pressure neutralizer to form ammonium nitrate solution which is further concentrated in an evaporator and passed straight to the top of the prilling tower to produce prilled ammonium nitrate.

In the manufacture of N. P. K. compounds, phosphoric acid comes from the storage tanks to the neutralizer where it meets metered amounts of ammonium nitrate solution and a further injection of ammonia. This passes then to the ammonium nitrate phosphate evaporator and thence to the top of the prill tower where it meets finely ground and heated potassium chloride and thence to a rotary prill bucket. From then on, either prilled ammonium nitrate as such or prilled N. P. K. compounds passes to the cooler, is then screened, coated and stored temporarily in bulk storage before bagging. Approximately 5% offsize product is taken off at the screening station and passed back for recycle to the N. P. melt.

3. MARKET ACCEPTABILITY AND PACKAGING

a) The British farmer has been used to a craggy granule and, as fertilizer distributors are set to cope with these, normally a prilled product is very smooth and flows rather quickly compared with the conventional granule. The coating which we put on to our fertilizer has a dual effect:

(i) securing the keeping quality for bagged storage,
(ii) slows down the rate of flow in the fertilizer distributor and thus makes its behavior indistinguishable from that of the original granular type fertilizer.

As 90% of the final product falls between the range of 1.5 mm and 3.0 mm diameter, we are able to produce a standard product of even size manufacture which will have a constant distribution behavior in the field.

b) Packaging

Up to three years ago we indulged in the use of a rather nondescript plain package for our products, but it was decided that we should have something rather more distinctive and easily recognizable for the new prilled product. Most other British manufacturers have a ready identification for their product in the field by the color of their bags. We decided to be different and have a distinctive and striking design by which we could be readily identified.

The requirements were put to our advertising agents who came up with a distinctive design intended to identify us clearly with a prill motif.

4. THE COMPANY'S MARKET IMPACT AND COVERAGE

The Agricultural Section of A. C. C. Division is made up of four very old established companies.

> The first dealt entirely with merchants being based at a factory on Teesside. The second, which dealt mainly with farmers, had a factory in the East Riding of Yorkshire at Beverley.

The third, which had been largely farmer owned, had two factories situated in North Lincolnshire and dealt direct with farmers. The fourth in South Lincolnshire dealt almost entirely retail.

It has been our policy on the manufacturing side to concentrate our activities on the new plant and three of the smaller granulating plants have been closed down. Due to our closeness to our customers and our concentrated retail activity with farmers throughout the intensive arable area of the East of England, over which we operate, we decided that, due to our size, an extension of this with marginal trading to merchants outside this preferred area was the best way in which we could consolidate our position for the future. Although we have only a small proportion of the total market, we do take up between 18% - 22% of the potential in the areas in which we trade directly with the farmer. We consider that this is the most attractive method of marketing and one of our important strengths. The three giants in our industry market entirely through merchants and it will be readily appreciated that, had we followed their methods, we would find ourselves dealing with probably a large number of smaller merchants whose credit rating could very well be questionable. With our own method we have had direct contact and retention of the goodwill of the ultimate user, and our debtors are spread much more widely and in smaller units.

5. DIVERSIFICATION

Albright and Wilson's Agricultural Sector has a unique place in the market in England because we are the only major manufacturer, or manufacturer of the highest concentration product who offers an almost complete service to the farmer. Our total range of goods and services offered is as follows: --

Compound Fertilizers
Ammonium Nitrate
Other Straight Fertilizers -- Superphosphate, Granular Superphosphate, Ammonium Sulfate, etc.
Kainit
Kieserite
Basic Slag and Lime (mostly as Calcium Carbonate).

Our own manufacture of Compound Feeding Stuffs are sold by our direct selling representatives. We have within our Agricultural Sector a feeding stuffs manufacturing unit which also sells to merchants. We buy grain and this can be valuable as a contra against a fertilizer account.

We have an Agricultural Chemicals Sector offering a nationally branded range of products, and our retail representatives offer these in our direct selling area.

We grow and process cereal seeds and we offer grass and clover seed mixtures for sale. In addition to the above we operate a Contract Services Section which spreads fertilizers and sprays our full range of agricultural chemicals, whether these be foliar or residual herbicides, fungicides or insecticides. In this section we operate land service and also air service, using both fixed wing and helicopters.

In all we have a field staff of 50 direct selling representatives and four representatives who sell to agricultural merchants.

The British farmer, as will be well known, is something of a traditionalist, not only in his farming practice but also in his relations with his suppliers. It is a matter of some importance to him that we, as manufacturers and traders, have been present on the agricultural scene for a very long time and expect this to continue, e.g. all the constituent companies which go to make up our Sector were established before 1880 and one as early as 1828. We are now, therefore, dealing in many cases with the second and sometimes the third generation of farmers farming the same land. This is a matter of some importance because over this period of time we have gained, and guard jealously, our reputation for giving a fair deal over a long term.

6. COMPETITIVE PRICING

Over the past few years the Fertilizer industry in Britain has been suffering a downward spiral of realizations for its product. This has been due to several factors: --

(i) a pre-occupation of manufacturers with sales of tons, regardless of realizations, caused by a slight surplus of productive capacity
(ii) this has been exacerbated by the methods used to construct the pricing structure.

This whole situation proceeded gently at first until the market reached a bottom in the period June - August 1969. The pricing structure which helped this situation along was one where manufacturers used as a basis a list price for their products delivered on to farm. Merchants and farmers alike vied with each other to obtain the maximum knock - off this price. Merchants at that time enjoyed a system whereby they were placed on a basis of targets, realization of which brought them an end-of-season quantity rebate. They were, therefore, tempted to, and did, pass on every allowance and margin which they could receive from the manufacturer to their customer, leaving for their profit the expectation of the quantity rebate at the end of the season. This brought about a situation whereby all in the selling field were preoccupied with quantity to the exclusion of profitability. A change of heart, therefore, was necessary, and this has been achieved by changing the presentation of the prices to merchants in such a way that it is necessary for him, consciously and deliberately, to add a mark - up to his buying price.

Publication of a Farm Delivered price list has been discontinued, but the spring price is used as a basis for the arithmetic in arriving at a monthly selling price to merchants.

1. A standard percentage is deducted as a merchant's margin, with a haulage allowance dependent upon distance from factory or stores.
2. Monthly prices are then provided which are varied with incentives for: --
    (a) Out of season storage
    (b) Early payment.

This provides the merchant with an "all off" buying price at specified points month by month.

This changed system has discarded all deferred quantity allowance payments to merchants. Our retail representatives compete with merchants at the current levels in the market place.

In addition, strict adherence to charging the price ruling in the month of delivery is carried out. This type of system, with minor adjustments, is in general operation now in the country and has brought about a very large change in the market place where, for the first time in many years, some improved realizations are being achieved.

7. FIELD TECHNICAL BACK-UP

We have a field technical manager and a small group of technical advisors, all of whom have Bachelor degrees in Agriculture and are trained technicians. They provide product knowledge and husbandry knowledge to ensure that the farmer gets the best use from our products. At the same time we have a Soil Laboratory where soil analyses are carried out covering phosphates, potash and calcium requirements, and status levels are used as a confirmatory guide to the observations made by the technical advisors in the field. Some original research work and development work in new products is also carried out at this laboratory.

8. EFFECTIVE PUBLICITY

Our publicity takes the form of advertising nationally in farming newspapers in order to have a continuity of presentation of our product and its uses. We attend some agricultural shows, but these, as a communication method, are tending to be discarded in Britain in favor of demonstrations on actual use of products on particular crops, e. g. sugar beet and potatoes.

9. ACCOUNTING AND CREDIT CONTROL SYSTEMS, ETC.

It is no use selling a product if you are not going to get paid for it. It is equally no use trying to sell a product to a farmer without realization of his credit needs. In this context we are able to offer our farmers permissive use of credit facilities by adding to our compound fertilizer invoices (average price 35 pounds per long ton, $85) a credit charge of 4 pounds per long ton, i. e. just under $10. If they wish to take credit for the whole 10 months, then the net invoice price plus the 4 pounds becomes due at the end of the 10 months. If the account is paid in the intervening period, a proportional adjustment in the account of credit unexpired is given.

This method enables farmers to buy in spring and then pay after harvesting their crop. At the same time we are prepared to accept corn as contra payment against the account. Great difficulty is being encountered due to lack of cash resulting from the spiral of increasing costs and we have had to introduce penalties for non-payment. When an account outruns its credit period (no credit charge is given to merchants), then an interest charge of 1 1/2% per month is added.

These steps, firstly to provide credit facilities to our customers, and secondly to see that we get a proper return for working capital involved, are a very important strength of our overall marketing effort, particularly in our retail outlets which represent some 66% of our total sales.

We have in the last few years, by intensive training of our sales managers and sales representatives, greatly increased their measure of job satisfaction, particularly by making them feel part of a whole team and making them much more aware of the hard economic facts which go to make the operation profitable. The response to their increasing awareness of their accountability and responsibility has been most encouraging and successful.

Thursday, November 5th, 1970
Afternoon Session
MODERATORS: ALBERT SPILLMAN AND GRANT C. MARBURGER

Business Meeting

CHAIRMAN SPILLMAN: Secretary Marshall advised me this noon our registration at this time is 278. We estimate our final count at around 285. Registration for the previous two meetings, at Washington was, 1969 (279) and 1968 (356).

Housden Marshall has done the usual, excellent job of keeping the records of our Association for the past year, 1969-70, and he will now give you his report.

Secretary's Report

Housden L. Marshall
BALTIMORE, MARYLAND

Welcome. Glad you could come to our meeting. I have had excellent cooperation from Our Chairman, Officers, Committees and from our Membership. I thank you. My financial report is self-explanatory. To keep our Organization operating in the black, and figuring on the basis of a registration of approximately 300, it may be necessary to raise the dues per meeting to $25.00 or $30.00. This matter will receive a thorough discussion by Our Board of Directors during their next meeting in April, 1971, at Baltimore.

RE: 21ST ANNUAL MEETING, NOVEMBER 1971

SECRETARY MARSHALL: We have firm confirmation at the Mayflower Hotel, Washington, D.C. and at this hotel (Sheraton Peabody, Memphis) for the second week in November, 1971.

Financial Status:

November 1, 1969 Cash on Hand		$586.21
Income During 1969 - 1970.		
Registrations 1969	$5560.00	
Membership Lists 1969	360.00	
Reprints 1969 Papers	478.00	
Sales 1969 and previous Proceedings	1664.27	
		8062.27
Total Cash Handled 11/1/1969 to 11/1/1970		$8648.48
Disbursements 1969 - 1970		
November 1, 1969 to November 1, 1970		

1969-70 Meeting Costs	$3040.82	
1969 Proceedings Paid on Account	3535.21	
(Note Total Costs $4553.21. We still owe the printer $1018.00. This was Paid in Jan. 1971)		
Postage, Transcript, 1969 - 1970 Office, Secretarial, Miscellaneous	1078.18	
1969 Membership lists	167.00	
Total Cash disbursements		$7821.21
Cash on hand November 1, 1970		$827.27

Note: The balance of $827.27 corresponds with The Bank Statement as of November 1, 1970.

ASST. SECRETARY P. PROSSER: Mr. Spillman reported to you earlier that our registration as of noon was 281, and that the final count would show around 285. At our 18th annual meeting, Washington, D.C., 1968, attendance was 356; at our 19th annual meeting last year in Washington, D.C., attendance was 285. It would appear that there is no real change in attendance, due to a change in location of the meeting. I would like to suggest that we again hold the meeting in Memphis in 1971.

I would also like to comment on Secretary Marshall's suggestion that registration dues be increased from $20.00 to $25 or $30. The financial report shows a balance of $1018.00 due the printer, as of November 1, 1970. The bank balance on November 1, 1970 is $827.27.

Printing the Proceedings costs approximately 65% of our annual income. Our membership has insisted (and I am in agreement) that the Proceedings are most valuable,-- and have on several occasions voted to continue the Proceedings, and pay the costs.

Mr. Spillman, we have discussed the subjects of dues and location of the meeting quite fully, and it is time to make some decision on these questions.

MR. ED COUNTESS: I make a motion we meet at Memphis for 1971 on November 11, 12 and 13.

Unidentified member seconded the motion.

By a great majority of hands raised, the motion was passed.

Secretary Marshall was instructed to notify the management of the Sheraton-Peabody Hotel to confirm the 1971 date for the 21st annual meeting of the Fertilizer Industry Round Table as November 11, 12 and 13, 1971.

MR. SPILLMAN: We have no elections of officers and/or directors for this meeting. If you have nothing more to bring up at this business session, we will adjourn and go on with the afternoon program on "Pollution Control". Joe Whittington will introduce Bill E. Adams, panel leader of the "Pollution Control" discussions.

Pollution Control Panel

Joe. E. Whittington
BALTIMORE, MARYLAND

JOE WHITTINGTON: "If you're not part of the solution, you're part of the pollution." That sign in a hippie store window confirms that pollution is one of the things nearly everybody talks about, and everybody does something about - like contribute to it. Let's not ape the hippies who are prone to over-discuss it, while continuing their constant contribution to it, nor their opposites who are prone to under-discuss it, in the vein of Cleopatra on the royal barge, who, when Marc Antony wailed, "Cleo, this Nile river is terribly polluted," chided him passionately, "Marc, I'm not prone to discuss pollution."

When friend Raistrick from England talked to us yesterday about eutrophication, including water pollution from detergents, it brought to mind the policeman who yelled, "Hey, you can't bathe there. People drink that water," to which the kids screamed back, "Don't worry, we ain't usin' no soap."

Seriously folks, with the population explosion decreasing space per person in the face of increasing waste per person, it is imperative that we discontinue fouling our environment under the wasteful influence of our affluence, or we will be buried under our effluents. Now it will be helpful to hear a discussion of our industry's problems and their solutions, by a panel gathered and monitored by our longtime friend and helper, Billy Adams, manager Fertilizer Equipment Development for Agricultural Chemicals Division of Allied Chemical Corporation, also member and Executive Committeeman of The Fertilizer Round Table.

So Billy, if you and your panel members will clear the cobwebs out of our minds on the troublesome aspects of anti-social public pollution, we'll be clear-eyed and bushy-tailed for a more pleasant form of social personal pollution at our cocktail party this evening.

Pollution Control

Panel Leader, Billy E. Adams

MANAGER FERTILIZER EQUIPMENT DEVELOPMENT
AGRICULTURAL CHEMICALS DIV.
ALLIED CHEMICAL CO.
HOPEWELL, VIRGINIA

BILL ADAMS: Our program this afternoon on "Pollution Control", is of concern to everyone, on a world-wide basis. Our panelists have had lots of experience on this matter, and bring you the latest information available.

Thomas L. Craig, our first speaker, is manager Pollution Control, Wellman Lord, Inc., Lakeland Florida. Tom is a chemical engineering graduate from McGill University. He has worked with Shell Oil Company, U.S. Industrial Chemicals and Commonwealth Oil Co. of Puerto Rico. Tom has had many years of production experience in chemicals, and for the past 3 years has worked in administration, economics, planning and pollution abatement.

Commercial Experience in the Wellman-Lord SO $_2$ Recovery Process

T. L. Craig, F. Hughes, S. Watts

WELLMAN-LORD, INC.
LAKELAND, FLORIDA

There are areas in this paper which are not complete because of business and technical confidentiality considerations. We believe, however, that the information and data presented is sufficient to inform the engineer of the technical and economic features of the Wellman-Lord Process as applied to a sulfuric acid plant. From this presentation, each of you will be able to judge the applicability of the process to other or similar processes at which sulfur oxides abatement is or could be a problem. I might add that a large number of organizations, in excess of one hundred, which have had a specific sulfur dioxide abatement problem, have executed non-disclosure agreements with our firm and have been given detailed disclosures of the process.

The timing of this paper was ideal when we were first notified of the Institute's plan to have it presented at this meeting. Completion and start-up of the plant had been scheduled for May 5 which would have given us ten weeks or so of operating data to analyse. Unfortunately, the area in which the plant is located was struck by construction crafts on May 1, and we were unable to complete construction. We started up in mid-July. We have then, a much shorter period of actual operations and, consequently, the data collected is less in quantity than we would like to use for projections of final design parameters. Although operating trends have been evaluated, our conclusions and bases for future planning, at this time, may not be those we ultimately use.

DEVELOPMENT OF THE PROCESS

Wellman-Lord's activities in the design and construction of chemical fertilizer plants and the attendant pollution problems associated with such account for our familiarity with the requirement for containment of sulfur dioxide and sulfur trioxide. For many years, our company had been using and continues to use the classic technology and hardware for reduction of these noxious gases where such are adequate. In line with the evolution of stricter regulations, however, and coincidentally, in 1966 and 1967, with the development of a world-wide sulfur shortage, Wellman-Lord embarked upon a program to develop a process which would both satisfy the oncoming statutes and provide a supplementary source of sulfur.

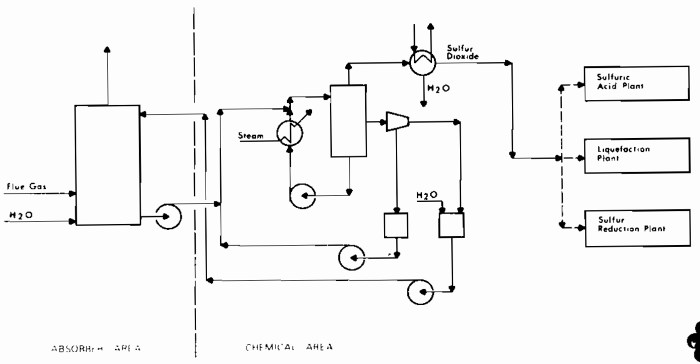
The company's Process Development Group screened the available processes and concluded that none passed the criteria of reasonable economics and wide applicability. It was decided then, in 1966, to take Dr. Johnstone's work (circa 1930, University of Illinois) and improve upon it. Wellman-Lord's early efforts were dedicated to refinements of Johnstone's data. A potassium sulfite system was selected and piloted at Tampa Electric Company's Crane Station in 1967. Further to this preliminary pilot plant, a group (1) consisting of four utilities, one chemical company, the parent company and our organization funded and operated a demonstration plant in the Baltimore area. This 25 megawatt plant treated a slip stream from a coal-fired boiler and was operated from January through October 1969. This small plant verified the reliability of the process design, but, at the same time, vividly demonstrated the need to incorporate much more flexibility and reliability into any future units. Of equal importance was our inability to achieve the significantly lower energy requirements which were necessary to give the process an advantage over Dr. Johnstone's projections.

The Process Development Group had been working with the sodium system during this period and found that refinements of the original processes did, indeed, deliver a scheme which does an excellent job of reducing sulfur oxides at a reasonable cost. From this experience and with the assistance of a number of consulting engineers and chemists, the process, as applied to the commercial plant at Paulsboro, was developed.

SUMMARY OF OPERATIONS

The Olin sulfuric acid plant at Paulsboro is a regenerative plant handling a variety of spent acids from the South Jersey -- greater Philadelphia

FIGURE 1
WELLMAN LORD, INC.
SULFUR DIOXIDE RECOVERY
SODIUM SYSTEM



Baltimore Gas and Electric Company
Delmarva Power and Light Company of Maryland
Potomac Electric Power Company
The Potomac Edison Company
W. R. Grace Company
Bechtel Corporation

TABLE 1

OPERATING REQUIREMENTS

OLIN CORPORATION
PAULSBORO, N. J.

1. CAUSTIC MAKE-UP, NaOH	
a. Design rate, STPD	2.5 maximum (100% basis)
b. Temperature, °F	100 maximum
c. Concentration, % by weight	50
2. STEAM	
a. Design rate, lb/hr	30,000
b. Pressure, psig	150
c. Temperature, °F	366
3. PROCESS WATER (WELL WATER)	
a. Design rate, gpm	60
b. Temperature, °F	75
c. Pressure, psig	50
4. ELECTRICAL POWER	
a. 440 v., 3 phase, 60 cycle	
Total connected kVA	310
Operating kVA	250

area. The Wellman-Lord SO2 Recovery Plant selected for Olin's facility is designed to treat the tail gases from the sulfuric acid plant, remove the sulfur trioxide and to recover and return the sulfur dioxide to the sulfuric plant. Wellman - Lord's recovery plant guarantees 90% removal and recovery of the SO3 and SO2, respectively, guarantees a stack emission level of less than 500 parts per million, as well as the energy and makeup chemical requirements. The Process is a regenerative sodium sulfite system, designed to accommodate the use of standard available hardware and to avoid the creation of any secondary pollution problems.

Following the initial charge of chemicals, the unit has operated very well, absorbing greater than the design requirement of sulfur dioxide and running continuously for twenty - one days. Coincident with a shutdown of Olin's sulfuric acid plant, we did a fairly comprehensive inspection of the unit to make a preliminary evaluation of the materials of construction and the hardware components. At the same time, we modified the absorber internals to achieve better mixing of the liquid and gas phases which had been less than anticipated. Following this shutdown, we have been back on stream on a continuous basis.

The operations to date, although limited in measure of time, have demonstrated that the plant is designed very conservatively. We find that the major equipment components are oversized; thus, the capital costs of future plants can be reduced. The flexibility of the unit and its adaptability to changes in quantity and quality of the feed gas has been gratifying. We feel that more automation and the use of additional and more sophisticated continuous monitoring of some streams may enable us to offer future units which will require little or no operator staffing.

PROCESS DESCRIPTION AND COSTS

The Wellman - Lord SO2 Recovery Unit at Paulsboro is designed to process 45,000 SCFM of a sulfuric plant tail gas having a sulfur dioxide content of from 2,000 parts per million and upward, return the greater part of this sulfur dioxide to the acid plant drying tower and exit to the atmosphere a stack gas having less than 500 ppm. A simplified flow sheet of the Process is included.

Wellman-Lord's contract with the client guarantees the following:

1) Level of sulfur dioxide emission.
2) Steam usage.
3) Electric power usage.
4) Chemical makeup.

We have enclosed a table detailing these various operating requirements for the Paulsboro installation.

MR. ADAMS: Our next speaker is a graduate of Georgia Tech, 1938. He has worked for T.V.A. since 1938, with time out for army service. Jim's present title at T.V.A. is staff chemical engineer of the Agricultural and Chemical Engineering Division.

Environmental Control of Air and Water Wastes in Fertilizer Operations

J. C. Barber
TVA
MUSCLE SHOALS, ALABAMA

Standards for environmental control have been established in some instances and serve as guidelines for the abatement of air and water pollution at fertilizer manufacturing operations. Environmental controls for water wastes have been established in accordance with the Water Control Act of 1965. This Act provides for quality standards of water in the lakes and streams. The standards depend on the designated use of the streams; the uses designated are for public water supply, shellfish harvesting, water-contact recreation, fish propagation and wildlife, agricultural water supply, industrial water supply, navigation, and treated waste transportation. Specific water quality standards are given for each water use. State water quality control agencies prepared the standards, with approval from the Federal Water Quality Administration, and the state agencies see that discharges into the state streams do not exceed the specified quality of water in the streams All 50 states now have water quality standards; these standards vary somewhat among the states, but a summarization of these standards has been made (1).

The state water quality standards generally include 10 water quality parameters. These are: hydrogen ion concentration (pH), temperature, dissolved oxygen, bacteria, radioactivity, turbidity, color, taste and odor, solids, and toxic substances. The pH of water in a stream is usually limited to the range of 6.0 to 8.5; fluorine content is limited to 1.4 to 1.6 mg. per liter when the water is used as a public water supply, or 10 mg. per liter when the water is to be used for other purposes. Many states limit the concentration of toxic substances in water to one-tenth the concentration known to be toxic, and some states limit nutrient content in the receiving streams. Furthermore, some states may have quality standards somewhat more stringent than those allowed by the Federal Water Quality Administration.

Guidelines for the discharge of wastes into the air have not been formulated to the same extent as the water quality guidelines. The Clean Air Act of 1967 provides for the establishment of air quality control regions -- areas where the general pollution potential is uniform and control may be exercised uniformly. The air quality regions are designated by the National Air Pollution Control Administration, with 32 regions originally designated, and a total of 91 such regions in various stages of being designated. Specific procedures and time limits are provided for establishing air quality standards in a designated region and for implementing control of these standards.

The standards for a designated region are to be based on air quality criteria prepared by the National Air Pollution Control Administration. The effects of exposure of specific air pollutants on people, plants, animals, and property are studied. Concentrations above which adverse effects occur are determined and given as the criteria for a specific pollutant. The criteria are intended to be used as a basis for establishing ambient air quality standards, and from this allowable rates of emissions from a pollution source can be derived. But so far, criteria have been prepared for only five pollutants -- particulate matter, sulfur oxides, carbon monoxide, hydrocarbons, and photochemical oxidants. Particulate matter and sulfur dioxide are pollutants which may be of particular interest in the manufacture of fertilizers. The criteria documents state that adverse health effects are noted when the annual mean level of particulate matter in air exceeds 80 micrograms per cubic meter (0.00003 grain per cubic foot). Visibility was reduced when the concentration exceeded 150 micrograms per cubic meter (0.00006 grain per cubic foot). Adverse health effects were reported when the annual mean level of sulfur dioxide in air exceeded 115 micrograms per cubic meter (0.04 p.p.m. on a volume basis); adverse health effects were noted when the 24-hour average levels exceeded 300 micrograms per cubic meter (0.11. p.p.m.) for 3 to 4 days.

Air quality standards have not progressed enough to give very meaningful guidelines. But criteria for particulate matter and sulfur dioxide in ambient air would indicate derived emissions standards for these pollutants will be excessively severe unless available abatement technology is given importance in deriving the standards. At the National Fertilizer Development Center, dust collecting equipment is purchased with the specification that the exhaust gas will have a maximum dust loading of 0.05 grain per standard cubic foot. This specification approaches or exceeds the capability of most dust collectors.

