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Tuesday, October 30, 1984

Morning Session
Moderators:

Harold D. Blenkhorn
Edwin Cox III, P.E.

Opening Remarks—Chairman Harold D. Blenkhorn

Good morning ladies and gentlemen. It is a pleasure to welcome you to the thirty-fourth Annual Fertilizer Industry Round Table. I would like to extend a special welcome to those who have travelled great distances to attend and take part in our program. I am pleased to report that we have representation from most of the countries of Europe, and from such far-flung corners of the world as India, Australia and Brazil.

As I am sure you will all agree, it is also a pleasure to be in this fine hotel overlooking the inner harbor of Baltimore. The city of Baltimore has a special significance for a seminar dealing with fertilizers, for it could be quite correctly stated that Baltimore is the cradle of the fertilizer industry in North America. It was here in the early 1850's that Davison, Kettlewell and Company established themselves as "grinders and acidulators of old bones and oyster shells". They were followed shortly after by Gustavus Ober and Sons, who produced superphosphate by acidulation of mineral phosphates. These two companies later merged to become the Davison Chemical Corporation. Another name long associated with fertilizer manufacture in Baltimore is that of Baugh and Sons. Baugh began manufacturing superphosphate in Pennsylvania about 1860, and expanded their operations to Baltimore just after the turn of the century. We have first-hand knowledge of local developments in the fertilizer industry since that time. Paul J. Prosser Senior, still living at the age 89, joined Baugh and Sons at the age of fifteen in the year 1910, later becoming president of the Company. Mr. Prosser recalls that there were no less than twenty fertilizer manufacturing plants operating in and around Baltimore during the period of the first world war. His son, Joseph L. Prosser, tells me that in the late 1940's, the annual production of superphosphate in Baltimore amounted to 1,500,000 tons. Among the manufacturers were such familiar company names as American Agricultural Chemicals, Baugh, Davison, Olin-Mathieson, and Royster. It should also be mentioned that the concentration of fertilizer plants in Baltimore gave rise to many service industries. One that has survived from the early days is the well known equipment manufacturer A.J. Sackett and Sons, who have been in operation since 1887.

Baltimore also has a particular significance for the Fertilizer Industry Round Table. In 1951, the late Vincent Sauchelli, Director of Agricultural Research for The Davison Chemical Corporation, assembled a small group of local fertilizer industry chemists and production managers who met around a table for the purpose of exchanging ideas and experiences in fertilizer manufacturing techniques. This was the modest beginnings of the "Round Table" which is recognized today as a unique International forum in the field of fertilizer manufacturing technology. Our program for this year's meeting provides the usual diversity of information on new processes and on major trends taking place in our industry. We hope your stay in Baltimore will be enlightening and enjoyable.

Keynote Speaker

Kent V. Stromsted
President, Top Yield Industries
Cargill, Incorporated

Good morning, everyone. It's a pleasure to be with you today and to have the honor of being your first speaker. We have an ambitious agenda drawn up for the next few days, and I hope I'm up to the task of getting it off to a good start. Just about a year ago, I delivered a speech at a dealer meeting of a regional fertilizer firm in Ohio. I was maybe 30 seconds into it when a flapping sound in the front row caught my attention. A gentlemen was slouched in his seat, head back, eyes closed and his mouth wide open looking very much like a rain gauge. The flapping sound was the beating of an enormous uvula in his throat. Rather than disturb him in the midst of such deep slumber, I lowered my voice and he slept on peacefully. Now I don't see that uvula yet in this audience, but if I do I'll quiet things down a bit this time, too.

Well, we all know how disappointing it is when things don't meet our expectations. For example, back during those wonderful days of Calvin Coolidge, the White House called the top brass at the Pentagon and told them "the President wants to have breakfast with you the day after tomorrow." So for the next two days, the entire Pentagon worked feverishly on charts, tables, position papers, diagrams—everything you can imagine to bring the Commander In Chief up to date on U.S. Defense and Strategic Planning. After all this work, they showed up at the White House and were escorted into the presidential dining room. In a few minutes, President Coolidge appeared, took his seat and began wolfing down his oatmeal. No one said a word, waiting for the president to open the long-awaited discussion. Only silent Cal lived up to his nickname. Not a word was spoken. As soon as his bowl was empty, Calvin stood up, said "thanks for coming," and strode out of the room.

Now, I don't know what your expectations are of me today. But I can promise you that you won't have 20 minutes of silence. In my remarks this morning, I would like to offer a few observations on the current conditions in the agricultural marketplace, as well as some ideas on what I see ahead for the United States in the International Agricultural Markets. I also want to talk a little bit about what that's likely to mean for the fertilizer industry. And I'd like to take this chance to submit a few ideas on things we can do to make the future brighter for the farm economy and everyone who is involved in it.

As a starting point, let me tell you a little bit about Top Yield and Cargill. Most of you probably already are familiar with Top Yield. We are a regional fertilizer manufacturer, wholesaler and retailer operating in the Ohio River Valley. Back in March of this year, Top Yield became part of Cargill.

Describing Cargill takes a bit more time. Shortly after acquiring Top Yield, our regional superintendent from Chattanooga was trying to find our plant in London, Kentucky. He stopped in at a gas station to get a steer and an old gentleman offered, "Oh yeah, they're the outfit that's just been bought by the biggest company in the world." Cargill is good sized but not in that league. Cargill is a merchandiser, warehouser, transporter and processor of commodities. You're probably aware of it as a grain merchant and oilseed processor. But Cargill is involved in many other activities as well, many of them oriented around serving the needs of the farmer and the agricultural sector in general. Cargill has been involved for years in selling feeds, seeds, chemicals and fertilizer used by farmers. And we look forward to doing even more to help farmers meet their future needs for farm inputs, and to remaining an active, contributing member of the fertilizer industry.

The U.S. Farmer and World Markets

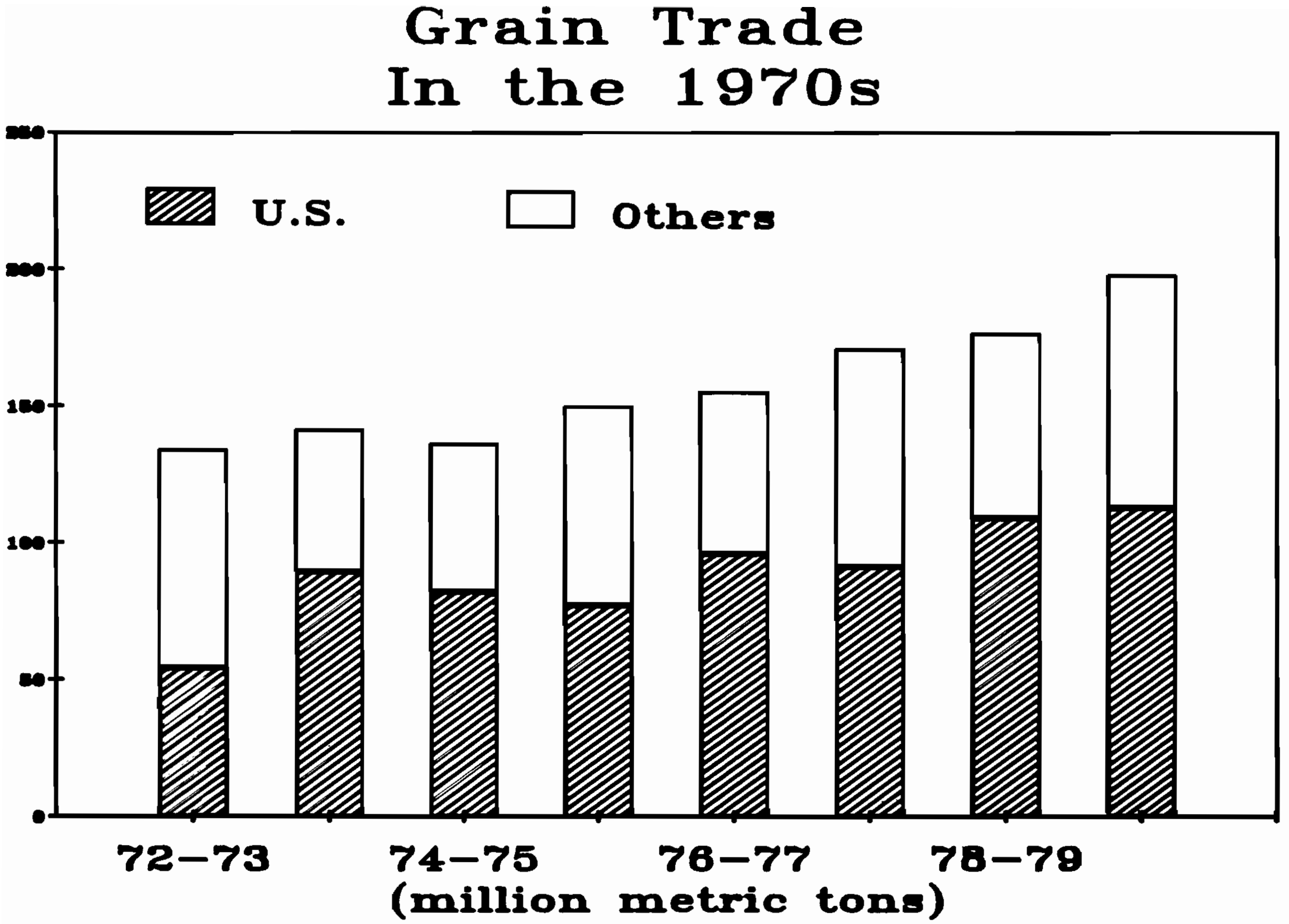
In a way, that means I'm wearing two hats today. I've been with Cargill for 12 years now, and I've held a variety of marketing positions for our commodity marketing division in locations from the west coast to the Ohio Valley. But for the past 1/2 year or so, my job has been Top Yield and nothing else. Today, I'm directly involved in meeting the needs of the farmer for his essential production components. But I'm also able to look with some experience at another important need of his—namely, the markets upon which he depends for his economic livelihood.

Over the past decade or so, the U.S. farmer has become fully integrated into a world agricultural marketplace. The days of producing solely for a domestic market are long gone. And everyone involved in farming will tell you that's good. The domestic market can't absorb any significant increases in domestic farm production. Today, it's the export market that shapes the farm economy.

Take a look back at the 1970's. We saw an unparalleled growth in demand for agricultural commodities, which translated into unparalleled good times for the farmer and the suppliers that farmers depend upon. During the 70's, we saw major new buyers of grain emerge on the world scene. We saw commitments from foreign nations to improve diets. We saw generally strong worldwide economic performance and easily available credit. We saw major production shortfalls in some of our competitor exporting nations. And we saw farm policies that allowed the producer to tap into that explosion in demand.

What did this mean for U.S. agriculture? Between 1972 and 1980, world trade in wheat, coarse grains and soybeans increased 90 million tons, or roughly 65 percent. U.S. producers captured nearly 60 percent of that growth. U.S. grain export volume jumped 250 percent. The value of U.S. grain exports increased fivefold. By the beginning of the 80's, U.S. farmers were sending nearly two of every five acres of production into overseas markets, and farm income stood at record or near-record levels.

You know what that meant for our industry as well. Farm production was up, and demand for the farm production components you and I sell was strong. You also know equally well what has happened since then. We've seen market conditions turn completely around. The global economy is in a mess. Credit is tight, and for many of the developing nations that served as major new markets in the 70's, credit just isn't available. The strong dollar makes U.S. grain more expensive. And competing nations have stepped up their efforts to sell abroad, often with the aid of subsidies. To top it all off, we have seen our government embargo sales to the Soviet Union that cut



our share of the soviet market from a high of nearly 75 percent to a low point last year of below 20 percent.

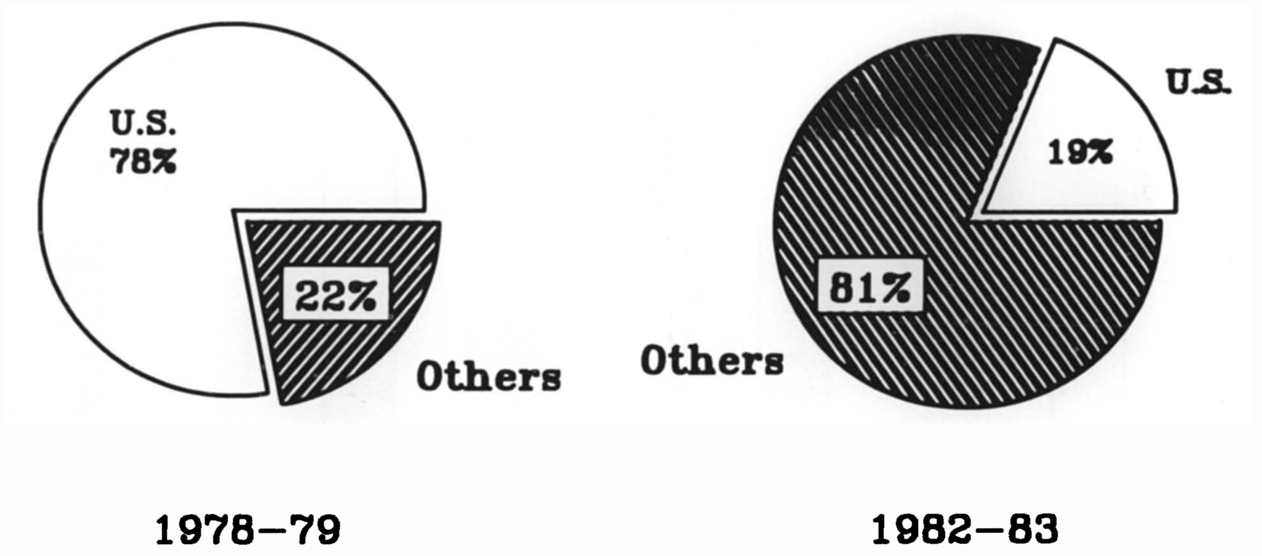
U.S. exports, which had climbed to 5.1 billion bushels in 1980–81, have stagnated at about 4.4–4.5 billion for the past three years.

A Changed World Marketplace

I wish I could tell you that things are going to turn around, and that brighter days are ahead for all of us. I wish I could say that the government will adopt fiscal and monetary policies that will lead to 8-percent interest rates, or that a combination locust swarm, drought and prairie fire will wipe out the crop of a major competitor. But I can't. What I can tell you for sure is this. We've seen a major change in market conditions. The 70's are gone, and it's not likely that we'll see a return of the conditions we enjoyed then. The 1980's will be a buyer's market—not a seller's market. And we've got to take some steps to deal with that changed reality.

Let's take a very quick look at our current conditions. Over the past three years, as world trade in grain has stagnated, the United States by and large has been left holding the bag. World trade has dropped from 215 million tons to about 200–210 million. At the same time, we've become the world's residual supplier—that is, customers come to us only when they can't obtain their needs from other sources. As a result, the United States has seen its share of markets actually decline in recent years. Not only has the world trade pie shrunk, but our share of it has grown smaller.

We've already touched on some of the reasons for this—the strong dollar, increased competition, commodity programs that keep U.S. prices above world levels, and so forth. Nothing that has happened in this crop year indicates that situation will change appreciably. Incidentally, if you've wondered



U.S. Share of Soviet Market 1978–79 vs. 1982–83

Source: USDA

about whether barter is a factor in grain trading—the answer is no—or, at most, very limited.

Let's talk for a moment about the '84–'85 column on the chart. This year's corn crop will be about 7.5 billion bushels. That's up sharply from last year, when we had the Pik Program, but still below record production of 8.4 billion in 1982–83. Despite continuing efforts through government programs to keep supply in better balance with demand, we are still going to wind up with sizable carryout stocks. Domestic use of corn will be around 5.1 billion bushels. Exports will take another 2.1 billion, but another 1.1 billion bushels will be left in the bins.

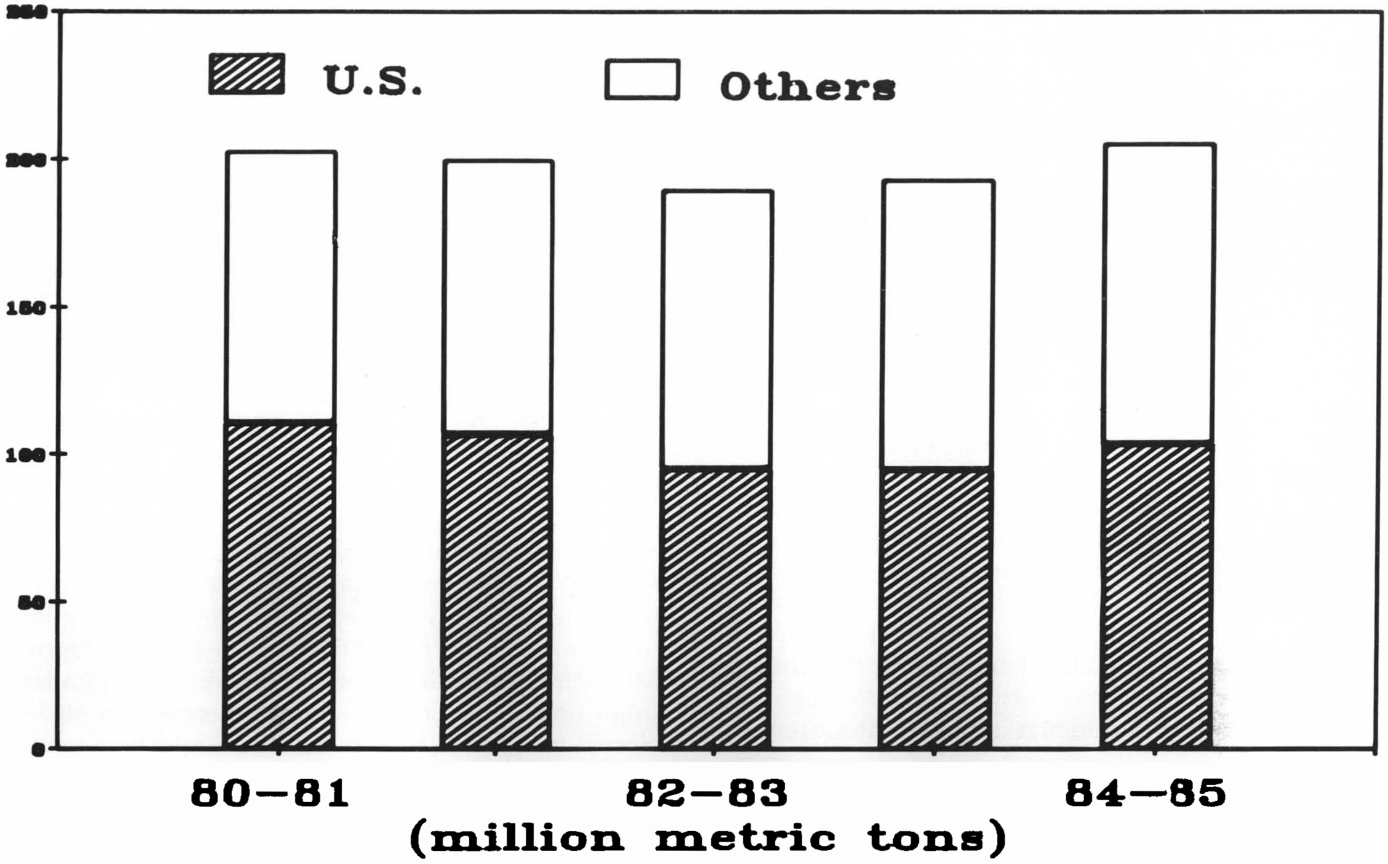
The wheat situation is similar. We'll see a crop of about 2.5–2.6 billion bushels, exports of about 1.5 billion, and a carryout of almost 1.4 billion.

Market-Oriented Farm Policies

If all this sounds too much like doom and gloom, take heart. I believe there's room for some optimism. Granted, we're not going to see the salad days of the 70's again. But if we can take advantage of an opportunity in the coming year to make some fundamental adjustments in our farm policies that reflect the changing nature of the marketplace, then all of us can look forward to some better days. If we have the political will and the political courage to build some market-oriented farm policies, we can get world markets growing again, and the U.S. farmer and the U.S. agricultural sector can be the biggest beneficiary. And that also means that the U.S. fertilizer industry can benefit.

What do I mean by "market-oriented" farm policies? First, let me tell you what that doesn't mean. For the past 50 years, we've seen government policies that sought to protect farm income through programs designed to maintain a desired relationship between supply and demand. In strong markets, that didn't mean too much. But in weak markets, it meant extensive use of set-asides, target payments and a whole

Grain Trade In the 80s



litany of program activities. Has it worked? There are differing interpretations.

No one quarrels with the legitimacy of a government role in providing an adequate supply of food for the consumer, or with the need for farmers to earn an adequate return. The argument is over how best to accomplish that goal. I believe the evidence suggests that those goals are best reached when market forces are allowed to work—that is, when the farmer is free to make his own judgements in response to supply and demand conditions.

In today's market conditions, our current policies just aren't working as well as they need to. Farm income remains a major concern. Farm program costs are skyrocketing and generating all sorts of concern in and out of government. Export markets—our principal source of farm economic growth—are languishing.

We have no real alternative to market-oriented policies. The marketplace isn't going to provide the sort of spectacular conditions that will bail us out of the current situation. Growth will be slower and less dramatic, at best. We must adopt policies that will enable us to improve that outlook.

As a starting point, we need to make some changes in the price support mechanism that will enable the United States to be competitive in world markets. The loan program, for example, could be made more flexible and responsive to changing world conditions if we established non-recourse loans at, say, 70 percent of a moving average of world market prices.

Second, a simplified, limited buffer-stock policy would assure domestic and foreign customers that this country is a reliable supplier of reasonably priced commodities.

Third, annual set-aside and acreage-reduction programs should be eliminated. Instead, a long-term paid diversion should be initiated to move some fragile lands now in cropping back into less-intensive, more soil-conserving uses.

And fourth, a focused program of income and government aids should be developed to facilitate the transition to the more robust market demand that this policy will stimulate. This program would replace the existing target-price and deficiency-payment systems, which have proven to be costly, ineffective and counter-productive.

Building Stronger Export Markets

You don't have to be an expert in agricultural policy to recognize that this sort of change will be controversial in some circles. Some epeople won't like it, especially when they realize that it won't be an easy or painless transition. It will mean greater supplies and lower prices initially. But the long-term gains for U.S. agriculture are real and substantial.

Many of you may be asking, "if it's so controversial, why should the fertilizer industry get involved?" There's one very big reason. The economic prosperity of this industry is directly tied to the health and prosperity of the farm sector. And if we don't make these policy changes—if we don't become more market oriented—both farmers and their suppliers face a continuation of our bleak conditions. But conversely, if we make the switch, we can regenerate world growth in agricultural trade, and the United States can be the chief beneficiary of it. We have the most efficient and productive agricultural system in the world. If we let it compete, we're all going to be the winners—farmer and supplier alike.

I'll even crawl out on a limb and tell you just how much we stand to gain from the shift. An increase of just a half-percent in world grain use can mean an increase of 5–8 percent in annual U.S. grain exports. Look at that in terms of groups of specific buyers. By 1990, exports to centrally planned economies and developing nations could grow by 50 percent under market-oriented policies.

As a result, U.S. grain exports by 1990 could be 20–30 million tons higher every year than they otherwise would be under a continuation of existing policies. That's 10–15 percent more grain exports than we would see as the world's residual supplier. What would another 20–30 million tons do for the farm economy, and for all those who provide the farmer with his production needs? Think about it.

Trade Policy and Long-Term Interests

I'll climb down off that soapbox for a moment and step onto another that I believe is especially appropriate for this group. This one is labeled "trade policy."

I'm extremely concerned that we recognize the importance of liberalized trade to our economic well-being. Today, one-quarter of the U.S. gross national product is trade related. For agriculture, the figure is closer to 40 percent. None of us can say that trade isn't important to us.