Air quality criteria are expected soon for nitrogen oxides and fluorides -- pollutants of particular concern in the fertilizer industry. The nitrogen oxide criteria are expected to show adverse health effects when the 6-month mean concentration in ambient air exceeds 0.06 p.p.m., or when the 24-hour mean concentration exceeds 0.15 p.p.m. nitrogen oxides in ambient air. It may be necessary to install equipment to decompose nitrogen oxides at nitric acid plants in order to meet emission standards based on criteria for nitrogen oxides in ambient air. The Tennessee Air Pollution Control Regulations may indicate likely criteria for fluorides in ambient air (3); these regulations call for maximum fluoride concentrations, expressed as HF, of 1.5 p.p.b. for a 30 - day period, or 3.5 p.p.b. for a 24 - hour period. Just about all the fluoride discharged at a fertilizer plant would have to be collected in order to meet these ambient air standards.

Existing procedures for establishing air quality standards are undergoing change. The establishment of national air quality standards has been proposed, and national emission standards may be put into effect for some of the more important pollutants. All this will take considerable effort, and meaningful national guidelines may not be available for the fertilizer industry for some time. In the meantime, state and local regulations will continue to provide guidelines for environmental control of wastes discharged into the air.

CONTROL OF WASTES FROM PLANTS PRODUCING BASIC FERTILIZER MATERIALS

The processes for the production of basic fertilizer materials -- ammonia, urea, nitric acid, and phosphoric acid -- have undergone significant technological development during the past two decades, and these developments have brought about substantial decreases in the amounts of wastes discharged into the air and water from plants producing these materials.

Ammonia is made from natural gas by a process generally represented by the diagram shown in figure 1. The natural gas is reformed and the gas mixture is then treated and purified mainly by gas phase reactions which involve very little loss of materials to either air or water. One potential loss is ammonia in purge gas at the ammonia synthesis converter. This loss is about 9 pounds of ammonia per ton of ammonia produced when the purge gas is discharged. However, purge gas is burned in the reformer and the discharge of the waste ammonia to the air is prevented. Some ammonia is lost when condensates are removed from the gas stream, but the amount of such loss is only about 0.5 pound N per ton of ammonia produced.

A diagram of the urea process is shown in figure 2. Most of the losses from this process result from the necessity to purge inert gases from the system. Effluent gases are cooled, and condensate is removed before the gases are exhausted to the air by a steam ejector. Some additional losses may come from leakage at pumps and from miscellaneous spillage.

A 200-ton-per-day urea solution plant is being constructed at TVA, and nutrient losses from this unit are expected to be held in the range of 2 to 3 pounds N per ton of urea produced. Achieving these low nutrient losses will depend on close control of water usage to eliminate the need to discharge aqueous ammonia when excess ammonia recycled to the reactor is recovered.

The process for the production of nitric acid is shown in figure 3. Anhydrous ammonia is burned with air to form nitrogen oxides, and these oxides are absorbed in water to produce nitric acid. About 0.29 ton of ammonia is required to produce a ton of nitric acid (100% HNO_3 basis).

Absorption of nitrogen oxides is not complete, and some oxides are discharged into the air after energy has been recovered from the pressurized gases. Control of nitrogen oxide waste discharge is required to prevent adverse atmospheric conditions and to prevent health hazards from nitrogen oxides in the air (2).

With good operational control, modern nitric acid plants can limit nitrogen oxide losses to an equivalent of about 6 pounds N per ton of nitric acid produced. In addition, some losses will result from pump leakage and spillage, but this loss can be held to less than 1 pound N per ton of nitric acid. However, catalytic combustion of the absorption tower exhaust gases may become necessary to reduce the discharge of nitrogen oxides in the air to values which may be required for anticipated air quality standards.

Phosphoric acid is produced by both the wet-process and the electric-furnace methods, but it is estimated that about 95 percent of fertilizer phosphoric acid comes from the wet - process method. Wastes from wet-process plants are therefore of greater interest in fertilizer manufacture than waste discharges obtained during the production of phosphoric acid by the electric - furnace method.

Figure 4 illustrates a wet-process plant. The phosphate ore is finely ground, treated with sulfuric acid to extract phosphoric acid, and the

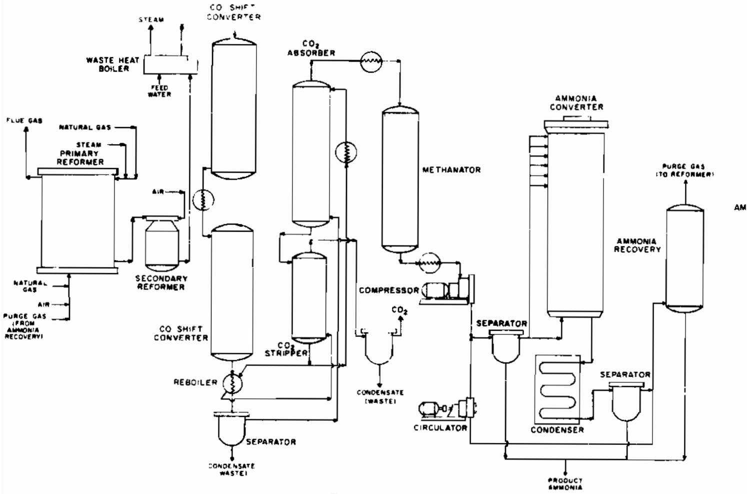


FIGURE I
DIAGRAM OF AMMONIA PLANT PROCESS

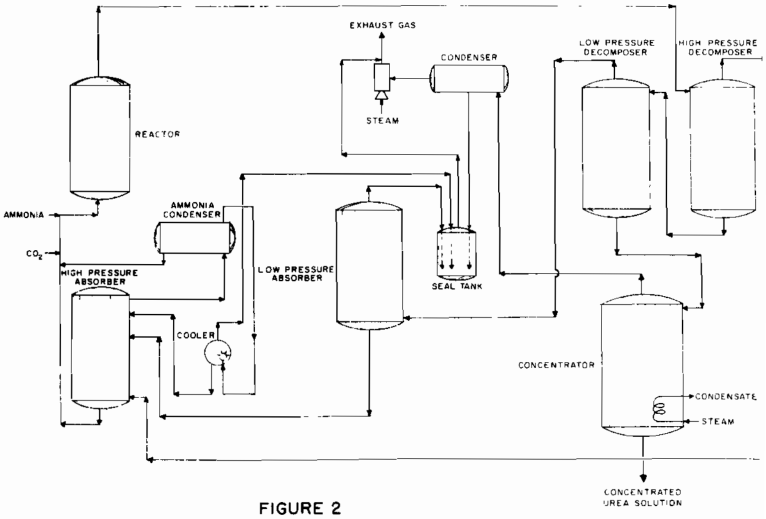


FIGURE 2
DIAGRAM OF UREA SOLUTION PROCESS

phosphoric acid is separated from the insoluble gypsum by filtering. The phosphoric acid is then concentrated by vacuum evaporation.

Grinding and handling the phosphate gives rise to dust discharges, and these dusts must be effectively recovered to avoid pollution as particulate matter and as fluorides. Wet scrubbers, such as venturi scrubbers, are normally required for efficient removal of phosphate rock dust.

Production of wet-process phosphoric acid results in the discharge of 113 to 240 pounds of fluorine per ton of P2O5 in the acid (4,5). Fluorine must be collected to avoid pollution problems, and water scrubbing of the exhaust gases is reported to collect 99.9 percent of the discharged fluoride (5). With Florida phosphate, most of the fluorine comes off in vapors from the concentration of the acid.

At some wet-process phosphoric acid plants the phosphate is calcined to burn out organic matter and to upgrade the material by decomposition of the carbonates. Calcination of the phosphates will cause some fluorides to be volatilized. Scrubbing of gases to remove fluorine from calciners is required for air pollution abatement.

About 5 percent of the P2O5 in phosphate remains unextracted in gypsum residue during the production of phosphoric acid. Additional P2O5 is lost in leakage, spillage, and in fumes; the fumes are collected when the gases are scrubbed to collect fluorine. Wastewater and gypsum slurry go to a pond where the gypsum settles out, and much of the water is reused in the process.

Disposal of gypsum and aqueous effluents from gypsum ponds is a problem at wet-process plants. The gypsum is produced at a rate of 4.5 tons per ton of P2O5 in acid, and enormous piles of the material accumulate because economical methods for the utilization of the gypsum have not been developed. Gypsum ponds may be 100 to 200 acres in size, and discharge of water from these ponds may result in discharge of P2O5 and fluorides as liquid wastes unless the effluents are limed. Also, unlimed gypsum ponds are reported to be sources of fluoride emission in the air (6). Liming of the gypsum ponds to control loss of P2O5 and fluoride imposes a significant economic burden on wet-process phosphoric acid manufacture. Methods need to be developed for the economic utilization of the byproduct gypsum, and methods need to be developed for treating and reusing scrubber water so as to avoid ponding and discharge of liquid wastes.

CONTROL OF WASTES FROM PLANTS PRODUCING GRANULAR FERTILIZERS

TVA produces three types of granular fertilizers at the National Fertilizer Development Center -- ammonium phosphate nitrate, nitric phosphate, and ammonium polyphosphate. These materials are prepared from ammonia and from nitric, phosphoric, and sulfuric acids. In addition, nitric phosphates are produced by treating phosphate rock with a mixture of nitric, phosphoric, and sulfuric acids and the resulting slurry is neutralized with ammonia and granulated.

Preparation of the granular fertilizers involves neutralization, extraction, and granulation; the granules are dried, cooled, and conditioned in rotary equipment. Dusts and fumes come off during neutralization, extraction, and granulation steps. The granules are contacted by streams of air in the drying and cooling operations and dust particles are entrained in the moving air stream. Furthermore, spillages from conveying equipment cause cleanup and additional waste disposal problems.

Fumes discharging from the nitric phosphate extractor are scrubbed with a water - jet scrubber and the scrubber water is discarded. The discarded effluent contains a small amount of fluoride and the effluent is saturated with nitrogen oxides.

Experience at TVA in designing and operating dust and fume abatement facilities at the granular fertilizer plants disclosed that some difficult problems are encountered. The fertilizer dusts, particularly those containing nitrates, readily absorb moisture and become sticky. The original design of the dust collecting equipment in the TVA granular plant called for the installation of dry cyclonic type collectors followed by wet scrubbers. It was expected that the cyclone collectors would recover most of the dust, and this material would be returned to the fertilizer process. Dust particles going through the dry collectors, hopefully comprising only a small quantity of material as small sized dust particles, would be collected in the scrubbers and the liquid waste discarded. Unfortunately, the cyclone type collectors are unsuited for the collection of these dusts; the material adheres to metal surfaces, cyclone discharges clog, and the collectors become ineffective. The scrubbers collected most of the dust, and aqueous effluents caused a water waste problem from nutrient discharge. Since effective methods were not available for the removal of small concentrations of nitrates and phosphates from wastewater, scrubber solutions were concentrated by recirculating the solution in the various

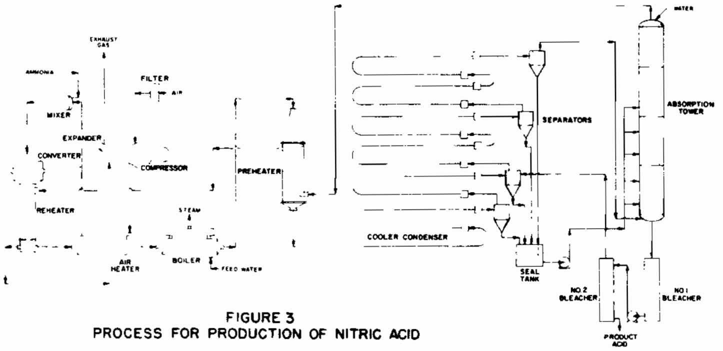


FIGURE 3
PROCESS FOR PRODUCTION OF NITRIC ACID

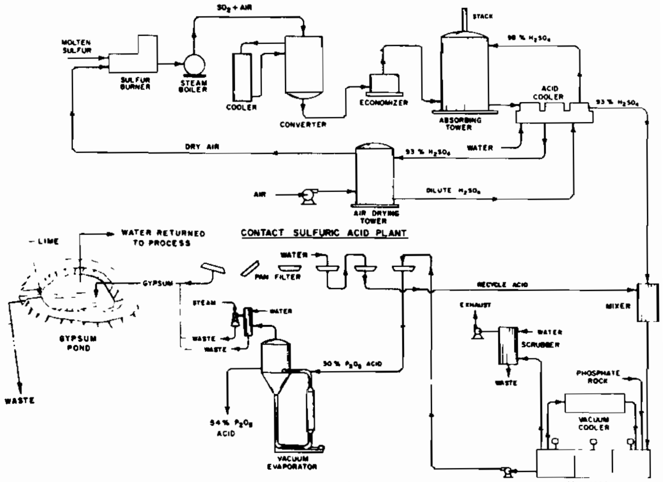


FIGURE 4
WET-PROCESS PHOSPHORIC ACID PLANT

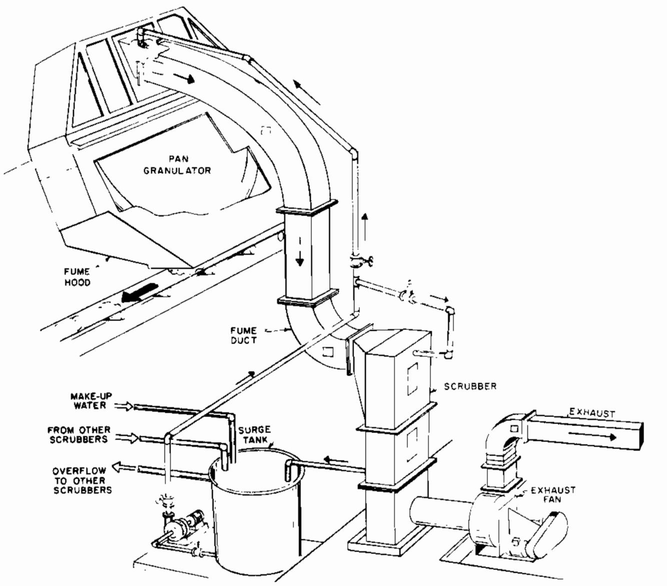


FIGURE 5
FUME AND DUST SCRUBBER AT PAN GRANULATOR

scrubbers and the concentrated solution was returned to the process for recovery.

Figure 5 illustrates the use of a scrubber for the collection of dust and fume at one of the pan granulators. Successful operation of such scrubbers depends on the incorporation of cleaning equipment, such as sprays, to prevent dust particles from adhering to the metal surfaces and stopping the outlet duct. The scrubber solution is recirculated to concentrate it, and the solution is then returned to the system. Material collected in the floor sump from spillage and cleanup is also combined with the scrubber water and returned to the process. When the recovered solution is recycled to fertilizers containing ammonium nitrate, an oil removal step is provided.

Scrubber liquor obtained during the collection of dusts, fumes, and gases from nitric phosphate operation will contain grit and insoluble coarse solid particles. Accumulation of such solid materials in the scrubber liquor will interfere with operation of the scrubbers. Grit and coarse particles are removed from aqueous effluents by a hydroclone, shown in figure 6. Underflow from the hydroclone is returned to the process and overflow goes back to the scrubber system.

Wet scrubbing of effluents from the TVA granular fertilizer operations generally provides satisfactory abatement of air pollution. Concentration and return of the scrubber liquors to the granular process requires some special treatments to avoid return of harmful contaminants, and to avoid interference with the scrubber performance.

The successful operation of a scrubbing system depends on maintaining a favorable water balance. A limited amount of scrubber liquor can be returned to the system and reused. Excess scrubber solutions may be accumulated at times when scrubber systems are emptied between runs. Highly concentrated acid -- nitric or phosphoric -- is mixed with the liquors to improve the water balance and help in the reuse of the accumulated liquors.

Effluent control from the TVA granular fertilizer plant is described in detail in another paper (7). The paper gives information on duct designs, duct air velocities, and methods used for the collection of spillage. The paper also discusses collection of process fumes of the "aerosol" type by a condensing type scrubber. The condensing type scrubber was used in pilot - plant development of the process and proved effective in the operation of both the pilot plant and demonstration plant.

Some producers of granular fertilizers have successfully used bag filters for the collection of dusts, and the dusts being returned to the process in a dry form. The bag filters are applicable when the dust - laden gases are well above the dew point and condensation in the filter media does not occur. Dryer exhaust gases may be a practical application for the filters, but it is doubtful that bag filters could be used successfully for fume and dust collection at the granulator shown in figure 6.

TVA has investigated the use of superphosphoric acid in fertilizer granulators to control the discharge of wastes in the effluent gases. When sulfuric acid and potash are used in ammoniation-granulation units, ammonium chloride fume is formed and this fume is very difficult to collect. The replacement of sulfuric acid by superphosphoric in the ammoniation - granulation unit eliminates the ammonium chloride fume; the granules are dry, and dust discharge from the dryer and cooler is decreased. The use of superphos-

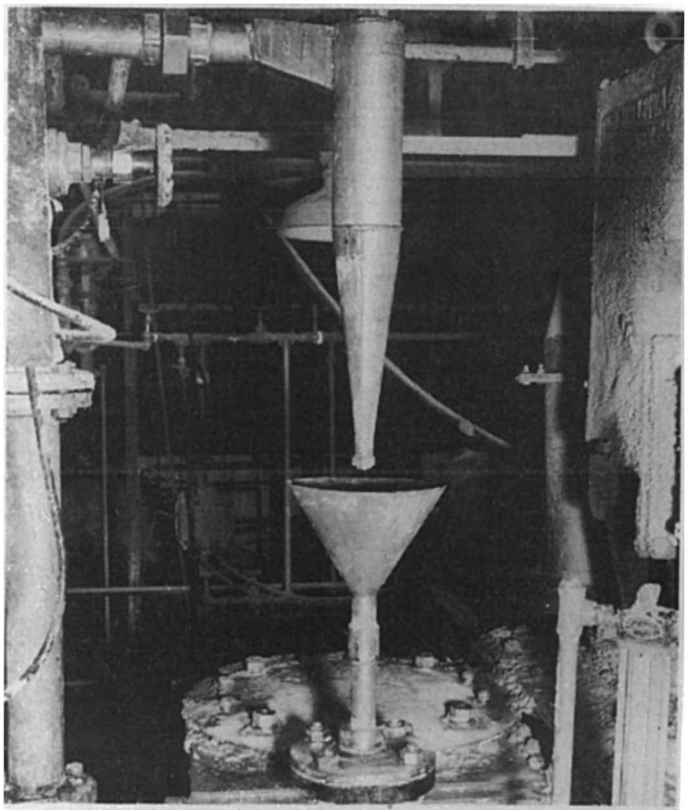


FIGURE 6
HYDROCLONE FOR CONCENTRATING
FERTILIZER WASTE FOR REUSE

phoric acid instead of sulfuric acid has effectively corrected dust emission problems at some ammoniation - granulation units.

ENVIRONMENTAL CONTROL WORK AT TVA

The facilities operated at the TVA National Fertilizer Development Center are subject to special regulations for environmental control (8). Federal agencies are required to provide leadership in the nationwide effort to protect and enhance the quality of our air and water resources. Air and water quality standards, including emission standards, adopted pursuant to the Clean Air Act and Federal Water Pollution Control Act, are to be adopted by TVA and other agencies as guidelines for operational control. But in those cases where no state or local air or water quality standards are being applied, the Federal agency is required to adopt standards which will fulfill the agency's leadership role. Such standards would be adopted after consulting with people in the National Air Pollution Control Administration or Federal Water Quality Administration. When deemed advisable, the Federal agency may assume the leadership role by adopting standards more stringent than those required by the state or local government.

In addition to the environment protection requirements of Federal agencies, TVA has an unusually broad role in maintaining a quality environment in the Tennessee Valley area in seeing that the resources are put to work usefully. The environmental aspects of TVA's agricultural program are also quite broad, and this program is interrelated with the conservation of our air and water resources.

Waste recovery is therefore an important part of the agricultural development program. Waste recovery methods are developed for new fertilizer processes and advanced abatement technology is provided at the facilities operated for the production of fertilizers on a demonstration scale. Furthermore, special reports and publications are prepared to provide industry assistance in meeting air and water pollution abatement requirements, and in some cases abatement technology is demonstrated at cooperating fertilizer plants.

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MR. ADAMS: The next report is on "Methods and Costs to Test for Routine Pollutants". This paper was prepared by Edwin Cox, partner in the engineering firm, Edwin Cox Associates, Richmond, Va. Since Mr. Cox could not be here today, Chris J. Pratt, Hoechst Corporation, Englewood Cliffs, N.J. will present the paper.

Air Pollution Sampling Costs

Edwin Cox III
EDWIN COX ASSOCIATES
RICHMOND, VA.

We have heard this morning about projected Federal Regulations and types of equipment for abatement of air pollution. This paper concerns the costs of sampling.

Obviously, before any equipment can be specified the composition of the waste stream must be known. There are those who insist that processes have their routine operating characteristics and that, accordingly, equipment can be specified based simply on size and throughput of the piece of equipment causing the pollution. There is something in this -- certainly conventional processes such as sulfuric acid units do have known flow rates, standard equipment and conventional loadings in both process and waste streams. On the other hand, because many of our fertilizer plants are not "off the shelf" but rather have been designed for particular performances using particular feed stocks, it is necessary that the units to be abated be measured, so that flow rates and loadings, with maxima and minima, and degrees of variation, can be defined.

Further, it will become the practice of the regulatory agencies in the various states and localities to insist that operators have permits for the operation of units such as fertilizer plants. To obtain these permits, it will be necessary for the owner first to describe his works to the regulatory agency and to demonstrate two things:

1. Theoretical performance of the unit in terms of air pollution.
2. Numbers which show that the owner is doing what he says he will do in terms of pollution.

Said differently, if .02 pounds per thousand cubic feet of emitted gas is the allowed particulate loading, then he must be able to demonstrate that that is the maximum concentration of solids he is discharging.

Thus, we see two reasons for measurement. First, from an engineering standpoint to define a problem and to insure that equipment is operating as it is supposed to. Second, to demonstrate to regulatory agencies proper operation of equipment.

Our earlier speakers have alluded to the two types of air pollution regulations which are:

1. Emission limits
2. Air quality standards

It is obvious that air quality results from limited emissions. Accordingly, there must be two types of measurements made -- that of the emitting facility and that of the air whose quality is of interest. These differences give rise to two types of sampling.

It has been our practice to describe any tests of an emitting facility as a stack test, whether or not a stack is involved. The reason is obvious-- flows and pollutant loadings must be determined in these measurements. Further, since normally all such operations are vented or soon will be, the unit to be tested will be discharging through a "stack." The stack may be horizontal, it may be a hundred feet tall, it may be 10 inches or six feet in diameter. Its temperatures may vary from ambient to approximately 2000 degrees F. Flow rates obviously vary remarkably. Within all of these variations, however, it does have the characteristics of a defined source, a unit directional flow at some point, and so the same types of sampling equipment are used.

(The other type of sampling, to determine air quality, is a static type of measurement. Some of the equipment applicable for stack sampling is also applicable here, but since stack sampling is by and large sensitive to flow rates, it is more difficult than on - site monitoring of air quality.)

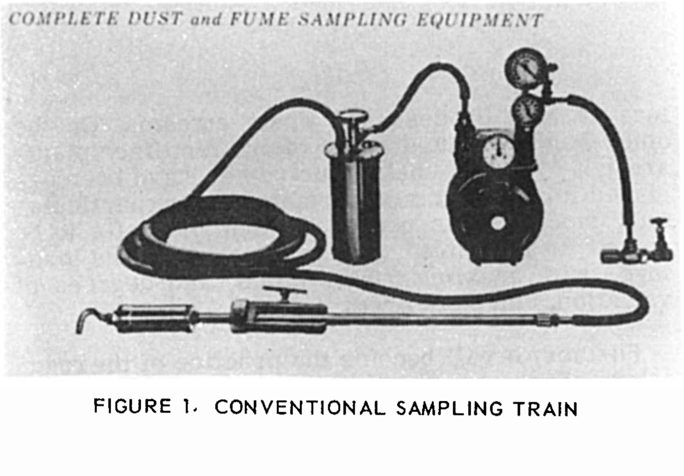


FIGURE 1. CONVENTIONAL SAMPLING TRAIN

One particular limitation which must be borne in mind is that to sample a stack for anything other than a gas the sample must be pulled from the gas stream at the same speed at which it passes the sampling probe. If the sample is pulled faster than the rate of flow past the probe, then the measured solids loadings will be low. Similarly, if the sample is pulled at a lower rate than the rate at which it is flowing past the probe, the reading will be incorrect and high.

I should first like to discuss stack sampling equipment and then go on from that to the types of equipment used in air quality monitoring. In discussing the equipment I will from time to time allude to the laws/regulations involved so that we can see how the equipment must vary, dependent upon the use of the data. At the same time, I shall attempt to give you approximate capital costs for the equipment, its operating difficulties and also the routine charges for these services. My purpose is to give you an understanding of the amount of dollars involved in simply measuring -- not abating -- so that you can make your own decisions as to whether or not you want to buy equipment or to rent the services of the many firms now offering air pollution sampling.

Figure #1 shows the standard equipment which has been used over the years for stack sampling. There are three test methods in which this equipment can be used -- they are about the same, varying only in certain details. These are the Society of Mechanical Engineers Test Codes, Western Precipitator Methods -- the so - called WP 50, and the Incinerator Institute of America. The units tested using this equipment vary from large power boilers to incinerators, but the equipment and test method, in principle and in use, are about the same. In the illustration you see first a sample probe -- a device which must go into the stack to pull the sample. This device is used after a survey has been made of the stack to determine its flow rate. Gas is pulled through an alundum thimble in the probe (for high temperature work) to trap particulates. Paper thimbles can be used for low temperature work. Many other collecting devices can be substituted such as impingers, gas bags, and the like. Downstream of this solids holder is a water cooled condenser, which has the job of reducing the temperature of the collected gas and condensing out all materials which have a boiling point higher than 212 degrees F. A gas meter further downstream then measures the dry gas temperature (although it is not in fact dry) and the flow rate. Temperature of the gas is measured at this point so that conversions can be made to standard cubic feet.

A small electric pump, a filter pump or some other device can be used as a source of sampling vacuum.

This equipment, ready for operation costs about $1500. It is simple to use because its calculations are straightforward. Western Precipitator division of the Joy Manufacturing Co., has done a splendid job in writing up instructions.

Two men are required to sample -- one holds the probe to the stack and the other monitors the flow rates and records data as necessary.

The disadvantages of this equipment are obvious. It requires a pre - measurement of flow rate and then an assumption that flows remain constant throughout the test. Further, fines which will go through the thimble will accumulate throughout the sampling train unless the impingers are used. The metal condenser imparts many impurities to the condensate. Chemicals requiring specific scrubbing require additional equipment.

Advantages of this equipment are that it is heavy duty, is readily available, and is easy to use. Its major disadvantage is that it does not permit sampling at the rate which is required due to stack velocities, particularly under varying conditions, because the sampling equipment and the velocity measurement equipment are separate. While it is possible to put a pilot tube beside the sampling probe, constantly record flow rates and make changes, these changes are not as easily made as it would appear, and the method simply does not work.

As I have said, the approximate capital cost of this equipment is $1500. It requires two men to operate. Our laboratory routinely charges $250 per day for a crew of two men, plus their expenses, to use this equipment. The cost to sample one stack is approximately $1000. Three samples are pulled during the day, the remainder of the charge is mobilization -- setting up on the job -- then writing the report. The report is quite simple unless the requirement is for negotiation with regulatory agencies. In that case, no time estimate can be assigned. The report must conform with whatever format is assigned by a particular regulatory agency.

Unfortunately, regulatory agencies in different states vary in what they want. Methods of testing, criteria and report formats all vary.

One mission of the NAPCA, a part of the Department of HEW, is to standarize procedures. Succeeding illustrations show the new equipment designed by the NAPCA. This equipment is good, it lends itself to much more representative sampling, and hopefully it will be adopted as the standard by the various regulatory agencies throughout the states. It is obviously more complex than the WP-50 type equipment. Accordingly, it costs more. One unit costs approximately $3000. A complete set, which permits sampling as fast as possible, costs approximately $6000. To do this, three collecting devices are required.

Figure #2 is a schematic of the train. You will notice that it is much more complex. Impingers are not an option but rather replace the alundum thimbles. The probe itself is heated and has a constant flow measuring device, all part of the same unit. By using slica gel in the last impinger, dry gas passes down to the vacuum pump. The operator can check his sampling rates and the flow rates past the sampling tube and make on the spot corrections throughout the sampling period.

Figure #3 shows the sampling device. The long probe sticking out to the right is the probe that goes into the stack. Its length varies with the diameter of the stack to be tested. The collected gas passes into a cyclone where the heavy particulates settle out. This particular part of the chamber is electrically heated to keep it above 212 degrees F. A filter is optional. (This illustration, made from manufacturer's literature, shows the "heart" of the system to be a filter. Depending on the analysis being made, this filter may be omitted.) The impingers are in an ice bath. All condensables, fine

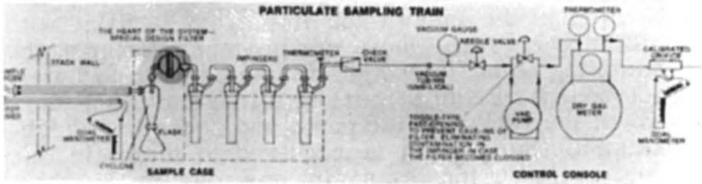


FIGURE 2. NAPCO (HEN) SAMPLING TRAIN

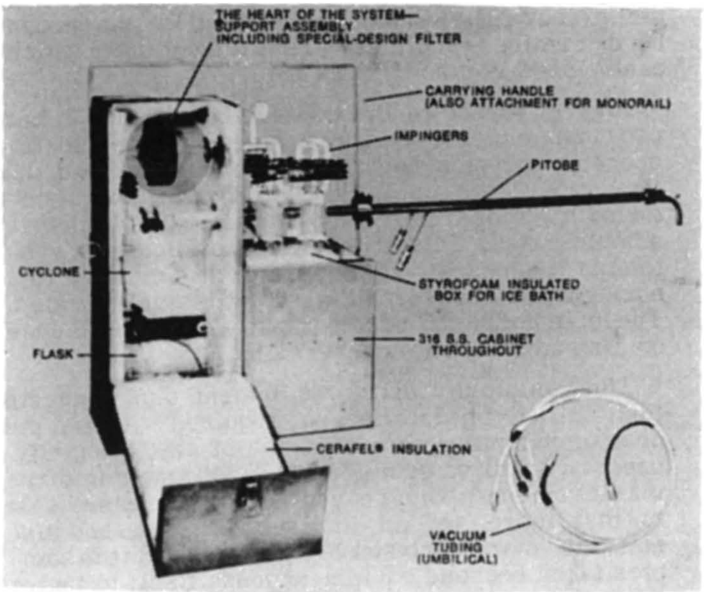


FIGURE 3. NAPCO DESIGN. SAMPLING PROBE AND COLLECTORS

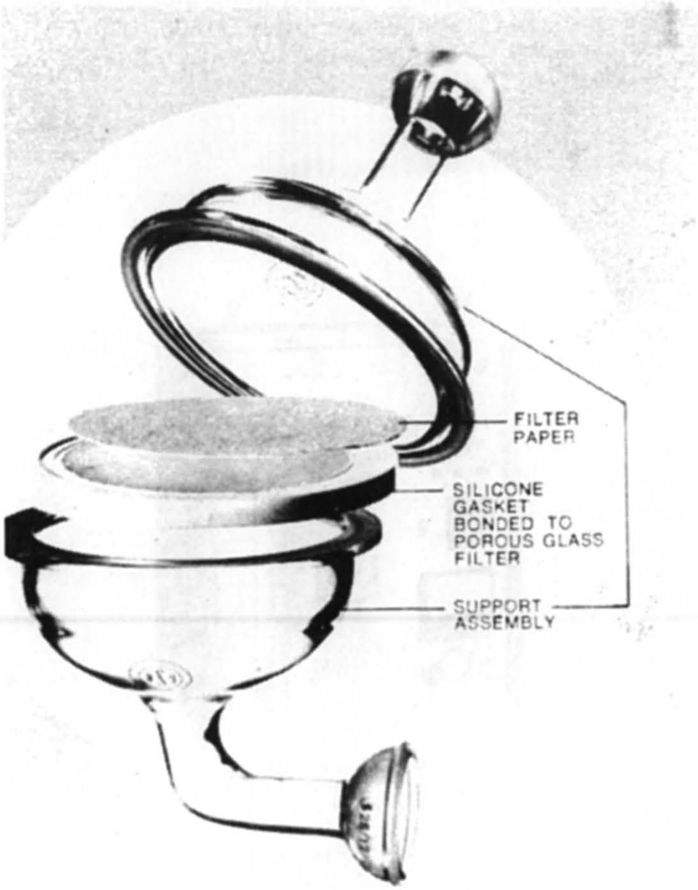


FIGURE 4. NAPCO DESIGN FILTER FOR PARTICULATE COLLECTION

particles and water vapor come out at this point. Normally, the last of the impingers is filled with silica gel. This whole device must be up at the sampling point. Its weight as used is approximately 100 pounds. From it there is a long umbilical cord which goes down to the pump and recording mechanisms. One person is required to maintain this equipment during the sampling program. Further, breakage and handling require some training on the part of the operators.

Figure #4 shows the small filter. By selecting the proper filter medium, particulate sizes can be determined, and there are different units which can be used in place of this filter.

Figure #5 shows the control box itself. It has two manometers, mounted side by side, so the operator can see both the sampling rate and the flow rate in the stack. He has provision for monitoring all temperatures and can immediately change sample rates. This is not as sophisticated a system as it appears -- the operator still must go to a nomograph to convert flow rates to sampling rates. The size nozzle he uses naturally has an influence on his sampling rate conversions.

The complexity of the equipment thus suggests that skilled operators are required. Again, the cost of sampling here is $250 per day. Normally one stack will be sampled for $1500 (making three measurements). One reason for the increased cost is that more set up time is required, and also normally more analyses are performed on the samples taken because equipment lends itself to better samples.

To test one stack with the WP-50 equipment costs approximately $1000. To test using the HEW method the cost is approximately $1500. The HEW test method is much superior, particularly for solids.

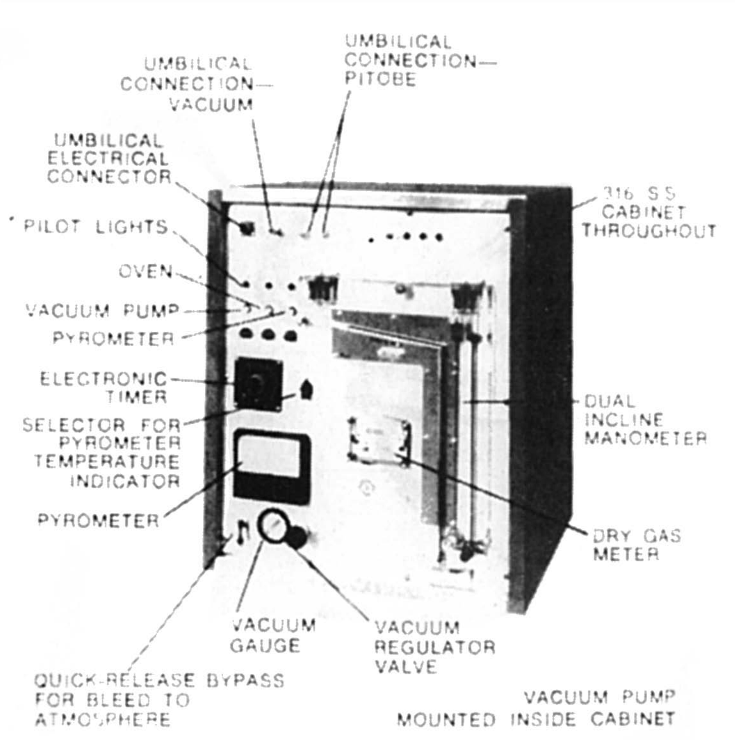


FIGURE 5. NAPCO DESIGN CONTROL BOX

Gas phases, however, are considered to be homogeneous throughout the gas stream, so sampling for them is relatively simple.

These costs have all been quoted for single stacks. They do vary significantly and the cost per stack decreases rapidly, as the number of stacks increases. On a recent job, approximately 1000 miles from our base, to sample 29 separate stacks and to perform approximately 2 analyses on each sample selected, our fixed fee quotation was $13,500. Another group bid $14,000. Accordingly, it can be seen that these costs are pretty standard throughout the industry, and the cost per stack dropped to $500 per stack as the number increased. One major saving that is effected in sampling multiple stacks is that the analytical costs in support of the sampling drop rapidly as multiple samples are delivered to the laboratory for the same determination.

One factor which will rapidly escalate costs, because professional people are involved on a per diem basis, is the requirement for negotiations with any regulatory authority. If these are required -- negotiations -- I strongly recommend to you that they be conducted before any testing or any other contact is made and that the person who will submit the test results be the person who does the negotiating. Much confusion can be saved in this manner, costs can be kept down, and difficulties in the form of arguments can be prevented.

The above discussions have dealt with sampling emissia on a test basis. Once a unit has been tested, approved, or is in operation, if regular reports are required of the emission of the unit, particularly in those areas currently having "smog alerts" and like efforts, then there are specific devices which can be installed on the stack and left permanently in place. These are highly recommend-

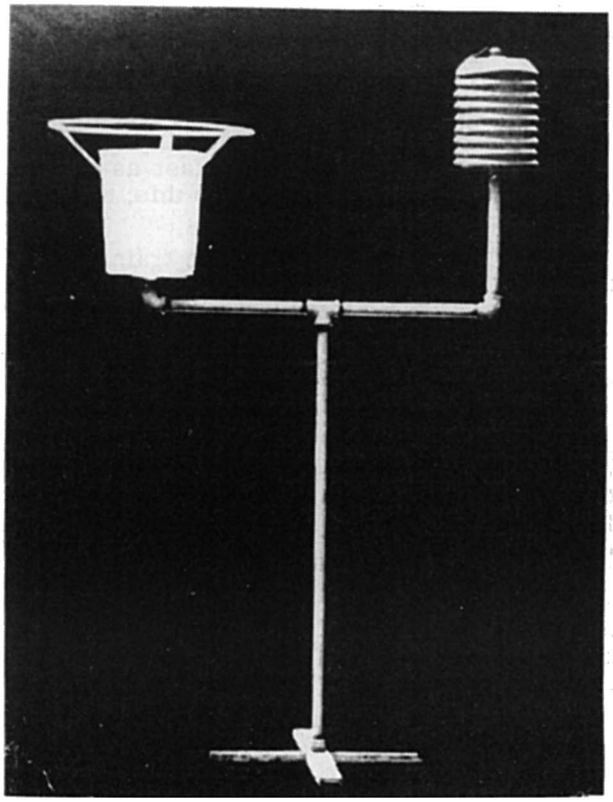


FIGURE 6. STANCHION WITH DUST FALL HOLDER AND SO2 CANDLE SHELTER

ed as substitutes for the very expensive single tests. I shall not go into them in detail, but for a cost of between $2 and $10,000 a permanent monitor can be installed on a stack which will read out in total particulates and size distribution of particulates. Others will sample or analyze for particular components.

Having discussed the emission side of air pollution, let us now discuss air quality. The terms of air quality are concentrations as opposed to total weights in emissions. Many monitors are available which will sample, will locally analyze and print out specific analyses for oxides of sulfur, oxides of nitrogen, specific oxides of each, fluorine and like components. The difficulty of these is that they are not as reliable as they appear. They must be calibrated in a laboratory or under laboratory conditions much too frequently. By and large they represent efforts by manufacturers of laboratory equipment to simply find another market for their equipment. They are not new and novel offerings and are not designed for the rigors of field service.

As pollution has attracted attention it has also attracted money. Instruments are now being evolved -- although they are not yet on the market -- which will remotely record or monitor and record concentrations and loadings, and even flow rates. These devices are by and large by - products of our aero - space programs. They will be extremely expensive, but should be paralleled with cheaper, sturdy and reliable equipment in time.

There are remote recorders to measure the particulate loading -- the dust -- in the air. Originally this was reported as co - efficient of haze and co - efficient of haze meters were developed. Our laboratory currently has seven. They are from two suppliers -- both leave a lot to be desired. My estimate of their maintenance costs is approximately 100% of their purchase cost, when they are used for any length of time. The timing assemblies and pumps are extremely weak parts of their systems.

A simple method for determination of any chemical component in air is the use of an impinger when it can be assumed that the component being sampled is uniformly distributed. A device to measure flow rate in the system and a method of determining the amount of gas sampled, will give concentration, which can be converted to a total weight or left as a concentration. Where relatively simple components are to be analyzed, the simpler water test methods can be used on the job site and readings can be obtained directly. Again the cost here is approximately $150 per day. The cost for automated equipment is extremely high -- normally it must be attended and has high maintenance factor.

Figure #6 shows one of the simplest and still most reliable devices in air pollution. This is the so - called dust fall bucket and the sulfur candle. The sulfur candle has been replaced by a small dish, but the principle remains the same. The candle is in the louvered shelter at the right of the picture .... It is a lead peroxide and a gum mix exposed to the atmosphere under conditions of fixed surface area. After 30 days (or whatever time is desired) the lead peroxide gum is brought in and analyzed in the conventional manner for total sulfur. By knowing the area and time of exposure a report of sulfur oxides (normally as SO2) is given per unit area per unit time. This can be roughly converted to concentrations per day, but there is no firm correlation.

The dust fall bucket literally collects airborne particulates which fall into it. Units of dust are considered in terms of tons per square mile per month, with a residential area standard considered to be about 20 tons and an industrial area about 35. The little ring is for a bird to sit on, so that his fertilizer plant does not produce into the bucket and contaminate the sample.

This unit can have attached to it a sticky paper jar -- simply adhesive tape set backwards on a round jar. It is oriented to north and removed after 15 days. By correlating the origin of the most wind blown dust on the sticky paper it is possible again to get a fix on the source of dust pollution. By having several stations, and it takes about 10 or 12, it is possible by fitting the least square methods of dustfall data and sticky paper data, to fix the origin of the dust rather accurately. In one city, we were able to come within 100 yards of the stack in question which caused better than 50 per cent of the pollution in that area. Since these devices are out 24 hours a day, they do not know time. Accordingly, they give only average results -- but they also find out what happens when it is dark and the operators start to dump or to blow their stacks.

I strongly recommend to any one getting into an air quality study, that you first monitor your plants with these simple units. They cost approximately $50 per unit. Charges for their use are $5 for the dust fall determination and $10 for candle preparation and analysis, per station per month. Thus you can see that 10 stations would have a cost of $150 per month plus the capital investment (on either a lease or purchase basis). This survey will identify problem areas for you which can then be studied in detail by sequential samplers, impingers, or any of the more sophisticated pieces of equipment. Said differently, a good survey will permit you to take a delightful shot and get much more for your money in your analyses.

I hope this talk has given an understanding of what it costs to sample for pollution whether you do it yourself or have an outside group do the job for you.

MR. ADAMS: The final presentation by the panel is by John Surber, who has appeared many times before the Fertilizer Industry Round Table. John is a graduate in chemistry from Vanderbilt University and has been involved in fertilizer production since 1954. He has had considerable experience in the manufacture of granular fertilizers, pre-neutralization, ammonium phosphates and specialty fertilizers. John works in the Technical Service Department of International Minerals & Chemical Corp. His paper is concerned with customer production problems, both domestic and foreign.

Control and Operation of Pollution Equipment in the Fertilizer Plant

John Surber
INTERNATIONAL MINERALS & CHEMICALS CORP.
SKOKIE, ILL.

What form the final anti-air pollution legislation will take is anybody's guess. One of the main areas of disagreement will involve whether to stay with the 1967 formulation of air quality control regions which is just starting to be implemented or, as the President suggests, scrap this approach in favor of national standards.

The public has shown increased interest in air pollution, especially air pollution regulations. In one state, air quality standards had to be revised and made more stringent because of public pressure. This close interest is likely to continue and even intensify, and industrialists would do well to take it seriously, because one day soon they will be forced to take action. The natives are restless, and it is going to take more than the usual public relations effort to pacify them.

Continuous plants for the manufacture of granular fertilizers, utilizing the maximum amounts of the cheapest possible raw materials, are found throughout the country in both industrial and rural areas. Gases from the dryer, cooler and ammoniator granulator are usually vented to the atmosphere through cyclones followed by some form of wet scrubber.

The objectionable features of these effluents arise from dust, fume and noxious gases which range from large-size particles down to sub micron fumes. Many large companies have their own specialists, but smaller companies need expert guidance in choosing equipment suited to their own needs.

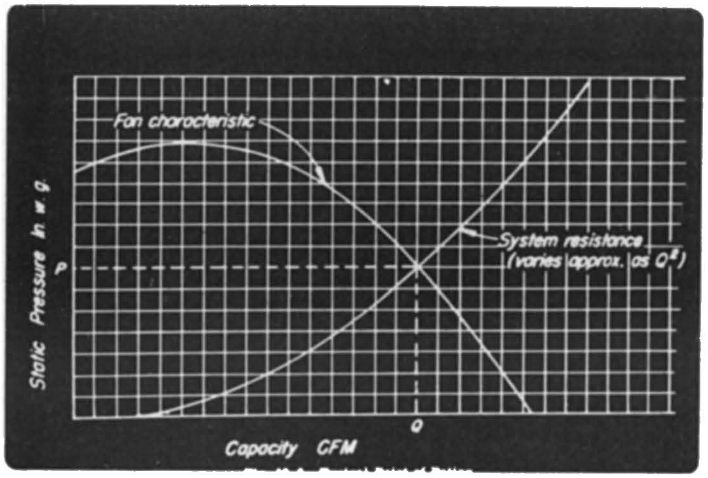
I would refer any of you to read the references used for this paper, as well as previous proceedings of the Round Table relating to this subject. Rather than reiterate what has been discussed again and again, I will discuss a few of the basics in both design and operation.

The first step, no matter what type equipment you have and whether or not secondary collectors are in use, is to put your system in as close a condition to its designed air flows as possible. By system is meant the path through which air is pushed and/or pulled. Methods to determine the resistance of a system are well known and can be found in many texts and manufacturers' literature.

In a system the static pressure varies as the square of the velocity and cfm. (Fig. 1) With this knowledge it is possible to predict the static pressure that will be needed to push any CFM through a system if only one static pressure vs. CFM relationship is known. Plotting this information gives a system curve. No matter what amount of air flows through the system, or the type and size of fan used, the relation of static pressure and cfm cannot change.

Laboratory tests establish fan performance and show that regardless of the system the fan must operate somewhere on its performance curve. It would thus seem a simple matter to determine the operating point as the intersection of the two curves.

Actual fan installations can be expected to deliver the fan's full rating only when the actual system allows the fan to operate as it would in a laboratory test. Any deviation will cause a change, invariably to the detriment of the system's performance. These rating tests are made under con-



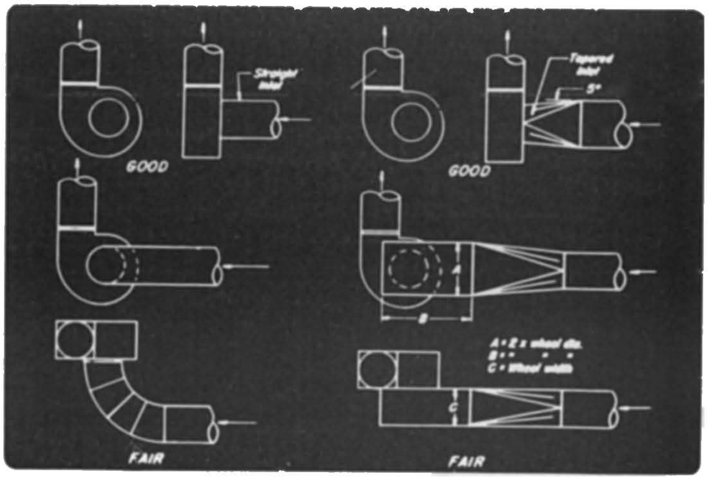


FIGURE 2. ECCENTRIC FLOW

ditions that effectively eliminate the three most important causes of poor fan performance in the field. These are:

1) Eccentric flow into fan inlet.
2) Spinning flow into fan inlet.
3) Fan discharge ductwork that does not allow full development of fan pressure.

Eccentric flow is caused when air makes a single plane turn to get into the fan. (Fig. 2) The detrimental effect is proportional to the degree of eccentricity.

The table (Fig. 3) lists some common inlet connections producing eccentric flow, the percent drop in fan capacity to be expected for each, and the percentage increase in static pressure required to compensate for eccentric flow.

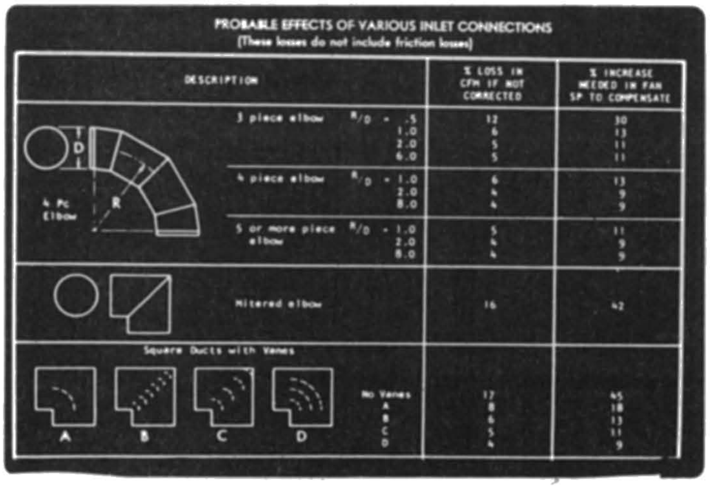
Spinning occurs principally from one of two reasons. Either air makes two consecutive turns in perpendicular planes (Fig. 4) that form a corkscrew path, or air is introduced to the duct or plenum tangentially. In either case, the angle of spin is important in determing the effect on fan performance. If the air spins in the same direction as the wheel is rotating, the net effect is similar to slowing down the fan, both capacity and horsepower are reduced. If the spin is opposite to the wheel rotation, the net effect is reduced capacity and increased horsepower. Judicious use of simple turning vanes and egg-crate straighteners can eliminate spinning and reduce eccentric flow.

The connection made to a fan's outlet (Fig. 5) cannot affect its performance as much as can the inlet connection, as the fan has done its work on the air by the time it reaches the outlet. However, the discharge connection does affect fan performance, and its design is important. If the discharge duct is omitted, a loss equal to roughly half the average fan outlet velocity pressure occurs, and a system resistance calculation should include this pressure loss as additional required static pressure.

Proper duct design (Fig. 6) dictates that, whenever space permits, elbows should be a minimum of 2 diameters of the centerline radius for round ducts, and if rectangular ducts must be used (Fig. 7) the aspect ratio as shown in the illustration should be kept as high as possible.

The reasons for stressing these fundamentals become obvious when collection equipment is considered.