But nonetheless, we're seeing an increasing array of initiatives that smack of protectionism. Many of them stem from legitimate concerns about the actions of our trading competitors. But they all have consequences in the international marketplace, and we had better make darned sure we recognize what those consequences are, and what they could mean for our long-term interests. Let me give you one example of what I'm talking about.

A few months back, the United States and China were locked in a trade dispute involving textile imports from the PRC. After months of negotiation and outright argument, the United States acted to limit imports. That may have helped some of the folks in South Carolina. But it cost U.S. wheat farmers nearly $700 million when the PRC cut its wheat imports by nearly 60 percent in retaliation.

Another trade issue of great concern to this group involves fertilizer imports and upstream subsidies. If duties on imports are imposed, it will raise the price of fertilizer to U.S. farmers. It also will change the competitive advantage enjoyed by U.S. farmers, particularly when foreign farmers continue to receive the benefits of lower-priced fertilizer. I'm not going to get into the specifics of the case, or argue its merits. My point is much simpler. We are all dependent upon trade, and not just upon the trade that strikes closest to home. Trade policy has important ramifications for all of us—many of them unintended, and many of them unforeseen. We've got to build a sound trade policy that works in all our long-term best interests.

The 1985 Farm Bill

My time is almost up, and I feel a bit like those Pentagon generals with their papers, charts and graphs. I haven't shown you a fraction of all that I'd like to. At least you've seen some of it. But then and again, you didn't get a bowl of oatmeal to go with it, either.

If I leave you with no other thought, let it be this. Conditions have changed in the agricultural marketplace, and they're not likely to improve dramatically in the foreseeable future. But the U.S. farmer, and businessmen such as you and I, nontheless can look forward to something better, if we build ourselves some farm and trade policies that allow us to compete in world markets and take advantage of our advantages in productivity and efficiency.

If 50 years of experience with farm programs have taught us anything, it should be that attempts to manage supply to guarantee farm income don't work very well. The 70's demonstrated that exports are the growth market for U.S. agriculture. If we can build policies rooted in the marketplace, we can regenerate world agricultural markets, resume our leading role as a supplier and get the farm economy moving again. If we can make those policy changes, we could be looking at another 20–30 million tons in agricultural exports by the end of the decade.

We have the opportunity to make those changes in the coming months. Congress takes up the 1985 farm bill right after the first of the year. And I suppose it's necessary to use a tried and true cliche in this case: that bill is going to be watershed legislation for U.S. agriculture, and for our industry as well. I hope we have the courage to make the right decisions, and I ask for your help in making them. The fertilizer industry is an important voice in farm-bill debate, and legislators listen when the industry speaks. And I hope I've convinced you today that the industry has a major stake in building market-oriented farm policies.

Thanks once again for the opportunity to be here. If any of this has generated questions, I'd be more than happy to talk with you about them at your convenience. I'll turn the soapbox back over to our host now. Thanks for coming, and thanks for having me here.

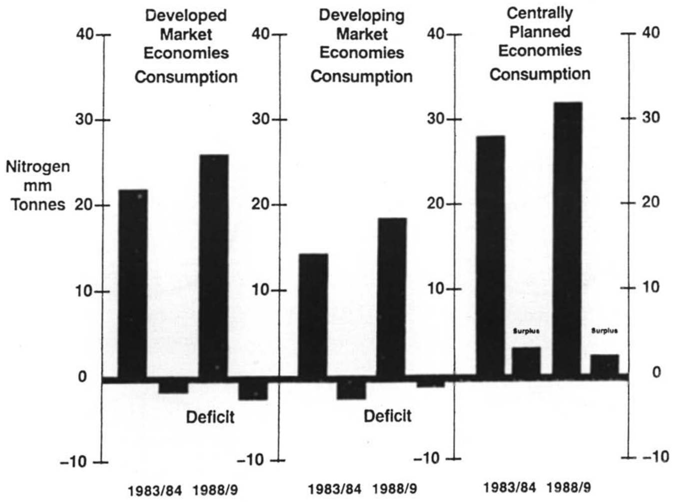
Nitrogen—World Demand and Supply

J. Neil Black
Manager—Nitrogen Chemicals
Agriculture
C-I-L Inc.

Thank you for the opportunity to share my thoughts on nitrogen with you. C-I-L Inc. supplies North American customers with nitrogen from its major plant in southwestern Ontario. Like all nitrogen producers, C-I-L is affected by the winds of change that blow across the world of nitrogen. No one involved in providing the nitrogen ingredient for agriculture and industry is immune. The challenge for the North American nitrogen industry is to recognize and understand what influences its well-being and to make decisions accordingly.

I will not be presenting any new forecasts as there are many people more adept than myself in that field. There is the work of the World Bank/FAO/UNIDO Fertilizer Working Group available to us. They have published a consensus viewpoint on nitrogen supply/demand through to the middle of 1989. I will use data from it. The Working Group divides countries into three blocs which are: the developed market economies, the developing market economies and the centrally planned economies. For convenience I will refer to these as developed, third world and communist blocs.

My first slide compares estimated 1983–84 nitrogen consumption in each bloc with the projected 1988–89 consumption in the same bloc. Also shown is the nitrogen surplus or deficit in each bloc.

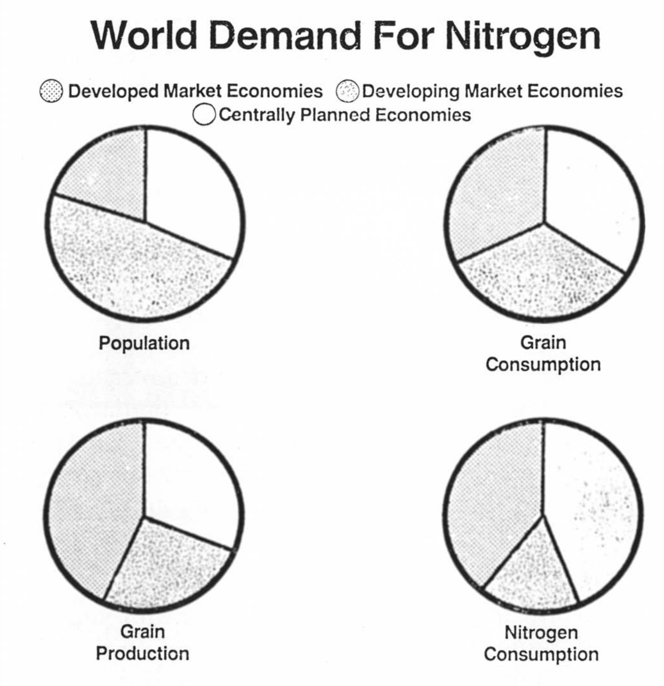


Starting from this nitrogen history and supply/demand projection, I will explore some of the important assumptions behind the data and discuss a number of the issues which arise from it. As we are aware, nitrogen, whether as anhydrous ammonia or its derivative products, is a freely traded commodity in most markets. All producers are affected by the world supply/demand balance for nitrogen. This applies even though governments may impose taxes or grant subsidies during the production, the distribution or the sale of nitrogen products.

Nitrogen, in turn, is influenced by the supply/demand balance and the prices of two other key commodities. On the nitrogen demand side, grains in general, and feedgrains and corn in particular, dominate trends in demand. In North America, for example, over half the nitrogen applied as fertilizer goes on corn and wheat. On the nitrogen supply side, virtually all ammonia is made from natural gas or other hydrocarbons. The cost of this natural gas to the nitrogen producer is affected by the supply/demand balance for energy. Natural gas is no longer being sold in the developed world as a by-product at 25 cents per Mcf.

As for nitrogen, I will not be presenting new scenarios for grain and natural gas. In 1983 Chase Econometrics did a study for C-I-L Inc. on the future of North American agriculture. I will use information from this study. In addition, I will refer to a 1983 multi-client study by Arthur D. Little, Inc. concerning the relationship between natural gas supply and ammonia manufacture.

I will look first at the demand side for nitrogen, i.e. the future for grain. The basic theoretical model underlying the supply/demand balance for nitrogen is simple. Population growth and economic development in all parts of the world lead to increased grain demand both directly and via livestock. Therefore grain production has to increase to satisfy this increasing demand. Since the supply of land is not



inexhaustible in most parts of the world, the increase will be achieved by increasing yields. The use of fertilizers, and in particular nitrogen, are key inputs. The reality is we are not dealing with a simple theoretical model but with a massive economic conundrum which is subject to many variables, not the least of which is the weather.

The three economic blocs consume about the same quantity of grain measured as a total of wheat and feedgrains.

While the demand for grain in the third world is the smallest of the three blocs, total demand is growing fastest in this group, largely due to population growth (2.4% per year). In addition, most economists predict that overall economic growth will take place in the third world, leading to increased grain consumption per capita. This higher standard of living would support a projection that the third world will catch up with the developed bloc in total demand for grain by the end of 1989.

Only the developed bloc is a grain exporter. It provides 16% of the third world's current grain demand and 18% of the communist bloc's needs. The third world is frequently unable to purchase all of the grain it requires due to the lack of foreign exchange. How do they earn the foreign exchange to buy grain? This is usually achieved through the sale of commodities such as oil, cocoa, coffee and metals. Oil, however, occupies a central position in that many of the third world countries must purchase all of their oil or its derivatives on the world market. Most of the third world countries which do earn foreign exchange by exporting oil are not major grain importers. If the downwards trend in world oil prices continues, the heavily populated third world countries will be able to purchase more grain in addition to oil. However, if the relative value of the U.S. dollar remains high, grain prices to these same countries (as well as Japan and other richer importers) will be high, thus restraining demand. In general, the demand for grain is a function of the prosperity of the third world. If the third world becomes more prosperous, both grain farmers and nitrogen producers will be asked to supply more.

The prosperity of the grain farmer is dependent on the grain supply/demand balance. There has been a dramatic growth in supply of grain from the developed market economies over the last decade. The U.S., for example, exports over four times as much feedgrain today as it did at the beginning of the 1970's. Grain exports have not increased in the 1980's due to recession and the resulting slowdown in world trade activity. If grain exports do grow, it is likely to be at a much lower level of annual growth. We do not yet know what permanent structural changes will result from the recent recession nor what dampening effect these may have on a resurgence of overall world trade activity.

The nitrogen demand data shows nitrogen consumption increasing dramatically in the third world. The ability of third world farmers to convert this increased nitrogen into increased crop yields will have a significant effect on world grain trade. Failure on their part to increase crop productivity to feed ever-increasing populations within their own countries will lead to increases in demand on the developed world's grain exports. On the other hand, success beyond current expectations would lead to lower demand for grain from the developed countries.

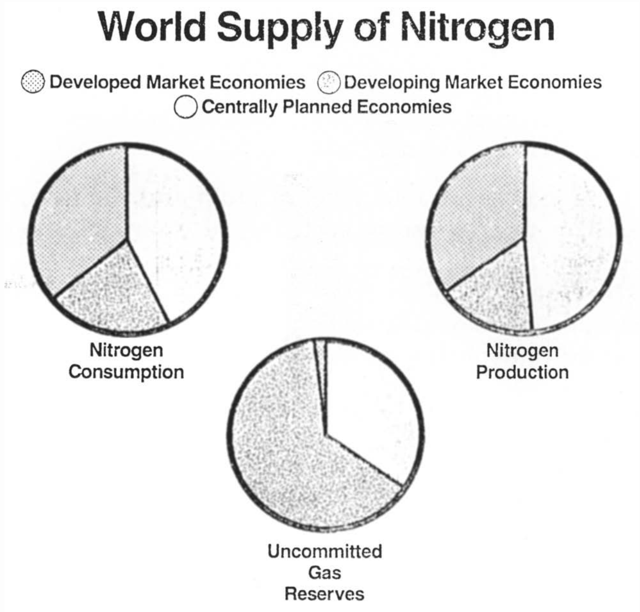
The Working Group is projecting a major increase in nitrogen capacity. The largest portion of this increase will occur in the third world, at an annual rate of 7%. The developed bloc is shown increasing capacity by less than 1% per year. The communist bloc is showing increases in nitrogen capacity of less than 2% per year, now that the major round of Russian expansions started in the mid-1970's is largely complete. If Russia's objective is to improve its agricultural performance, much of the nitrogen now being exported should be retained for domestic use. If Russian farmers can utilize Russia's increased nitrogen supply efficiently, the world grain supply/demand balance will be dramatically affected. While it is unlikely they can match the efficiencies of North American and western European grain farmers, the productivity of Russian agriculture is certain to improve. You will note on the above slide that the efficiency of nitrogen utilization is much greater in the developed countries than in the communist bloc.

The additional nitrogen required to grow more grain will be produced as ammonia with natural gas as the feedstock. The fixing of nitrogen directly by growing plants will not significantly affect the nitrogen supply/demand balance in this century.

The major growth in nitrogen capacity is forecast for the third world. Huge amounts of capital will be required to pay for the nitrogen expansion projects, whether the projects are financed under private or state auspices. This requires a demand for the nitrogen products at prices which are high enough to earn a margin over the input natural gas to justify the investment. The cheaper this natural gas is, the more likely the project is to proceed. In countries with large quantities of uncommitted gas reserves, feedstock for a new ammonia plant could be priced very cheaply.

Where are these reserves in relation to current nitrogen consumption and production? This slide has been developed from Arthur D. Little, Inc.'s work.

Three quarters of this natural gas is found in the USSR, Iran, Indonesia and in Qatar. Pipelines are now in place to move Russian natural gas to western Europe, and this may increase the marginal value of their gas.



Iran's uncommitted gas is about a quarter of the world's total. Whether it could utilize this to become a major source of nitrogen is questionable because of political instability. Indonesia is self-sufficient in nitrogen, and will provide regional exports. Qatar, and other Gulf states, will continue to make investments in export based nitrogen projects. Economics generally favour manufacturing nitrogen products close to the market in which they are to be consumed, provided that natural gas is available at market-related energy values.

The state-owned proportion of world nitrogen capacity has increased in recent years. Nevertheless, the basic economics of converting natural gas to nitrogen through ammonia will continue to directly influence the provision of new ammonia capacity. Thus, so long as nitrogen is perceived to be freely available on world markets, at a relatively cheap price, there is no incentive for either state or private enterprise to invest in an import substitution project. As the supply/demand balance tightens, however, the world price must inevitably rise to restrain consumption. This in turn will prompt both state and private enterprise to look for opportunities to invest profitably in the nitrogen business.

In summary, the nitrogen demand forecasts assume population growth and increasing standards of living leading to greater grain demand and production and hence nitrogen demand. This increased nitrogen demand can only be provided by an increase in nitrogen capacity world-wide. Recent history has shown that the projected tightening of the nitrogen supply/demand balance will not occur in an orderly fashion once the now idle North American production capacity is operating again. After that, because the pace of new nitrogen investment has slowed considerably since the U.S. and USSR rounds of expansion in the mid-70's, the world appears to be approaching a time of nitrogen shortages. This will not occur for at least two reasons. Firstly, the price of nitrogen will rise to match consumption with available supply. Secondly, the perception of possible nitrogen product shortages will encourage opportunistic investment in the industry. As Arthur D. Little points out, major investment is required to upgrade or replace obsolete plants. This vital reinvestment is more likely to occur when returns are good.

I believe that world and North American demand for nitrogen will increase both in spite of and because of the variables I have discussed. I further believe that the North American industry will be an active participant in meeting this demand. To do this successfully we require the following:

1. an assured supply of natural gas, the price of which is established by unfettered market forces
2. an expanding world economy which fosters trade in both agricultural and nitrogen products
3. the availability of capital at a cost which reflects the real value of money
4. exchange rates which will permit developing countries to purchase North American products
5. the application of improved nitrogen manufacturing technology and finally,
6. consistent government policies which support the export of grain from North America.

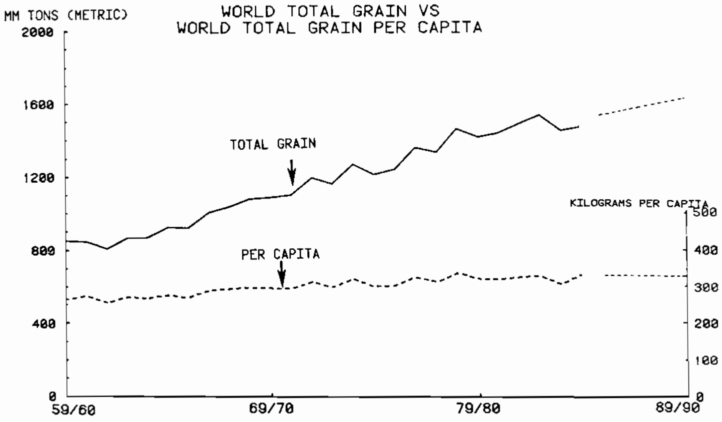
The World Outlook For Phosphates

Eugene B. Graves
Vice President-Planning & Economics
Agrico Chemical Company

The following charts cover the highlights on a worldwide basis for P_2O_5 and more specifically, the U.S. outlook for the 1984/85 Fertilizer Year. The data is shown on a metric ton basis for the world, while the U.S. data is in short tons. Most of the data is on a fertilizer year basis, that is, from July 1 of one year to June 30 of the next. Some countries, however, report on a calendar year basis. In that case, the calendar year data is generally incorporated with the fertilizer year data so as to best reflect the data on a year-to-year comparison.

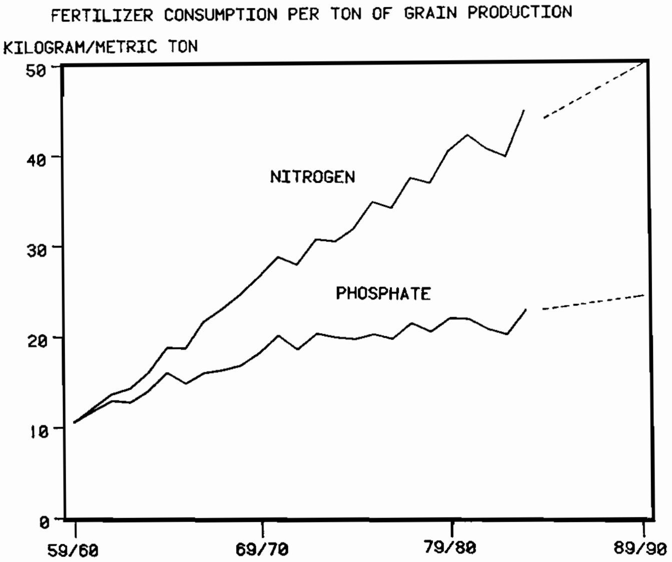
World Grain Data

The underlying demand for fertilizer is based on grain to feed a growing population. During the past 20 years, grain consumption per capita has increased by about 50 kilograms per person, from 275 kilograms to 325. Virtually no increase is expected for the remainder of this decade. As a result, total grain consumption is expected to grow with the rate of population, reaching about 1.7 billion metric tons by the year 1990.



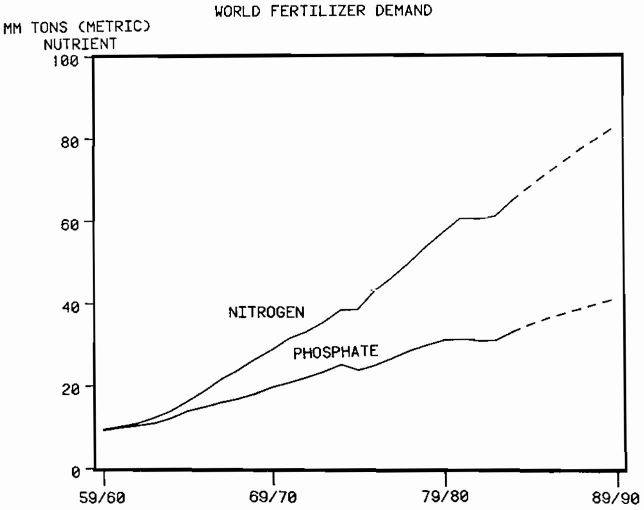
Fertilizer Consumption Per Ton of Grain Production

A second factor in determining the total level of fertilizer consumption is the rate of fertilizer applied to grow a ton of grain. Over the past 20 years, the rate of phosphate application per ton of grain production has doubled from about 10 kilograms per metric ton to slightly in excess of 20. This trend is likely to continue. As a matter of interest, nitrogen use per ton of grain production has more than quadrupled from 10 kilograms to more than 40 during the past 20 year period, and is expected to reach about 50 kilograms per metric ton of grain by 1990. This indicates that the world is moving further up on the response curve; that is, it takes an increasing amount of fertilizer to grow the next ton of grain.



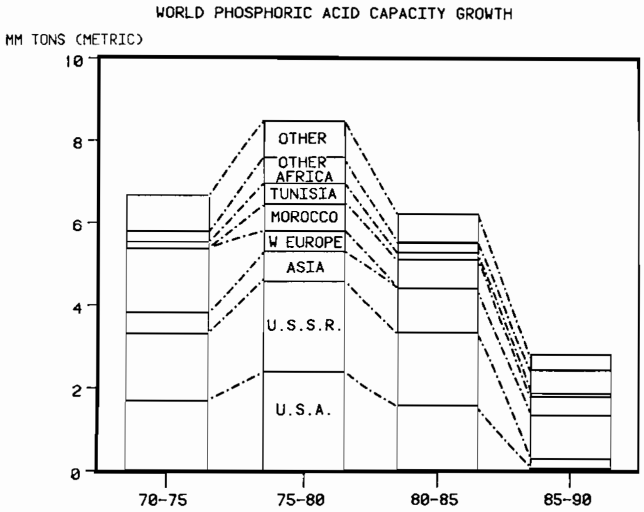
World Fertilizer Demand

Based on the total level of grain and the rate of fertilizer used to grow each ton of grain, nitrogen fertilizer is expected to reach a total demand level exceeding 80 million tons by the year 1990, with phosphates at about 40 million metric tons. The growth rate for phosphates during the decade of the 1980's, is about 3%.



World Phosphoric Acid Capacity Growth

This shows new capacity in five year increments. During the 1970's, new capacity kept pace with the increasing demand levels, with particularly large increases in the U.S.S.R. and the U.S. However, for the decade of the 1980's, the rate of new capacity has slowed, with new capacity for the period 1980/85 at a rate of only about 70% of the previous five year period and much further declines for the 1985/1990 period. There are a number of reasons for this slow down, but perhaps the overwhelming reason was the worldwide depression of the past several years and the corresponding depressed prices for fertilizer materials. As a result, bankers were less anxious to provide the funds to expand capacity.

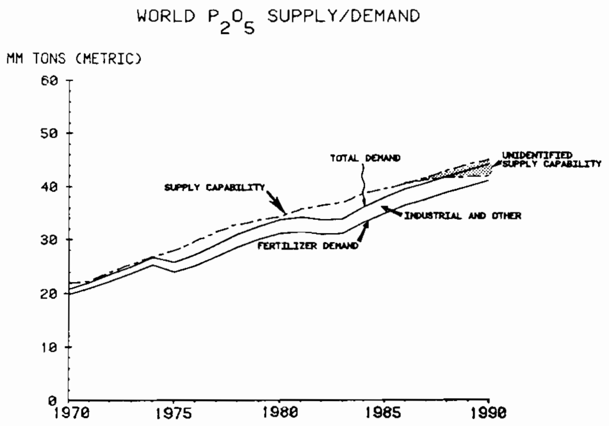


World P205 Supply/Demand

Taking into consideration some delays, the P_2O_5 supply/demand balance should be tightening fairly soon. However, because of the uncertainty regarding operating rates that can be achieved in various parts of the world, it is impossible to either ascertain the exact quantity that could have been produced had the demand been there, nor to predict precisely what can be produced in the future. The key, however, is to look at trends.