Items of collection equipment are designed for a particular CFM and pressure drop. When they are installed in a system, which through poor installation of fan inlets and ductwork results in lower than design CFM and pressure drop, they cannot be expected to achieve good efficiencies. If field testing shows the system is handling less than the desired amount of air, there are only two ways of increasing the volume. One is to decrease the static pressure by changing the system as we have discussed, and the other is to speed up the


PROBABLE EFFECTS OF VARIOUS INLET CONNECTIONS
(These losses do not include friction losses)

DESCRIPTION		% LOSS IN CFM IF NOT CORRECTED	% INCREASE NEEDED IN FAN SP TO COMPENSATE
3 piece elbow	R/D = .5 1.0 2.0 6.0	12 6 5 5	30 13 11 11
4 piece elbow	R/D = 1.0 2.0 8.0	6 4 4	13 9 9
5 or more piece elbow	R/D = 1.0 2.0 8.0	5 4 4	11 9 9
Mitered elbow		16	42
Square Ducts with Vanes	No Vanes A B C D	17 8 6 5 4	45 18 13 11 9

FIGURE 3. SOME COMMON INLET CONNECTIONS

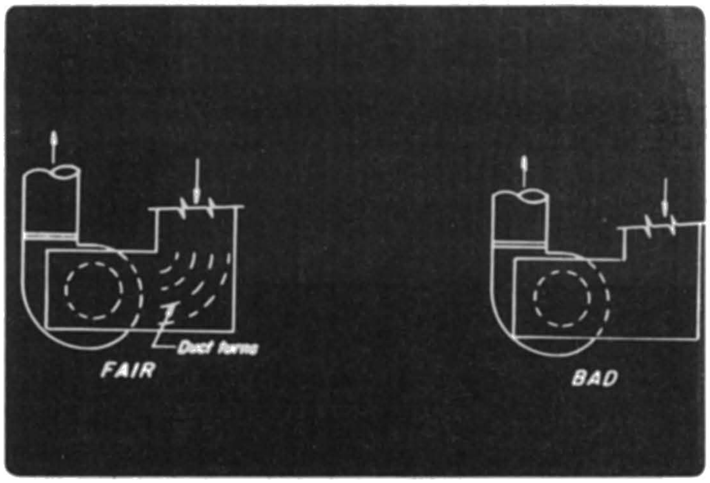


FIGURE 4. SPINNING REASONS

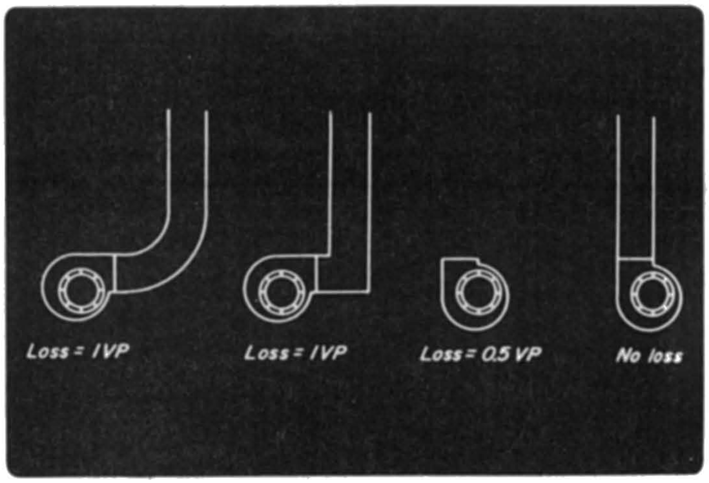
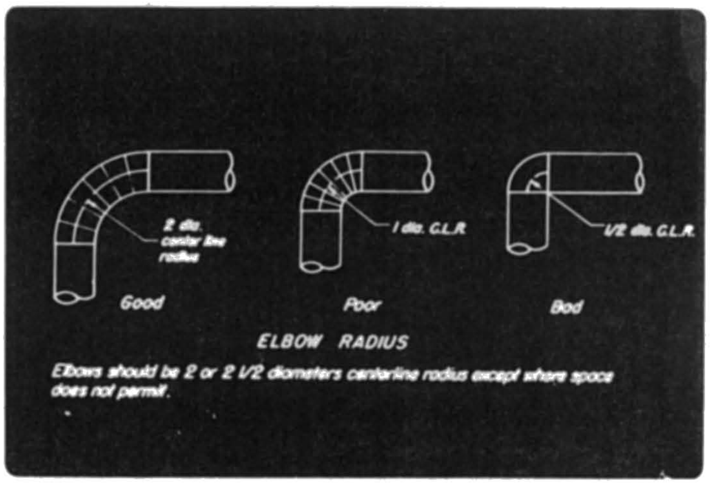


FIGURE 5. FAN CONNECTIONS



Elbows should be 2 or 2 1/2 diameters centerline radius except where space does not permit.

FIGURE 6. PROPER DUCT DESIGN

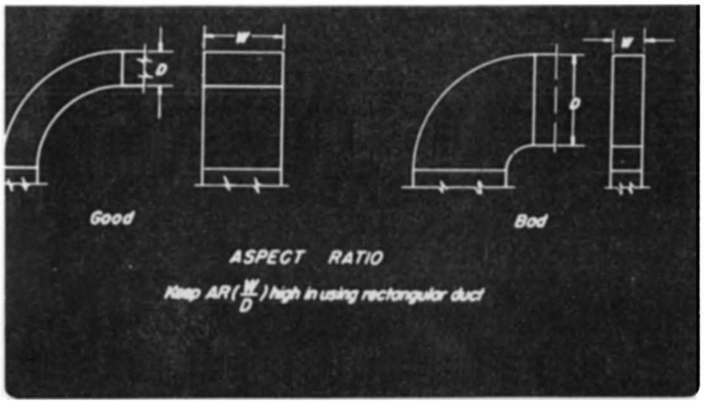
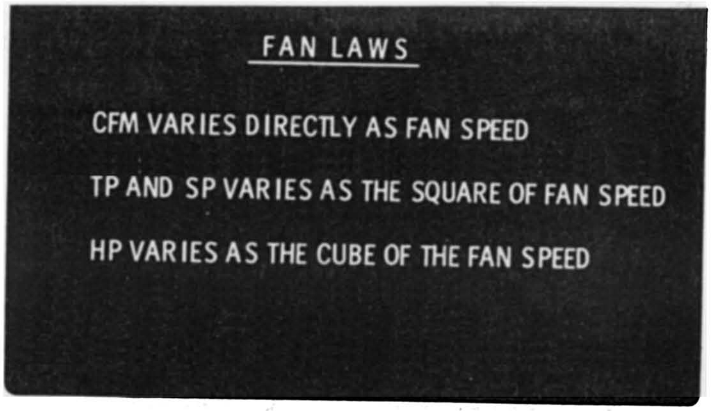


FIGURE 7. RECTANGULAR DUCTS



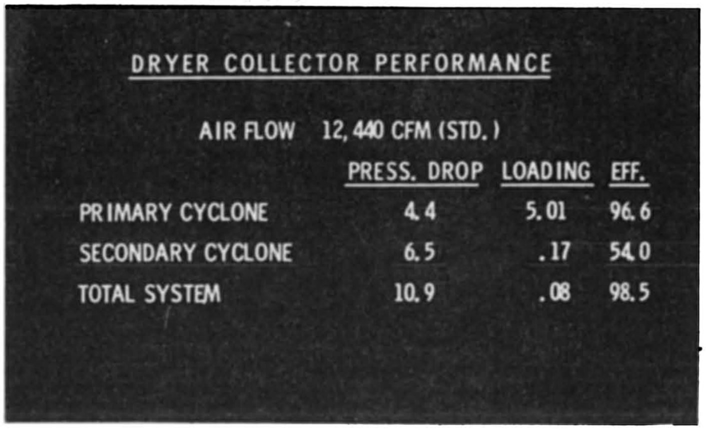
FAN LAWS

CFM VARIES DIRECTLY AS FAN SPEED

TP AND SP VARIES AS THE SQUARE OF FAN SPEED

HP VARIES AS THE CUBE OF THE FAN SPEED

FIGURE 8. FAN LAWS

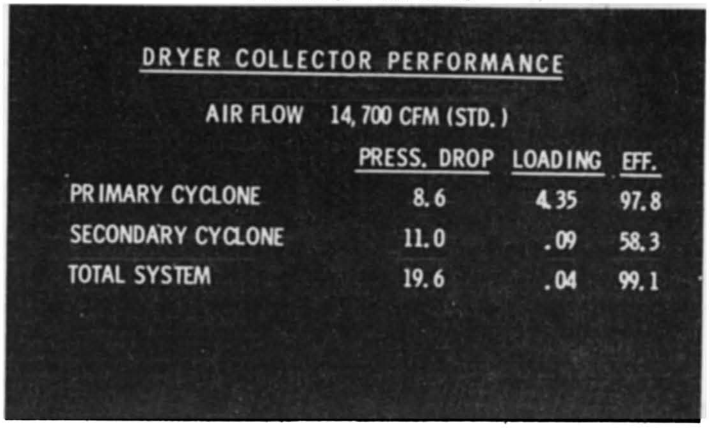


DRYER COLLECTOR PERFORMANCE

AIR FLOW 12,440 CFM (STD.)

	PRESS. DROP	LOADING	EFF.
PRIMARY CYCLONE	4.4	5.01	96.6
SECONDARY CYCLONE	6.5	.17	54.0
TOTAL SYSTEM	10.9	.08	98.5

FIGURE 9. DRYER COLLECTION PERFORMANCE. AIR FLOW 12440 CFM (STD)

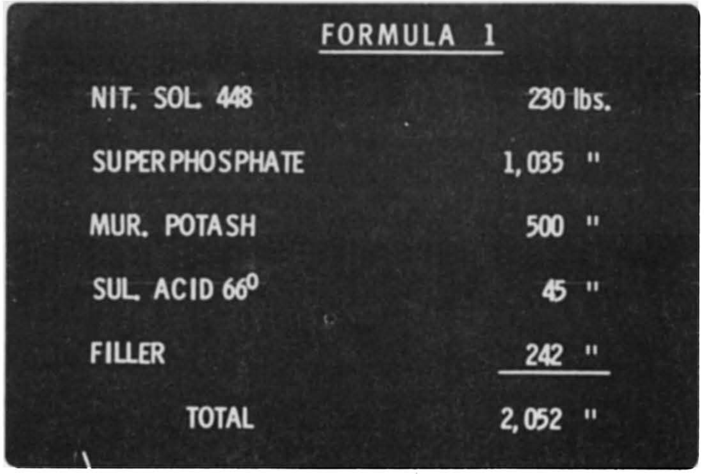


DRYER COLLECTOR PERFORMANCE

AIR FLOW 14,700 CFM (STD.)

	PRESS. DROP	LOADING	EFF.
PRIMARY CYCLONE	8.6	4.35	97.8
SECONDARY CYCLONE	11.0	.09	58.3
TOTAL SYSTEM	19.6	.04	99.1

FIGURE 10. DRYER COLLECTION PERFORMANCE. AIR FLOW 14,700 CFM (STD)



FORMULA 1

NIT. SOL. 448	230 lbs.
SUPERPHOSPHATE	1,035 "
MUR. POTASH	500 "
SUL. ACID 66⁰	45 "
FILLER	242 "
TOTAL	2,052 "

FIGURE 11. FORMULA #1

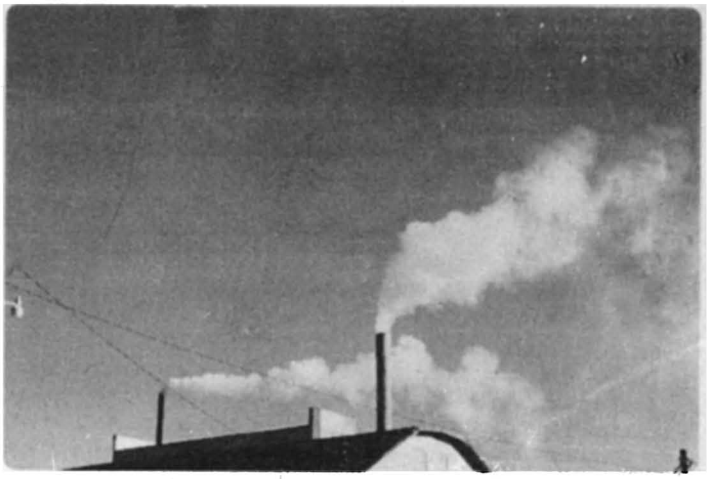
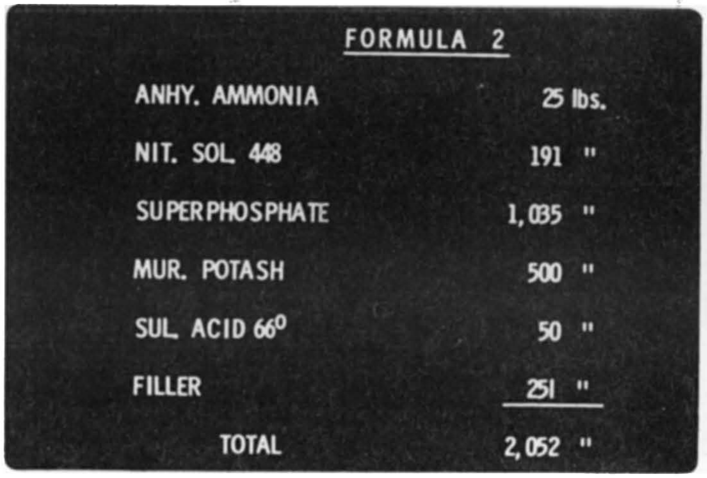


FIGURE 12. FORMULA #1 STARTUP

FIGURE 13. FORMULA #1 AFTER 1 HOUR OPERATION



FORMULA 2

ANHY. AMMONIA	25 lbs.
NIT. SOL. 448	191 "
SUPERPHOSPHATE	1,035 "
MUR. POTASH	500 "
SUL. ACID 66⁰	50 "
FILLER	251 "
TOTAL	2,052 "

FIGURE 14. FORMULA #2

fan. An increase in fan speed (Fig. 8) of let's assume 20% will yield a directly proportional increase in air volume, or 20% more CFM. The required horsepower will increase 73%, however, since brake horsepower varies as the (RPM)3.

I would like to show you at this point several examples of work which has been done to conform with state regulations regarding emissions. Particulate matter emissions are currently receiving the most attention, due to the fact that most complaints stem from dust on cars, laundry, windows and the like.

First is an example of a wet scrubber added to an existing system to scrub all of the air streams, including ammoniation exhaust, dryer and cooler cyclone exit streams, as well as handling a bulk mill.

This installation showed that dust loading from the ammoniator was .02 grains/SCF, the dryer cyclone exit .8 grains/SCF and the cooler cyclone exit 1.7 grains/SCF. Efficiences of the dryer cyclones were 95% and the cooler cyclones 90%. The scrubber in this case operated at 93% efficiency on the particulate matter, and further reduced the total particulate emission to the atmosphere to an acceptable figure of .03 grains/SCF.

As well known, the problems with utilization of a wet scrubber are many. The major one is what to do with the water. In many instances all that is accomplished is to transfer the problem from one agency to another, since any discharge of water will surely bring officials from water pollution agencies or the fish and game commission into the act.

Recirculation of the scrubbing water can be achieved to some degree, but usually the system will require ponding for any extended periods of use. In addition, any particulate collected is usually lost as far as plant food values. In the case just discussed, this loss amounted to about 100 lbs. per hour.

Depending on the water rates, a scrubber in the medium pressure drop range may be expected to be 60-80% efficient in removal of free ammonia from the gas stream, however only the high pressure drop scrubbers such as the Venturi are effective in removal of sub micron particles such as ammonium chloride fumes.

The use of a wet scrubber necessitates careful attention to other details in the system, such as cyclone discharge gates, since it tends to hide deficiencies. For example, a discharge gate on a cyclone may stick in such a manner as to seriously reduce the efficiency and not materially change the discharge from the scrubber. While this is commendable from the plant neighbor viewpoint, it is serious when the loss of plant food is considered.

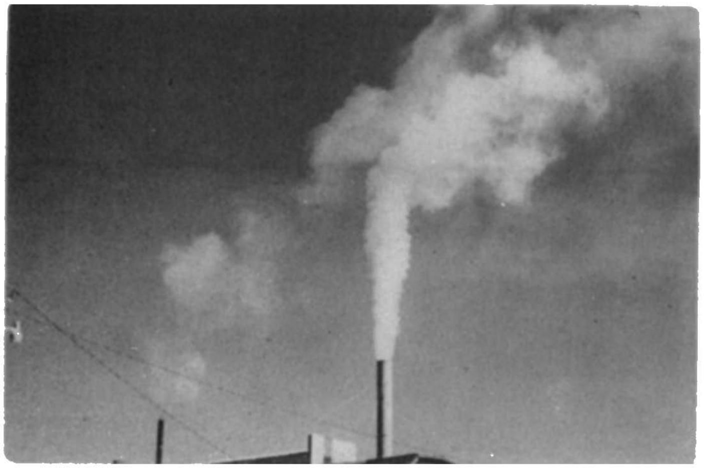


FIGURE 15. FORMULA #2 STARTUP

My point is that whenever a wet scrubber is utilized the entire air handling system should be gone over thoroughly, to gain the greatest possible efficiencies from existing dry collectors. These collectors should be checked on a periodic basis to ensure their efficient operation, thereby minimizing the particulate load on the scrubber.

In another plant location a ponding area was not available and a decision to use secondary high efficiency cyclones was reached.

As apparent in Figure 9, the system achieved an additional efficiency of about 53% on the particles remaining in the gas stream exiting the dryer cyclones, raising the total system efficiency from 96.6% to 98.5%. Unfortunately the grain loading of the emission was .08 grains/SCF and not acceptable in this location. A check of the fan motor amperage showed that the CFM and static could be increased by speeding up the fan, and this was done with the results as shown. (Fig. 10) The efficiency of the primary cyclones was increased to 97.8%, the secondary cyclones to 58.3% and the overall efficiency to 99.1%, resulting in an acceptable grain loading of .04 grains/SCF in the final emission. Similar results were obtained with the cooler cyclones.

The primary advantage of the system is that all particulate matter collected is returned to the system in a usable condition.

The cost of such a system when all factors are considered is less than that of a wet scrubber, but problems with gas and fumes remain and must be dealt with through formulation or other means. Fumes emanating from the ammoniator may be reduced by elimination of sulfuric acid from formulations or by controlling the reaction in a preneutralizer. Gas streams from the ammoniator can be scrubbed with phosphoric acid to reduce free ammonia and utilize it in the process.

A series of slides taken at a granulation plant, show what can be done with formulation. The small stack on the left in the illustration is from the ammoniator, and the larger one on the right from an impingement scrubber handling the gas streams from the dryer and cooler.

Formula 1 (Fig. 11) is a typical formula used in granulation of a 5-10-15 fertilizer. The stack during startup (Fig. 12) looks quite heavy and would have to be called typical. The same grade one hour later (Fig. 13) shows some improvement as the system heats up and equilibrium is reached.

Formula 2 (Fig. 14) utilizes a small amount of anhydrous ammonia and 5 pounds more of sulfuric acid. Most plants would achieve at least a standoff in material cost with this formula as compared with Formula No. 1.

During initial operation, the plume is visibly heavy, (Fig. 15) and as is apparent in (Fig. 16) there is no visible improvement even after one hour's operation.

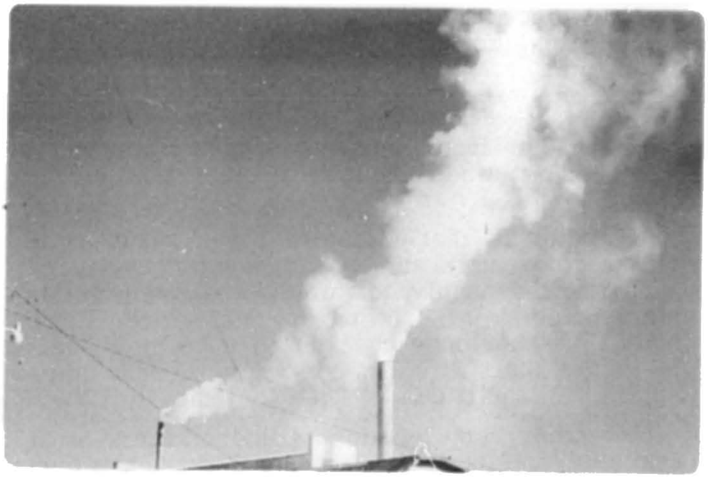
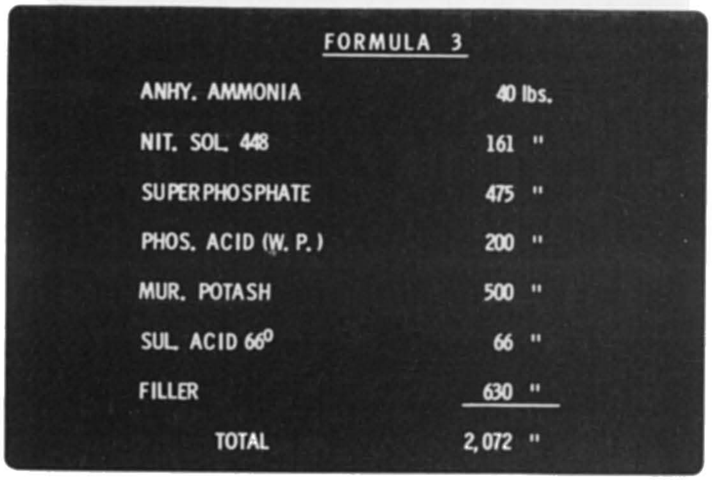


FIGURE 16. FORMULA #2 AFTER 1 HOUR OPERATION



FORMULA 3

ANHY. AMMONIA	40 lbs.
NIT. SOL. 448	161 "
SUPERPHOSPHATE	475 "
PHOS. ACID (W. P.)	200 "
MUR. POTASH	500 "
SUL. ACID 66°	66 "
FILLER	630 "
TOTAL	2,072 "

FIGURE 17. FORMULA #3

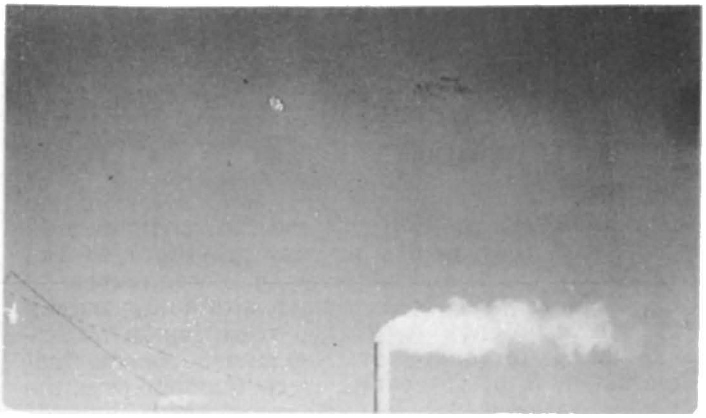
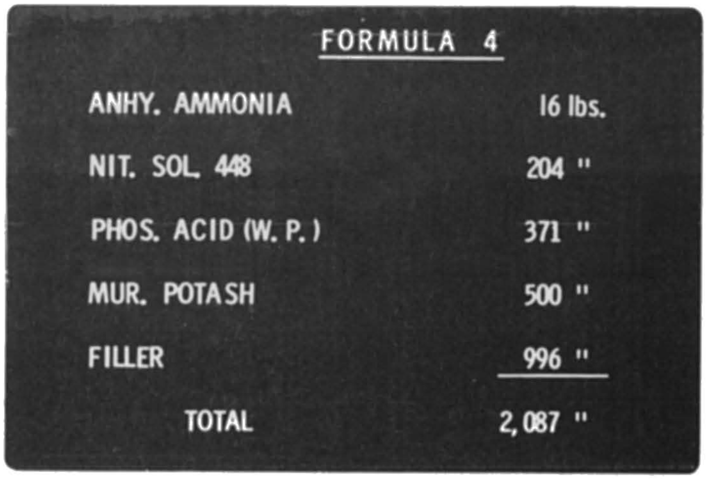


FIGURE 18. FORMULA #3 STARTUP

FIGURE 19. FORMULA #3 AFTER 1 HOUR OPERATION



FORMULA 4

ANHY. AMMONIA	16 lbs.
NIT. SOL. 448	204 "
PHOS. ACID (W. P.)	371 "
MUR. POTASH	500 "
FILLER	996 "
TOTAL	2,087 "

FIGURE 20. FORMULA #4

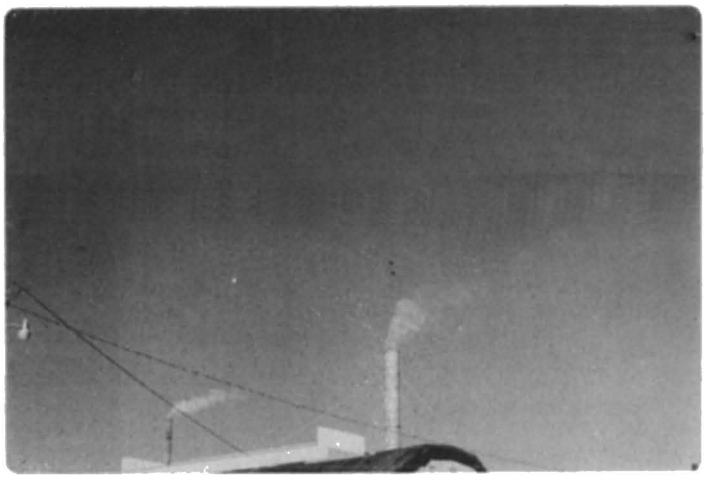


FIGURE 21. FORMULA #4 STARTUP

FIGURE 22. FORMULA #4 SCRUBBER PUMPS OFF

FIGURE 23. FORMULA #4 SCRUBBER PUMPS ON

Formula 3 (Fig. 17) substitutes 200 pounds of 54% wet process phosphoric acid for a portion of the superphosphate. Also the anhydrous ammonia is increased to 40 lbs. and the sulfuric acid increased to 66 lbs.

Fig. 18 shows that there has been a definite improvement, and after one hour of operation the stacks still look very good. (Fig. 19).

Formula 4 (Fig. 20) derives all of the P205 from the wet process phosphoric acid which necessitates a large quantity of filler, and the sulfuric acid is completely eliminated from the formulation.

The results are visibly better when compared with the operation of Formula No. 1. (Fig. 21) To illustrate how much of this is water vapor, the scrubber pumps were turned off, (Fig. 22) The result--a clear stack! Startup of the scrubber pumps immediately shows up as a visible plume. (Fig. 23)

A clear stack is not proof of harmless emissions, nor is a dirty one proof of great damage. Plant neighbors, however, would like to see clear stacks for aesthetic reasons, if nothing else. What the public wants it will, after enough time passes, get. It is at this point that the engineer'sheadaches begin, since the translation into control equipment is a difficult job. Clearness of a stack is a subjective rather than an objective quality, dependent upon such things as individual eyesight, illumination of the plume and contrast of the plume with its background.

Attention to formulation practices, utilization of sound air handling principles, and selection of proven collection equipment will enable granulation plants to meet their obligations with regard to emissions.

REFERENCES:

"The Chemistry and Technology of Fertilizers", edited by V. Sauchelli, ACS Monograph No. 148 (1965)

"Industrial Ventilation" - A Manual of Recommended Practice, 10th Edition, Committee on Industrial Ventilation, American Conference of Governmental Industrial Hygienists (1968)

"Engineering Letters" - The New York Blower Co.

QUESTIONS & ANSWERS

MR. HAROLD GREEN (Cotton Producers Association): Mr. Surber; What is the maximum temperature you can tolerate without having pollution of burnt fertilizers?

MR. SURBER: This is a personal opinion, and it will probably depend on the composition of the formulation you are running. Obviously, a formula that perhaps has a very high concentration of ammonium nitrate might be expected to act differently than formulations with a high concentration of urea.

MR. ADAMS: The questions is, 'At what temperature?'

MR. SURBER: Are you speaking of dry room temperature or exit air?

MR. GREEN: Inside the dryer.

MR. SURBER: The temperature on that is probably 180 to 185 degrees F., just above the dryer discharge.

MR. ADAMS: Does anyone else have a suggestion of a good running temperature on the dryer to keep down pollution?

ALBERT SPILLMAN: I found in our operations, that it was well to formulate so that the exit air temperature at the dryer could be held at a maximum 180 to 200 degrees F, varying with the formulas used.

MR. DON WARREN (W.R. Grace & Co.): With regards to the use of "phosphoric acid in scrubbing." We have done this and noted the formation of ammonium chloride. Have you noted this? If so, what did you do about it?

MR. SURBER: We have not had this experience in drying. I merely suggest as a possible alternative, and in your case, if the chloride is a problem, this would have to be dealt with. My first reaction would be that you would have to look for a more efficient scrubbing method.

MR. HATTIANGADI (Continental Oil Co.): How does a sulfuric acid plant using the single absorption process in conjunction with a clean plant, compare with a plant using the double absorption process, as far as investment and operating costs are concerned?

MR. ADAMS: On a new plant, double absorption is less expensive than a single absorption in the end.

MR. M. VAN SICKELS (Haldor Toppoe Inc.): When you pass the stale gas through your scrubbers, I presume there is a water-base solution. Won't you get a steam fume problem and how do you eliminate this if you do?

MR. SURBER: Yes, you will get this situation around 120 degrees, and then with an alternate facility we can reheat with the hot air. In other installations, you might have a heat exchanger on the front end.

MR. GEORGE DUDLEY (Richmond Guano Co.): Standards for eliminating air and water pollution vary in many states. I doubt that many plants now operating with only dust collectors will be able to meet the law, and thus they will need to install the necessary scrubbing and miscellaneous equipment to abate the problems. What would be the cost for this equipment to operate a 25-ton per hour granulating plant?

UNIDENTIFIED MEMBER: A wild guess of $35,000 to $50,000 depending on available space and available housing in the building at the particular plant to be equipped.

MR. SURBER: Without specifics on type and layout of the pollution equipment, it is difficult to give a cost figure. The costs will be high. However, to keep your plant operating, it will be absolutely necessary to satisfy your area "Air and Water Pollution Codes".

MR. J. RUBIN (Freeport Chemical Co.) The state of Louisiana is presently looking at Water standards, primarily in two areas: heavy metals and phosphoric acid. I would like to know if Mr. Barber has any information on these components?

MR. BARBER: I do not have this information.

MR. ADAMS: Does anyone here wish to comment on Mr. Rubin's question.?

MR. ROBERT L. SOMERVILLE (Pan American Consulting): I talked to Mr. Rubin a short time ago on this very important question, and this is something we should all be concerned about. Mercury caught some of us by surprise. Chlorination by itself is a pollutant. What next? I know that when you are working with some of the other raw materials, you can find some of the heavy materials. This is something that we should be quite concerned about. Is there anything that we are now doing that is suddenly going to catch up with us someday?

MR. FRANK NIELSSON (IMC): I have no question for Mr. Rubin, who probably knows the answers. We have been involved a little bit with heavy metals due to gypsum problems, and one thing that will surprise you, when you start analyzing and start looking for sources of heavy metals, your problems may be different than what they are now. Talking about pollution, I want to mention that with the increasing impact on plumes and those of you who have dryers, if you have one of those dryers which is punched full of holes, you will probably have a job trying to keep everybody satisfied on the plume. You need to get yourself a combustion chamber and put all the primary air through the combustion chamber from a source which is outside the fertilizer flame where you can get some clean air.

MR. T.A. BRANCH (Charles W. Priddy & Co.): Has anyone tried bag type filters from the cyclones?

MR. BARBER: I think the requirement there would be that the gases would need to be well above the dew point. I do not believe that will work.

MR. ADAMS: I am going to concur with Jim (Barber) on his thoughts. I have spent a little time with bag filters, and the problem is the same as Jim pointed out. Are there any more questions?

MR. SPILLMAN: Thanks, Bill, to you and your panelists for that outstanding discussion on "Pollution".

You are all invited for cocktails this evening. Our hosts for this gathering are:

CHEMICAL CONSTRUCTION CORP. (CHEMICO)
EDWIN COX ASSOCIATES
DAY & ZIMMERMAN, INC.
DORR-OLIVER, INC.
FERTILIZER ENGINEERING & EQUIPMENT CO., INC.
FERTILIZER EQUIPMENT SALES CORPORATION
GRINELL SUPPLY COMPANY, INC.
KIERNAN-GREGORY CORP.
THE LUMMUS COMPANY
THE PROSSER COMPANY, INC.
EDW. RENNEBURG & SONS CO.
THE A. J. SACKETT & SONS CO.
WELLMAN-LORD, INC.

The Entertainment Committee, whose members should be credited for the fine job they have done at this meeting, consists of: Thomas Athey (Chairman); Paul Prosser of Prosser Company; and Walter Sackett, Jr. of A. J. Sackett & Sons Co.

Friday, November 6th, 1970
Morning Session
MODERATOR: HERMAN G. POWERS

MODERATOR POWERS: I would like to extend a cordial welcome to you at this closing session of the 20th annual meeting of the Fertilizer Industry Round Table. I recall some remarks that were made at the closing session of the Round Table several years ago.

At that session, we had the privilege of a discussion by the director of maintenance for the DuPont Company. The gentleman did a great job of conveying to us the merits of a preventative maintenance program. At the close of his talk he looked the audience over and remarked that if anyone was not sold on preventative maintenance, he would suggest that they not fly home.

This morning the subject of our panel discussion is "Ammoniation and Granulation". For those of us that have been exposed to these two topics for sometime, I have often thought they could be called "Trials and Triviations".

Our panel leader for today's session is Mr. Quentin S. Lee of Cotton Producers Associates. Quentin is a native of Georgia, educated in Georgia and possibly has some distinction in the fertilizer business by the fact that he has been with the same company for some 17 years.

It is now my pleasure to relinquish control of the session to Quentin Lee.

Ammoniation and Granulation

PANEL LEADER: Quentin S. Lee

MANAGER PLANT FOOD DEPT.
· COTTON PRODUCERS ASSOCIATION
ATLANTA, GA.

PANEL LEADER, QUENTIN S. LEE: Ammoniation and granulation are basic operations in fertilizer operations. An up - to - date discussion on the practices, techniques and problems is always useful and welcome. The participants on the panel discussing these subjects today will surely give all of us some new ideas -- and perhaps the membership will add to the comments of our panel group.

Professor Jumpei Ando, from Japan, will discuss "Developments in Granulation." He is a graduate from the University of Tokyo and has a Ph.D. from the University of Alabama. He has twice resided in Alabama, from 1961 to 1963 and from 1965 to 1966. He has also been associated with T. V. A.

Professor Ando is on the faculty of Chuo University, Tokyo, Science and Engineering Division, teaching organic and inorganic chemistry. He is also an advisor to the Japanese Mixed Fertilizer Producers.

Developments in Granulation of Mixed Fertilizers in Japan

Jumpei Ando

CHUO UNIVERSITY
TOKYO, JAPAN

Important changes have occurred in the production and use of fertilizers in Japan for the last ten years. The use of straight fertilizers has almost ceased and now nearly 80% of total fertilizer is in the form of granular mixed fertilizers with hundreds of grades. High analysis granular mixed fertilizers based on wet-process phosphoric acid and urea or ammonium chloride have been produced in large amounts. Fertilizers containing nitrates are not popular, although they are growing rapidly. The status of granular mixed fertilizer production and some chemistry and technology of the granulation will be described in this paper.

PRODUCTION OF MIXED FERTILIZERS

The production of granular mixed fertilizers in Japan was started some 40 years ago and has increased substantially since 1950. In 1968 production reached 4,500,000 metric tons as shown in Figure 1.

Between 1950 and 1960, most of the granular mixed fertilizers were low analysis grades formulated from ordinary superphosphate. High analysis granular mixed fertilizers which contain a total of 30% or more in N, P205, and K20 have increased remarkably since 1960, while low analysis fertilizers have decreased since 1964. Production of non-granular mixed fertilizers reached about 500,000 tons in 1955 and has not changed much since then.

Figure 2 illustrates the relative amounts of N, P205, and K20 consumed in the form of mixed fertilizers from 1962 to 1969. Nitrogen in the form of mixed fertilizers increased from 49 to 72%, P205 from 66 to 76%, and K20 from 54 to 84%. The rest of the plant nutrients was consumed mainly in the form of straight fertilizer; liquid and bulk blend fertilizers are of minor importance in Japan.

The remarkable growth in the use of granular mixed fertilizers in recent years may not continue in the future because more than 70% of the plant nutrients are already being produced in mixed form. Moreover, over-production of rice has become a serious problem in Japan recently. Rice is the main crop in Japan, and accounts for about 40% of total fertilizer consumption.

PRODUCTION OF PHOSPHATE AND NITROGEN FERTILIZERS

Figure 3 shows the production of wet-process phosphoric acid and phosphate fertilizers in Japan. The production of phosphoric acid has increased measurably since 1960 as the demand for high analysis mixed fertilizers increased. Production reached 550,000 tons of P205 in 1969. In recent years, about 80% of the acid has been used for fertilizer.

Ordinary superphosphate production reached a maximum of 350,000 tons of P205 in 1960 and has declined since that year. Triple superphosphate has been produced in small amounts, while fused calcium magnesium phosphate prepared from serpentine reached 100,000 tons of P205. All of the phosphoric acid and the phosphates are essentially for domestic consumption.

MATERIALS FOR GRANULAR MIXED FERTILIZERS

Table 1 compares the amount of the plant nutrients used in granular mixed fertilizers from various sources in 1966 and 1968. In the case of nitrogen, large amounts of urea and ammonium chloride were used in addition to ammonia and ammonium sulfate. Both urea and ammonium chloride have been about 10% cheaper than ammonium sulfate on the nitrogen basis. The amounts of nitric acid and ammonium nitrate have also increased, but the tonnages are still small. The nitric acid is used mainly for the production of nitric phosphate. It should be noted that slow-release nitrogen fertilizers, isobutylidene diurea (IBDU) produced by Mitsubishi Chemical Industries and cyclo diurea (CDU) produced by Chisso Co., are used for the production of mixed fertilizers in increasing amounts.

All the phosphate rock has been imported. In 1968, about 2,300,000 tons came from Florida and 950,000 tons from Morocco, Taiba, Togo and other areas. Recently Japan has imported phosphate fertilizer intermediates. In 1968, about 20,000 tons of triple superphosphate and 30,000 tons of diammonium phosphate were imported from the USA.

Production of nitrogen fertilizers is shown in Figure 4. Urea production has increased markedly since 1954 and reached 1,000,000 tons of N in 1968. Japan has been the largest producer of urea in the world. Ammonium sulfate production reached about 500,000 tons of N in 1958 and has not changed much since then.

Unlike the situation in the United States and European countries, production of ammonium nitrate is very minor, while that of ammonium chloride (a by-product of soda ash production) has increased since 1955 and reached 200,000 tons of N in 1968. The nitrate is not suitable for paddy application, while the chloride has shown good agronomic response. About 70% of urea as well as about 60% of ammonium sulfate and chloride have been exported recently.

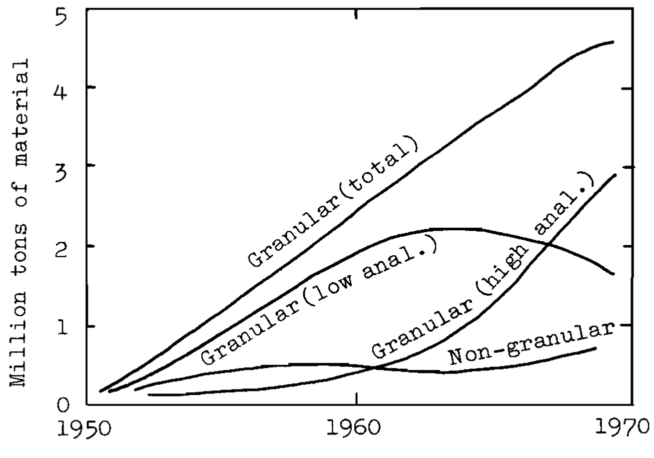


Figure 1 Production of mixed fertilizers in Japan

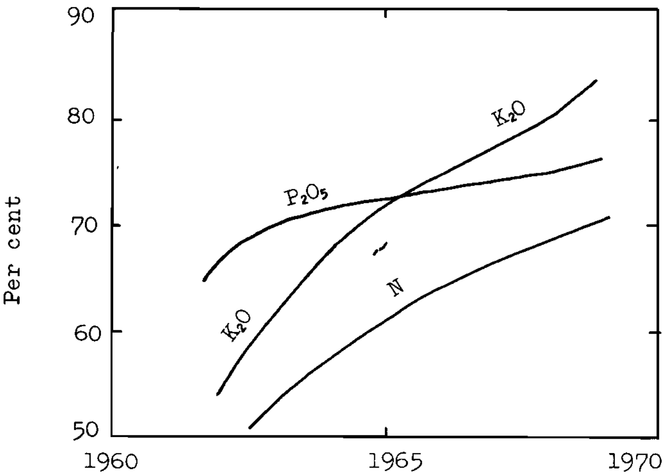


Figure 2 Relative amounts of N, P_2O_5 and K_2O consumed in the form of mixed fertilizers(per cent of total)

TABLE 1

Materials used for granular mixed fertilizers 1)
(1,000 metric tons of plant nutrients)

Materials	1966	1968
Ammonia	156	201
Ammonium sulfate	131	152
Urea	71	99
Ammonium chloride	45	58
Nitric acid	10	15
Ammonium nitrate	1.5	4
Isobutylidene diurea	0.9	1.8
Cyclo diurea	0.4	1.4
Phosphoric acid	280	377
Ordinary superphosphate	133	124
Triple superphosphate	10	14
Fused phosphate	6	5
Calcined phosphate	2	3
Potassium chloride	360	434
Potassium sulfate	49	62

The main source of P205 is wet-process phosphoric acid. Considerable amounts of ordinary superphosphate, and smaller amounts of triple superphosphate, fused phosphate and calcined defluorinated phosphate have also been used.

Potassium has been supplied mainly as potassium chloride which has been imported. Some potassium sulfate is also used. About half of the sulfate has been imported and the remainder has been produced in Japan from potassium chloride and sulfuric acid.

Table II Main Grades Produced in 1966 and 1968
(1,000 metric tons of material)

1966		1968	
Grades	Amount	Grades	Amount
8-8-5	246	8-8-5	169
8-8-8	176	14-14-14	157
16-16-16	135	8-8-8	142
14-14-14	133	16-16-16	111
6-9-6	93	6-9-6	81
14-10-13	85	15-15-10	78
13-17-12	81	14-10-13	78
13-13-13	77	12-16-14	74
15-15-10	58	13-13-13	73
14-17-13	53	15-15-15	72
10-20-20	47	12-18-14	71
12-18-14	44	13-17-12	71
15-15-15	43	14-17-13	66
8-8-6	42	18-0-16	57
18-0-16	38	16-10-14	56
14-12-9	38	10-20-20	53
11-11-11	37	10-14-12	49
9-6-7	34	16-0-16	48
16-0-16	32	14-18-14	46
12-16-14	32	18-18-18	34
18-18-18	28	12-8-10	33
9-7-8	29	17-0-17	33
3-10-10	29	18-11-11	33
16-10-14	28	19-41-0	31
12-8-10	28	11-11-11	30
Total of 25 grades	1,666	Total of 25 grades	1,746
Total of all grades	3,882	Total of all grades	4,579

MAIN GRADES OF GRANULAR MIXED FERTILIZERS

The amount of the top twenty-five grades of granular mixed fertilizers produced in 1966 and 1968 are shown in Table II. The low analysis products, 8-8-5 and 8-8-8, have been the most popular, but their use is decreasing. Among high analysis mixed fertilizers, the most popular type is based on ammonium phosphate, ammonium sulfate and potassium chloride. The main grades are 14-14-14, 14-10-13, 13-13-13, and 14-17-13. The grades 16-16-16, 15-15-15, 18-18-18, etc, contain urea, while 12-18-14, 18-0-16, and a part of 14-14-14, etc. are made with ammonium chloride.

The total tonnage of the twenty five grades accounted for 43% of all granular mixed fertilizers in 1966, and 38% in 1968. The total tonnage of the leading ten main grades represented only 29% (1,137,000 tons) in 1966 and 23% (1,035,000

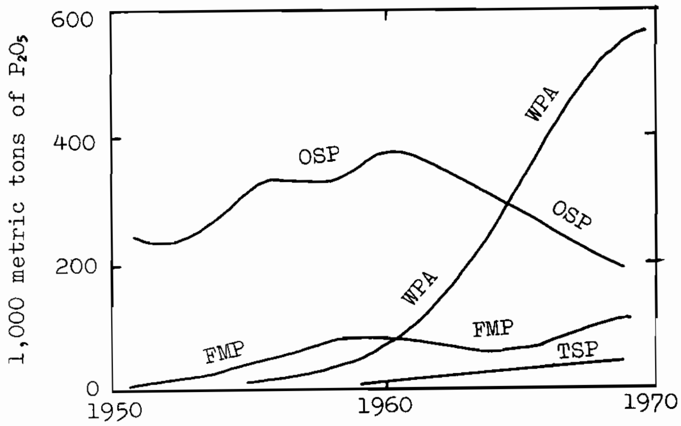


Figure 3 Production of wet-process phosphoric acid(WPA), ordinary superphosphate(OSP), fused calcium magnesium phosphate(FMP), and triple superphosphate(TSP)

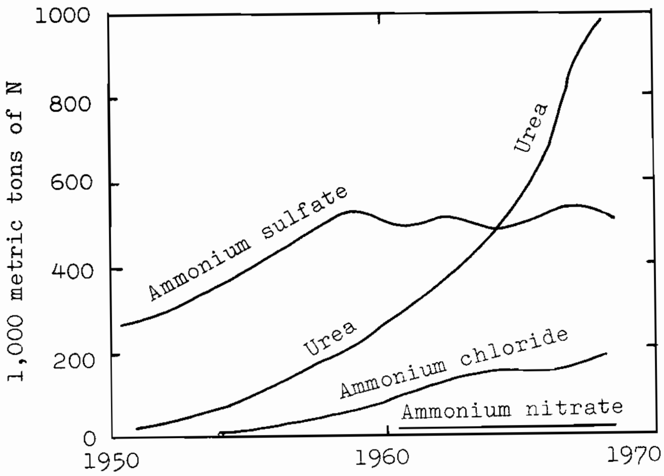


Figure 4 Production of nitrogen fertilizers

tons) in 1968, as compared with about 40% (8,500,000 tons) in the United States in recent years. 2) This shows that many grades have been produced in Japan in small amounts.

The most popular size of the granules is 1.5 to 3.5 mm (about 4 to 12 mesh). Smaller granules 1 to 3 mm and a small amount of special large granules 5 to 10 mm have also been used. For conditioning granular high analysis mixed fertilizers, kieselguhr and talc have been widely used at a rate of 1 to 2%. The use of conditioners is none, or less than 1% for low analysis products.

PRODUCTION OF WET-PROCESS PHOSPHORIC ACID

The production capacity of wet-process phosphoric acid and solid ammonium phosphate by each producer is shown in Table III. The table includes all of the producers of wet-process phosphoric acid who have been using the acid for fertilizer. There are two other producers who produce the acid in small quantities for other industrial use.

Until several years ago, the acid was produced by small plants with a daily production capacity of 30 to 100 tons of P2O5. Recently, larger plants with capacities of 100 to 230 tons from a single train have been built, and total production capacity reached 798,000 metric tons of P2O5 per year in 1970. Most of the wet - process phosphoric acid has been produced by a hemihydrate - dihyrate process developed in Japan such as the Nissan process, the NKK (Nippon Kokan) process and the Mitsubishi process. Recently three plants have been built which use the Central - Prayon process developed by a collaboration of Central Glass Co. and Prayon. All of the by - product gypsum is utilized for wall-board and also as an additive to cement.

The production of solid diammonium and monoammonium phosphates has increased recently. The yearly production capacity was 290,000 tons of material in 1966, 390,000 tons in 1968 and reached 667,000 tons in 1970. The ammonium phosphates have been produced by various processes developed by a number of producers including Nissan, TVA, Prayon, Scottish Agricultural Industries and Fisons.

Table III also shows the production capacity of high analysis mixed fertilizers based on slurry and solid ammonium phosphates. In addition to those listed in Table III, there are many smaller producers who buy ammonium phosphate and produce high analysis mixed fertilizers. In 1968 about 60% of wet - process phosphoric acid used in high analysis mixed fertilizers was in the form of ammoniated slurry, and most of the remainder as solid ammonium phosphate.

FORMULATION AND GRANULATION OF MIXED FERTILIZERS

HIGH ANALYSIS MIXED FERTILIZER USING AMMONIUM SULFATE

Production of high analysis granular mixed fertilizer was started nearly 40 years ago by Nissan Chemical Industries who developed a spray tower process (3) and by Sumitomo Chemical Industries who also developed their own process using pug mills.

TABLE III. Production capacity of wet-process phosphoric acid (1000 metric tons of P2O5) solid ammonium phosphate and high analysis granular mixed fertilizers (1000 metric tons of material) per year (1970)

COMPANY	LOCATION OF PLANT	PHOS-PHORIC ACID	SOLID** AMMONIUM PHOSPHATE	MIXED FERTILIZERS BASED ON	
				SLURRY	SOLID
Mitsui Toatsu Chemicals	Hokkaido	20	37 M	53	59
	Hiroshima	48	24 M	0	0
	Chiba	0	0	0	130
	Omuta	14	26 M	0	119
Nitto Chemical Industries	Hachinohe	30	46 M	60	99
Rasa Industries	Miyako	57	50 M	63	42
Tohoku Hiryo K. K.	Akita	68	64 D	228	74
Nihon Suiso Kogyo	Onahama	15	0	137	0
San Kagaku K. K.	Higashiko	80	35 M	64	0
	Ishiyama	0	0	99	52
Toyo Gas Chemical	Niigata	12	24 M	0	56
Nissan Chemical Industries	Toyama	39	67 D	194	0
Japan Union Fertilizer	Chiba	15	0	102	10
Nihon Phosphoric Acid	Chiba	68	136 D	0	0
Nippon Kokan K. K.	Koyasu	21	6 D	122	52
Ishihara Sangyo--K. K.	Yokkaichi	13	27 D	0	121
Taki Fertilizer Manuf.	Befu	20	25 M	78	53
Konoshima Chemical Ind.	Konoshima	12	0	96	0
Ube Industries	Ube	25	34 M	290	0
Central Glass	Ube	75	0	279	0
Sumitomo Chemical	Niihama	49	21 D	173	39
Kyushu Chemical	Tobata	12	24 D	0	72
Mitsubishi Chemical Ind.	Kurosaki	44	21 D	185	84
Chisso	Minamata	34	0	240	0
Onoda Chemical Industries*	Onoda	27	0	0	0
Total		798	667	2463	1062

*Production capacity for calcined defluorinated phosphate 105,000 tons.
**M: Monoammonium phosphate, D: Diammonium phosphate.

Since 1960 demand for granular high analysis mixed fertilizers has increased remarkably and many producers have started to use the Dorr process. In Dorr's standard process, a mixture of filter grade wet - process phosphoric acid and sulfuric acid is ammoniated to a degree necessary to form ammonium sulfate and monoammonium phosphate and then fed to a pug mill along with potassium chloride and recycle. The recycle ratio used to be greater than 10. The main grades of the products are 13-13-13, 10-14-13, 14-12-9, etc.