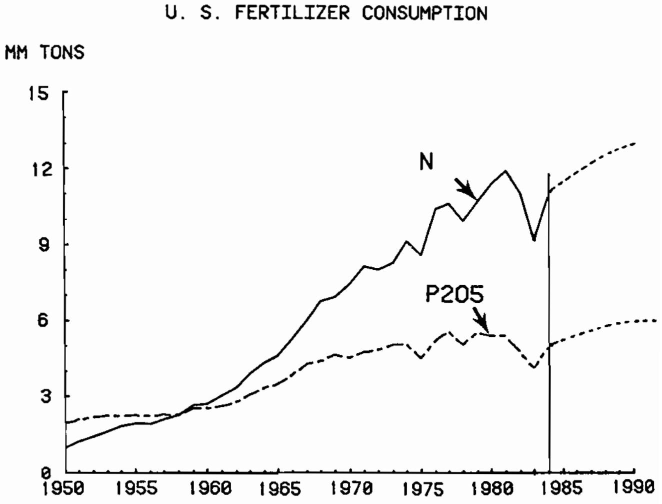
This shows that the surplus in supply capability that the industry is currently experiencing, was more a function of a slowdown in demand than it was an increase in new capacity. In 1974, the data clearly shows a very tight supply/demand balance. However, the slowdown in demand in 1975, coupled with some increasing capacity, led to rather substantial surpluses during latter half of the 1970's. By 1980, demand had again more or less caught up with supply capability and as a result, pricing was substantially improved. The slowdown in demand during the early 1980's resulted in a substantial imbalance. The recovery in P_2O_5 demand, which began late in 1983, is expected to result in an improving supply/demand balance over the next several years.

By the late 1980's, additional plants will have to be built in order to meet the continuing growth in demand. These are shown by the shaded area and labeled "unidentified supply capability."



U.S. Fertilizer Consumption

Turning now closer home, U.S. P_2O_5 consumption has increased from a level of about 2.5 million tons to a high of just about 6 million tons in the early 1980's, before dropping off to about 4.2 million tons in 1983. Demand has subsequently rebounded to a 5 million ton level in 1984/85 and is expected to increase to a level of about 6 million tons by 1990.

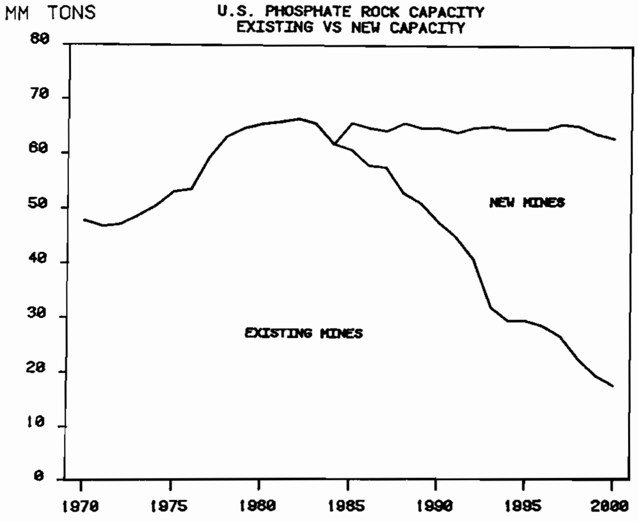


U.S. P205 Exports

This shows the long term trend in U.S. exports of P_2O_5. The U.S. is a major supplier of P_2O_5 to countries that do not have an adequate supply of their own. During the latter half of the 1970's, exports increased rather dramatically, from about 1.5 million tons to 4.6 million tons by 1980/81. There was a slight drop off to about 3.9 million tons in 1982/83, but exports rebounded rather sharply in 1983/84. Exports in 1990, could be in the 5.5–6 million ton range, essentially 50% of the production from U.S. P_2O_5 upgrading plants. The increased exports, coupled with the improving domestic fertilizer use, should result in using all available U.S. capacity within the next three years.

U.S. Phosphate Rock Capacity—Existing Versus New Capacity

Turning now to the outlook for U.S. phososphate rock, the U.S. is facing a rapid depletion of its existing mining base. Within the next ten year period or so, we will lose about half of our existing capacity. And by the year 2000, only slightly in excess of 20 million tons (30%) of mining capacity which is currently in existence will still be running at that time. This means that the industry will be facing a need to replace these depleting mines if we are to do no more than sustain the existing capacity levels.



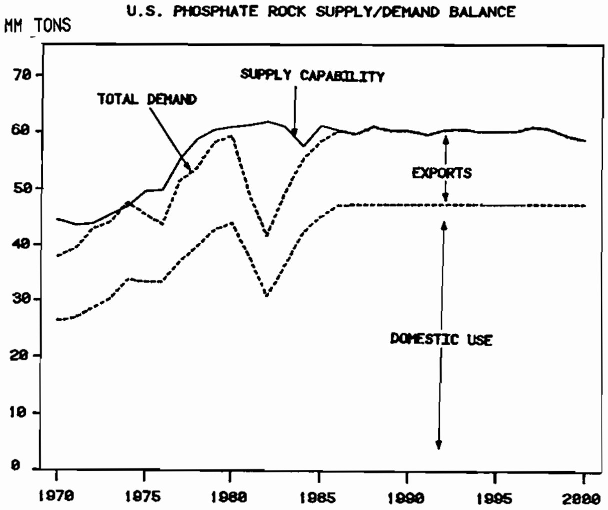
Phosphate Rock Supply/Demand

Recognizing that total capacity is likely to remain virtually flat from here forward, this shows how quickly demand will catch up with supply capability. Supply capability is defined as design capacity times the maximum sustainable operating rate.

Demand for phosphate rock is segregated between domestic use and exports. Domestic use includes phosphate rock used to produce finished products which are then exported.

The domestic use category clearly highlights the recovery which has already taken place in the use of phosphate rock. Wet process acid production, one of the primary users of rock, was at a level of 10.1 million tons for 1983/84, just 200,000 tons below peak production level of 10.3 million tons over the past several years. Thus, with a clear indication that our domestic P_2O_5 upgrading plants will be running at capacity within the next few years, the domestic use of rock will peak shortly. With very little additional P_2O_5 upgrading capacity anticipated in the near future, the domestic use of rock would level out. Thus, given a supply capability which is also fairly constant over time, we would anticipate exports to also level out at about 12 to 13 million tons.

The next several charts highlight the outlook for P_2O_5 in the 1984/85 fertilizer season.



U.S. Fertilizer Consumption

Fertilizer consumption for 1984/85 is projected to be about 3% over that of 1983/84, which in turn, was up 20% over the actual for 1982/83. The data for 1983/84 is still estimated since the USDA data will not come out until November. Based on the level of shipments for each of these nutrients, it appears that the consumption levels are likely to be much as shown here. However, because of the wet and thus late spring, some of the fertilizer applied this past spring may actually show up as fertilizer consumed in the 1984/85 year.

Corn for 1983/84 was back up to near the 80 million acre level. With essentially no change in the feed grains program for 1984/85, it appears likely that corn again will be in the 80–82 million acre range. Thus, consumption is likely to be up only slightly.

U.S. FERTILIZER CONSUMPTION
M TONS

	ACTUAL 1982/83	ESTIMATED 1983/84	PROJECTED 1984/85
N	9,195	11,000	11,300
P	4,163	5,000	5,200
K	4,852	5,800	6,000
TOTAL	18,210	21,800 + 20%	22,500 + 3%

U.S. P2O5 Supply/Demand

Looking at the U.S. P_2O_5 supply and demand in detail, total demand for U.S. P_2O_5 was 10.9 million tons this past year, with 5.3 million tons of that used for fertilizer, 1.3 million tons for industrial and other non-fertilizer uses, and 4.3 million tons as total exports. Most of the P_2O_5 supply was in the form of wet process acid which totaled 10.1 million tons, up 1.5 million tons over the production of the previous year.

For 1984/85, demand is expected to increase slightly with most of the increase coming for exports.

About half of the total wet process acid produced in the U.S. is used in producing DAP/MAP.

U.S. P205 SUPPLY/DEMAND
MM TONS

	ACTUAL 1982/83	ESTIMATED 1983/84	PROJECTED 1984/85
SUPPLY			
WPA	8.6	10.1	10.3
FGA	0.6	0.7	0.7
OTHER	0.5	0.5	0.5
CONVER. LOSSES	(0.4)	(0.4)	(0.4)
TOTAL	9.3	10.9	11.1
DEMAND			
FERTILIZER	4.4	5.3	5.4
NON-FERTILIZER	1.0	1.3	1.3
EXPORTS	3.9	4.3	4.6
TOTAL	9.3	10.9	11.3
INVENTORY CHANGE	-	-	(0.2)

U.S. DAP/MAP Supply/Demand

DAP and MAP demand for fertilizer use for the 1983/84 Fertilizer Year, reached an all time record of 6.7 million tons for domestic fertilizer and a record 6 million tons for exports. Domestic shipments are generally split 50/50 between fall and spring. However, for 1983/84, the fall shipments were much higher at 3.9 million tons, with only 2.8 million tons being shipped this spring. Exports were just the reverse, with an all time record of about 3.3 million tons being exported this spring.

For 1984/85, fertilizer shipments of DAP/MAP are expected to be up only slightly, but are more likely to be on a more normal 50/50 basis between fall and spring. In fact, with the dry weather that prevailed through much of the corn belt, it could be that more of the DAP and MAP will be shipped next spring versus this fall. Exports, on the other hand, are falling into a more normal pattern of higher fall shipments than spring. Total demand should be about 13 million tons, which will require a slight increase in production.

In summary, the outlook for the 1984/85 Fertilizer Year calls for a relatively modest 3–5% increase in fertilizer shipments, following on the heels of a 20% increase for 1983/84 over the previous year. However, with respect to domestic P_2O_5 upgrading, there are still some plants which are not operating and thus, there is some overhang which will have a negative impact on pricing, particularly next spring. As world demand continues to increase, U.S. exports are likely to go up and only then will the P_2O_5 prices be at levels which will begin to generate attractive rates of return. This is expected within the next several years.

U.S. DAP/MAP SUPPLY/DEMAND
MM TONS

	ACTUAL 1982/83	ESTIMATED 1983/84	PROJECTED 1984/85
SUPPLY			
PRODUCTION	10.0	12.6	12.8
IMPORTS	0.2	0.1	0.1
TOTAL	10.2	12.7	12.9
DEMAND			
FERTILIZER	5.0	6.7	6.8
EXPORTS	4.8	6.0	6.2
TOTAL	9.8	12.7	13.0
INVENTORY CHANGE	+ 0.4	-	(0.1)

The World Potash Outlook

Robert L. Schmidt
Vice President and General Manager
North American Marketing West
International Minerals & Chemical Corporation

It's a pleasure to be here today at The Fertilizer Industry Round Table and to be an active participant in what has become a prestigious series of programs . . . programs that have produced a wealth of information for the fertilizer industry. I'm especially happy to address this group about a product that is a big part of IMC and to give you our view on "The World Potash Outlook."

I have to admit, and I'm sure most of you would agree, that looking into the future, the picture can sometimes be clouded due to the vast number of unknowns and the cyclical nature of our business. However, I'll do my best to give you a clear view based on current facts and information that is available to us today.

Two years ago, one of my colleagues at IMC, Deneb Teleki, our Director of Corporate Market Research, presented the potash report at your 1982 Round Table.

At that time he reminded this assembly that potash and agriculture rise and fall together.

Denny said "Our fortunes are interlinked with the farmer, no matter if he grows corn in Iowa, wheat in France or rice in India."

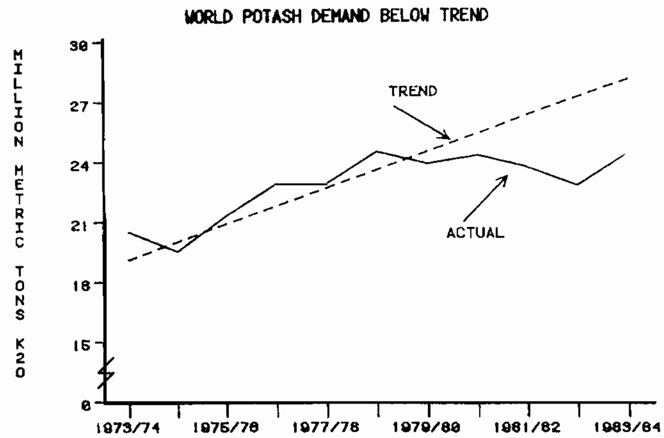
It's no different today. We all know how the problems of agriculture have impacted on all of agribusiness in the last two years. We're especially aware of what has happened within the fertilizer industry.

And we all are equally aware that this year's turnaround in agriculture in the U.S. and around the world has given the fertilizer business a badly needed shot in the arm, but that doesn't necessarily mean that happy days are here again.

We must remember that several negative factors have sidetracked our industry's growth trend which bear notice here today. The most important, of course, is the world-wide economic recession during the early 1980's which set global potash consumption back by nearly three years from trend-line. In the U.S., the combination of recessionary forces, government actions such as P-I-K and an over-abundance of grain resulting in weak grain prices, caused nearly a five-year departure from earlier trends.

In short, demand for potash is behind industry projections. And to magnify the situation, added capacity based on the expected level of demand has been put in place before the incremental demand has materialized.

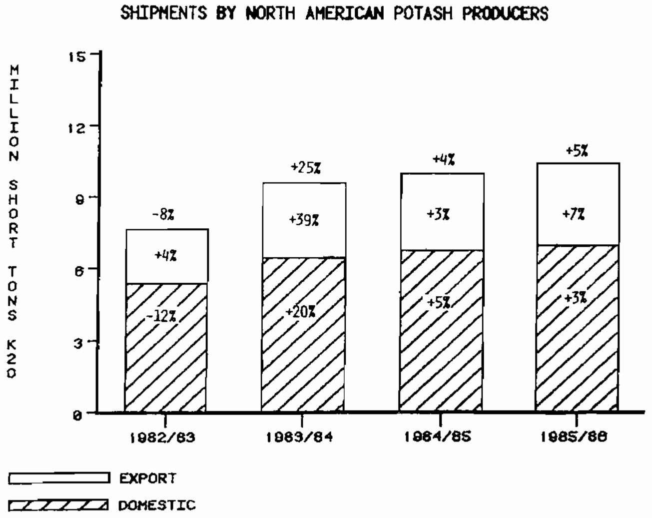
We like to boast of a strong dollar, but the strength of the U.S. dollar has been a double-edged sword. First, it has impinged on the North American potash industry's ability to export because of the dollar's strength . . . and


WORLD POTASH DEMAND BELOW TREND

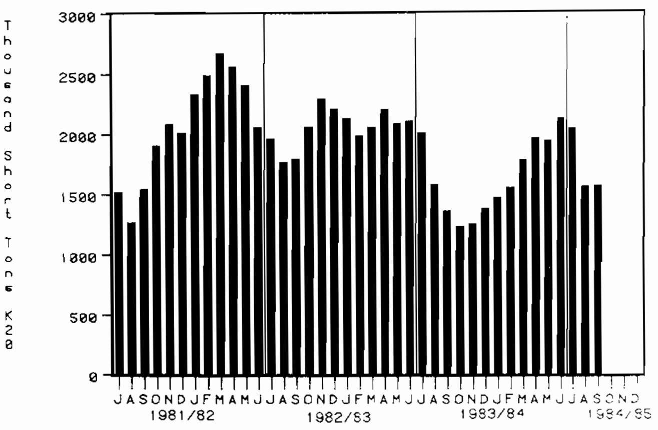
Secondly, it has encouraged higher imports from overseas. In many cases, foreign suppliers realize a net gain on the currency exchange, which is greater than their base margins on the product.

Looking deeper now let's examine the potash picture in three separate phases, beginning with the short-term outlook through 1986.

After rebounding by 25 percent in 83/84, total North American potash shipments are expected to increase by four percent in 84/85 and another five percent in 85/86. Domestic shipments will account for most of the increase in 83/84 while higher exports (+8 percent) in 85/86 will outpace domestic movement.


SHIPMENTS BY NORTH AMERICAN POTASH PRODUCERS

Above normal July-September shipments, particularly to the domestic market, have helped buyers adjust stocks to more average levels and resulted in a draw-down of North American inventories from a high level last June to a more manageable level at the end of September.


NORTH AMERICAN POTASH INVENTORIES HELD BY PRODUCERS

SOURCE P/PI

Production this fiscal year is expected to increase by only three percent after the 23 percent achieved between 1983 and 1984. The North American industry is expected to reach record production level in 85/86. Production in the September '84 quarter was well above the abnormally low level of last year. The balance of the current fiscal year should follow a more seasonally normal pattern.

However, production in the second half of this fiscal year should be about seven percent below second half 83/84 production as the industry struggles to maintain a more manageable inventory level going into the fourth quarter.

North American production potential will increase by about three percent from 83/84 during the 1984/85 year and an additional four percent in 1985/86. Increases in Canada will more than offset the decline in U.S. production potential.

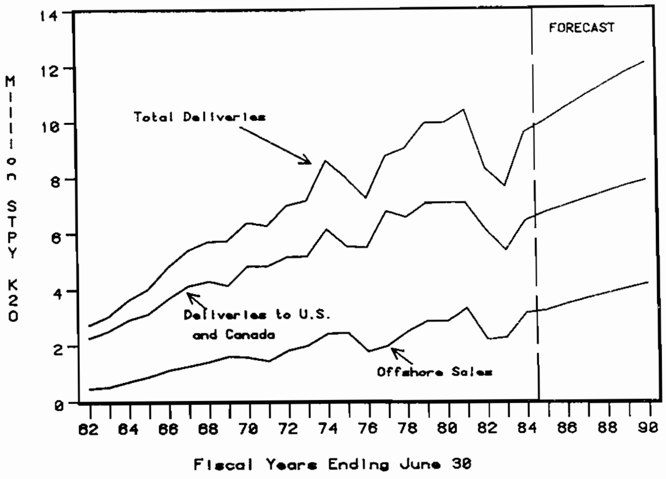
The outlook for offshore imports into the U.S. is somewhat foggy. As you may know, the U.S. Department of Commerce has published its decisions resulting from the investigation into potash imports from off-shore sources. These included recommendations on the rates of dumping duties and countervailing duties on potash imported from the USSR, East Germany, Spain and Israel.

In the case of countervailing duties recommended against Spain and Israel, the U.S. is currently collecting bonds for material imported from both countries awaiting the final outcome to be issued in late November.

Imports should hold flat this year (plus or minus 10 percent) in spite of the U.S. Commerce Department's countervailing duties. With increased production capability, a U.S. domestic market price higher than other large markets, and a strong U.S. dollar relative to the shekel, Israel no doubt will export as much material to the U.S. as it did in 83/84. The tighter U.S. sulfate supply, due to the flooding of Great Salt Lake's evaporation ponds, may encourage West Germany and Belgium to increase its SOP shipments to the U.S as well.

North American producers' stock on June 30 was 2.1 million tons K20, or about 22 percent of the industry's total 83/84 shipments. Average stocks to sales should be closer to 15 percent. Our current forecast calls for a slight reduction in inventories to 2.0 million tons K20 by next June, representing 20 percent of a year's sales in inventory. We expect the year-end stocks for 85/86 will again fall slightly and represent 18 percent of a year's business on hand.

DELIVERIES OF NORTH AMERICAN POTASH PRODUCERS BY MARKET



SOURCE: USBM. P/PI and IMC Forecasts

Looking further out, and speaking to the second phase, total shipments should rise between 3–4 percent between 1986 and 1990 as the world economy stabilizes and key Latin American markets rebound.

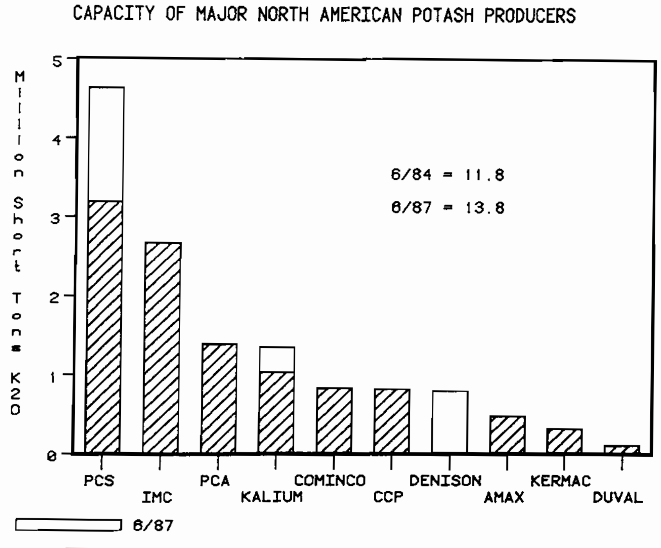
Inherent in this forecast is a significantly lower U.S. dollar against other currencies which, other things being equal, will help stimulate North American potash exports.

The North American production potential is expected to grow by 20 percent from today's level through the balance of the decade. Kalium has announced a 20–25 percent increase in potash capacity at its Belle Plaine mine in Saskatchewan.

Other projects contributing to the increase in North America's production potential include the PCS/Lanigan expansion, PCA and Denison in New Brunswick, and the possible return of production by GSL and Bonneville in Utah. Projects being evaluated but which have not been included in North American production potential totals include:

a) Manitoba—CANAMAX new mine (shaft)
b) Michigan—Kalium new mine (solution)
c) New Brunswick—BP new mine (shaft)

The industry shipping rate will dip ever slightly in the early part of this forecast period as additions to production potential outpace total industry ship-



SOURCE: TVA and IMC

ments. Still, the industry should be capable of operating between 85 to 90 percent during this period and will have sufficient capacity to meet market needs if the volumes forecast are understated.

Overseas, no new major expansions have been announced recently. If anything, we have learned that the Soviets do not intend to expand beyond what is already under construction.

Israel and Jordan will have minor expansions, while East Germany and Western European producers will stay about equal. Duvall may be in operation in Thailand by the end of the forecast period, but that target remains doubtful.

Now we reach even deeper into the future to look at potash in the year 1991 and beyond.

As stated before and as we still believe today, developed world potash markets will be rather mature by the 1990's, averaging one to two percent growth per year.

Demand will grow fast (6 to 8 percent) in most of the developing countries helping to keep the overall world growth around three percent in the early 1990's. It is not expected that any alternative for potash fertilizers will be developed during this time frame.

Unfortunately, demand growth and prices will continue to be cyclical in the future, and at times could exceed the magnitude of the cycles experienced in the past 20 years. However, capacity additions will be the most stable and predictable due to the costs and time required to bring on-stream a world-scale facility.

No new resources have been uncovered to displace Russia and Canada as having the largest and richest potash deposits in the world. For this reason, these two countries will supply an increasing share of world demand.

However, smaller new mines will develop in the 1990's in Thailand, China, Brazil, Peru, Mexico, etc. At the same time, older existing mines will be depleted and phased out of production in the U.S. and parts of Europe.

Finally, it appears likely that government involvement will increase in the potash business, based on the location of the economically mineable deposits and the political environment where most deposits are located.

Now let's zero in on some specifics concerning potash . . . supply/demand trends and data, plus a look at the major producers, capacities and the impact on the total picture for this basic fertilizer materials.

First . . . current history . . . U.S. potash consumption for the 1984 fertilizer year increased about 18 percent over a year ago to about 5.7 million short nutrient tons. We expect U.S. consumption to increase another four percent this year, to approximately 5.9 million short tons.

Domestic potash demand will respond to farm level demand and some further retailer stock rebuilding. Comparisons with last year will be more positive next spring than in the fall. However, it is expected that strong first quarter shipping gains will be offset by lower second quarter volume.

On the matter of imports, shipments from overseas should plateau this year as product movement increases from PCA's New Brunswick, Canada mine to the east coast markets.

Exports of North American potash, which rebounded by about 38 percent last year, are expected to record a much smaller gain this year.

That slight improvement marks a more positive market outlook than analysts saw just a short time ago, and comes largely from the return of some Latin American buying coupled with continued strong demand in the Asia/Pacific region.