The process was modified in recent years as demand increased for products containing diammonium phosphate, and also as the need arose to increase production capacity. The producers add a larger amount of ammonia to neutralizer. A few of them add some ammonia to pug mill. The grades of the products which contain most of the phosphate in the form of diammonium phosphate are 14-14-14 or 14-17-13, 14-10-13, etc. Many producers have recently used wet - process phosphoric acid concentrated to 40 to 50% and some solid ammonium phosphate. Production capacity increased by 30 to 70% as the recycle ratio decreased to 5 - 7.

Several producers have used TVA type ammoniator granulators recently. The recycle ratio ranges from 2 to 5. Other producers started granulating with solid monoammonium or diammonium phosphate along with ammonium sulfate and potassium chloride, using rotary drum or pan granulator. The recycle ratio ranges from 0.5 to 1.

Moisture content of the granulator product ranges from 5 to 9% and that of the dryer product from 0.5 to 1.5%. During the production processes, ammonium sulfate reacts with potassium chloride to form ammonium chloride and potassium sulfate. A portion of monoammonium phosphate also reacts with potassium chloride to form ammonium chloride and monopotassium phosphate. The products usually consist of ammonium chloride, diammonium phosphate, a solid solution of monoammonium phosphate with a small amount of monopotassium phosphate, and a solid solution of ammonium and potassium sulfates. (4)

HIGH ANALYSIS GRANULAR MIXED FERTILIZER USING UREA

High analysis granular mixed fertilizer containing urea was first produced by Nissan Chemical Industries in 1954. Many other producers started production several years later. Urea has been commonly used together with some ammonium sulfate to produce the grades 15-15-15, 16-16-16, 17-17-17, 10-20-20, etc. A few producers have manufactured 18-18-18, 20-20-14, etc. without ammonium sulfate. Rotary drum and pan granulators have been mainly used for granulation. The production capacity ranges from 6 to 25 tons per hour for most of the granulators.

As urea is highly water soluble and reacts with any free moisture to produce a liquid phase, moisture content of the material in the granulator is usually kept below 5%. Therefore, urea is added mainly in the solid form -- prills after being pulverized or crystals. Molten urea is also used in some plants. The recycle ratio ranges from 4 to 8 when ammoniated slurry of phosphoric acid is used, and from 1 to 3 when solid ammonium phosphate is used. Mitsubishi Chemical Industries has used a considerable amount of urea solution (about 80% concentration) in addition to urea crystals along with ammoniated slurry of phosphoric acid to obtain a better shape of the granules without increasing the recycle ratio. A TVA type ammoniator granulator of Mitsubishi's has produced as much as 25 tons of 16-16-16 or other grades per hour. The excessive use of urea solution increases the recycle ratio and decreases production capacity.

Another factor limiting production capacity is the drying as was reported by Meline, Hicks, Kelso and Norton. (5) The temperature of the granules in the dryer is normally kept below 85 degrees C. to avoid melting. In some plants, two dryers are provided for each granulator. Moisture content of the dryer product is normally kept between 0.5 and 0.8%.

When ammonium sulfate is used along with urea, ammonium chloride (which is formed by the reaction of the sulfate and potassium chloride) combines with urea to form a compound NH_4Cl-$CO(NH_2)_2$. An X-ray test with a sample of 16-16-16 showed that all of urea was present in the form of the above compound. (4) Such chemical reaction may change the nature of the materials and consequently affect granulation and drying. When neither ammonium sulfate nor ammonium chloride is used in the formulation, most of the urea remains in the product as uncombined urea. (6) The products of grades 18-18-18, 20-20-14, etc. to which all of supplemental nitrogen is fed by urea melt readily at elevated temperatures and are difficult to dry. They are usually produced with solid ammonium phosphate.

Mitsui Toatsu Chemicals Inc. has been using small amounts of formaldehyde in combination with urea. This application facilitates the drying, improves the physical properties of the product, and provides some slow - release nitrogen.

Production of granular high analysis mixed fertilizers containing slow-release nitrogen compound such as IBDU or CDU is also growing, and reached 55,000 tons in 1969. The main grades are 15-15-15, 16-10-14, etc. and about a half of nitrogen is in the form of the slow-release compounds.

FERTILIZERS USING AMMONIUM CHLORIDE

Production of high analysis mixed fertilizers based on ammonium chloride was first started by Central Glass Co. in 1960. By-product ammonium chloride contains 25% nitrogen and is cheaper than ammonium sulfate by about 10% on a nitrogen basis.

Filter grade wet-process phosphoric acid is ammoniated to form a slurry of monoammonium phosphate, and this is fed to a pug mill along with ammonium and potassium chlorides and recycle. The granulation is not as easy as with ammonium sulfate. This may be due to the nature of ammonium chloride which causes essentially no chemical reaction. The difficulty has been overcome by improved techniques, and production by the company reached 160,000 tons per year in 1969. The main grades are 14-14-14 and 12-18-14.

The recycle ratio ranges from 2 to 4. Moisture content of the granulator product ranges from 5 to 6% and that of dryer product from 0.5 to 0.8%.

In addition, Central Glass Co. has been producing about 100,000 tons yearly of N-K fertilizers, such as 18-0-16 and 17-0-17 with ammonium and potassium chlorides. These grades have been used for top dressing for rice and pasture land. Compacting machines have been used for the granulation because the materials of these grades are difficult to granulate by conventional granulators. The mixed material is pressed between rollers to form flakes which are then cut into pellets of sizes falling 5 to 10 mesh.

Two other producers have furnished similar products in recent years. In addition, there are several smaller producers who use some ammonium chloride along with ammonium sulfate or urea to prepare high analysis mixed fertilizers based on solid ammonium phosphate.

FERTILIZERS CONTAINING MAGNESIUM

Production of high analysis granular mixed fertilizers containing magnesium is growing. Magnesium is added mainly in the form of hydroxide precipitated from sea water. Principal grades are 12-20-16-5 and 18-10-10-4 containing urea and 10-16-12-5, 10-20-15-3, and 12-16-14-4 without urea. Fluorine in the phosphoric acid or in the ammonium phosphate affects the constitution and properties of the products in the following ways: (7)

It reacts with magnesium and ammonium phosphate to form a compound

$$MgNH_4HFPO_4$$

or a similar amorphous compound and thus depresses the formation of

$$MgNH_4PO_4 \cdot H_2O$$

Fluorine greatly increases the viscosity of the reaction product. Moreover, a small portion of potassium becomes water insoluble by combining with the above fluorine compound.

San Kagaku K. K. (former Niigata Ryusan) has used serpentine as a source of magnesium. Serpentine is decomposed by a mixture of wet-process phosphoric acid and sulfuric acid. The slurry is ammoniated and granulated with potassium chloride and recycle, using a TVA type ammoniator granulator to produce 65,000 tons yearly of 11-11-11-4, 10-14-12-4, etc. In addition, San Kagaku has produced 20,000 tons yearly of 10-20-10-6 in large granules 5 to 10 mm in diameter, using extruding pelletizers. The large granules are used for paddy fields.

As another special type fertilizer for paddy fields, Mitsubishi Chemical has produced about 10,000 tons yearly of 10-10-10-1 with ordinary superphosphate, fused phosphate (serpentine fused), IB, and potassium chloride. The granules are 4 to 8 mm in diameter being granulated by a special type of rotary drum granulator. They are very hard due to the reaction between the superphosphate and fused phosphate, and do not break down in water for about a month.

OTHER HIGH ANALYSIS GRANULAR FERTILIZERS

Nitric phosphate has been produced by Asahi Chemical Industries for about 20 years. In a recently developed process by this company, phosphate rock is decomposed by a mixture of nitric acid and potassium sulfate to precipitate a portion of calcium as gypsum, which is then filtered off. The mother liquor is ammoniated and granulated to produce 15-15-12, 16-10-14, etc. Production capacity reached 200,000 tons per year.

Mitsubishi Chemical Industries recently built a plant to produce 50,000 tons yearly of nitric phosphate by its own process using potassium sulfate. Sumitomo Chemical Co. and Nissan Chemical Industries recently built nitric phosphate plants that use the mixed acid process developed by TVA. (8)

There are many other types of high analysis mixed fertilizers containing micro nutrients, pesticides, nitrification inhibitors, organic materials, etc.

LOW ANALYSIS GRANULAR FERTILIZERS

Most of the low analysis granular mixed fertilizers are based on ordinary superphosphate, ammonium sulfate and potassium chloride. Since high water solubility of P2O5, above 80%, is preferred by most farmers, ammoniation is carried out only slightly (just sufficient to neutralize free acid of superphosphate) or is often omitted entirely. Drum and pan granulators have been widely used. The popular grades are 8-8-5, 8-8-8, 6-9-6, etc.

Granulation is quite easy. The recycle ratio is usually less than 0.5. In some plants, more than 85% of the granulator product is on size -- between 5 and 14 mesh. Moisture content of the granulator product usually ranges from 7 to 12% and that of the dryer product from 1 to 1.5%.

During the production process, ammonium sulfate readily reacts with potassium chloride and also with monocalcium phosphate and calcium sulfate from the ordinary superphosphate as illustrated by the chemical equations (1) to (4). The products consist mainly of monoammonium phosphate, ammonium chloride, ammonium calcium sulfate, and potassium calcium sulfate (syngenite). (9)

(1) $(NH_4)_2SO_4 + 2KCl = K_2SO_4 + 2NH_4Cl$

(2) $(NH_4)_2SO_4 + Ca(H_2PO_4)_2 \cdot H_2O = 2NH_4H_2PO_4 + CaSO_4 + H_2O$

(3) $(NH_4)_2SO_4 + CaSO_4 + H_2O = (NH_4)_2SO_4 \cdot CaSO_4 \cdot H_2O$

(4) $K_2SO_4 + CaSO_4 + H_2O = K_2SO_4 \cdot CaSO_4 \cdot H_2O$

Several producers have used ammonium chloride in place of ammonium sulfate to produce 9-9-9, 10-7-9, etc. By using the chloride, essentially no chemical reaction occurs during production; granulation is not as easy as with ammonium sulfate.

Products containing urea with the grades of 10-10-7, 12-8-7, 10-10-10, etc. have been produced for the last 15 years. By using urea, replacing ammonium sulfate, production capacity decreases by 10 to 30% due to increased difficulty in drying. Urea reacts with monocalcium phosphate and calcium sulfate from ordinary superphosphate to form the compounds $Ca(H2PO4)2\text{-}4CO(NH2)2$ (10) and $CaSO4\text{-}4CO(NH2)2$. Ammonium sulfate reacts with these compounds following the equations (5) and (6). (6) Urea also combines with ammonium chloride as already mentioned. These reactions may affect the properties of the products.

$$(5)\quad Ca(H_2PO_4)_2\cdot 4CO(NH_2)_2 + (NH_4)_2SO_4 = CaSO_4\cdot 4CO(NH_2)_2 + 2NH_4H_2PO_4$$

$$(6)\quad CaSO_4\cdot 4CO(NH_2)_2 + (NH_4)_2SO_4 + H_2O = (NH_4)_2SO_4\cdot CaSO_4\cdot H_2O + 4CO(NH_2)_2$$

TYPES OF GRANULATORS

A rough estimate of the relative amount of granular mixed fertilizers produced in recent years by each type of granulator is shown in Table IV: the amounts are expressed as per cent of total.

TABLE IV. Mixed fertilizers produced by each granulator (per cent of total)

GRANULATORS	HIGH ANALYSIS	LOW ANALYSIS
Rotary drum	40	60
Pan	15	30
Pug mill (Blunger)	25	0
Others	20	10
Total	100	100

For high analysis mixed fertilizers, about 40% has been produced by rotary drum, 15% by pan, 25% by pug mill, and 20% by other methods, which include spray tower, fluidized granulator, extruding pelletizer, and melt granulation, as will be mentioned later. For low analysis mixed fertilizers, about 60% has been produced by rotary drum, 30% by pan, and 10% by others.

The hourly production capacity for each rotary drum granulator ranges from 5 to 25 tons for high analysis or 7 to 30 tons for low analysis fertilizer. The hourly production capacity for each pan granulator ranges from 5 to 9 tons for high analysis or 6 to 15 tons for low analysis fertilizers, while that of the pug mill ranges from 5 to 18 tons for high analysis fertilizer.

SPRAY TOWER

Spray tower type granulators have been developed and used by Nissan Chemical Industries for more than 30 years. A mixture of wet-process phosphoric acid, sulfuric acid, and pulverized potassium sulfate is sprayed from the top of a short tower, while gaseous ammonia is introduced in the lower part (Figure 5). The droplets immediately react with a rising stream of ammonia and are dried by the heat of reaction to form porous granules 1 to 3 mm in diameter. The main grades are 15-15-10 and 14-17-12.

Both the unreacted ammonia and the small amount of dust leaving the tower are recovered and recycled. Production capacity is about 200 tons per day for a tower about 8 meters in diameter and 8 meters high. Simplicity is the main advantage of this process. Both capital and operating costs are said to be lower than those for other processes of equal capacity.

Four years ago, two towers were built in Australia by Nissan to produce 240 tons of semigranular ammonium phosphate per day. More recently, two others were built in Japan to produce 400 tons per day of powdery diammonium phosphate 18-46-0 to be shipped to other mixed fertilizer producers.

FLUIDIZED GRANULATOR (10), (11)

Ube Industries Ltd. has developed a new granulation process using a fluidized bed with a funnel shaped gas distributor. Pulverized material and liquid (water, solution, or slurry) are fed into the granulator as shown in Figure 6. A jet stream of air is introduced directly through a tube at the bottom of the granulator to cause forced circulation of the materials and promote the dispersion of the liquid phase throughout the bed. The gas jet stream

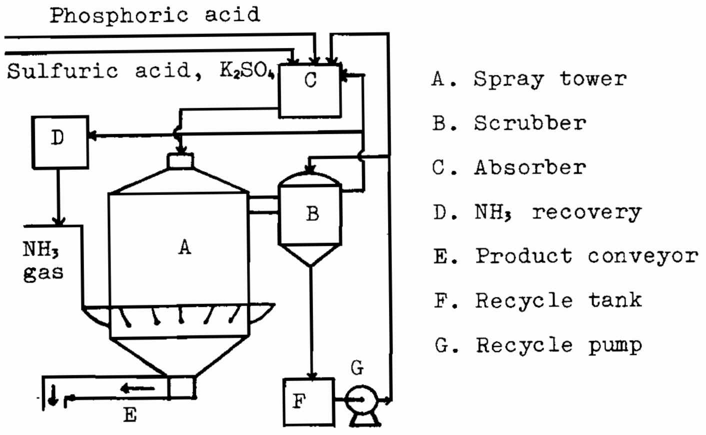


Figure 5 Nissan spray-tower process

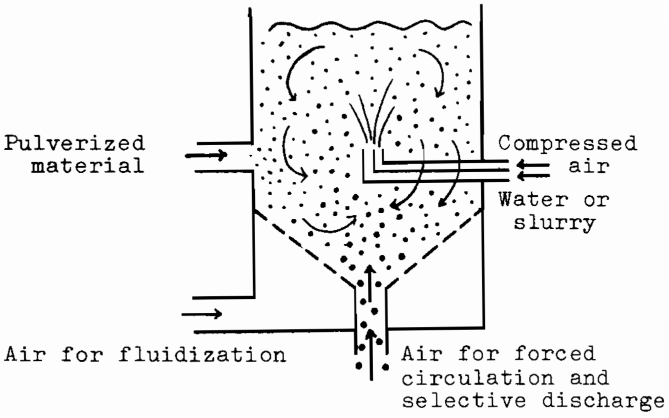


Figure 6 Ube fluidized granulator

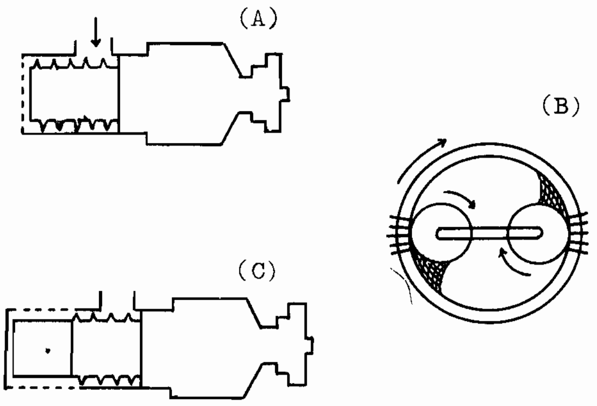


Figure 7 Extruding pelletizers

is also useful for selective discharge of the granules that have grown to a desired size.

Pilot plant tests have been carried out with a granulator 30 cm. in diameter having a production capacity of 100 kg. per hour, and also with a larger granulator 80 cm. in diameter with a capacity of nearly 2 tons per hour. A fully automatic operation has been achieved.

By controlling parameters such as feed rate of pulverized and liquid materials more than 90% of the granulator discharge can be in the desired size range of 5 to 14 mesh. The granules are nearly spherical. About 1 or 2% of the charged material is carried over the granulator and is recovered by a cyclone, thereby giving almost no dust loss. This granulator has been used commercially by a fertilizer producer to manufacture various grades such as 15-15-15 and 16-16-16 containing urea and 15-9-13 and 12-13-14 without urea.

EXTRUDING PELLETIZERS

A usual type of extruding pelletizer as shown in Figure 7 (A) has been used for pelletizing organic fertilizers such as by product oil cake and bean cake and also specially large granules of mixed fertilizer 5 to 10 mm in diameter. These pelletizers are not suitable, however, for most of the regular types of fertilizers because of their limited production capacity.

An improved type of pelletizer has been developed by Japan Gas Chemical Co. Inc. and Tsukishima Kikai Co. Ltd. This pelletizer has a rotating cylinder with many holes on its side and rollers inside the cylinder. The materials are adequately moistened, kneaded and extruded through the holes of the cylinder and cut in a desired length to form cylindrical pellets (Figure 7,B).

Using this pelletizer, Japan Gas Chemical has been producing many grades formulated from urea, ammonium sulfate and phosphate, potassium chloride, triple superphosphate and ammonia. Each pelletizer of 100 horse power produces 3 to 5 tons of pellets per hour. Essentially all the pellets are in desired size range. The main grades are 15-15-15, 16-16-16, 15-20-15, and 15-10-15.

Another improved type of pelletizer has been developed recently by Fuji Denki Kogyo Co. Ltd. This machine has a cylindrical screen built around a screw, as shown in Figure 7 (C). The kneaded material is extruded with little pressure to produce porous, soft pellets which are then granulated in a small rotary drum for about 4 minutes into round, hard granules of uniform size.

Dan Kako Co. Ltd. has installed four of these pelletizers to produce 15 tons per hour of 17-0-17, based on ammonium chloride and potassium sulfate. The company is going to produce 50,000 tons yearly of potassium sulfate by a double decomposition of ammonium sulfate and potassium chloride. The by - product ammonium chloride and a part of potassium sulfate which was not separated from the chloride are used for the production of 17-0-17. This grade is very difficult to granulate by conventional granulators. By the new process more than 85% of the product is expected to be in the desired size range of 6 to 10 mesh.

MELT GRANULATION

Mitsui Toatsu Chemicals Inc. has produced 25-0-25 with urea and potassium chloride, and also 22-0-22 with urea, ammonium sulfate and potassium chloride by a melt granulation process. The molten material is prilled in a tower 25 meters high, which was built years ago to produce prilled urea.

Pilot plant tests of melt granulation of N-P-K fertilizer containing urea have been carried out recently by a few producers including Mitsui Toatsu. Commercial production has not yet begun mainly because the necessary increase in demand is not expected under the present situation.

ACKNOWLEDGMENT

The author wishes to thank Mr. Masayasu Mori, Chief, Production Branch, Japan Phosphatic and Compound Fertilizers Manufacturers' Association, for the information used in this article.

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QUENTIN LEE: Thank you Professor Ando. You called superphosphate "ordinary" -- some people call it "normal," and we down here call it "ornery." Your comments will be very helpful to our operators in offering some thoughts on how to iron out some granulation operating problems.

The next discussion is on the "Swift DirectMAP Process," which will be presented by Mr. Everett N. Mortenson, chief chemical engineer, Swift Agricultural Chemicals Corporation. Everett has a degree in chemical engineering. He has been associated with Swift for 36 years and is director of research and development. Prior to his business career, Mr. Mortenson was a Northeastern Iowa farmer.

Swift's Direct MAP Process

E. N. Mortenson
CHIEF CHEMICAL ENGINEER
SWIFT AGRICULTURAL CHEMICAL CORP.

Monoammonium Phosphate, 11-55-0, (MAP) made by the Swift process offers the following advantages:

1. A simple, low cost operation.
2. An economical form of P2O5 to ship and store.
3. It can serve as a high analysis phosphatic intermediate with excellent granulation characteristics.
4. It yields high water solubility products.
5. Minimum capital investment per ton output.
6. It can convert high solids phosphoric acids into useful dry product.

It is truly a direct one-step operation which involves feeding anhydrous ammonia into a two-fluid nozzle for highly turbulent intermixing with phosphoric acid which, after a very short passage through a pipe line, is flashed into a collection chamber where the powder MAP settles to a collection rake. The vaporized water is carried away by a counter - flow current of air.

A review of the current technical and patent literature will pretty well convince anyone that there really can't be much new or novel under the sun in ways to produce phosphoric acid, ammonium phosphates or granulate fertilizers. In spite of this, we believe that the Swift process for manufacture of a powder MAP and its use as such or for conversion to other high analysis products provides excellent utility and is really something new!

It is not my purpose to make extensive comparisons between the respective processes. Nor do I intend to present the formulation techniques and advantages of the same in using powder MAP either as a product or as an intermediate. Mr. Hignett mentioned them in his keynote address on new fertilizers. Moreover, those of you who were fortunate enough to have attended the 8th TVA demonstrations at Muscle Shoals (Oct. 6-7, 1970) had an opportunity to see Swift's powder MAP used to produce a 14-14-14 in which 12 units of the 14 units P2O5 were derived from an 11-55-0.

The purpose of these formal comments is to describe briefly the design and operational features of our MAP process. Then, if there are questions with respect to the use of MAP, we will try to supply answers for you when the panel is open for discussion.

Tables I and II list some of the routes which can be used to convert phosphoric acid and ammonia into granular ammonium phosphate.

In addition to those indicated in Tables I and II, there are a variety of modifications which have, as far as we know, seen only limited commercial

TABLE I
CONVENTIONAL PROCESSES FOR MAP OR DAP
FROM WET PROCESS PHOSPHORIC ACID

1. Staged neutralization in open tanks with intermediate filtration, crystallization, centrifuging and drying. (1)
2. Granulation - ammoniation in rotary drum or blunger using concentrated slurry from a preneutralizer -- requires effective vapor scrubbers. (2)

TABLE II
PROCESSES FOR MAP MANUFACTURE

1. Granulation - ammoniation in rotary drum or blunger -- conventional scrubbers.
2. Scottish Agricultural Industries' (SAI) slurry neutralization to 1.3 mol ratio and then reacidification to 1 mol ratio in blunger.(3)
3. Fison's two step neutralization under pressure in a reactor vessel and steam release therefrom, followed by flash ejection of hot concentrated slurry into tower.(4)
4. Swift's direct reaction process in two fluid nozzle with line reactor and flash ejection into tower. (5)

TABLE III
REACTION OF PHOSPHORIC AND AMMONIA FOR MAP

Theoretical (Lb.Moles)

$$\underset{17}{NH_3(l)} + \underset{98}{H_3PO_4(l)} \longrightarrow \underset{115}{NH_4HPO_4(S)} \qquad H = -42,280 \text{ BTU}$$

Actual (Lbs./Ton of 10.5-53-0)

$$\begin{matrix}\text{Liquid Anhy.}\\ \text{Ammonia}\end{matrix} + \begin{matrix}\text{49\% } P_2O_5\text{WPA}\\ \text{with 22\% } H_2O\end{matrix} \longrightarrow \begin{matrix}\text{10.5-53-0}\\ \text{MAP (4\% Mois.)}\end{matrix} + H_2O$$

H = -634,000 BTU (Approx.)

$$\begin{matrix}\text{256 lbs. } NH_3\\ \text{(210 lbs N)}\end{matrix} + \begin{matrix}\text{2162 lbs. WPA}\\ \text{(1060 lbs} P_2O_5\text{)}\end{matrix} \rightarrow \text{2000 lbs MAP + 404 lbs vaporized } H_2O$$

application. Two which should be mentioned are the Nissan process and the Finnish process mentioned by Dr. Weber in the earlier panel discussion.

PROCESS CHEMISTRY

The reaction of phosphoric acid with anhydrous ammonia to a level of 1 mol NH_3 to 1 mol H_3PO_4 is highly exothermic and yields a product relatively stable at the temperature attained (260 degrees F). The indicated dissociation pressure of dry monoammonium phosphate at that temperature is only 0.05 mm Hg. Quite obviously this fact and the heat development are the essential factors which make the direct reaction system successful. Line mixing can provide exceptionally thorough intermingling of reactants in a relatively short length of time provided velocities are high enough. That is quite easy to assure in this process with sufficient pressure on the input liquids plus the high flow velocity development by the steam generated. The weight relations of ammonia to phosphoric acid and heat release are shown in Table III on both a theoretical and an actual basis, with latter for a 10.5-53-0 having 4% moisture.