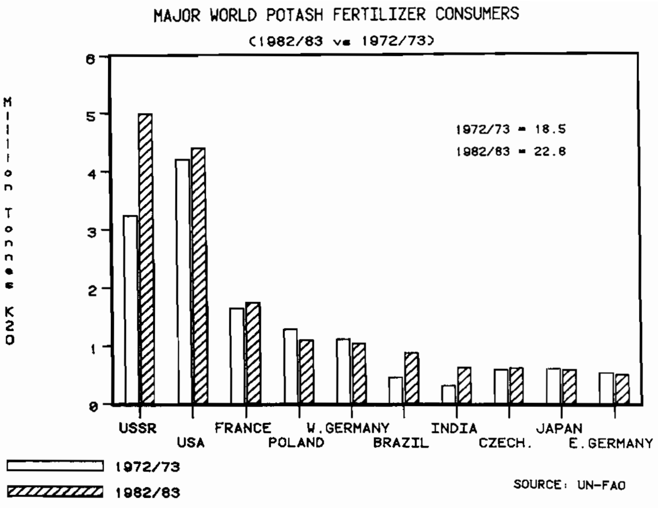
We also project additional product available from other producing areas, including Israel, Jordan and PCA in New Brunswick, but expect to see East Germany and the Soviet Union less aggressive in the export picture than a few years ago.

Putting it together, world potash consumption last year increased about seven percent to about 24.4 million short nutrient tons . . . and that total will continue to move upward about four percent this year, reaching 25.4 million tons by next June.

In the production area, North American potential should edge up by about one percent this year as PCA's New Brunswick mine comes more fully on stream. But potassium sulfate production remains stopped at the Great Salt Lake operation due to flooding problems.

Operating rates for North American potash producers averaged 86 percent last year when shipments reached 9.6 million short tons against a production potential of 11.16 million tons.

In the current year, that rate should increase to 88 percent as shipments move upward to 9.94 million



SOURCE: UN-FAO

tons with production potential of about 11.27 million tons.

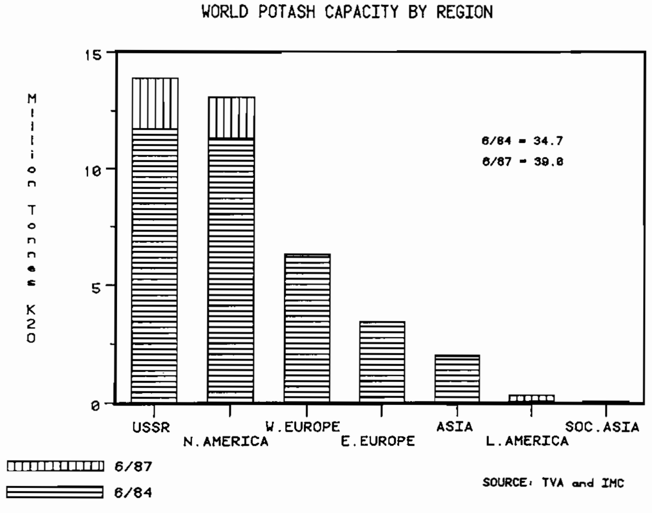
Looking at the major world potash producers, we must examine the data for fiscal 1983 as the latest available information for the global industry. In that recession-impacted year, total potash output was 24.4 million tonnes, down five percent from the previous year. The Soviet Union produced 8.08 million tonnes, down about four percent from the 8.45 million ton record it set a year earlier.

Eastern Bloc countries, as a group, reduced production by four percent from the previous year, while non-Communist producers cut output by about five percent.

The top five producing countries accounted for 85 percent of world output, with Canada and the U.S.S.R. producing about 55 percent of the world's potash production.

In perspective, world potash output grew by 21 percent from 1973 to 1983.

During that period, Canadian output increased by 41 percent, and the U.S.S.R. nearly doubled its production. Meanwhile, older, established industries in the U.S. and Europe have either declined in production or have expanded to the limits of their reserves. The two new entries in the world potash industry are in New Brunswick, Canada, and Jordan, where commercial scale operations have begun producing.



SOURCE: TVA and IMC

On the consumption side, we must review the 1983 data as the latest available for the world picture. In that year, world consumption was recorded at 22.8 million tonnes, down about four percent from the previous year, another sign of the distressed economy that impacted world agriculture at that time.

Worldwide usage was nearly seven percent below the record level of 1979, as the U.S. and the U.S.S.R. accounted for about 41 percent of total consumption. The top 10 countries, in terms of usage, accounted for about 71 percent of the total tonnage consumed.

In retrospect, world consumption had increased an average of two percent a year between 1973 and 1983. However, prior to the most recent two years, (1982 and 1983), consumption had achieved an average annual growth rate of between four and five percent.

As you know, consumption in industrialized nations has been relatively flat, but from a large base, while in developing regions, potash often was the last of the three basic fertilizer materials to gain widespread acceptance. Despite that fact, annual growth rates reached 10 to 20 percent a year in those areas. Consumption in China and India, for example, has recorded annual consumption gains of over 20 percent as agricultural demand has soared.

Based on the belief that the world has recovered from the declines of the two previous years, it is expected that consumption will keep pace with the trendline growth rate of between three and four percent as discussed earlier.

The final piece of the potash puzzle under scrutiny here today involves capacity by region around the world.

Officially stated or announced plans call for world potash production capacity to expand about 12 percent over the next three years.

However, as discussed earlier, the world will continue to become increasingly dependent upon the U.S.S.R. and Canada for future supplies of this vital plant nutrient.

Plans for a 19 percent expansion of Soviet capacity in three years may appear overly optimistic in view of recent production setbacks, but the growth will be achieved in time.

In North America, two expansion projects currently are under way, and a new mine recently came on stream in Canada. Against this growth, however, we must note that several other projects originally slated to come on-stream after 1985 have been postponed or cancelled.

What does it all mean? A lot depends upon where one is positioned as he observes the industry. But one thing is certain. Demand for potash will continue to grow as the world fertilizer industry is called upon to deliver the huge additional tonnage that will be needed to fuel agriculture's requirements between now and the year 2000.

The producers and marketers who are prepared to meet those challenges will succeed. The ones who fail to adapt to changing conditions will suffer the consequences.

That is why meetings such as this Annual Fertilizer Round Table are so valuable in communicating within our industry. We all must use these opportunities to measure our business, our markets, our problems and our sometimes under-valued strength in dealing with this complex industry.

The fertilizer business is too vital to the future of mankind's growth for us to allow it to weaken or continue our efforts at anything less than 100 percent.

We must grow in productivity and in marketing awareness to serve world agriculture. And, to accomplish that objective, we must learn all that we can about our customers' needs as well as our own.

This Round Table is one practical aspect of that critical learning process, and we're proud to be taking part in it along with each of you here today.

1984 Fertilizer Review—1985 Outlook

Gary D. Myers
President
The Fertilizer Institute

Outline

I. *1985 Fertilizer Year: Somewhere Between Better and Worse*
- As we look ahead, we need to rely on facts from recent performance.
- In doing so, I see fertilizer year '85 close to '84 with possibly a 3 to 5 percent tonnage increase.
- Now, my rationale . . . . .

II. *Review of Fiscal Year '84*
- TFI's *Fertilizer RECORD* for year ending June 30: Domestic disappearance was 14 percent above '83. That's up 6 million tons to 48.2 million, but far below our '81 record of 54 million tons.
- Overall production for '84 increased only 8 percent, leaving June ending inventories 15 percent below '83 levels.
- Exports: barely above '83—3 percent.
- Imports: up sharply—27 percent.
- However, we had positive trade balance of three-quarters of a billion dollars.

III. *Farm Situation*
- Net cash income fell by $4 billion in '84 . . . not good.
- Major cash flow problem: debt-to-asset ratios keep climbing.
- Credit is the means of farmer purchasing . . . but lenders are tightening screws. In Iowa, farmers pay more for credit than for fertilizer.

IV. *Farm Product Exports*
- Key to stability and prosperity.
- While volume increased in '84, value per unit did not.
- This issue must be addressed in our '85 Farm Bill.

V. *Acres Planted*
- As acres planted go, so goes fertilizer tonnage.
- Rates per acre have remained nearly constant for the past six years.

VI. *Outlook for 1985*
- Strong disappearance thus far—movement for July and August up 19 percent from a year ago.
- Production is up 36 percent, exports up 62 percent, imports up 27 percent.

VII. *'85 Farm Situation*
- Farm acres about the same as '84 . . . probably.
- Farm programs might draw 8 million or so acres farm production.
- Credit situation is bound to intensify.
- No real promise yet on improving ag exports.

VIII. *Fertilizer Situation*
- Since '85 represents a continuation of '84, the only factor to boost fertilizer would be higher application rates per acres . . . something we haven't seen for awhile.
- This means we've got to get back to influencing our farmers' attitude about fertilizer rates for different crops.
- Downsizing of agriculture, and the effort to improve exports, will place greater demand on individual farmers to produce more.
- National Commission on Ag Trade & Export Policy.
- Presidential Task Force on Farm Credit.
- Industry market promotion is essential to improving per-acre rates and overall sales.
- RESULT: continued industry growth, lower per-unit costs for farmers, more efficient production per acre.

Legislative

The 98th Congress, after efforts to reauthorize six major environmental laws, adjourned having revised only Resource Conservation and Recovery Act

(RCRA), the law governing treatment storage and disposal of hazardous wastes. The unfinished business or reauthorizing five environmental laws now rests with the 99th Congress when they convene in January, 1985. Briefly, here is what we see:

Resource Conservation and Recovery Act—The law governing disposal and recycling of hazardous wastes. Congress revised and expanded the law. TFI succeeded in maintaining small generator exemption for retail fertilizer deals (100 kg per month or less) and excluding phosphate mining wastes from double liner requirements.

Superfund—A tax on industry for the clean-up of abandoned hazardous waste sites. Superfund expires October, 1985. TFI succeeded in obtaining amendments to exclude the fertilizer industry from at least $142 million in feedstock taxes, over $1 billion in waste end taxes, and over $1 million in feed phosphate taxes per year.

Clean Water Act—Law governing pollution protection of surface water (rivers and lakes). TFI requested and received amendments to proposals that potentially could have regulated fertilizer application as a means of reducing nutrient runoff.

Safe Drinking Water Act—Law to protect sources of underground drinking water. TFI monitored closely the proposals for impact on manufacturing waste disposal by underground injection.

Toxic Substances Control Act—The law governing testing and use of chemicals. TFI ensured that the proposals did not limit the use of fertilizer chemicals.

Clean Air Act—Provide for control of air pollution and acid rain. TFI monitored proposals impact on fertilizer manufacturing, particularly emissions from sulfuric acid and nitric acid plants.

Tuesday, October 30, 1984

Afternoon Session
Moderator:

Mabry M. Handley

Development of TVA Pressure Reactor For Production of Ammonium Phosphates and Its Retrofit in Conventional Plants

David G. Salladay
Chemical Engineer
Field Engineering Staff
Division of Agricultural Development
National Fertilizer Development Center
and
William H. Paulson
Process Engineer
The Royster Company

Introduction

During the last several years TVA engineers have been helping install pipe-cross reactors (PCR) in regional NPKS granulation plants. Most of these reactors have been 6 or 8 inches in diameter and 10 or 12 feet in length. A typical design of one of these Hastelloy C-276 reactors is shown in figure 1. About 30 of these reactors have been installed in the United States and at least a dozen have been installed overseas. These reactors have normally been used to produce a wide range of NPKS homogeneous granular fertilizer grades.

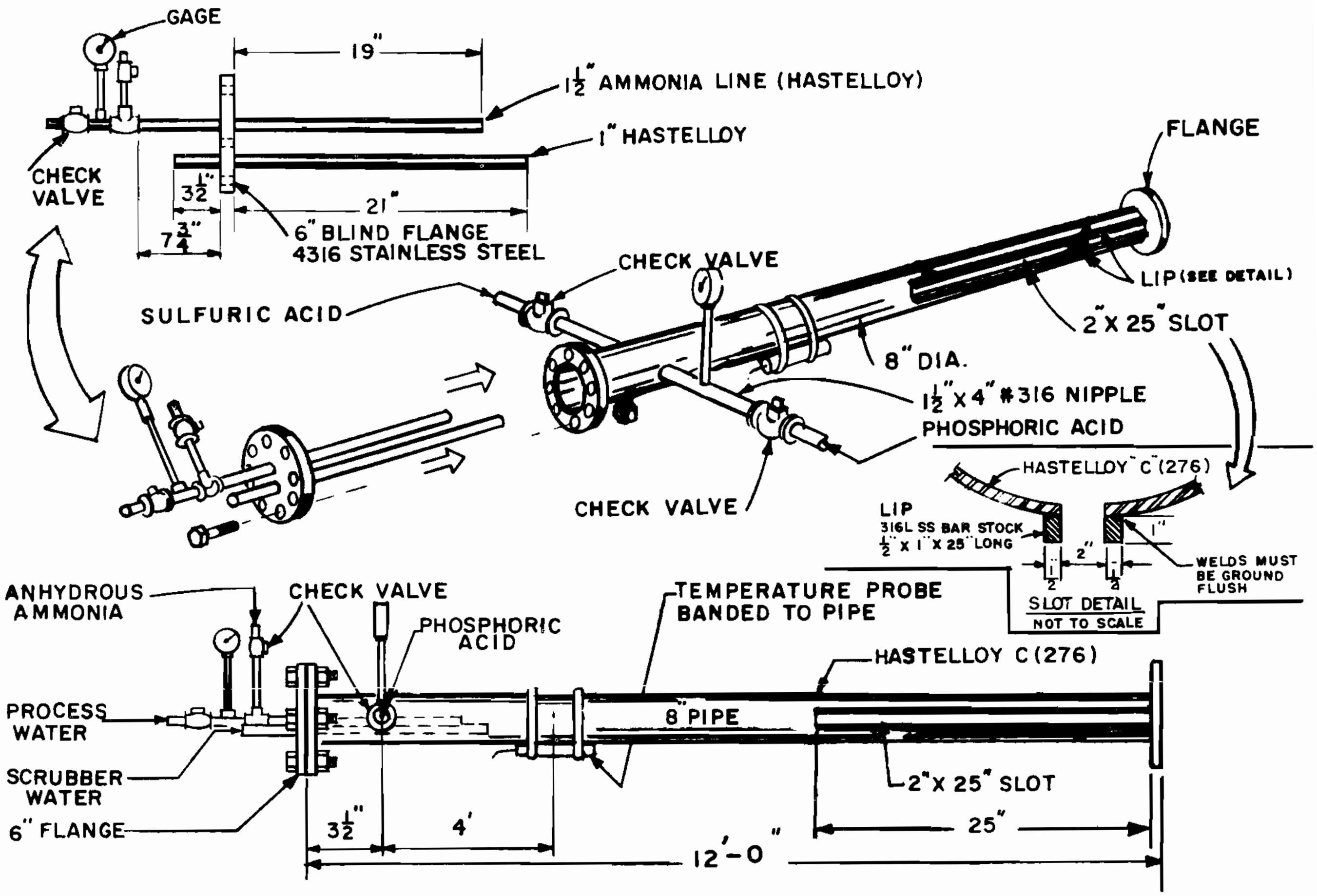
At first, variable diameter nozzles were installed at the discharge end of these reactors. Recently, however, variable cross-sectional area slots have been used to accommodate the fertilizer grades produced. These plants normally have 8-foot diameter by 16-foot long TVA rotary ammoniator-granulators and produce about 25 tons per hour. Most of these PCR's have been operated at pressures of 0 to 10 psig and have used large quantities of sulfuric acid.

In 1977 TVA engineers began working in a basic producer's diammonum phosphate (DAP) plant in Louisiana. This plant, which had a production capacity of about 2,000 tons per day, was equipped with a 10-inch diameter PCR of the design shown in figure 2 (1). This PCR was later modified with smaller diameter reactor pipes extending into the granulator. Tests were conducted in which the slurry from the conventional tank preneutralizer was fed simultaneously with higher pressure, higher temperature, melt discharge from this PCR. Production increases and reduced need for fossil fuel drying of the DAP granules were obtained. The design of this PCR, shown in figure 2, was influenced by earlier work at Consolidated Fertilizers Limited in Brisbane, Australia. The 90° bends in these PCR's were patterned after the design of the TVA pipe reactor process for high polyphosphate fluids. This paper will discuss the current design and operating parameters of a large pressure reactor designed to produce 70 to 80 tons per hour of DAP or monoammonium phosphate (MAP). This paper will also discuss present changes in the design and operation of TVA rotary ammoniator-granulators using this retrofitted pressure reactor technology.

Trends in Ammoniator-Granulator (Dryers)

Twenty-eight years ago, F.T. Nielsson of TVA was issued a patent for the rotary drum ammoniator. This apparatus was developed to ammoniate and granulate mixtures that contained superphosphate as a major source of P_2O_5. The ammoniating solution contained ammonia, ammonium nitrate, and water. Other crystalline material, such as byproduct ammonium sulfate and potash, was added to the mixture during granulation. Sometimes extra heat was supplied to the drum by ammoniating small quantities of sulfuric acid and phosphoric acid and by adding steam. As previously mentioned, these superphosphate granulation plants have changed signficantly; many of them now use PCR's to ammoniate large quantities of phosphoric acid and sulfuric acid.

TVA has recommended, and some companies have accepted, the principle of converting the ammoniator-granulator to an ammoniator-granulator-dryer. This is accomplished simply by increasing the airflow through the granulator. Figure 3 shows the ammoniator-granulator-dryer equipped with forced air and induced-air fans. Air is blown into the granulator through the center support beam and is withdrawn through a hood at the discharge end by the



PPI SEC.-TVA
R.S.W
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FIGURE I
PIPE-CROSS REACTOR
8 INCH DIAMETER HASTELLOY "C" REACTOR TUBE

exhaust fan. TVA recommends an air velocity through the granulator of 5 ft/s.

Ammoniator-granulator-dryers now in use often have rubber linings and usually only one sparger is submerged in the bed of fertilizer granules. Many of these granulators have been lengthened and have had their rotational speeds increased. The ratio of length to diameter should be from 2.0 to 2.3:1. The optimum ratio is 2.3:1. The retention time of fertilizer granules should be 2-4 minutes. The volume of the bed of fertilizer granules should be 20-30 percent of the total cylindrical volume. Usually, smaller plants have the lower volumes of material in the granulator. The surface area of the cylindrical portion of the granulator should be 2.0-4.0 ft^2/ton.h of throughput. The pass flux should be 2-5 tons/h.ft^2 of cross-sectional area. Usually, larger plants have smaller surface areas per ton of throughput. The current recommendation for the rotational speed of the granulator is about 36 percent of critical rotational speed or

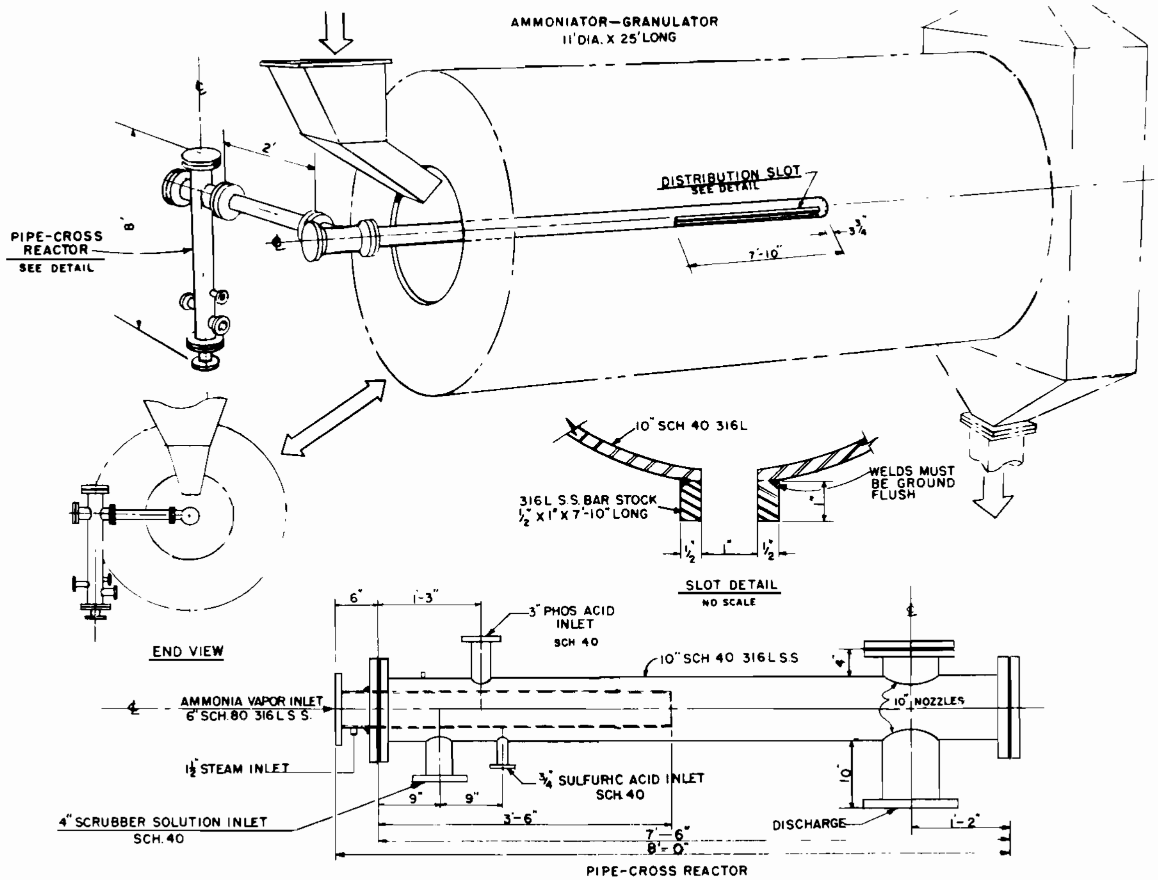
$$\text{Rpm} = \frac{28}{\sqrt{\text{drum diameter, ft}}}$$

At this speed, there is good mixing in the drum and less tendency to form oversize and have high ammonia losses.

The design of the ammonia sparger for the bed of the granulator is critical. Although many diverse designs for ammonia spargers have evolved, TVA experience continues to show that the original drilled-pipe design is the best. The diameter of this pipe should be the minimum size that will adequately supply ammonia to all of the holes.

Adding a small amount of water to liquid ammonia (0.1 lb H_2O/lb NH_3) gives several advantages. A smaller diameter pipe can be used for the ammonia sparger, and a smaller sparger causes less disruption of the flow of granules in the moving bed. Adding water to the ammonia helps prevent troublesome frozen caked material from forming around the sparger, and tests show that it helps to lower ammonia loss from the ammoniator-granulator-dryer.

The ammonia sparger should extend over almost the entire length of the bed. Normally, a sparger pipe extends to within 1 or 2 feet of the ends of the bed. Maxmimum hole spacing is 2 inches but 1-inch spacing is preferred. The total area of the holes for liquid ammonia should equal 0.0002 in^2/lb NH_3.h. The total area of the holes for gaseous ammonia should equal 0.001 in^2/lb NH_3.h. When these hole sizes are used, there is uniform flow of ammonia from all holes and a minimum of ammonia blows through the bed. TVA



PIPE-CROSS REACTOR
DAP PRODUCTION
FIGURE 2

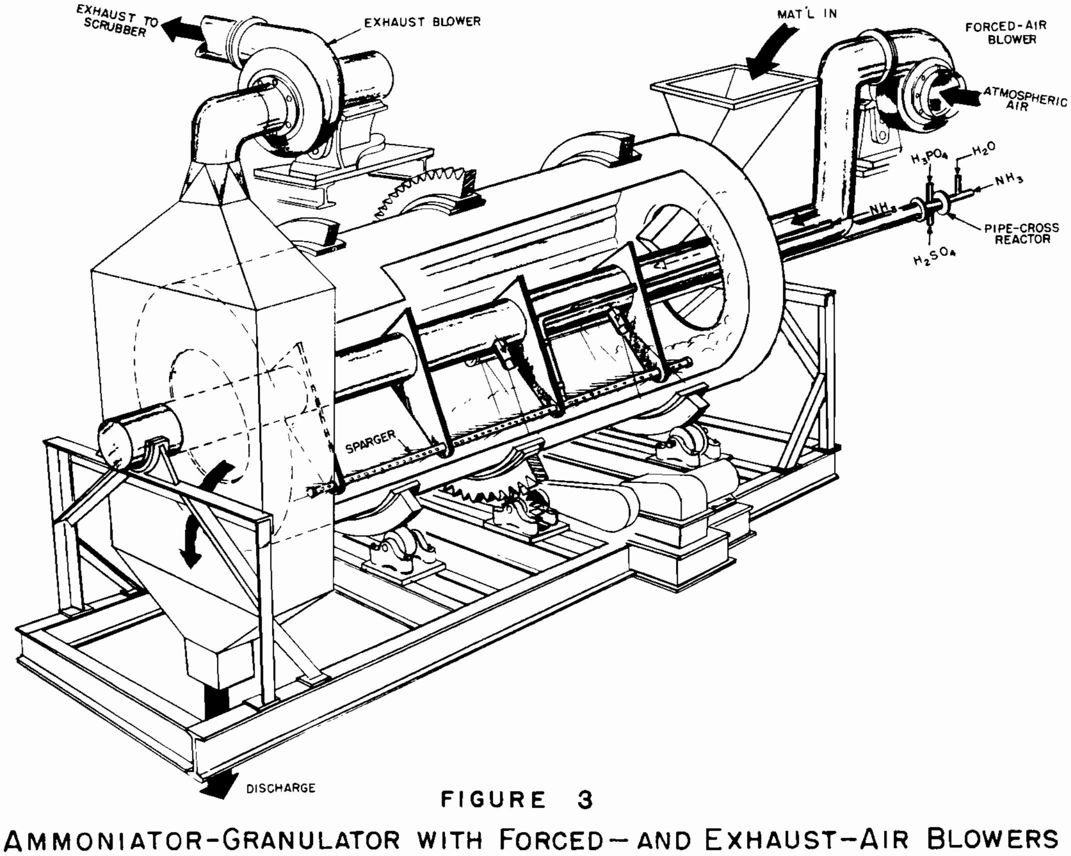


FIGURE 3
AMMONIATOR-GRANULATOR WITH FORCED—AND EXHAUST-AIR BLOWERS

experience indicates that duckbill deflector plates do not need to be welded to sparger pipes if smaller size Schedule 80 pipes are used. The sparger should be placed one-third of the total bed depth from the shell of the granulator. At this location the materials mix well and the sparger causes minimum disturbance to the rolling-bed action of fertilizer in the granulator.

Another criterion is that the height of the discharge dam in the granulator should equal 18 to 22 percent of the drum diameter. Also, this dam should normally be about 1 foot from the discharge end of the drum.

A summary of selected design criteria for melt granulation technology is shown in table 1.

TABLE 1
Selected Design Criteria TVA Ammoniator-Granulator-Dryer

Criteria	**Size, feet**		
	8 × 16[1] (18.5)[2]	**10 × 20 (23)**	**12 × 24 (27)**
	NPKS-PCR	**MAP/DAP-PR**	**MAP/DAP-PR**
Rpm	9.9	8.9	8.1
% of critical	36	36	36
Mass flux, ton/hr-ft^2	2.0	3.5	5.3
Bed volume, %	20	25–30	25–30
Surface area, ft^2/ton/hr	4.0	2.3	1.5
L/D, ft/ft	2.0 (2.3)	2.0 (2.3)	2.0 (2.3)
Retention time, min	1.79	1.94	1.53
Throughput, tons/hr	100	275	600
Production rate, tons/hr	25–30	60–70	135–145

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1. Length of bed of granules
2. Nominal (total) length of rotary vessel

TABLE 2
Ammonia Loss from Various Ammonium Phosphate Granulation Sytems

Grade Produced	**Operating Conditions**		**% Ammonia Losses[a]**
	N:P Mole Ratio(s)	**A/G Bed Temp. °F**	
MAP, 11-53-0			
to 10-50-0	1.0 PCR	225–230	3
MAPS,			
16-20-0	1.2 PR	220–225	7–9
DAP, 18-46-0	1.3 –1.4 P/N		
	1.90–2.00 A/G	180–190	7–8
DAP, 18-46-0	1.4 P/N		
	1.90+ A/G	215–220	15–20+
DAP, 18-46-0	1.4 PR at 290°F		
	1.90+ A/G	215–220	19–21

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a. The amount of ammonia evolved from preneutralizer (tank or pipe) and granulator as a percentage of the total ammonia fed.

Abbreviations: MAP —monoammonium phosphate
MAPS—monoammonium phosphate sulfate
DAP —diammonium phosphate
PCR —pipe-cross reactor
P/N —tank preneutralizer
A/G —ammoniator-granulator
PR —pressure reactor

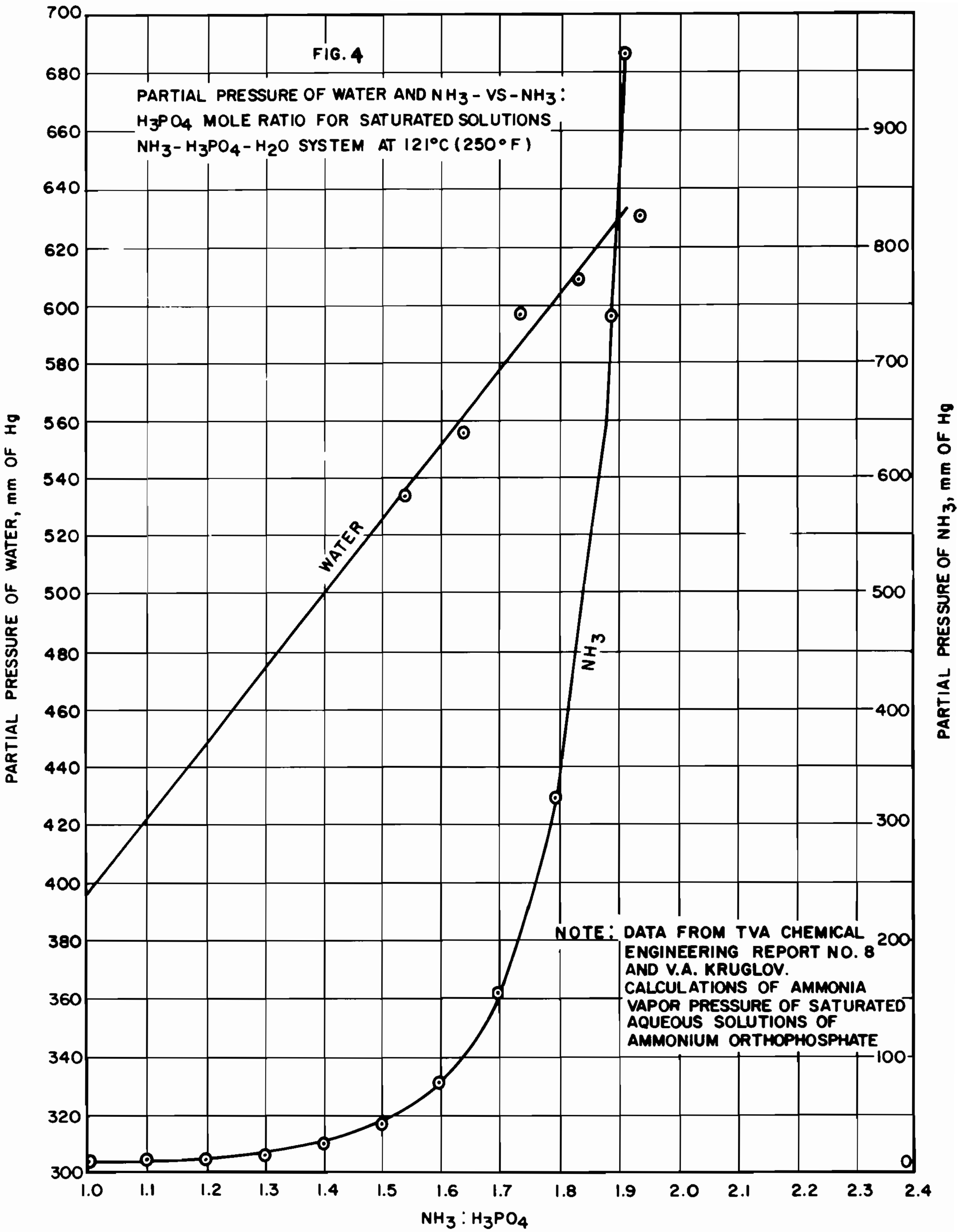

FIG. 4

PARTIAL PRESSURE OF WATER AND NH_3 - VS - NH_3 : H_3PO_4 MOLE RATIO FOR SATURATED SOLUTIONS NH_3-H_3PO_4-H_2O SYSTEM AT 121°C (250°F)

NOTE: DATA FROM TVA CHEMICAL ENGINEERING REPORT NO. 8 AND V.A. KRUGLOV. CALCULATIONS OF AMMONIA VAPOR PRESSURE OF SATURATED AQUEOUS SOLUTIONS OF AMMONIUM ORTHOPHOSPHATE

Ammonia Loss from Ammonium Phosphate Granulation Systems

While MAP production by either conventional tank preneutralizer processes or pipe reactor processes provides only a small ammonia loss to be scrubbed into the system, DAP production does involve the scrubbing and recirculation of a signficant amount of ammonia. Table 2 summarizes several ammonium phosphate granulation systems and their resulting ammonia loss. When MAP is produced in a PCR system the ammonia loss will normally be about 3 percent of the ammonia fed. When a MAP-ammonium sulfate grade such as 16-20-0 is produced using an N:P mole ratio of about 1.2:1 in a pressure reactor, about 7 to 9 percent of the ammonia fed is lost to the scrubber loop. When the first granulated DAP work was done in the early 1960's (2), ammonia losses were significantly lower than those being encountered today. In this 1964 patent work, even when hot recycle was used and the bed temperature was maintained at 180 to 190°, only 7 to 8 percent of the ammonia fed was lost to the scrubber loop. When cooled recycle was used, losses were as low as 2.7 percent. Losses from current production of DAP using tank preneutralizers at 1.4:1 mole ratios with the ammoniator-granulator mole ratio at 1.90+:1 and the temperature in the bed at 215 to 220°F, are considerably higher. Most of today's DAP granulation plants are having to scrub about 20 percent of the ammonia fed. However, the Royster plant at Mulberry, Florida, when using the tank preneutralizer to produce DAP, only has to scrub about 15 percent of the total ammonia fed. When this plant uses the pressure reactor with a mole ratio of 1.4:1 at 290°F with the granulator operated at a 1.90+:1 mole ratio and 220°F, the ammonia loss is about 21 percent. These ammonia losses listed in table 2 are believed to be representative of granulation systems being used for ammonium phosphates. The level of these losses would be expected considering the partial pressure data of the ammonium phosphate water system which is plotted for 250°F in figure 4 (3). Although the higher bed temperatures and higher pipe reactor temperatures do result in less fuel use for fossil fuel drying and significantly lower recycle ratios, scrubbing of the ammonia loss becomes a major process consideration.

Description of the Royster DAP Granulation Plant, Mulberry, Florida

This granulation plant built by Wellman-Lord began operation in early 1967. A simplified flow diagram of the plant is shown in figure 5. Equipment includes a 10-foot diameter by 20-foot long TVA type rotary ammoniator-granulator, 10-foot by 70-foot rotary dryer, and an 8-foot by 40-foot rotary cooler. This dryer is equipped with a 30 million Btu per hour combustion chamber. The plant contains 180 square feet of oversize screens and 240 square feet of fine screens. Oversize material is fed to two cagemills and recycled to the granulator. Exhaust from the tank preneutralizer, granulator, and screens is fed to a venturi scrubber utilizing weak (filter grade 30% P_2O_5) phosphoric acid. Exhaust from the dryer is also fed to a venturi scrubber utilizing weak phosphoric acid. These two venturi scrubbers use a common sump. Exhaust from these venturi scrubbers goes to two separate packed-bed, pond water scrubbers. Exhaust gases from the cooler go to a third packed-bed pond water scrubber. Airflow through the ammoniator-granulator, when the tank preneutralizer exhaust duct is blocked off, is about 20,000 acfm. With the tank preneutralizer in use, the ammoniator-granulator airflow is 14,000 acfm. This plant has a throughput capacity of about 275 tons per hour. Using the tank preneutralizer this plant is capable of producing DAP at 54 tons per hour.

Description of the Pressure Reactor

The design of the TVA pressure reactor is shown in figure 6. This 316L stainless steel pipe is 10 inches in diameter and 45 feet long. The inclined part of the pipe which is outside the granulator is fully insulated. This pipe, which can be equipped with variable size slots, is fitted with 48-inch long by 3/8-inch wide continuous slot. Production tests have shown that a continuous slot operates much cleaner than does a series of slots. The pipe has inlets for both 54 percent P_2O_5 strong phosphoric acid and 30 percent weak phosphoric acid from the filters. The pipe is designed for gaseous ammonia which is fed to a 4-inch 316L sparger pipe. The pipe is capped on the end and has a series of 1-1/4-inch, 1-inch, and 3/4-inch diameter holes on the bottom. When this pipe is used to produce MAP or DAP, relatively low ammonia loadings, 0.3 to 0.7 pounds ammonia per cubic inch per hour, are obtained. The cross-sectional area heat flux of this 10-inch diameter pipe range from 500,000 to 750,000 Btu's per square inch per hour. The heat fluxes on the slotted discharge vary from about 1 million to 3 million with the resultant pressure in this pipe varying from 30 to 90 psig. The pipe is mounted to the side of the ammonia sparger support pipe. Plans are being made to place this ammonia sparger support pipe about 24 inches above the center line of the granulator. The horizontal section of the pressure reactor will then be inserted in this ammonia sparger support pipe. This horizontal section will also be insulated. This change in position will be made to increase the distance from discharge of the pipe to the top of the bed in the granulator. In its present position, the inclined part of the pressure reactor is sloped at 10° above horizontal. The repositioning of the pipe will have this incline at less than 15°. The pipe is equipped with an inlet for steam and pond water and with a drain at the low end. This pipe is

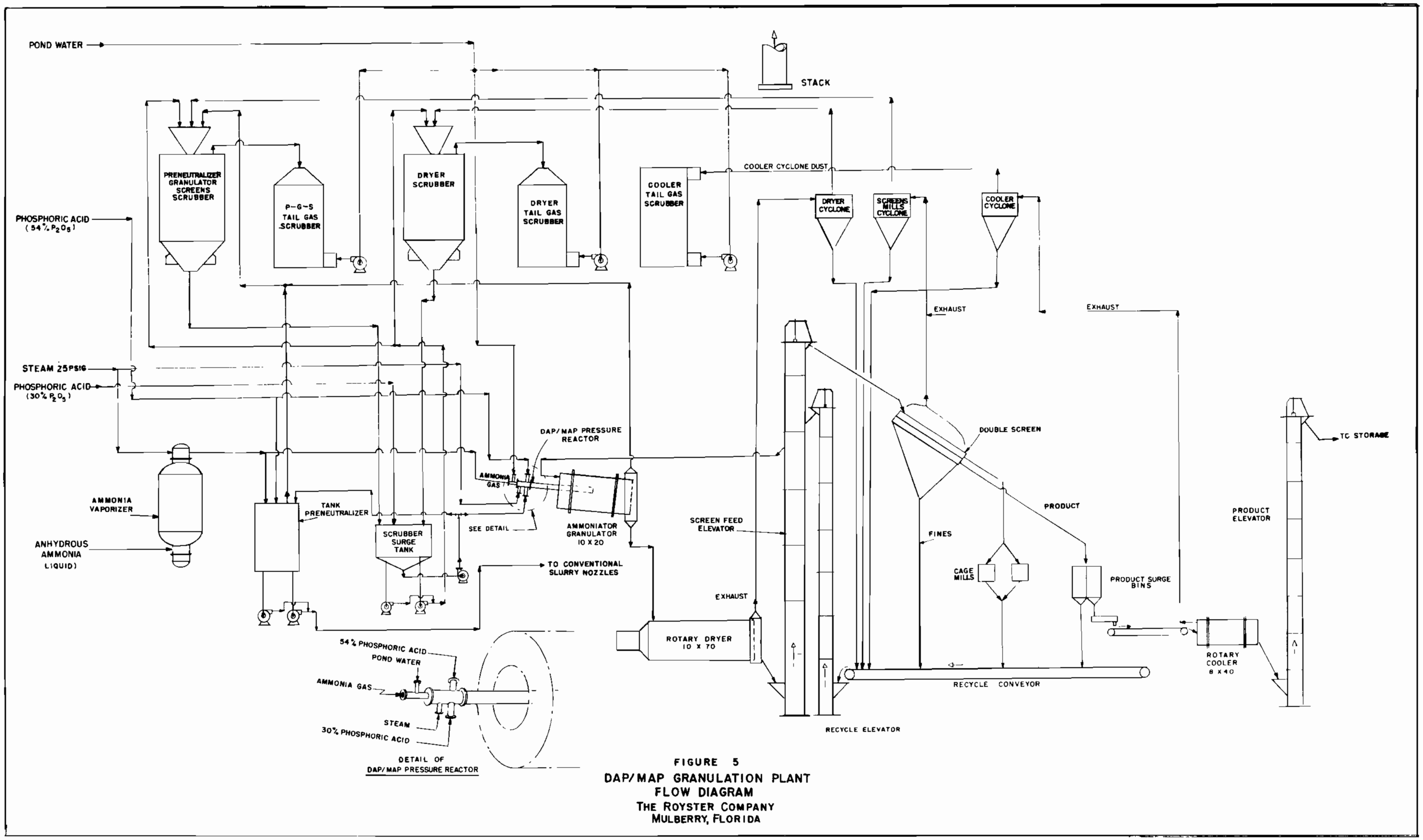

FIGURE 5
DAP/MAP GRANULATION PLANT
FLOW DIAGRAM
THE ROYSTER COMPANY
MULBERRY, FLORIDA

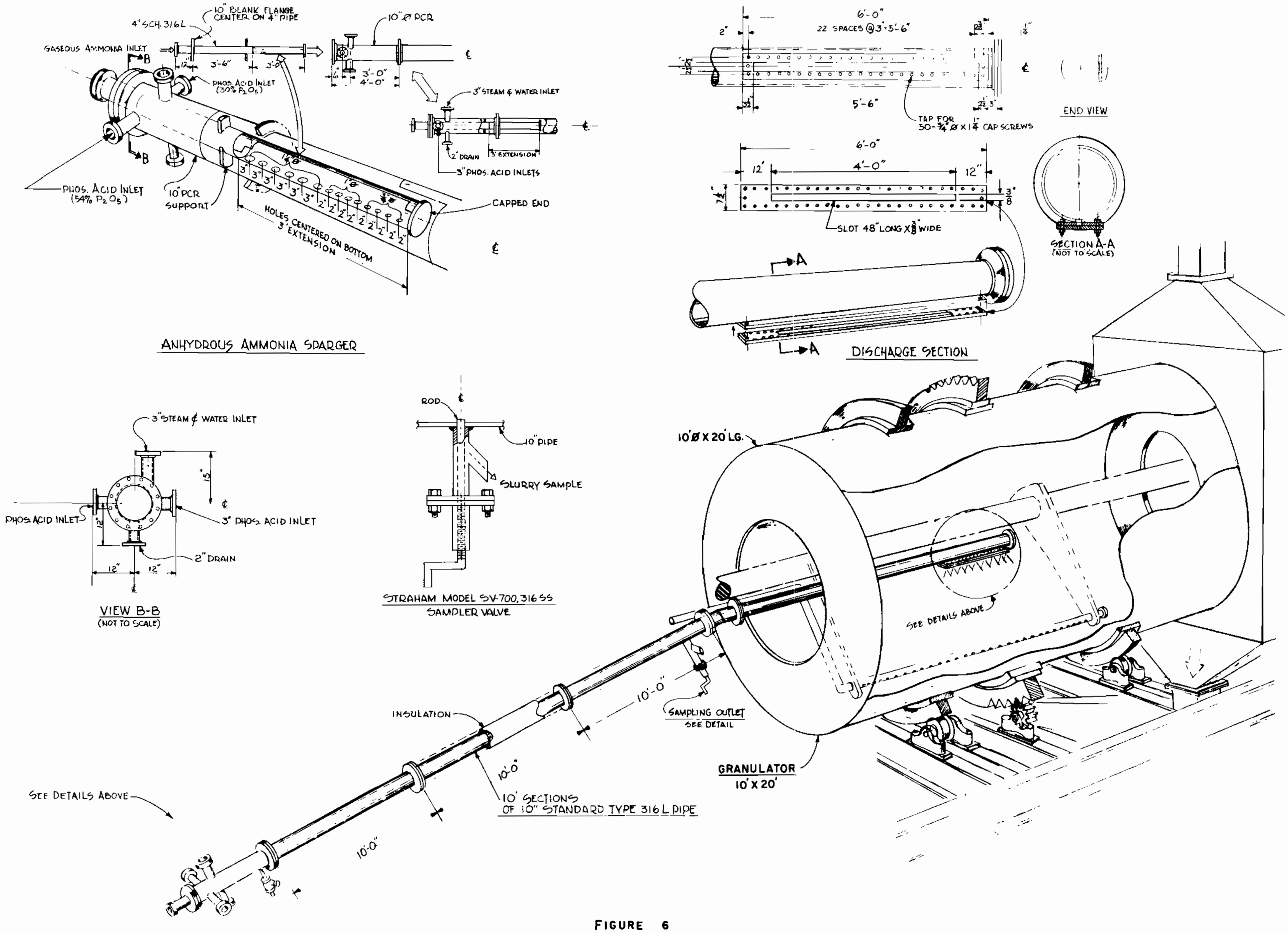

FIGURE 6

TVA PRESSURE REACTOR FOR GRANULATION OF MAP-DAP

THE ROYSTER COMPANY
MULBERRY, FLORIDA

intended for the large scale, dual production of MAP and DAP. However, this pressure reactor has also been designed for test work on the large scale production of granular ammonium polyphosphate.