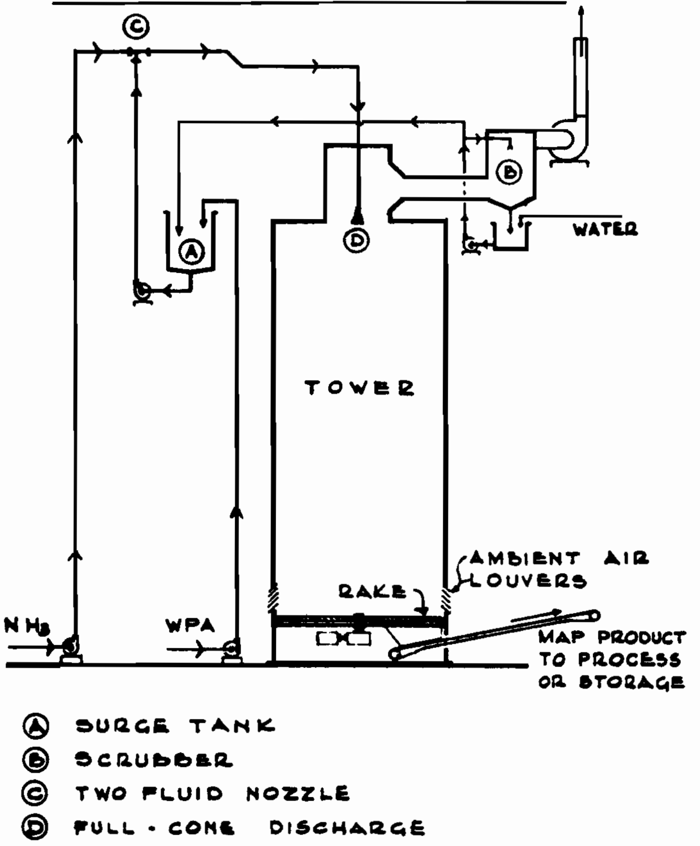
With more concentrated acid, the resulting powder MAP will have correspondingly less moisture. The MAP furnished for the TVA demonstration was made using 52% P_2O_5 acid and that MAP had only 0.9% moisture!

PROCESS DESCRIPTION

In Figure I we illustrate in a schematic flow diagram the principal elements for the direct process.

FIG. I

THE SWIFT MAP PROCESS



Wet process phosphoric acid is pumped at a metered rate to a small surge tank (A) where water over-flow from a scrubber (B) combines with it. This water serves the dual function of recycling back the very small quantity of finely divided particulate carried out of the tower by induced draft. The latter provides an actual velocity to the upward air flow of about 80 FPM! Hence, the particulate losses are quite insignificant and the ammonia shrink negligible. This water also provides necessary dilution of the phosphoric acid back to a 49% - 50% P_2O_5 level. Too concentrated an acid gives a drier product than required and may even yield some polyphosphate.

A pump brings the diluted acid to the mixing tee (C) to mix with a metered stream of anhydrous ammonia. Both acid and anhydrous feed streams are at sufficient pressure to insure uniform flow and no development of "slugging."

The specially designed two fluid nozzle induces a very rapid and thorough mix of the two reactants so that by the time the combined flow reaches the end of a 12' length of line with two 45 degree ells and a 90 degree ell, all the ammonia has combined with the H_3PO_4. Measured shrink of the input ammonia has never been more than 0.02%, which we think is very good performance.

At the end of the discharge line we use an open pipe and obtain very uniform dispersion of the MAP and steam. MAP formation at the pipe exit is complete even though it has been only a fraction of a second after the ammonia and acid met. So we have a mixture of finely divided MAP and steam at about 260 degrees F ejected into the tower. It is a Swift process indeed!

MAP, of course, settles to the bottom of the tower where it is scraped out by a rotating rake. Steam and dilution air exit by induced draft through a wet cyclonic scrubber. Any small MAP particulate carried over is quite effectively recovered and reclaimed by the water used to cut the phosphoric acid.

This process will yield a MAP having an analysis range as shown in Table IV.

With a total plant food content of 64 to 66% depending on the quality of acid used, powdered MAP provides a low cost phosphate source of P_2O_5 in formulating mixed goods. Because it is formed

TABLE IV

TYPICAL POWDER MAP

Chemical		%
Total Nitrogen		10.5 to 12.0
P_2O_5		
Total		52 to 55
C.I.		0.1 to 0.2
Water Soluble		48 to 51
Moisture		0.5 to 4.0
pH	3.8 - 4.0	

Screen (U.S. Std. Sieve Size)	%
plus 14	1.1
minus 14 plus 16	0.4
minus 16 plus 20	1.3
minus 20 plus 30	5.0
minus 30 plus 40	10.4
minus 40 plus 60	36.2
minus 60 plus 100	36.5
minus 100	9.1

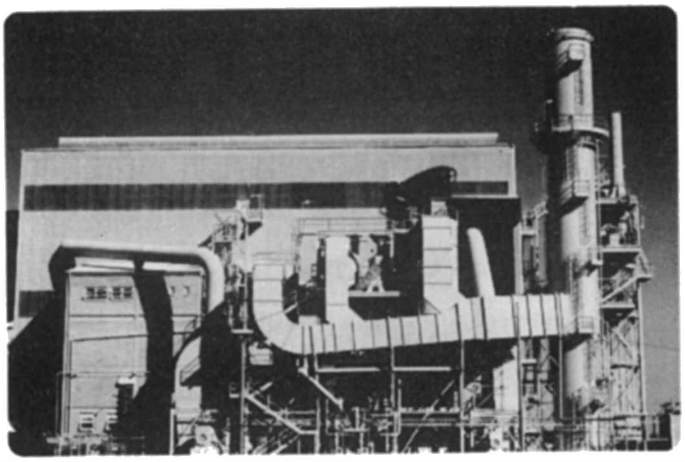


FIGURE II Exterior view of large granulation plant which produces and uses powder MAP

in such instantaneous fashion in this direct process, it has little or no enlarged MAP crystals and is therefore an excellent granulating agent. Moreover, with the short reaction time, practically no citrate insoluble is formed even when the impurities are fairly high. We want to emphasize also that it is not necessary to de-sludge the acid used in the Swift process, if the undissolved solids are thoroughly dispersed and are not so large as to clog the nozzle. Acid direct from evaporators or stored acid in which the sludge has concentrated up to 24% solids can be converted satisfactorily into a dry powder MAP. Typical operating conditions are shown in Table V.

Figure II shows an overall view of the exterior of the granulation building at a large plant recently put on-stream which uses powdered MAP. In this view can be seen ducts leading to the scrubbers handling air and vapors from the granulator, dryer and cooler. The windows at the upper left indicate the location of the control center for the plant. The MAP tower is barely visible at the far right in Figure II. Figure III is a full view of the MAP tower designed to produce 37 TPH of powder.

The process is available for licensing under issued patents and engineering can be contracted for with Swift Agricultural Chemicals Corporation.

TABLE V
TYPICAL OPERATING CONDITIONS
GRADE 11.5-54.5-0

Production Rate	25 Tons/Hr.
Input Acid	
P_2O_5 %	54.23
H_2O	18.2 (K.F.)
Temperature, degrees F	75
Pressure at Nozzle, PSIG	45
Input Ammonia	
Temperature, degrees F	45
Pressure at Nozzle, PSIG	210
Product Temp. degrees F	190 - 200
Air Flow, CFM	25,000

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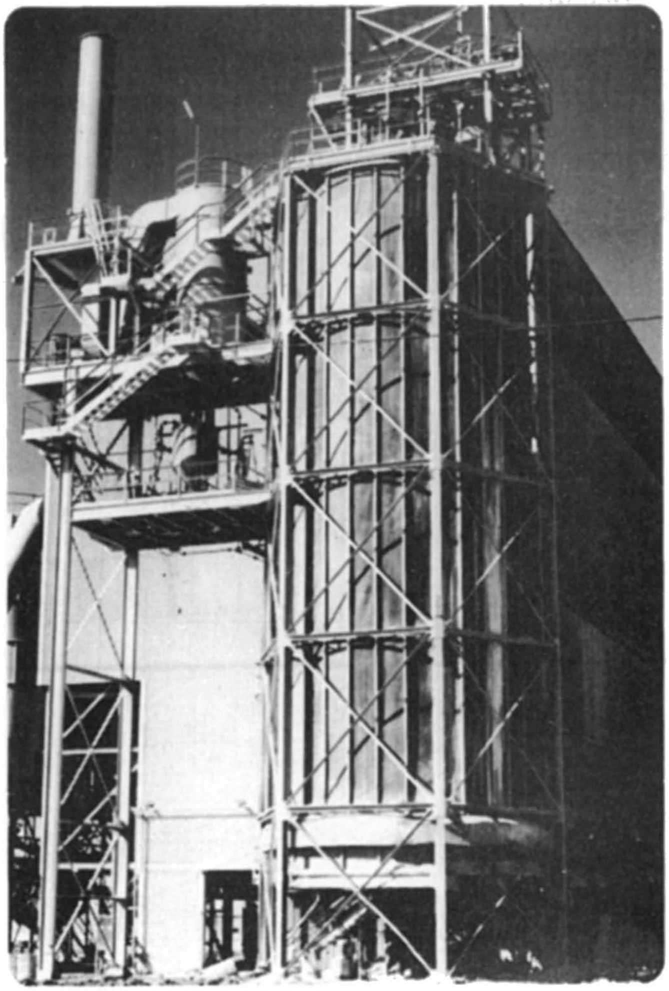
FIGURE III
Close-up view of a 37 TPH
powder MAP tower



PANEL LEADER LEE: W. F. Sheldrick, manager production and distribution Fisons, Ltd. Suffolk, England, will discuss the techniques for prediction of granulation performance in the granulator. Bill is a member of our Round Table Executive Committee. He has been extremely active in helping to make our meeting a success. On several occasions at previous Round Table meetings, Bill has discussed a number of valuable and interesting subjects, covering numerous operating techniques. He has a B. S. in Mechanical Engineering and an M. S. in Chemical Engineering. He has the full responsibility for the manufacture of approximately two million tons of fertilizer a year.

Prediction of Granulation and Plant Performance From Temperature, Moisture Relationships in the Granulator

W. P. Sheldrick
OPERATIONS MANAGER
FISONS, LTD.
SUFFOLK, ENGLAND

Until recently, the design of fertilizer granulation plants was based on simple empirical methods of predicting granulation performance and recycle ratio. With low grade analysis fertilizers based mainly on superphosphates, ammonium sulfate and potash, temperature was not a vital consideration, and recycle ratio was largely a function of granulation efficiency.

Most plants could be operated easily with recycle ratios of 1:1 or less, and at the same time the product could be screened and crushed hot, without difficulties. In many cases it was not even necessary to cool the product to ensure satisfactory storage properties.

The increasing use of such materials as urea and ammonium nitrate with ammonium phosphate, to produce more concentrated fertilizers, has posed many problems in fertilizer production, as it has resulted in soluble salt systems where the quantity of fluid phase is very sensitive to temperature and moisture content. Apart from the difficulty in controlling granulation, screening and crushing operations have become more difficult, and it is necessary to cool the product to ensure good storage properties.

In order to predict within reasonable limits, the conditions of granulation, recycle ratio and the sizes of drier, cooler, screens and conveyors, it is now necessary to have a quantitative knowledge of the relationship between temperature and moisture in the granulator, as well as the heat balance across the granulation plant.

A method is proposed which enables us to predict granulation plant performance for specific fertilizer products from simple laboratory tests. The method has been confirmed from full-scale plant performance over several years, and has been used to optimize granulation plant design and operation in terms of investment and operating costs.

BASIC RELATIONSHIPS IN THE GRANULATION PROCESS

(a) Moisture/Temperature

The relationship between moisture and temperature is shown in Fig. 1. Such a correlation refers only to one particular fertilizer composition produced from solid materials of fixed particle size. The area between the dotted lines represents the temperature at which an acceptable amount of material within the desired range of particle size will be produced in a granulator at any given moisture content.

Systems represented by points above the granulation area are too fluid. If near the gran-

FIG. 1. GRANULATION CURVE

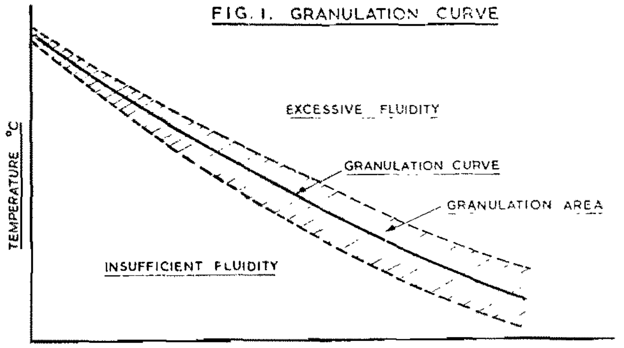
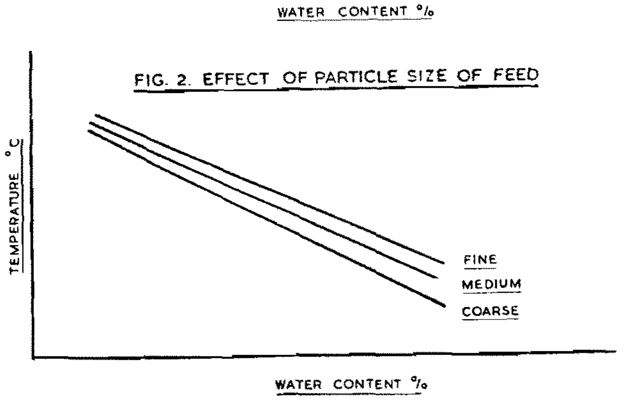


FIG. 2. EFFECT OF PARTICLE SIZE OF FEED



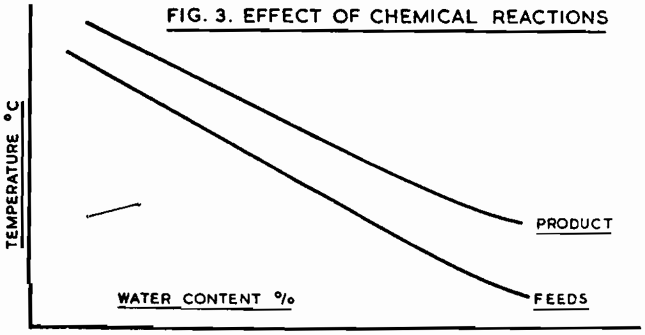


FIG. 3. EFFECT OF CHEMICAL REACTIONS

ulation area they make excessive oversize, if further away they are slurries. These systems need cooling and/or drying, as by the addition of returned fines. Similarly a system below the granulation area is insufficiently fluid and needs wetting and/or heating to avoid excessive production of fines.

It will be noticed that the temperature range within which acceptable granulation is obtained becomes narrower as moisture content is decreased. The lines, however, do not meet at nil moisture content in the diagram shown, which is typical of a mixed fertilizer containing potassium chloride, ammonium nitrate and ammonium phosphate.

A process based on this finding is operated by Fisons Limited in the U.K., granulating fertilizer by the addition of anhydrous molten liquor of ammonium nitrate and ammonium phosphate (1). This is one of the few known processes in existence using an anhydrous 'melt' for granulation. The use of concentrated solutions containing as little as 2%-8% water is common throughout the industry.

A single optimum temperature corresponding to a given moisture content should exist, at which a maximum amount of product size granules is produced. A line within the "granulation zone" may be taken as representing the "granulation curve" indicating conditions of maximum granulation efficiency.

(b) Effect of particle Size

The effect of particle size on the granulation curve is shown in Fig. 2 - the finer the solid, the higher the granulation temperature.

$2KCl = (NH_4)_2SO_4 \longrightarrow 2NH_4Cl + K_2SO_4$

$KCl + NH_4NO_3 \longrightarrow KNO_3 + NH_4Cl$

$Ca(H_2PO_4)_2 \cdot H_2O + (NH_4)_2SO_4 + H_2O \longrightarrow CaSO_4 \cdot 2H_2O + 2NH_4H_2PO_4$

$NH_3 + Ca(H_2PO_4)_2H_2O + H_2O \longrightarrow NH_4H_2PO_4 + CaHPO_4 \cdot 2H_2O$

$NH_4H_2PO_4 + CaHPO_4 + 2CaSO_4 + 7H_2O \longrightarrow Ca_3(PO_4)_2 \cdot 7H_2O + 2(NH_4)_2SO_4$

$Ca(H_2PO_4)_2 + 2NH_4NO_3 \longrightarrow Ca(NO_3)_2 + 2NH_4H_2PO_4$

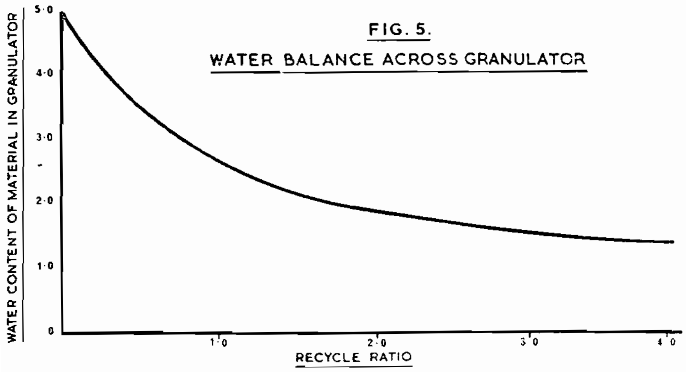


FIG. 5.
WATER BALANCE ACROSS GRANULATOR

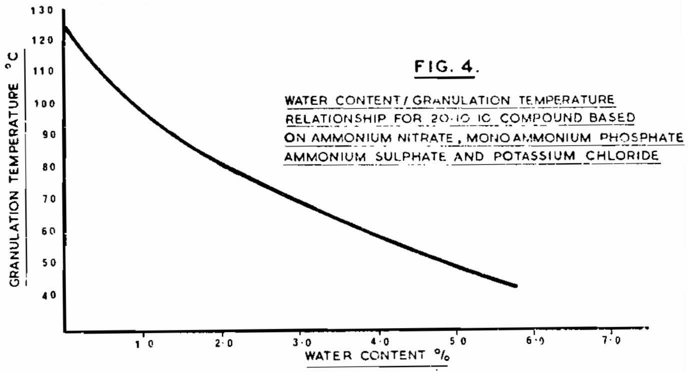


FIG. 4.
WATER CONTENT / GRANULATION TEMPERATURE RELATIONSHIP FOR 20-10-10 COMPOUND BASED ON AMMONIUM NITRATE, MONO AMMONIUM PHOSPHATE AMMONIUM SULPHATE AND POTASSIUM CHLORIDE

(c) Effect of Chemical Reactions

During granulation of mixed fertilizers from normal ingredients such as ammonium sulfate, ammonium nitrate, potassium chloride, ammonium phosphates, superphosphates and ammonia, various reactions may take place.

In addition to these chemical reactions, solid solution and double salt formation between the ingredients can also occur. Usually it is desirable to formulate fertilizers so that the final components are less soluble than the initial ingredients to avoid further granulation during the drying process. The way in which granulation is affected is shown in Fig. 3.

(d) Effect of Granulator Design

Different granulators can require different moisture contents for granulation, due to differences in the intimacy of mixing the feeds and the porosity of the granules.

The rotary drum, operated with a shallow bed of material has a high requirement of fluid phase. A granulation curve applicable to this type granulator will show higher granulation temperatures and moisture contents than curves applicable to most other types.

Blungers or paddle mixers differ considerably in their granulation characteristics. Low power blungers operated at high speeds give granulation curves close to that of a drum. A slow moving, high powered blunger will granulate at appreciably lower temperatures and moisture contents.

DETERMINATION OF GRANULATION CURVES

Granulation curves are normally obtained by laboratory scale granulation of the material concerned. Mixtures of fertilizer ingredients are granulated by the addition of water or steam under batch or continuous conditions at different temperature levels. The product is screened, and material within the desired size range is analyzed and the relationship between moisture content and temperature plotted. The technique used by Fisons Limited is a bench scale batch rotary drum

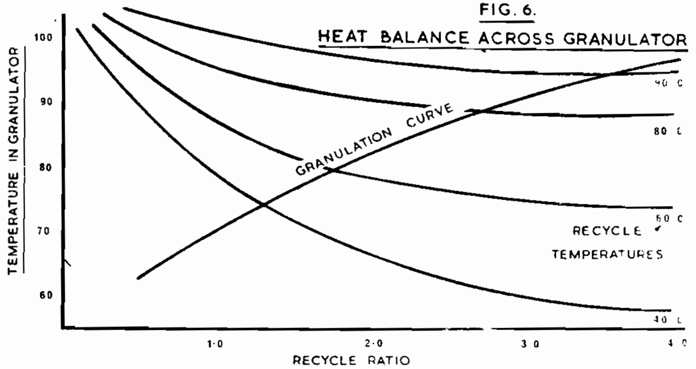
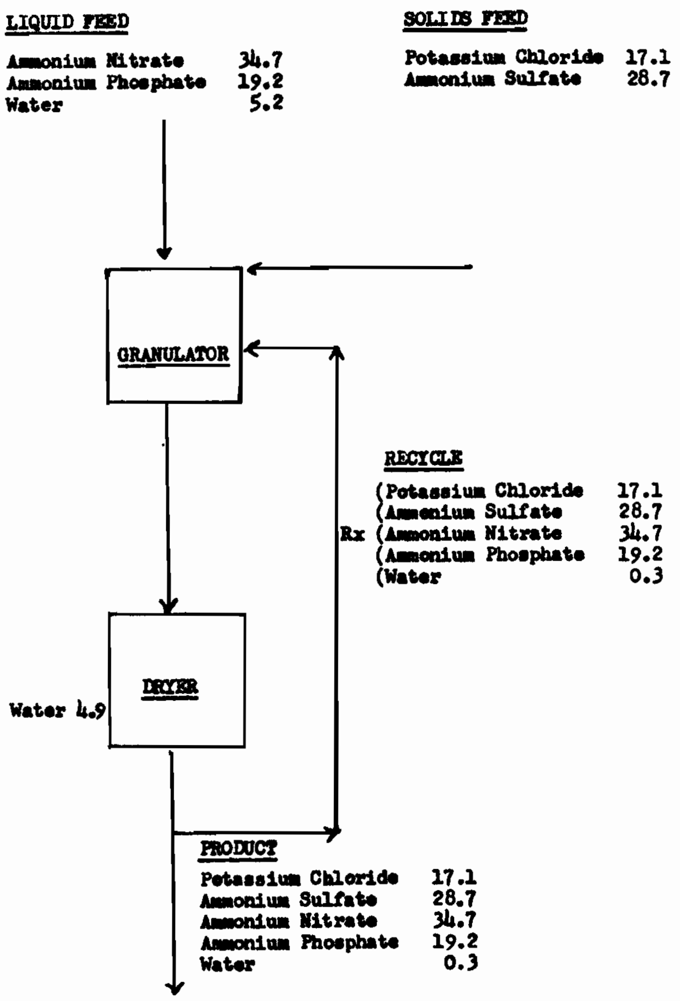


FIG. 6.
HEAT BALANCE ACROSS GRANULATOR

MATERIALS BALANCE ACROSS GRANULATOR



MATERIALS FLOWSHEET FOR 20:10:10 COMPOUND

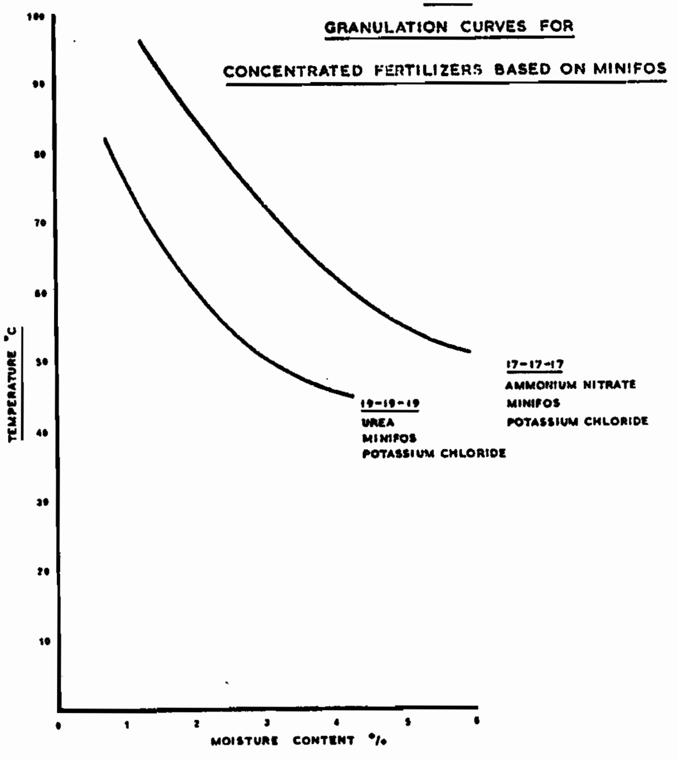


FIG. 7.
GRANULATION CURVES FOR
CONCENTRATED FERTILIZERS BASED ON MINIFOS

operating at the same percentage of critical speed as our full-scale granulators. Granulation temperature is controlled by heating the drum or by blowing air through the drum. Allowance is made for the chemical reactions occurring during the granulation by carrying out check runs with fully or partly reacted material. The granulation curves show a very smooth relationship between water content and temperature, and can be reproduced easily. There is usually very good agreement for specific fertilizer compounds between data obtained in the laboratory and full - scale operation.

HEAT AND MASS BALANCES IN THE GRANULATOR

(a) Obtaining a Heat Balance

Heat and mass balances in the granulator can be obtained by conventional calculations based on specific heats, heats of reaction, heats of solution etc. Such heat balances can be easily used and give good results.

A method which is both less laborious and much more accurate has been developed by Fisons (2) (3). A differential thermal analysis aparatus has been designed which can determine automatically the enthalpy-temperature relationships of fertilizer materials. The enthalph-temperature graph for one material is obtained in 24 hours with little effort, and can be used to provide accurate heat balances which automatically take into account solubilities, phase changes and double salt formation.

THE PREDICTION OF GRANULATION PLANT PERFORMANCES FROM GRANULATION CURVES AND HEAT AND MASS BALANCES.

The following method is mainly applicable to the case where granulation conditions are water and heat sensitive - for example when using materials such as ammonium nitrate, urea, ammonium phosphate and other soluble salts. Normally under these conditions, and particularly when ingredients are added as solutions or slurries, the need for recycle is governed by liquid phase consideration; that is to say, a requirement for recycle to absorb excess liquid phase.

In certain cases, for example at temperatures in the granulator above about 100 degrees centigrade, very little water has to be present -- i.e. less than 1 per cent. In fact in the limiting case materials will granulate readily as anhydrous melts, such as in the Fisons melt granulation process (1). At temperatures lower than 70 degrees centigrade it is usually necessary to have 3 or 4 per cent water in order to effect granulation.

As the granulation temperature is so critical in determining the amount of water that can be present during granulation, the recycle temperature as well as recycle ratio is a very important consideration in granulation plant design. The following example has been calculated to illustrate this.

The material under consideration has been taken as 20:10:10 compound formulated by spraying a mixture of ammonium phosphate and ammonium nitrate into a granulator. Ammonium sulfate and potassium chloride are added as solids.

The procedure is as follows:

1. The granulation curve given in Figure 4 shows the relationship between granulation temperature and moisture content. This has been determined experimentally for a 20:10:10 compound, and the results are also confirmed from large-scale plant operation.
2. Figure 5 is the water balance across the granulator, which has been calculated from the material balance given in Appendix I for a series of recycle ratios.
3. Figure 6 is the thermal balance across the granulator, which has been calculated to give a mean temperature in the granulator for various recycle ratios and recycle temperatures.
4. From Figures 4 and 5 it is possible to determine the relationship between recycle and the temperature at which granulation occurs. This relationship has been plotted in Figure 6.
5. The completed Figure 6 shows the relationship between recycle ratio and granulation temperature for varying recycle temperatures, for example:

Recycle Temperature	Granulation Temperature	Recycle Ratio
90°C	95°C	3.7
80°C	89°C	2.8
60°C	80°C	1.7
40°C	75°C	1.2

These figures illustrate very clearly the effect that temperature of recycle has on recycle ratio. For example, cooling the recycle from about 80 degrees C to 40 degrees C will halve the recycle ratio. If the recycle temperature is higher than 90 degrees C, recycle ratio will increase even more rapidly, for example greater than 4:1.

If can also be seen from Figure 4, 5, and 6 how recycle ratio, temperature and water content are interrelated in granulation for a specific fertilizer grade manufacture, and why it is difficult to refer to the conditions of granulation simply in terms of water content alone.

DISCUSSION

The development of granulation curves as typified by Fig. 4 for a wide range of nutrient ratios in the AN-AP, AN-AP Potash and Urea-AP - Potash systems has enabled Fisons to predict with a high degree of sucess the operational conditions over the granulation plant, and the validity of the data has been confirmed, not only on Fisons own process units, but also on the plants of other fertilizer manufacturers using similar technology.

The slope of the granulation curve increases significantly as the proportion of highly soluble salts increases. In particular the AN-AP, Urea-AP systems are steep, denoting the sensitivity of granulation to small changes in liquid phase. In these cases the maintenance of constant feed and recycle conditions (temperature and rate) cannot be overemphasized if stable conditions are to be maintained.

The effect of recycle temperature on recycle ratio is shown clearly in Fig. 6, and similar relationships have been used to design or modify plants to operate under the most economic conditions with regard to recycle ratio and temperature. Usually it has been found most economic with regard to investment costs and operating costs to operate with cooled recycle and low recycle ratio.

The use of granulation curves for predicting plant performance is also a useful method of evaluating new raw materials of different physical specifications. In our operations where we have twelve granulation plants producing about 50 different grades and well over a million tons of granular fertilizer per annum at relatively low recycle ratios, the effect of physical properties on granulation capacity can be very significant.

Often alternative methods of formulating compounds can be evaluated using granulation curves and then the results are used in a linear program to obtain the Company's optimum overall production plan.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues Mr. J. D. C. Hemsley and Mr. S. M. Janikowski for their help in the preparation of this Paper.

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APPENDIX

BASIS FOR THERMAL BALANCE CALCULATIONS IN THE GRANULATOR

Most of the physical data used in the following example are for pure salts, and the latent heat for the slurry is assumed to be the same as for ammonium nitrate. The example is regarded mainly as illustrative, and no allowance has been made for heat changes due to interionic reactions or heat losses from the granulator.

(Appendix figures on next page)

PANEL LEADER LEE: Our final paper in the panel discussion on ammoniation and granulation, will be given by Harold Green, production manager, Cotton Producers Assn., Fertilizer Division, Atlanta, Ga. Harold is a native of Georgia. At C. P. A., he has the responsiblity for manufacture of more than 150,000 tons of fertilizer.

ASSUMPTIONS

1. AN-AP slurry at 120°C. with 10% water
2. Latent heat of fusion of slury : 18 CHU/lb
3. Solid raw materials feed temperature : 20° C.
4. Fines recycle temperature : t° C.
5. Granulator temperature : T° C.
6. Recycle ratio : R
7. Water content of fines recycle : 0.3%
8. Datum for calculations : 0° C and 100 lbs of product

PHYSICAL PROPERTIES

Specific heat of ammonium nitrate : 0.40 CHU/lb$^{\circ}$ C.
Specific heat of ammonium phosphate: 0.35 CHU/lb$^{\circ}$ C.
Specific heat of potassium chloride: 0.17 CHU/lb$^{\circ}$ C.
Specific heat of ammonium sulfate : 0.39 CHU/lb$^{\circ}$ C.

Total heat content into granulator = heat content of slurry + heat content of solid raw materials + heat content of fines recycle

Heat content of slurry

$$
\begin{aligned}
&= 120 \{(34.7 \times 0.4) + (19.2 \times 0.35) + (5.2 \times 1) + (59.1 \times 18) \\
&= 120 \times 25.8 + 1064 \\
&= 4160 \text{ CHU}
\end{aligned}
$$

Heat content of solid raw materials feed

$$
\begin{aligned}
&= 20 \{(17.1 \times 0.17) + (28.7 \times 0.39) \\
&= 20 \times 14.1 \\
&= 282 \text{ CHU}
\end{aligned}
$$

Heat content of fines recycle

$$
\begin{aligned}
&= t.R \{(17.1 \times 0.17) + (28.7 \times 0.39) + (34.7 \times 0.4) + (19.2 \times 0.35) + (0.3 \times 1) \\
&= 35 \, t \, R \text{ CHU}
\end{aligned}
$$

Total heat entering the granulator

$$= 4160 + 282 + 35 \, t \, R$$

Total heat leaving the granulator

$$= T(35R + 25.8 + 14.1)$$

Therefore

$$T = \frac{35tR + 4442}{35R + 39.9}$$

The granulation temperature has then been calculated for various conditions of recycle temperature and ratio and plotted in Fig. 6.

Principles of Granulation

Harold Green
PRODUCTION MANAGER
COTTON PRODUCERS ASSO.
ATLANTA, GA.

I would like to change the title of my talk somewhat and call it "granulation southern style" because this is the type granulation I have become familiar with the past 11 years. In our area, granular fertilizer accounts for 82% of the total used. With liquids at 8% and blends 10%, one of the big factors that account for our continued use of granular products is probably our low freight rate on phosphate rock and sulfuric acid which gives us a P205 cost of around .90¢ per unit in the form of single superphosphate.

We also get the advantage of more secondary elements, the main one being sulfur. Also single superphosphate is conducive to good ammoniation and granulation.

Our feelings are that large granulation plants can compete with bulk blends and give the farmer a better product with:

1. Less segregation.
2. More secondary plant food.
3. Availability during the rush period due to stock piling.
4. Longer storage advantage.
5. More even distribution.

Our plants are from 55,000 tons (Fig. 1) to 140,000 tons (Fig. 2) capacity. Our newest plant, built three years ago, is rated at better than 100,000 tons. (Fig. 3) The equipment is essentially the same in all plants, but varies in size.

All raw materials are fed by bucket elevator into a 6 bin cluster hopper. (Fig. 4) The materials are discharged into a weigh hopper. Each material is weighed in accordance with the desired formula. The weigh hopper discharge is controlled by an electric timer which opens to discharge the mix at a given time.

The mix is discharged into a holding hopper equipped with a variable speed belt (Fig. 5) which feeds the mix into the T.V.A. type ammoniator at a given period of time. Here nitrogen solution, sulfuric acid, steam water and sometimes phosphoric acid (depending on the formula) are metered into the ammoniator. (Fig. 6)

We have in the past used anhydrous ammonia. We discontinued using anhydrous due to nitrogen loss which contributed to air pollution. We now use 49 solution, 34-60 ammonia and ammonium nitrate. This reduces the number of pipes in the bed and also cuts down on sparger buildup. Of course, the formula cost is increased. All things figured, we still prefer all solution. For metering of liquids we prefer rotometers on solution, water and sulfuric acid. They are not as accurate as magnetic, however, the maintenance is less and production time higher due to less maintenance. We do use magnetic flowmeters with phosphoric acid because this is the only method by which it can be metered accurately. Amp meters (Fig. 7) show any trouble spots that might develop.

Our ammoniators (Fig. 8) vary in size from 7' x14' to 10'x20'. Our production rate is from 30 to 50 tons per hour of grades 6-12-12, 5-10-15, 7-14-21 and 8-24-24.

All pipes and braces under the bed in the ammoniator are made of hastalloy 'C'. We find we can get at least 12 months' service from them. Our sparger pipes are located at about 5 o'clock. The ammoniator turns about 8 RPM counter clock wise. Bed depth is from 19" to 24". This is controlled by a retaining ring inside the drum four feet from the discharge end of the ammoniator. Most granulation occurs in the ammoniator, however, some granulation is obtained in the four foot granulation section and some in the dryer itself.

The sparger pipes are 8" from the shell and so arranged that the sulfuric acid pipe is on top, and two thirds the length of the ammoniator from the intake end. 1/8" holes are drilled on 1" centers and are directed upward with the flow of

FIGURE 1. 55,000-TON PLANT

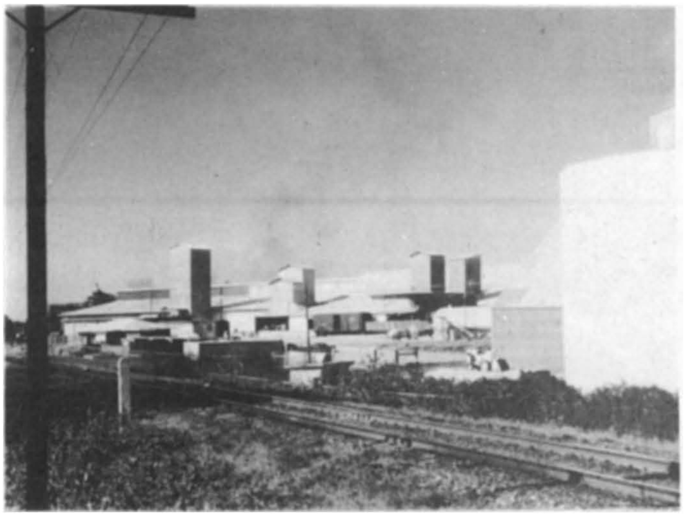

FIGURE 2. 140,000-TON PLANT

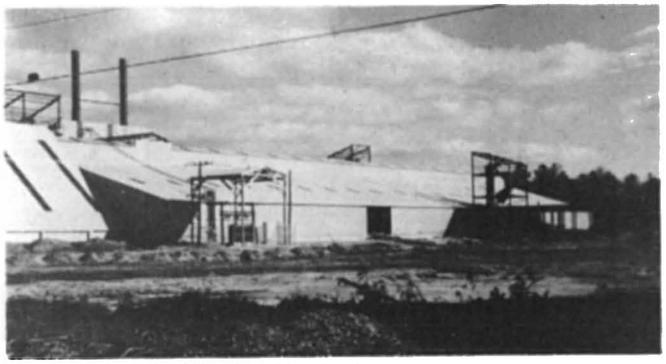

FIGURE 3. NEWEST 100,000-TON PLANT, BUILT 3 YEARS AGO

FIGURE 4. MATERIALS WEIGHED INTO HOPPER FROM 6-BIN OVERHEAD CLUSTER HOPPER SYSTEM

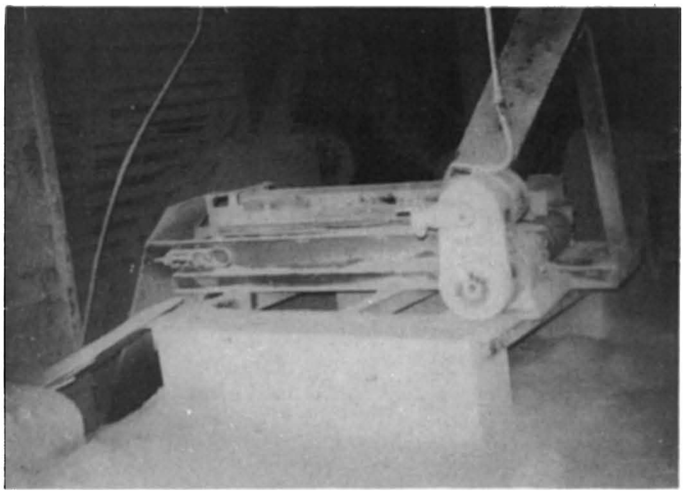

FIGURE 5. MATERIALS FROM WEIGH HOPPER FED TO AMMONIATOR BY VARIABLE SPEED BELT

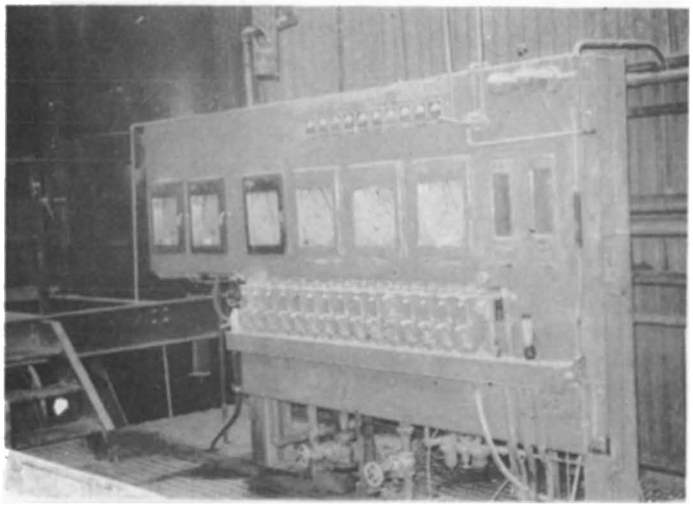

FIGURE 6. LIQUIDS ARE METERED INTO AMMONIATOR

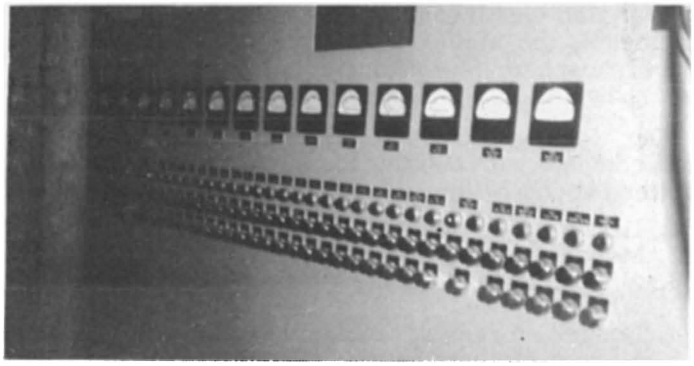

FIGURE 7. AMP METERS SHOW ANY TROUBLE SPOTS THAT MIGHT DEVELOP

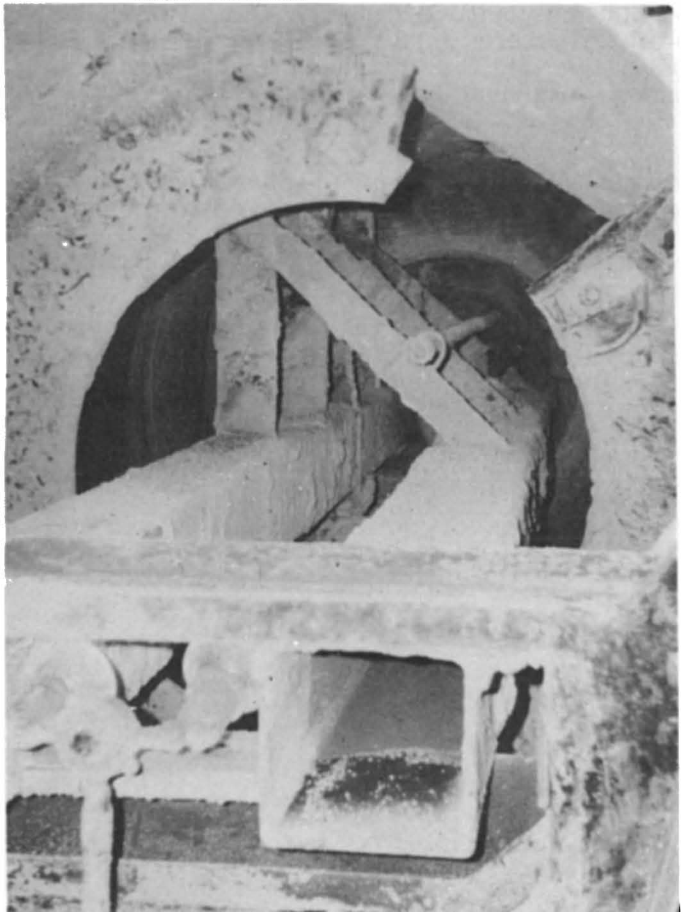

FIGURE 8. AMMONIATORS VARY IN SIZE FROM 7' × 14' TO 10' × 20'

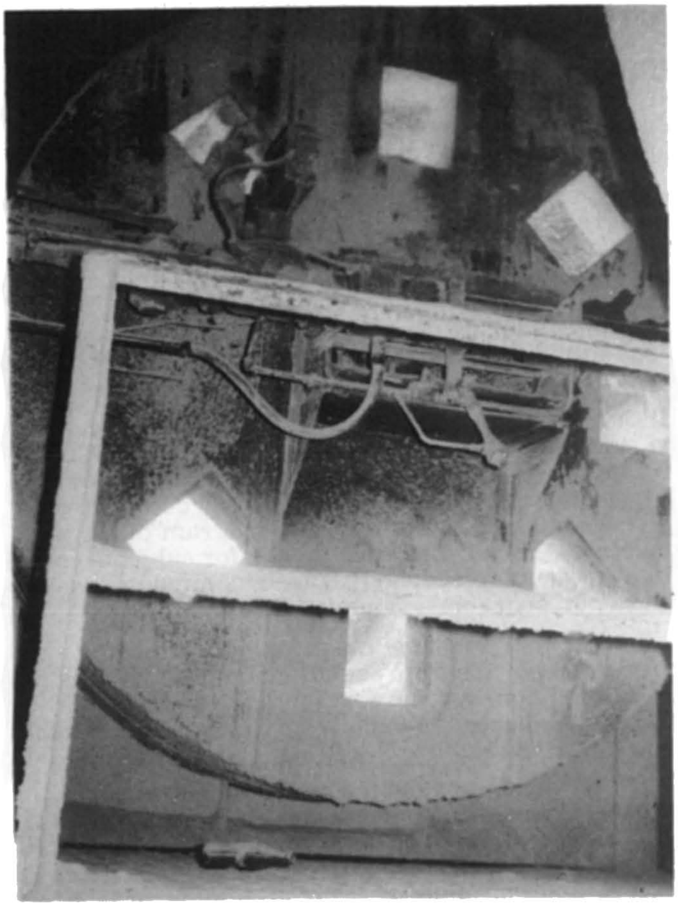

FIGURE 9. GAS FIRED BURNERS. 10,000,000 TO 30,000,000 BTU/HOUR

FIGURE 10. DRYER SIZES VARY FROM 8' × 50' TO 9' × 60'

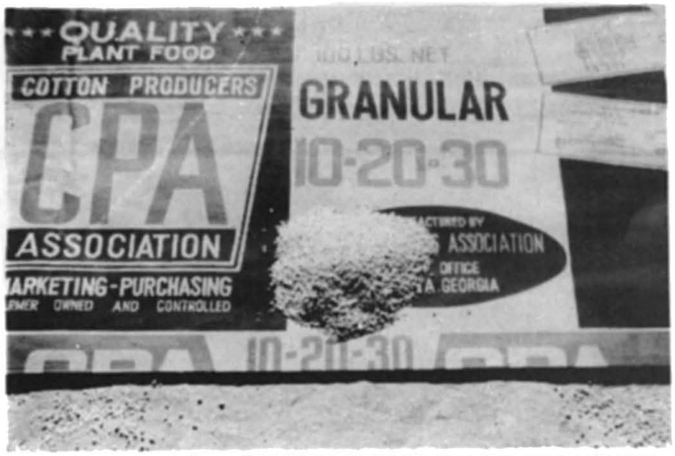

FIGURE 11. C.P.A. PRINTED 10-20/30 GRANULAR PACKAGE FRONT AND BACK

materials. This reduces wear on the other pipes and reduces sparger caking. It is said that this also reduces ammonium chloride losses out the stacks.

Located about 2" under the acid pipe is the solution pipe. This extends the length of the ammoniator, with holes drilled 1/8" on 1" centers. These holes should face about 7 o'clock or slightly facing the flow of materials. Under this is the steam pipe mounted in the last half of the ammoniator on the discharge end. Hole size is not so important if holes are equally spaced and sufficient volume is obtained to promote heat and granulation. Holes should be directed about 1 o'clock or opposite direction of solution pipe.

For phosphoric acid we use a 1 1/2" S.S. pipe drilled 1/8" holes on 1" centers inserted two thirds the length of the ammoniator from the intake end. Acid is dribbled on top of the rolling bed. Any water that is used is also dribbled on top of the bed. All water used is from our 24" venturi type scrubbers. This is used for acid-water scrubbing of fumes from ammoniator stack. Hammer type knockers on the ammoniator were not successful in avoiding buildup inside the shell and scraper bars require too much maintenance and downtime. We think the oscillating scraper does a much better job, with less maintenance.

We feel there are six things essential in the granulation of fertilizer:

1. Bed depth.
2. Location of spargers.
3. Proper formulation including liquid phase between 600 and 800 pounds.
4. Heat (from sulfuric acid, ammonia and steam) around 170,000 BTU is desirable with discharge heat of 190 to 225 degrees.
5. Long runs on same grade for good analysis.
6. Size of raw material.

We have a very difficult time granulating high potash grades such as 7-14-21 using standard potash, so we use a 50-50 mix of standard and coarse. The coarse particles serve as a core and collect coatings of the other materials to form the granules.

After the granules are discharged from the ammoniator, they enter into a rotary dryer with a gas fired burner on the intake end. A huge fan pulls hot air from the burner. The flights in the dryer lift the material to the top, discharging and exposing it to the hot air current. Our burners are rated from 10,000,000 to 30,000,000 BTU per hour. (Fig. 9)

We use two different size dryers 8'x50' and 9'x 60'. These dryers are equipped with 18" wheel type knockers on the intake end to shake loose any damp material that sticks to the flights. Discharge material from the dryer has a heat of from 125 to 200 depending on grade. (Fig. 10).

Material then goes out of the dryer into the rotary cooler of the same size and construction and discharges into an elevator that carries it to the hummer vibrating screens. We size from 6 to 14 mesh. All fines are returned to the ammoniator. Some manufacturers discharge these fines into a hopper and control their recycle back into the ammoniator.

All over size is passed through a cage mill to be crushed and returned back to the screens. Desired size goes to the storage bin at a temperature of 90 to 120 degrees.

We have used a prenuetralizer. Here ammonia is mixed with phosphoric acid to form diammonium phosphate and pumped into the ammoniator as a slurry to be mixed with potash. This operation was unsuccessful due to the small amount of high analysis that was used in our area.

All formulas are figured on a finished moisture of 1 1/2 to 2%. We would prefer a lower moisture content but our drying capacity is such that we would have to reduce our rate of tons per hour to achieve this. (Fig. 11)

We think granulation will be with us for a long time, and until our bank withdrawals begin to exceed our deposits, we will continue to keep our stacks steaming, fill up our bins and give the farmer the best possible product on the market today, "granular fertilizer."

MR. POWERS: Quentin, your panel has been most informative in their comments on ammoniation and granulation.

COMMITTEE'S NOTE: We're sorry to report that something went wrong with the recording equipment at this point. We regret that the questions and answers for this session are not available. The Committee entertains suggestions on how a more positive method may be used for recording questions and answers.

CHAIRMAN ALBERT SPILLMAN: I wish to take this opportunity to thank all of the Executive Committee, various sub - committees, members of the press, hotel personnel, Memphis Chamber of Commerce, for their part in making this a successful meeting of the Fertilizer Industry Round Table.

My special thanks to our moderators, panel leaders, panelists and all speakers for their most informed, up - to - date and valuable presentations. I am sure you will appreciate the discussions held during this three - day period, when you review them in the Proceedings of the meeting. We hope to mail copies to each registrant by April 10, 1971.

Our next meeting (the 21st) will be held here at the Sheraton Peabody Hotel, Memphis, Tenn., Wednesday, Thursday and Friday, November 10, 11, and 12, 1971. Your executive committee is already making plans for the program of the next meeting ... send your suggestions for subjects you'd like to hear discussed. These comments should go to our secretary, Housden Marshall.

I wish to recognize those of you attending our meeting who are representing firms from outside the United States. (The foreign delegates stood, and were applauded.) Please return next year. Thank you for coming.

(Note: foreign delegates from the following countries were represented at the meeting: Canada -- 10 delegates; England -- 4 delegates; India -- 9 delegates; Japan -- 2 delegates; Mexico -- 2 delegates; and Puerto Rico -- 1 delegate. Total -- 28 foreign representatives.

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