Discussion of Pressure Reactor MAP Production

Table 3 summarizes data from two recent MAP production runs in this Royster granulation plant. The run shown in test No. 784 was made over almost a week's time. Limitations on the production rate of 62.0 tons per hour are the screening capacity, airflow through the ammoniator-granulator and the closeness of the pipe to the bed of moving granules in the granulator. Production of MAP in this pressure reactor has generally been successful. Even with the previously mentioned production limitations, MAP can be made at high enough production rates to elim-

TABLE 3
Pressure Reactor Production
Granular Monoammonium Phosphate
Royster DAP Plant, Mulberry, Florida

Test Number	**1283**	**784**
Duration of tests, hours	36.2	129
Average production rate, tons/hr	47	62.4
Production, tons	1700	8000
Formulation, lb/ton		
Pressure reactor		
Phosphoric acid (46% P_2O_5)	2196	2244
Anhydrous ammonia	213	196
Ammoniator-Granulator, Bed		
Anhydrous ammonia	71	76
Pressure Reactor Melt		
Pressure (feed phosphoric acid) psig	29	47
Mole ratio, N:P (titrated)	0.88	0.79
Specific gravity	1.680	1.650
Temperature No. 1, 5 ft from NH_3 discharge, °F	205	—
Temperature No. 4, 30 ft from NH_3 discharge, °F	278	288
Scrubber Seal Tank		
Specific gravity	1.359	1.370
pH	1.1	1.3
Ammoniator-Granulator Product		
Exit temperature, °F	236	242
Mole ratio, N:P (calculated)	1.17	1.10
pH	4.6	4.4
Dryer, exit temperature, °F	174	186
Recycle return, temperature, °F	214	225
Recycle rate tons recycle/ton of product[a]	4.85	3.4
Product Chemical Analysis, %		
N	11.7	11.2
P_2O_5	50.5	51.6
H_2	0.73	0.55
Product Screen Analysis, %		
+6	0.5	0.7
−6 +16	90.8	90.3
−16	8.7	9.0
Design-Operating Parameters		
Ammonia loading, lb/in^3-hr	0.40	0.47
Heat flux, cross-sectional area, Btu/in^2-hr × 10^{-6}	0.446	0.522
Heat flux slotted discharge Btu/in^2-hr × 10^{-6}	2.07	2.28

---

a. Estimated from throughput capacity and production rate inate the need for producing triple superphosphate. The triple superphosphate plant has not operated since December 1983. The 46 percent feed phosphoric acid used in these MAP production runs is a blend of 30% filter grade phosphoric acid, sludge 54% acid, regular 54% acid and clarified 54% phosphoric acid. The final grade of the MAP in the current production scheme is determined by the amounts of these phosphoric acids available from the phosphoric acid plant storage tanks. MAP instantaneous analyses during the production run have varied from 11-50-0 to 11-53-0. Blended sludge phosphoric acid containing 17 to 18% solids and 46% P_2O_5 has been successfully processed in this pressure reactor. In contrast to PCR work in past years in which 11-53-0-3s has been produced by ammoniating clarified merchant-grade acid and small quantities of sulfuric acid and ammonia with no buildup of scale, the processing of sludge acid does result in some buildup. Laboratory analysis showed that the water insoluble fraction of this buildup in the pressure reactor had the following analysis:

%N	5.5
%P_2O_5	33.8
%SO_4	0.1
%F	4.3
%Al	3.7
%Mg	1.9
%Ca	2.5
%Fe	6.2

This water insoluble portion of the buildup was about one-third of this buildup while the other two-thirds was MAP. Royster personnel are able to control this buildup by periodically steaming the pipe and also using pond water recirculation to flush out this material.

Experience indicates that operating the pipe at 285 to 290° while the bed of the granulator is held at 235 to 240° provides the best production of MAP. With feed acid strength of 46 percent P_2O_5 and gaseous ammonia, there is no fossil fuel drying needed. Since the ammonia loss for the production of MAP is low compared to DAP there is actually a need to increase the N:P mole ratio in the weak acid scrubber loop. This can easily be done by adding enough ammonia to the scrubber sump to bring the mole ratio up above 0.4:1 N:P so the fluorine losses will be minimal.

Although MAP has been produced in pipe reactors for a number of years, using pipe reactors using sludge phosphoric acid at high production rates require more plant modifications and fine tuning of the melt granulation process. TVA is expecting this work to eventually lead to the large scale production of granular ammonium polyphosphate by basic producers.

Discussion of Pressure Reactor DAP Production

Table 4 summarizes the results of a test using the pressure reactor to produce DAP. In this test, a

TABLE 4
Pressure Reactor Production, Granular Diammonium Phosphate,
The Royster Company,
Mulberry, Florida—June 1983

Production rate, tons/hr	58
Recycle ratio, tons recycle/ton product	3.7
Pressure reactor operating conditions	
Pressure, psig	40
Temperature (estimated), °F	290
Mole ratio, N:P	1.4
Feeds	
Weak phosphoric acid (27% P_2O_5), gpm	136
Strong phosphoric acid (51% P_2O_5), gpm	64.4
Gaseous ammonia, lb/hr., 80°F	17,759
Ammoniator-Granulator	
Gaseous ammonia, lb/hr., 80°F	7,611
Granular fertilizer discharge temperature, °F	220
Ammonia loss, % of ammonia fed to pressure reactor and granulator	19.0
Heat fluxes, 10^6 Btu/in^2-hr	
Cross-sectional area (10-inch diameter)	0.417
Slotted discharge (½-inch × 30-inch)	2.180
Ammonia loading lb NH_3/in^3-hr	0.628
(based on inclined 30-foot reactor section)	
Product analysis, %	
N	18.05
P_2O_5	46.03
H_2O	0.95

production rate of 58 tons per hour was obtained. As previously discussed, increased feed rates to the pipe and repositioning of the pipe within the granulator will help improve production rate for DAP; however, the major problem with DAP production is operation of the scrubber loop. As previously discussed, this plant normally experiences a 15 percent ammonia loss in producing DAP by the conventional method. To successfully scrub the 20 or more percent loss when using the pressure reactor, Royster is investigating possible modification of the Granulator scrubber loop as shown in figure 7. This new system will use two-stage ammonia scrubbing followed by third-stage pond water scrubbing for fluorine control. In tests, the high discharge heat flux, of more than 2 million Btu's per square inch per hour, has contributed to very good granulating conditions with excellent water removal from the granulator. When plant modifications are complete, a production of almost 70 tons per hour is expected.

Summary

The Royster Company and TVA have cooperated in the design and operation of a large pressure reactor for producing MAP and DAP. The Royster plant previously produced DAP by the conventional plant preneutralizer process at a rate of about 50 tons per hour. Using this pressure reactor, DAP has been produced at almost 60 tons per hour and MAP has been produced at more than 60 tons per hour. This production increase in MAP has enabled the Royster Company to shut down their triple superphosphate plant. When modifications are made to the scrubber system, ammonia vaporization feed system and the phosphoric acid feed system, this granulation plant should be able to produce 60 to 70 tons per hour of DAP and 70 to 80 tons of MAP. While plant modifications are necessary to get these production increases, the overall cost of this project remains very low compared to the cost of a new granulation plant.

This plant test work with a large pressure reactor is also considered to be a step toward the eventual large scale production of granular ammonium polyphosphate fertilizer from sludge phosphoric acid.

TVA is grateful to Royster management and operating personnel who have demonstrated this granulation technology.

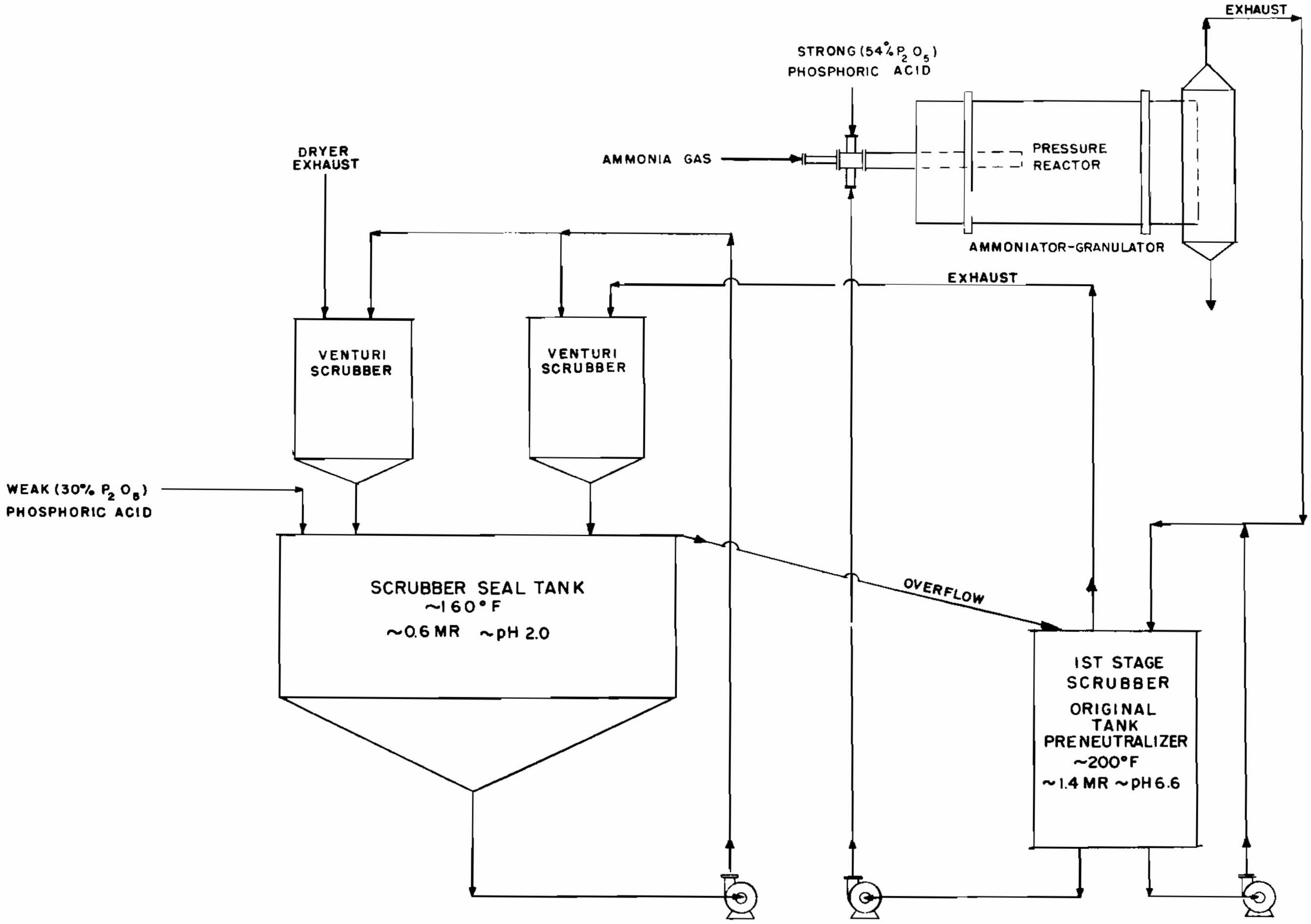

FIGURE 7

PROPOSED SCHEME FOR SCRUBBING
PRESSURE REACTOR DAP PRODUCTION
THE ROYSTER COMPANY
MULBERRY, FLORIDA

REFERENCES

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2. Achorn, Frank P., Ronald D. Young, and Gordon C. Hicks, "Production of Granular Diammonium Phosphates," U.S. Patent No. 3,153,574, October 20, 1964.
3. Achorn, Frank P. and David G. Salladay, "Latest Developments in Use of the TVA Rotary Ammoniator-Granulator," for presentation at American Institute of Chemical Engineers Meeting, Washington, D.C., November 1983.

Energy Conservation in DAP-NPK Plants

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Chief Engineer—Process Design
Feeco International, Inc.

Presented By:
James E. Madigan
President
Feeco International, Inc.

One cannot effectively minimize energy use in a plant without first identifying the energy users and energy losses. Hence an energy balance is a necessary first step.

Considerable amount of energy can be conserved in existing DAP-NPK plants especially if these plants are fairly old. Detail evaluations would be required to determine the potential saving.

The flow sheets for FEECO DAP and NPK plants are shown in Figures #1 and #2. The basic reactions involved in the process are the neutralization of the wet-process phosphoric acid with anhydrous ammonia and sulfuric acid with ammonia as shown by the following main reactions:

$$NH_3 + H_3PO_4 \text{———————} NH_4\,H_2PO_4 \quad + \text{heat}$$
$$2NH_3 + H_3PO_4 \text{———————} (NH_4)\,_2HPO_4 \quad + \text{heat}$$
$$2NH_3 + H_2SO_4 \text{———————} (NH_4)_2\,SO_4 \quad + \text{heat}$$

The phosphoric acid fed to these plants is usually 28% P_2O_5 and 54% P_2O_5 acids. Normally 28% P_2O_5 acid is used in scubbers to recover escaped ammonia and dust present in the air from dryer, cooler, granulator, etc.

The 54% P_2O_5 acid is sometimes fed to the preneutralizer. 2 to 3% sulfuric acid is contained in the feed phosphoric acid. When phosphoric acid is fairly clean, a small stream of sulfuric acid is added to the system to prevent product over formulation.

Simple description of FEECO's DAP plant shown in Figure #1 is as follows: In this process, phosphoric acid containing 42% to 54% of P_2O_5 is fed to the preneutralizer, granulator and dryer scrubber sump. The 28% of P_2O_5 acid is used as scrubbing media for cooler and equipment dust scrubbers. In this particular process for cooler and equipment dust, a dust collector is used in place of cyclones and scrubbers. The scrubber liquor, having a mole ratio (NH_3/H_3PO_4) of about 0.6, is pumped partially to the preneutralizer and partially to the pipe cross reactor (PCR). The addition of ammonia vapor to the preneutralizer and PCR is regulated to maintain a mole ratio of 1.5 and 1.4 respectively. Maximum solubility of $NH_3 - H_3PO_4 - H_2O$ system occurs at a mole ratio of about 1.4. Greatest advantage of the PCR used in conjunction with the preneutralizer is that if preneutralizer, for some reason or other, becomes inoperable, the plant could still be operated at about 50% of its capacity. Therefore, there will be no complete shut-down. The slurry from PCR and preneutralizer is further neutralized in a TVA type granulator or pugmill. Fines, crushed oversize and some of the on-size product are recycled to the granulator to give a recycle to product ratio that may range from 4:1 to 5:1, depending on the type of impurities in the feed acid. For example, deficiency of iron in phosphoric acid sometimes leads to fines formation; therefore, higher R/P ratio becomes necessary. The granular product is dried in a direct fired rotary dryer and, after screening and cooling, the product is sent to the storage.

The flow sheet of FEECO's NPK plant is shown in Figure #2. In this unique process, practically any grade of dry NPK fertilizer can be produced. The greatest advantage of this system is that the ingredient in the product will not segregate. If the pugmill is used for granulation, well rounded pellets are produced.

As it is indicated in both flow diagrams, FEECO takes advantage of vaporizing liquid ammonia by using waste heat from the plant. In order to show energy savings in these plants, two different cases have been reviewed.

CASE I. DAP Plant using liquid anhydrous ammonia.
CASE II. DAP Plant using vaporized ammonia.
FOR BOTH CASES, THE FOLLOWING CONDITIONS WERE SET:

1. 28% P_2O_5 and 54% P_2O_5 acids were used.
2. Scrubber liquor mole ratio 0.6.
3. Preneutralizer slurry mole ratio 1.5.
4. PCR mole ratio 1.4.
5. Product moisture content 1.4%.
6. Recycle to product ratio 5:1.
7. Fuel gas heating value 967 BTU/C.F. at 60°F.
8. Ammonia recovery 98%.
9. P_2O_5 recovery 99%.

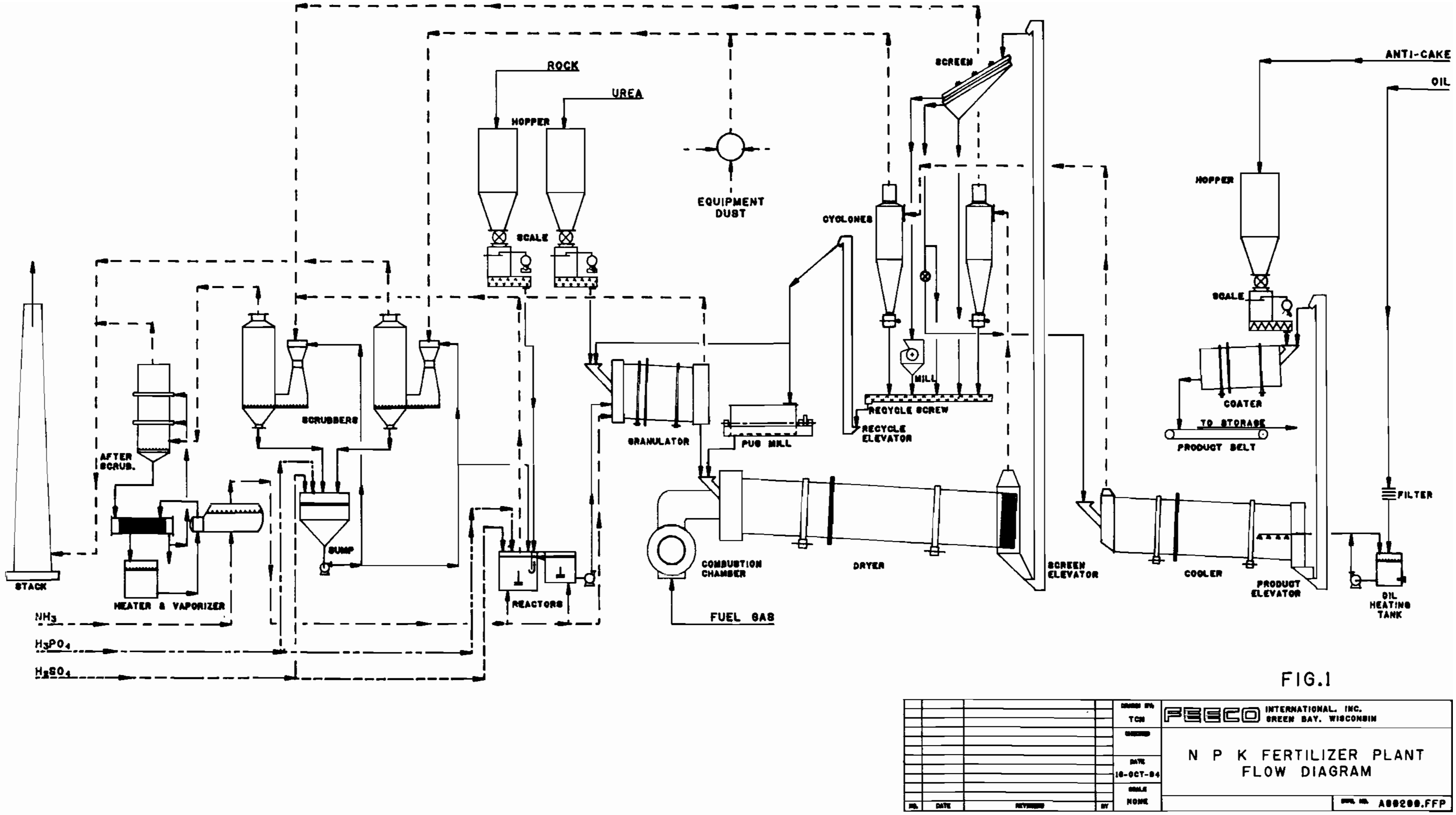
ANTI-CAKE
OIL
FILTER
OIL HEATING TANK
HOPPER
SCALE
COATER
TO STORAGE
PRODUCT BELT
PRODUCT ELEVATOR
COOLER
SCREEN ELEVATOR
SCREEN
CYCLONES
MILL
RECYCLE SCREW
RECYCLE ELEVATOR
DRYER
PUG MILL
COMBUSTION CHAMBER
FUEL GAS
GRANULATOR
EQUIPMENT DUST
ROCK
UREA
HOPPER
SCALE
REACTORS
SCRUBBERS
SUMP
AFTER SCRUB.
HEATER & VAPORIZER
STACK
NH_3
H_3PO_4
H_2SO_4
FEECO INTERNATIONAL, INC.
GREEN BAY, WISCONSIN
N P K FERTILIZER PLANT
FLOW DIAGRAM
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FIG.1

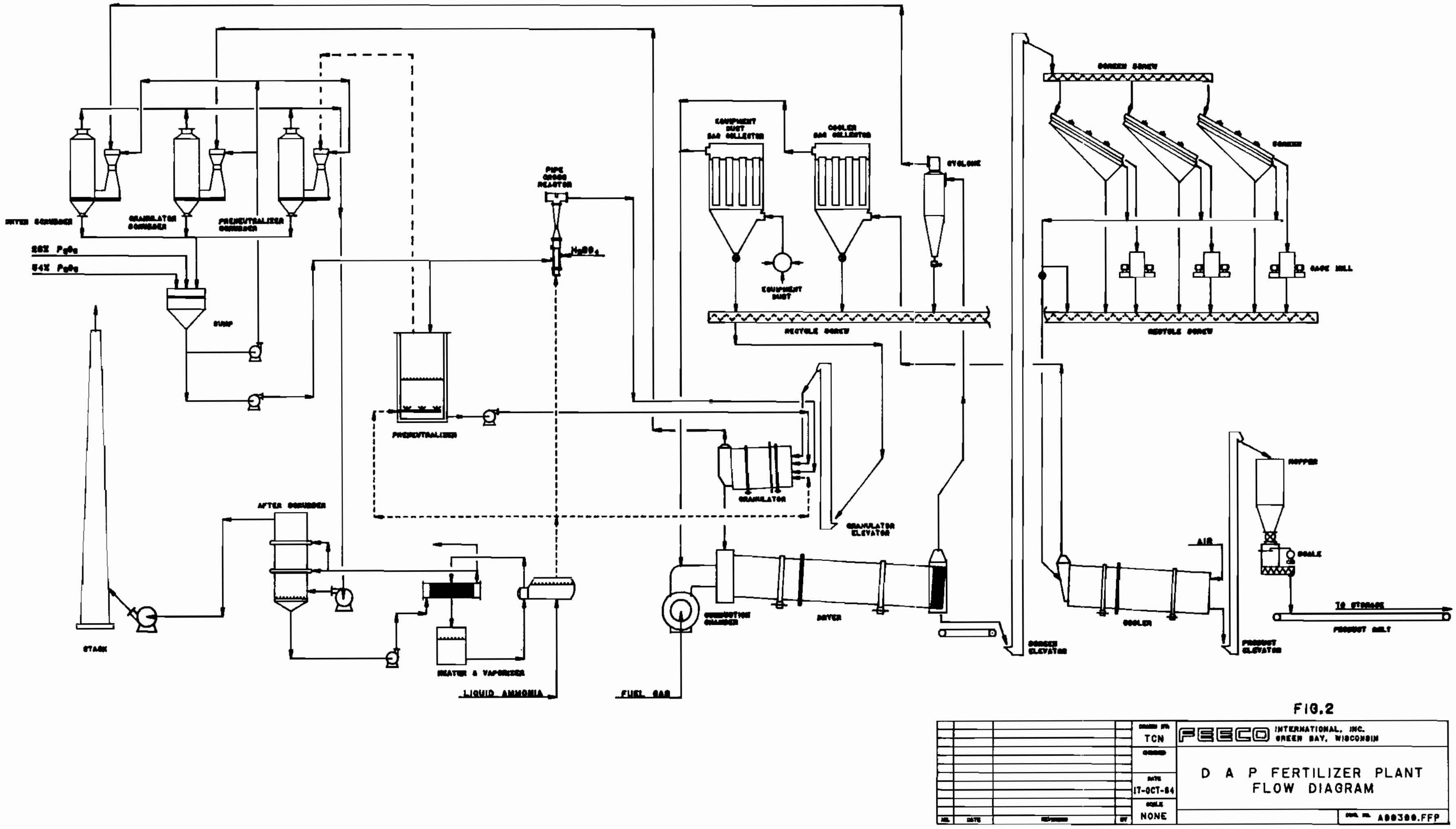
AFTER SCRUBBER
GRANULATOR SCRUBBER
PRENEUTRALIZER SCRUBBER
28% P2O5
54% P2O5
SUMP
STACK
AFTER SCRUBBER
PIPE CROSS REACTOR
H2SO4
PRENEUTRALIZER
HEATER & VAPORIZER
LIQUID AMMONIA
FUEL GAS
EQUIPMENT DUST BAG COLLECTOR
COOLER BAG COLLECTOR
EQUIPMENT DUST
CYCLONE
RECYCLE SCREW
GRANULATOR
GRANULATOR ELEVATOR
COMBUSTION CHAMBER
DRYER
SCREEN SCREW
SCREEN
CAGE MILL
RECYCLE SCREW
SCREEN ELEVATOR
AIR
COOLER
PRODUCT ELEVATOR
HOPPER
SCALE
TO STORAGE
PRODUCT BELT
DRAWN BY
TCN
CHECKED
DATE
17-OCT-84
SCALE
NONE
FEECO INTERNATIONAL, INC.
GREEN BAY, WISCONSIN
D A P FERTILIZER PLANT
FLOW DIAGRAM
DWG. NO. A00300.FFP
NO.
DATE
REVISIONS
BY

FIG.2

TABLE 1
Overall Heat Balance

	Temp. °F	lbs//Ton DAP	M. Btu/Ton DAP
CASE 1—Liquid NH_3 (Datum Temp. 77°F)			
HEAT INPUT			
Stream			
54% Phos. acid	160	1131.8	36.92
28% Phos. acid	150	1136.1	56.40
93% Sulfuric acid	100	44.7	0.37
Air to dryer & granulator	77	2805.5	0.00
NH_3 liquid	−28	448.3	−51.60
Fuel, natural gas (967 Btu/C.F.), C.F./Ton DAP	60	521.7	504.54
Heat of reaction	—	—	929.46
			1476.09
HEAT OUTPUT			
Stream			
Product	194	2000.0	77.76
Gases from preneut., granul. & the dryer	202	3961.7	138.12
Evaporation	77	768.0	806.43
Heat loss from dryer, granul., preneut., scrubbers, etc.	—	—	453.78
			1476.09

TABLE 2
Overall Heat Balance

	Temp. °F	lbs/Ton DAP	M. Btu/Ton DAP
CASE 2—Vapor NH_3 (Datum Temp. 77°F)			
HEAT INPUT			
Stream			
54% Phos. acid	160	1131.8	36.92
28% Phos. acid	150	1136.1	56.40
93% Sulfuric acid	100	44.7	0.37
Air to dryer & granulator	77	1986.6	0.00
NH_3 Vapor	65	448.3	−2.69
Fuel, natural gas (967 Btu/C.F.) C.F./Ton DAP	60	378.6	366.13
Heat of reaction	—	—	1159.18
			1616.31
HEAT OUTPUT			
Stream			
Product	194	2000.0	77.76
Gases from preneut., granul., & the dryer	202	3040.0	230.41
Evaporation	77	768.0	806.40
Heat loss from dryer, granul., preneut., scrubber, etc.	—	—	501.74
			1616.31

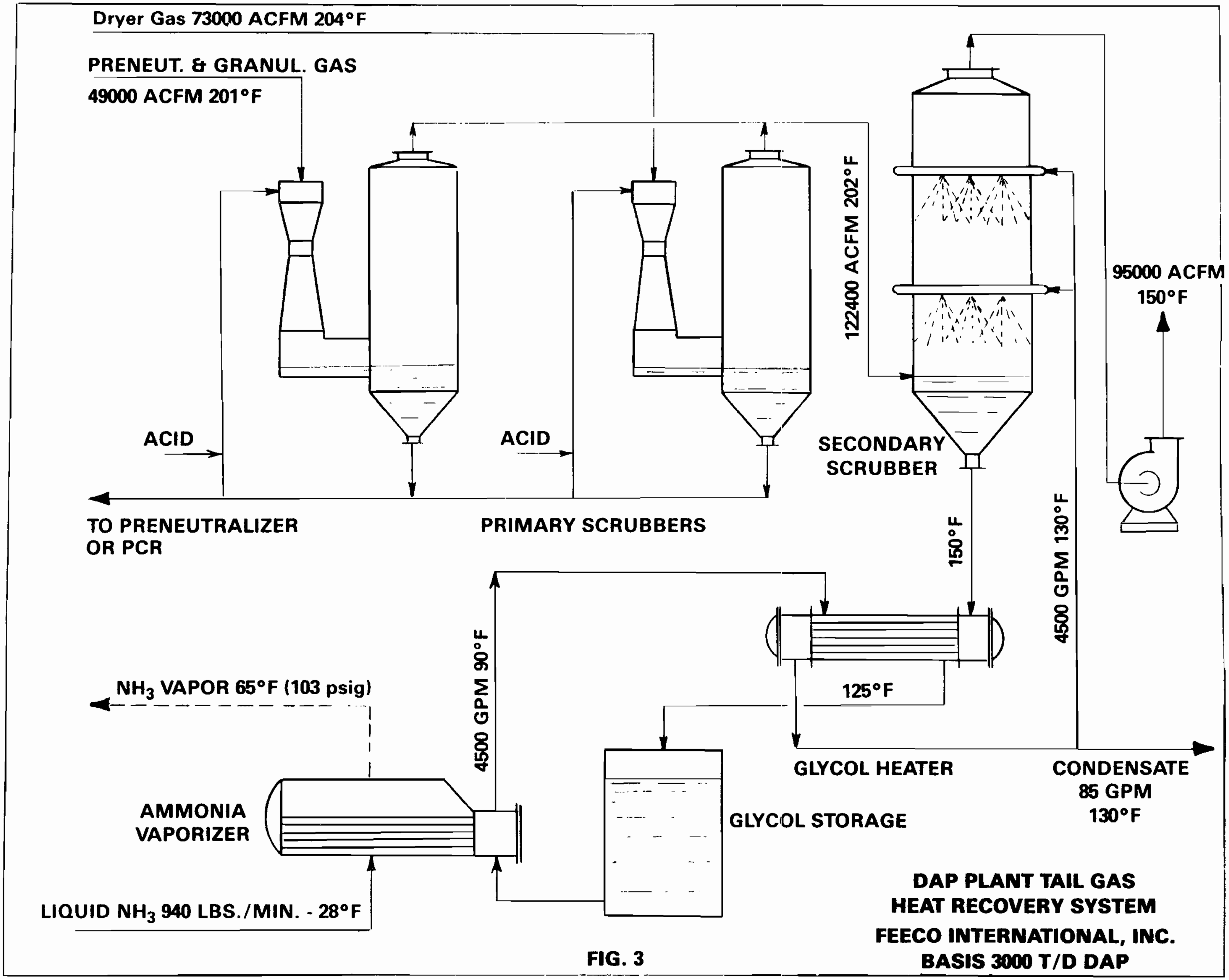

Dryer Gas 73000 ACFM 204°F
PRENEUT. & GRANUL. GAS
49000 ACFM 201°F
122400 ACFM 202°F
95000 ACFM
150°F
ACID
ACID
SECONDARY
SCRUBBER
TO PRENEUTRALIZER
OR PCR
PRIMARY SCRUBBERS
150°F
4500 GPM 130°F
4500 GPM 90°F
NH3 VAPOR 65°F (103 psig)
125°F
GLYCOL HEATER
CONDENSATE
85 GPM
130°F
AMMONIA
VAPORIZER
GLYCOL STORAGE
LIQUID NH3 940 LBS./MIN. - 28°F
DAP PLANT TAIL GAS
HEAT RECOVERY SYSTEM
FEECO INTERNATIONAL, INC.
BASIS 3000 T/D DAP

FIG. 3

The material and heat balances for the above cases have been summarized and tabulated in Tables #1 and #2 and in Figure #3. For comparing the energy requirements of DAP plant, Case I, using liquid ammonia, was used as a base case. By comparison, Case II, using ammonia vapor, requires more water to maintain the same moisture content in preneutralizer slurry. By the same token, the vapor ammonia supplied to the granulator provides an increase in heat and evaporates more water in the granulator. By lowering water fed to the dryer, it causes a reduction in fuel demand or facilitates less concentrated phosphoric acid feed to the DAP plant. Thus, depending on the installed capacity of phosphoric acid evaporators, an ammonia vaporizer is an alternate for increasing evaporator capacity at a small cost.

In fertilizer plants where sulfuric acid is produced, there is usually enough steam for phosphoric acid evaporation and ammonia vaporization. But, as the price of energy goes up, it is more economical to produce electricity with the steam and find other means to evaporate phosphoric acid and vaporize ammonia. One of the possible means is use of hot condensate from turbogenerator for evaporation, use of vaccum pumps instead of ejectors and hot water from secondary scrubbers to vaporize ammonia. Hot water from secondary scrubber could also be used for cake wash in phosphoric acid plant.

Vaporization of ammonia with secondary scrubber hot water has numerous economical advantages. In a 3000 T/D DAP plant, 35,000#/Hour steam is needed to vaporize ammonia. The yearly energy value of this steam, using $4/1000# steam, is about one million dollars. If ammonia is not vaporized, more fuel is needed to evaporate water in the dryer. The natural gas cost for this extra fuel is about $710,000 per year (using $0.5175/therm) or 71¢ per ton DAP.

Due to the fact that ammonia vapor evaporates more water in the preneutralizer, PCR and the granulator than liquid ammonia, the amount of water to be evaporated in the dryer is less. This has dual advantages. (A) It reduces recycle to product ratio from 5:1 to 4:1, which allows an increase in production rate. (B) Dryer size will reduce to 50%. For drying 3000 T/D DAP, dryer motor size will reduce from 630 HP to 400 HP.

Another advantage of the ammonia vaporation, with heat source from secondary scrubber hot water, is that the exhaust gases from the plant will reduce by 40%. Therefore, less atmospheric emissions. Exhaust gas fan HP reduction corresponding to this is about 460 HP. At $0.03 per KWH and using a 90% plant operating factor, savings from the above two motors alone runs to approximately $140,000 per year.

Other alternates that also warrant serious consideration, particularly in the design of new plants or modification of the existing plants, are:

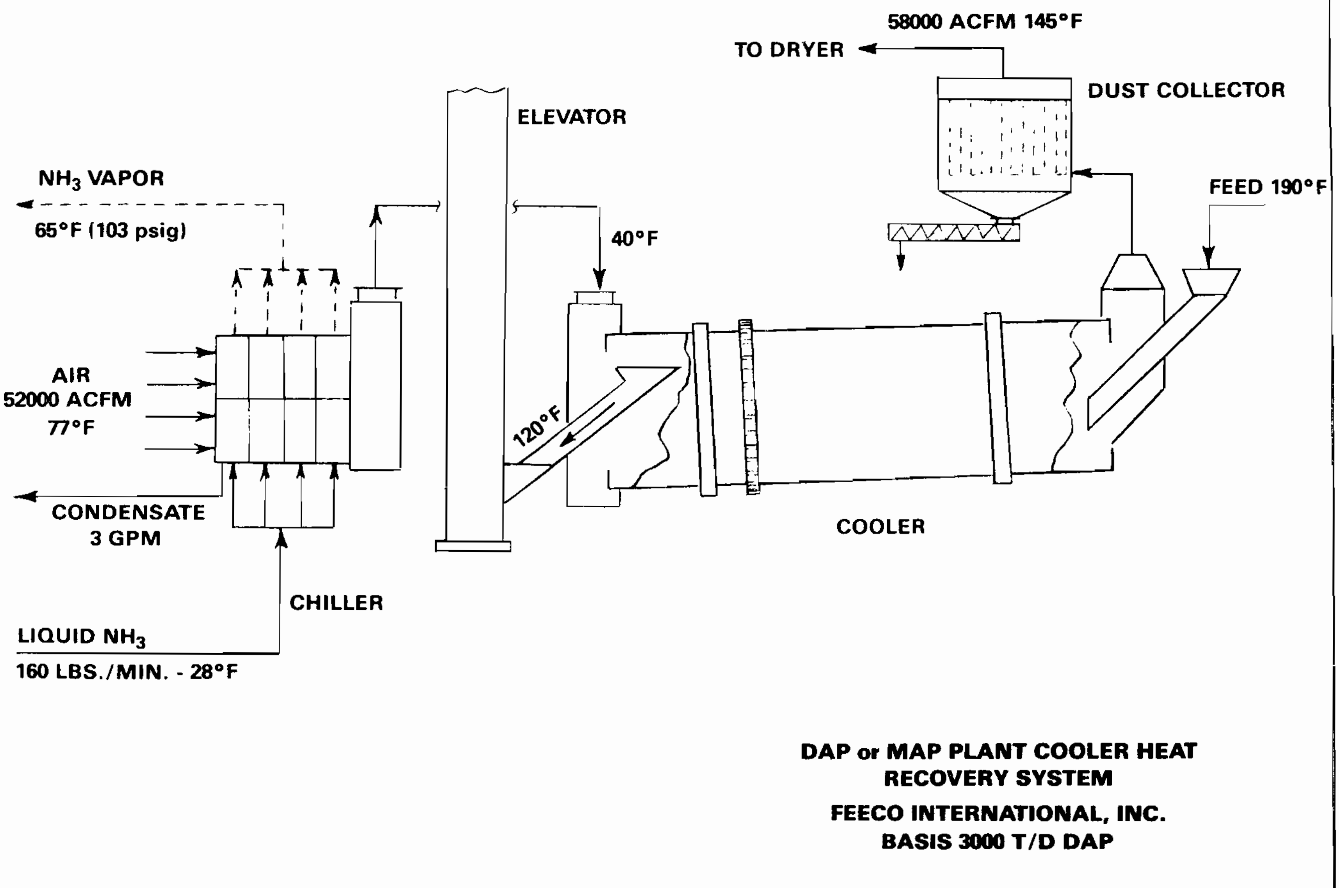
A. Use of ammonia air chiller to cool the product. Outside air, before entering cooler, could be cooled to about 40°F by heat exchanging with vaporizing ammonia, figure #4. This air can reduce the produce temperature to an ideal temperature of 120°F in a cooler 30% smaller than normal. Only 17% of the ammonia fed to the DAP plant is sufficient to cool the air. One of the major problems in increasing overall capacity of a fertilizer plant is lack of space for larger cooler an/or dryer. Installation of air chiller and ammonia vaporizer can reduce the size of this equipment.

B. Introduction of cooler exit air, as secondary air, to the dryer. This must be done after this air has been passed through a bag dust collector. The energy savings corresponding to this is about 3.8 million BTU/hour which translates to $150,000/year. Bag dust collector has much less pressure drop than Venturi scrubbers and when used for cooler and equipment dust, since there is no fluorine emission, it would not require after scrubbing. Due to low dust loading of the cooler and equipment airs, there is no need for cyclones ahead of the bag dust collector. (FEECO's closed loop.)

C. Insulating the dryer and using double shell combustion chamber. About 10% of the heat supplied to the dryer is lost by radiation and convection from this equipment. This heat loss is about 6.3 million BTU/hr. By insulating the dryer and using double shell combustion chamber, the savings realized is approximately $230,000/year.

Table #3 is the summary of the benefits that could be derived by using tail gas scrubber hot water to vaporize liquid anhydrous ammonia.

In conclusion, no matter what different trends develop in the world of fertilizer industry, the importance of energy conservation and raw material and equipment efficiency will remain of the highest importance. It is important that each individual plant be examined with regard to location, type of equipment installed and the method of operation to determine the best combination of energy savings. It is hoped that some of the ideas presented in this paper will enable our operating colleagues to assess their plants present energy status.



DAP or MAP PLANT COOLER HEAT RECOVERY SYSTEM

FEECO INTERNATIONAL, INC.
BASIS 3000 T/D DAP

FIG. 4

TABLE 3
Potential Savings Derived From Ammonia Vaporization Using Scrubber Water as Heat Source

BASIS—3000 T/D DAP Production	
Steam savings	35,000 lbs./hr.
Value of steam	$1,000,000/yr.
*Fuel savings	143 cf/ton
*Value of fuel	$710,000/yr.
Recycle/product ratio reduction	From 5:1 to 4:1
Dryer size reduction	65%
Exhaust gases reduction	40%
Phos. acid combined strength reduction	From 41% to 37.5%
System motor HP reduction	690 HP
Value of HP savings	$140,000/yr.

*Alternate using fuel instead of steam heat source.

High Efficiency Fluoride Removal for Recycling in the Fertilizer Industry

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(West Germany)

ABSTRACT

In the acidulation process of phosphate rock, noxious gaseous fluorides are emitted. These fluorides must be collected and removed from effluent streams to comply with environmental protection codes.

Processes have been developed to convert the captured fluorides into commercially useable products and/or recycle the fluorine as fluosilicic acid back to the production process to save process acid. For these processes, it is essential to employ absorbers with efficiencies greater than 99.9%. This system was developed and pilot-tested in Europe. A full-scale unit has been working since February 1983 producing continuously 24 hours per day 15 to 20% fluosilicic acid to be used in the acidulation process, saving 20 kg sulfuric acid per ton superphosphate. The energy consumption is below 1,5 kW per ton superphosphate. Total operating cost is only a small percentage of the savings achieved. Investment cost is amortized in less than one year. The effluent gas stream contains about 5 mg F/m^3 and the liquid discharge is zero.

INTRODUCTION

Phosphate rock is a complicated natural mineral consisting of many compounds. The principle constituent is apatite. The chemical formula for apatite is commonly written as:

$$3\ Ca_3(PO4)_2 - CaF_2$$

The fluorine content of most phosphate rock types available is approximately 3.5 to 4 percent. During the acidulation process volatile fluorine compounds, such as HF gas and SiF_4 gas (a reaction product from HF and silica) are released. These gases must be captured and removed from the exhaust gas stream to protect plant personnel and the general environment.

$$CaF_2 + 2\ H^+ \rightarrow Ca^{++} + 2\ HF \qquad (1)$$

$$4\ HF + SiO_2 \rightarrow 2\ H_2O + SiF_4 \qquad (2)$$

The amount of fluorine compounds being released depends upon the grind of the rock, the temperature of the rock and the acid reactants, as well as mixing action and contact time in the den. Approximately 20 – 30% of the fluorine from phosphate rock in case of single super, 10% of the secondary rock in case of triple super and 4 to 15% of the rock fed in case of phosphoric acid are emitted as gas phase from the reaction system.

FLUORINE REMOVAL

Ventilation hoods are recommended for reaction vessel and belt den in order to extract all vapors and gases without loss and with a minimum amount of air. The smaller the air volume, the smaller the size of the filter, exhaust fan and auxiliary equipment and, last but not least, investment and operating cost.

Hydrogen fluoride and silicon tetrafluoride are quite soluble in water and, therefore, relatively easy to remove from the exhaust gas stream by absorption with water. In use are various types of absorbers; e.g. spray chambers, wet cyclones, venturi scrubbers, jet eductors, and packed scrubbers. Most of the known fluorine scrubbers have one or more major weaknesses with some negative consequences such as:

unadequate mass transfer capabilities	—high stack emission rates, limited recovery
large fresh water requirements	—liquid disposal problem
high energy needs	—high operating cost
plugging potential	—high maintenance and down time cost

To overcome these problems, a multiple stage cross flow scrubber was developed by CEILCOTE to combine high fluorine removal efficiency with maximum recovery at low operating cost.

FLUORINE RECOVERY

Silicon tetrafluoride reacts with water to form fluosilicic acid and silica.

$$3\ SiF_4 + 2\ H_2O \rightarrow 2\ H_2SiF_6 + SiO_2 \qquad (3)$$

Silica reacts with HF to produce additional silicon tetrafluoride, which again reacts with water as shown above.

$$SiO_2 + 4HF \rightarrow SiF_4 + 2\ H_2O \qquad (4)$$

By adding the chemical formulas (3) and (4) the process can be described as:

$$SiF_4 + 2\ HF \xrightarrow{(H_2O)} 2\ H_2SiF_6 \qquad (5)$$

Fluosilicic acid is a strong and poisonous acid, which decomposes under high temperatures (reverse reaction no. 5). Its direct use in other industries is limited due to its low concentration and the relatively high amount of impurities from the scrubbing process.

To overcome these problems a technology has been developed, whereas the fluosilicic acid will be used in the acidulation process replacing some of the sulfuric acid. With this technology the fluorine is recycled back into the fertilizer product to form Fluorspar. At the same time the acid consumption, and thus the operating cost, will be reduced.

For the production of superphosphate fertilizer sulfuric acid is used. The process can be described as follows:

$$6\ H_2SO_4 + 3\ Ca_3(PO_4)_2 \rightarrow 3\ Ca(H_2PO_4)_2 + 6\ CaSO_4 \qquad (6)$$

If fluosilicic acid is used the reaction formula will be:

$$2H_2SiF_6 + 3\ Ca_3(PO_4)_2 + 4\ H_2O \rightarrow 3\ Ca(H_2PO_4)_2 + 6\ CaF_2 + SiO_2 \qquad (7)$$

The chemical reaction (7) shows that every mole of reaction H_2SiF_6 replaces three moles of H_2SO_4. Savings in the range of 20 kg sulfuric acid per ton superphosphate can be achieved.

The total recovery and recycle process can be summarized by adding up the chemical reaction formulas from (1) to (7) to obtain (8).

$$3Ca_3(PO_4)_2 \times CaF_2 + 6H_2SO_4 \xrightarrow{H_2O,\ SiO_2} 3Ca(H_2PO_4)_2 + CaF_2 + 6CaSO_4 \qquad (8)$$

The mineral apatite is converted to soluble calcium phosphate, calcium sulfate and harmless, solid calcium fluoride.

It must be noted that fluosilicic acid cannot exist in high temperature environments. Thus, a certain percentage of the acid formed per reaction (5) will decompose in the hot den before reacting with the phosphate rock. Based on this, the amount of gaseous fluorides will increase in the exhaust gas stream. Depending on operating conditions the flow rate of fluorine in the recycling process can be as high as two to four times of that experienced with a once through process.

In order to maintain a low gas exit concentration of fluorides with little make up water to produce a 15 to 20% fluosilicic acid, an extremely high efficient scrubber system is required.

CEILCOTE CROSSFLOW SCRUBBER

Wet scrubber designs vary widely in their mass transfer and particulate collection capability. Engineers selecting such equipment must carefully examine factors of scrubber design such as:

1. Number of mass transfer units available
2. Pressure drop vs. mass transfer efficiency
3. Pressure drop efficiency vs. particulate removal
4. Reliability of operation
5. Maintenance.

It should be noted that it is not always true that the greater the energy input the greater the particulate collection efficiency. Some scrubber designs give higher collection efficiency at lower pressure drop than others.

The Ceilcote Crossflow Fluorine Scrubber is especially designed for the fertilizer industry. This scrubber design is characterized by low liquid irrigation rates, high volume air flow and low pressure drop. The contaminated air is drawn horizontally through a packed bed and is irrigated by the scrubbing liquid which flows vertically down through the packing.

In applications where two or more stages are required, it is often desirable to have these units arranged as close as possible. This can readily be achieved with the crossflow scrubber because its flow geometry permits the use of two or more packed beds within one shell, allowing different scrubbing liquids or liquid concentrations to be used without mixing (Fig. 1). The crossflow scrubber is an excellent selection for those applications where solid particulates are present in combination with soluble gases and/or liquid particulates. High irrigation rates in critical zones as well as proper selection of the packing provide satisfactory operating reliability when fairly high concentrations of entrained or formed solids are present.

The Ceilcote Fluorine Scrubber is a multistage crossflow scrubber with integral sumps (Fig. 2). Each stage is processwise separated and operates independently with its own liquid recycling and distribution system (Fig. 4/5). Make up water is introduced to the last stage for final scrubbing of the air and production of a weak acid. The overflow of the last stage is fed as make up liquid to the stage before the last one. Scrubbing in this stage provides a higher concentrated acid overflow for the next stage cocurrent to the air flow until the desired acid concentration is reached in the first stage. The overflow of stage one is fed into a holding tank for further use in the production process (Fig. 3).

The concentration (normally 15 to 20%) of the fluosilicic acid can be varied by the addition of fresh water to the last stage. The system operates automatically and needs no special control instruments. Each compartment is equipped with a top side removable frame (Fig. 6). Cleaning of the packing can be done by high pressure water spray or simply by exchanging front and rear frames. In the last stages hydrofluoric acid prevails, it attacks and removes deposited silica. However, the system usually operates with excess silica in the fluosilicic acid leaving the system.

The pressure drop is much lower than known from venturi scrubbers and lower than experienced with other counter-current packed scrubbers. Low pressure drop and reduction of flooding potential are also aided by the fact that gas and liquid flow are non-opposing.

HIGH EFFICIENCY FLUORIDE REMOVAL FOR RECYCLING IN THE FERTILIZER INDUSTRY

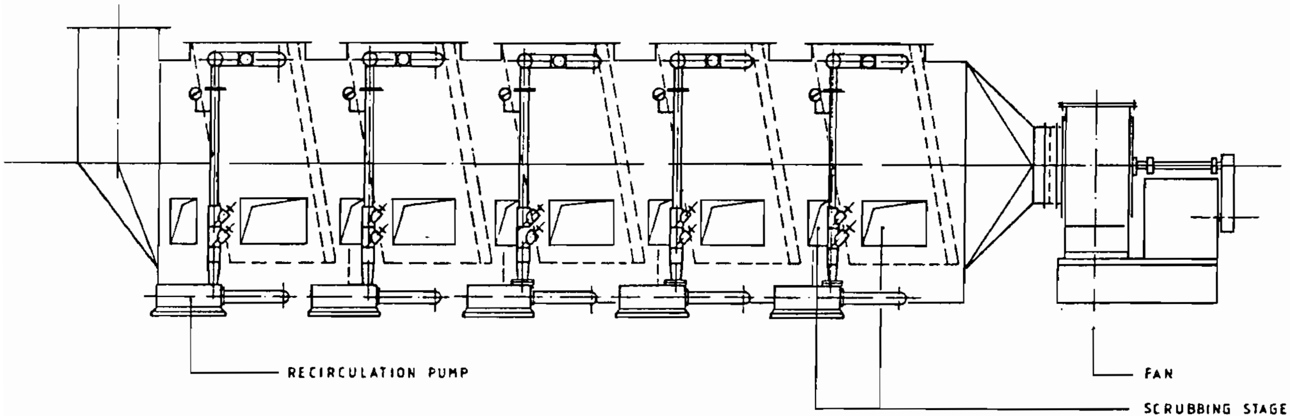

FIG. 1 5-STAGE FLUORIDE SCRUBBER

BASIC SKETCH: CEILCOTE GMBH, BIEBESHEIM, W-GERMANY

HIGH EFFICIENCY FLUORIDE REMOVAL FOR RECYCLING IN THE FERTILIZER INDUSTRY

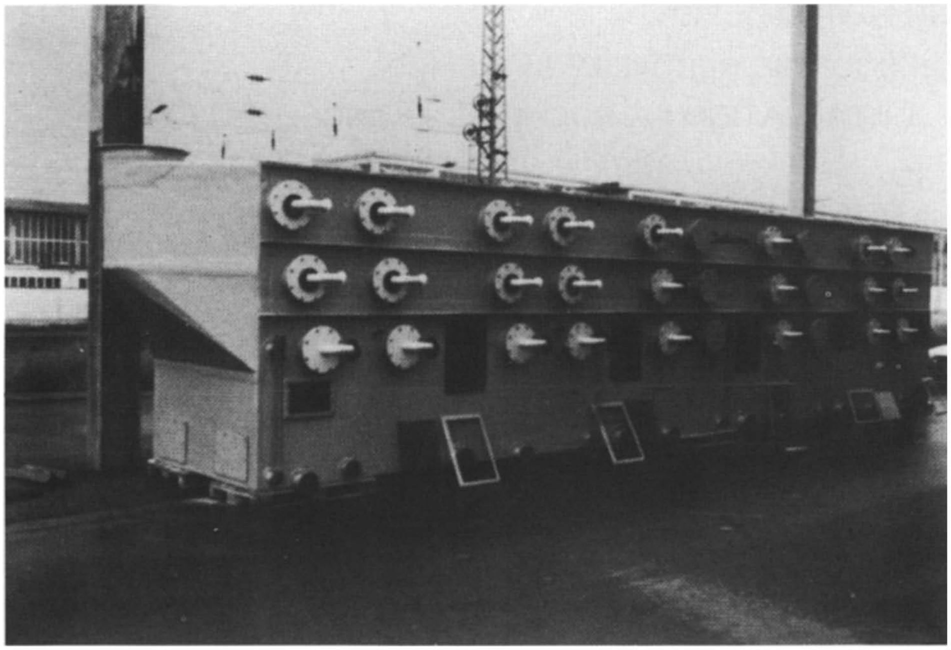

FIG. 2 CEILCOTE FLUORIDE SCRUBBER FOR FERTILIZER INDUSTRY

PICTURE: CEILCOTE GMBH, BIEBESHEIM, W-GERMANY

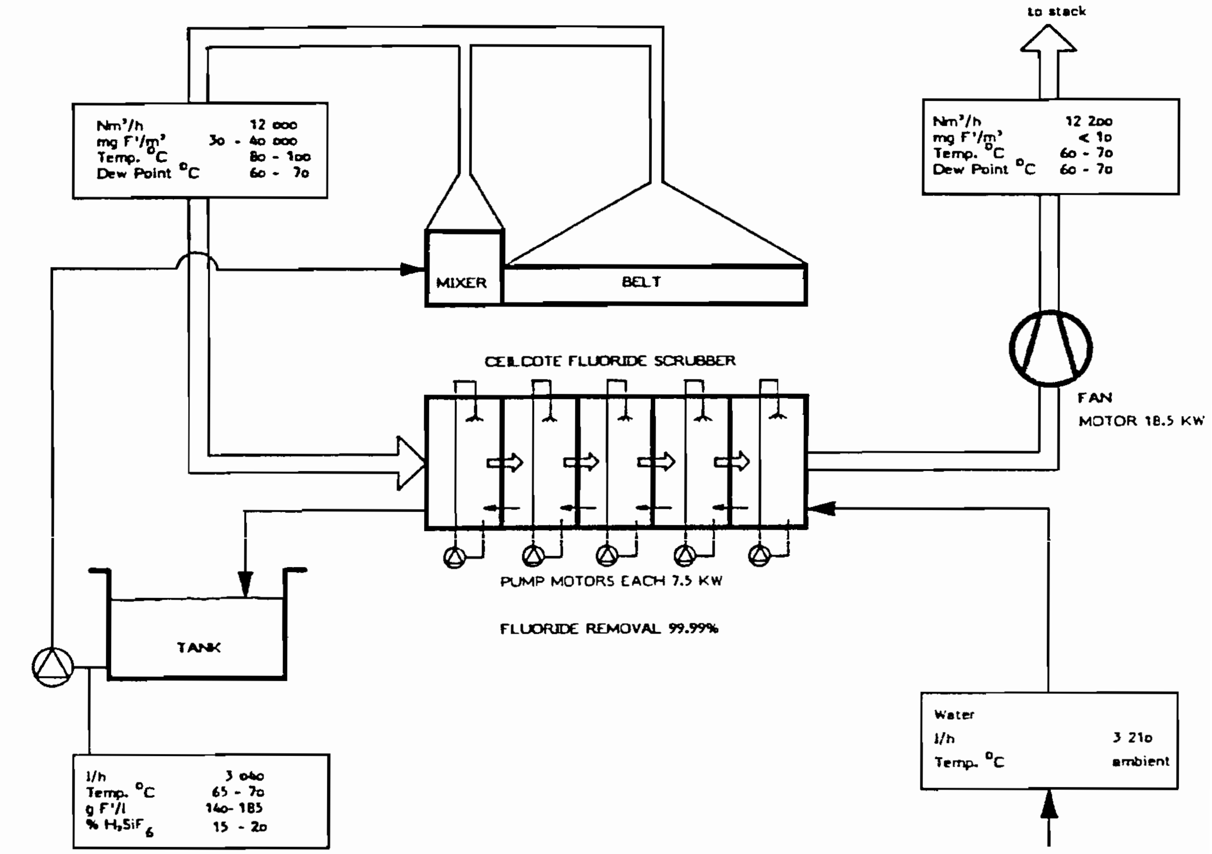

FIG. 3 FLUORINE RECOVERY SYSTEM
INSTALLATION LA ROCHELLE FRANCE 1983

FLOW SHEET: CEILCOTE GMBH, BIEBESHEIM, W.-GERMANY

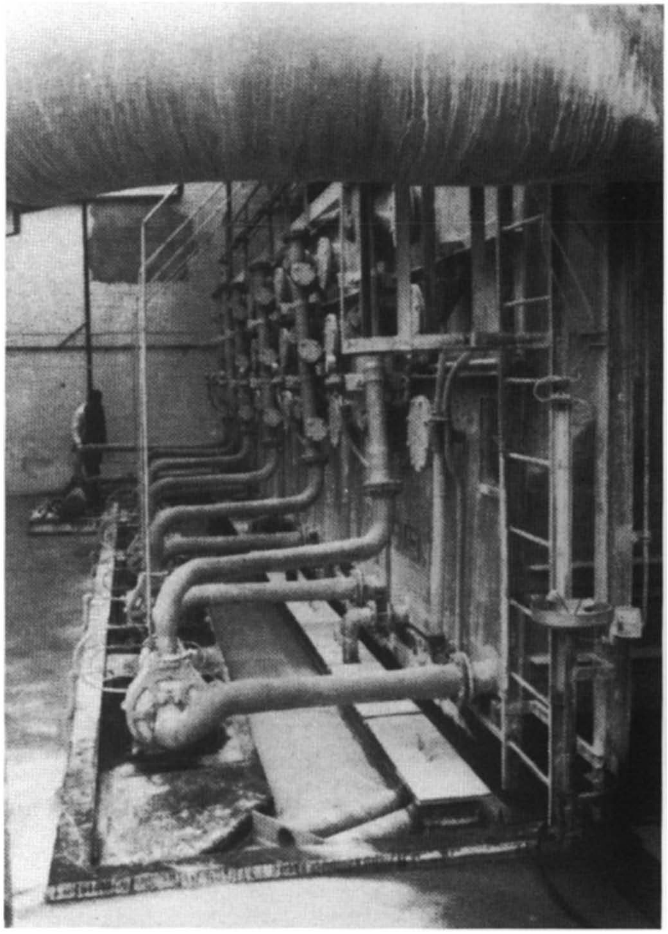

FIG. 4 FLUORINE RECOVERY SCRUBBER
LA ROCHELLE, FRANCE 1983

PICTURE: CEILCOTE GMBH, BIEBESHEIM, W-GERMANY

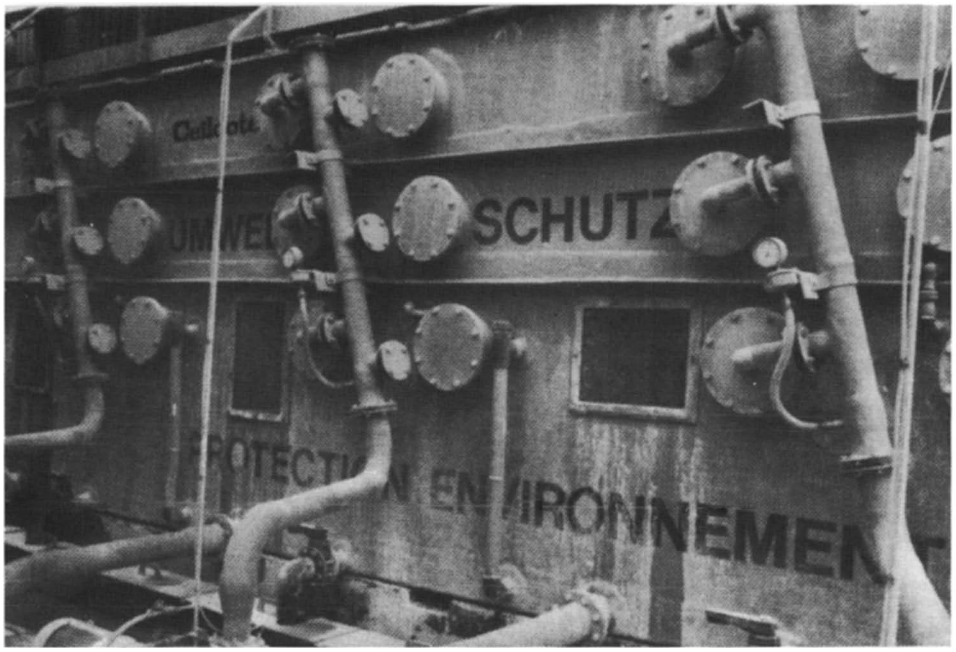

FIG. 5 FLUORINE RECOVERY SCRUBBER
RECIRCULATION SYSTEM

PICTURE: CEILCOTE GMBH, BIEBESHEIM, W-GERMANY

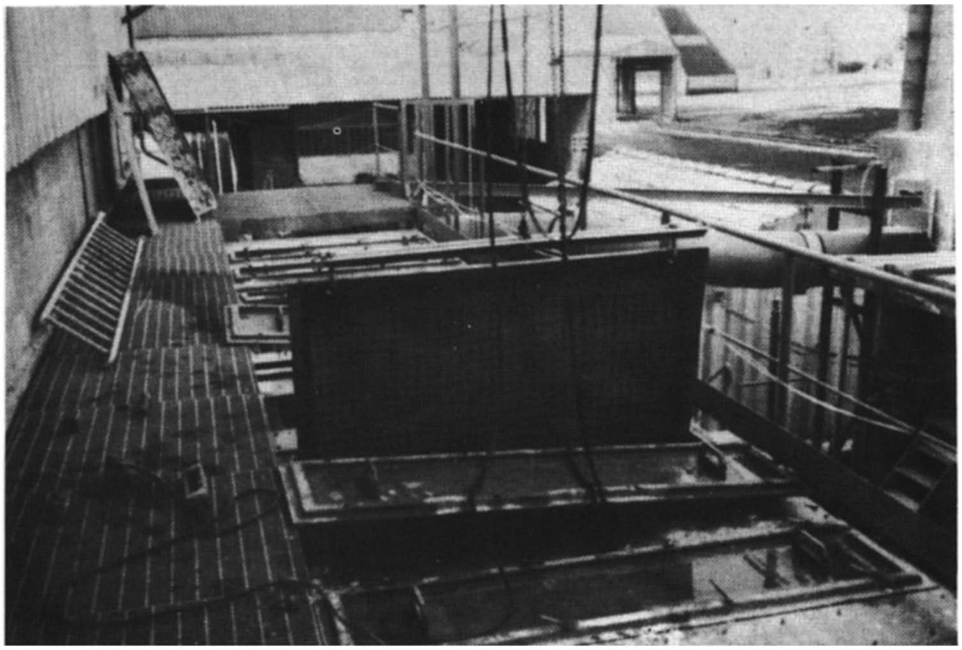

FIG. 6 FLUORINE RECOVERY SCRUBBER
TOP SECTION WITH REMOVABLE PACKING

PICTURE: CEILCOTE GMBH, BIEBESHEIM, W-GERMANY

It must be noted that all chemicals collected will be recycled. Additions are limited to the amount of water needed to produce fluosilicic acid and to replace evaporation losses. No liquid or solid waste materials are produced.

CASE HISTORY

The Cofaz Plant in La Rochelle, France, operates a belt-type continuous den. In case of recycling the fluosilicic acid to the mixer, the fluorine emission in the off-gas was expected to be 30–40,000 mg F/Nm^3. Less than 10 mg F/Nm^3 was aimed in the gas leaving the stack. A removal efficiency of 99.99% was required. Due to stringent water pollution regulations, neither pond water nor sea water for once through scrubbing was available.

Pilot plant tests were performed in 1982 to evaluate various operating conditions and to optimize design data for the full-scale unit, which had to operate under the following conditions:

Off-gases from a Continuous Belt-type Den from Single Superphosphate Production with a Capacity of 37 to/h

Inlet Conditions:	
Fluorine Rate	30–40,000 mg/Nm^3
Gas Volume	12000 Nm^3/h
Gas Temperature	80–100 deg. C
Gas Dew Point	60–70 deg. C
Outlet Conditions:	
Fluorine Rate	<10 mg/Nm^3
Fluosilicic Acid	15–20%
Waste Water	0
Performance:	
F-removal Efficiency	99.97
Energy Consumption	50 kW/h
Sulfuric Acid Savings	18–25 kg per to super

ABSORBER DESIGN

The pilot tests have proven that the extremely high removal efficiency of 99.99% fluorine was achieved despite the high dew point of the gas and the demand that no liquid waste is produced. The number of mass transfer units (NTU) required are calculated by the equation:

$$\mathrm{NTU} = \ln \frac{y_1 - y^*}{y_2 - y^*} \qquad (9)$$

y_1, y_2, y^* = fluorine concentration in the gas phase at inlet (1) resp. outlet (2) of scrubber and at equilibrium (*)

HIGH EFFICIENCY FLUORIDE REMOVAL
FOR RECYCLING IN THE
FERTILIZER INDUSTRY

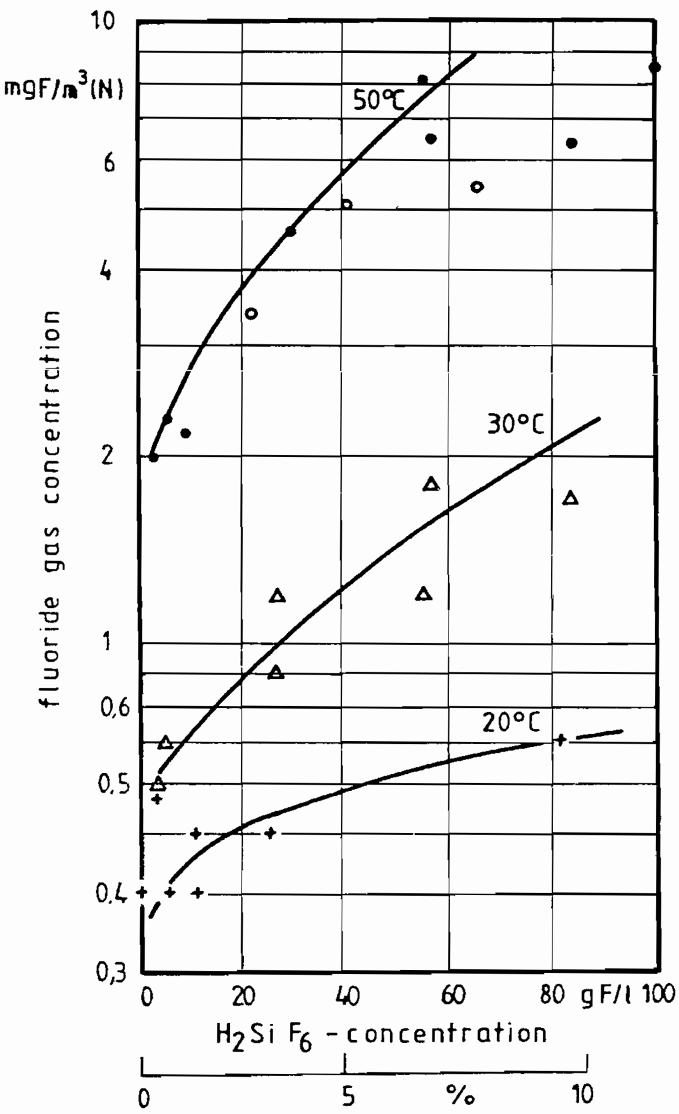

FIG. 7 FLUORIDE VAPOR PRESSURE

The NTU must be calculated separately for HF and SiF_4 since concentrations vary with inlet conditions, temperatures and vapour pressure over the acid concentration. The vapour pressure data available in the literature differ in some cases considerably. We have found that the curves published by K. Köthe and L. Müller (Fig. 7) comply best with our findings. The temperature of gas and liquid phase plays an important role in the determination of the NTU required, and thus the complexity of the scrubber system. The vapour pressure of fluoride over e.g. 5% H_2SiF_6 aqueous solution increases by factor 10 with a temperature change from 20 deg. C to 50 deg. C. The lower the temperature, the lower the vapour pressure, and thus the higher the driving force for the fluoride to become absorbed in the liquid phase. Therefore, the temperature should be as low as possible. Cooling could be accomplished by extracting more air, direct cooling of the air or indirect cooling of the recycled liquid, but an increase of the air volume would increase the system size, investment and operating cost. Direct cooling cannot be accomplished in many cases, since the required amount of water is either not available or the contaminated water is not allowed to be discharged as it is the case in the La Rochelle plant. Indirect cooling requires additional special alloy equipment which is less economical than using additional scrubbing stages. An evaluation of generally available data, as well as test data from the pilot plant, has resulted in the use of approximately 20 NTU distributed over five scrubbing stages by means of filamentous packing material.

It must be noted that the absorption rate of SiF_4 is higher in water than HF. This results in an enrichment of HF in the gas streams as the air travels through the stages. In the last stages mainly hydrogen fluoride acid is produced, which reacts with amorphous silica as it travels backwards to stage one. On the other hand in the first two stages mainly SiF_4 is absorbed forming fluosilicic acid and silica.

SOLID HANDLING

The scrubber system is designed to remove all liquid and solid particulates larger than 10 microns from the gas stream in the first stage. The collected dust will be dissolved or carried in suspension in the fluosilicic acid to finally return to the production process. The formed silica in the scrubber will not cause any clogging problems as long as is not allowed to dry out. Proper irrigation systems with large orifice, low pressure drop nozzles are essential to minimize solid build up. Due to fluctuations in the operating conditions, some build up, however, can occur in the packing. This is controlled by observing the pressure drop over each stage. To minimize shutdown and cleaning time, the packing is placed in removable frames. Exchange of the frames can be done within minutes. The packing can be cleaned either by pressurized water or simply by exchanging frames from the rear to the front. As previously stated, only in the front stages silica formation occurs. In the rear section of the system HF acid is available in excess to react with silica and to clean the frames from the front section.

CORROSION CONTROL

The material of construction must withstand a very corrosive environment. Proper material selection is important for troublefree operation. Best results have been achieved with polypropylene for the internals and Duracor D for the housing of the scrubber, and fan and ductwork. Duracor D is a fiber reinforced polyester with 70% resin and 30% glass and synthetic fibers. The glass fiber is totally confined and protected by the resin and the synthetic fibers. Duracor D has many advantages such as being light in weight, high in strength, exceptionally resistant to chemicals, requires no painting and being easily altered or repaired. The recycling piping systems are made of Duracor D as well. The housing and the impeller of the horizontal chemical pumps are especially designed to handle the abrasive solids in suspension and the aggressive fluosilicic acid. Material of construction is a special thermoplastic material. A mechanical type sealing made of silicon carbide is used.

PERFORMANCE

After 20 months of operation, the performance of the scrubber system has exceeded the expectation of the authorities and the user. Emission rates are below 5 mg F/Nm^3 even at higher inlet concentrations and gas temperatures. The energy consumption is below 50 kW/h and the maintenance cost is less than was anticipated. Total operating cost is only a small percentage of the savings from reduced sulfuric acid consumption and liquid waste expenses.

Cost Summary per Ton of Produced Single Superphosphates

		FF	US $
Energy	1.4 kW	0.42	0.055
Water	0.065 m^3	0.02	0.002
Maintenance and supervision		1.2–1.7	0.13–0.19

Savings Per Ton of Produced Single Superphosphate:

		FF	US $
Sulfuric acid	18–25 kg	9–13	1.00–1.44
Effluent cost (EPA taxation)		0.6	0.07

Total savings amount to US $ 1.1–1.5 minus cost of US $ 0.14–0.20 per ton single super phosphate. At a capacity of 37 to/h approximately US $ 40 per hour can be earned with the Ceilcote Fluorine Scrubber. Amortization time is less than one year.

CONCLUSION

The Ceilcote Fluorine Scrubber is used successfully reducing fluorine in the gas streams to acceptable levels with zero liquid waste, low energy requirements and subtantial savings from recycling fluosilicic acid to the production process. The scrubber is of solid plastic construction and thus corrosion proof inside and outside, light in weight, compact in design, easy to install and to operate.

Ideal applications are in the phosphate fertilizer and phosphoric acid production industry.

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Granulation of Mixed Fertilizers by Compaction

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Executive Vice President
Koppern Equipment, Inc.

INTRODUCTION

The demand for increasingly sophisticated fertilizer formulations to satisfy the requirement of specific soil conditions and/or particular crops, led to the development of mixed fertilizers with closely controlled nutrient (N, P, K) and micro-nutrient (trace elements) contents. As a result of the manufacturing processes or after grinding to improve the bulk mixing characteristics, the individual fertilizer components are relatively fine powders. Mixtures of such materials tend to segregation and dusting. Since, additionally, the fertilizer components may react chemically with each other and/or are water soluble, they are also prone to caking.

The modern, highly efficient fertilizer transportation, storage, and distribution systems as well as the high capacity mechanical spreaders cannot cope with these difficulties. A free flowing, dust-free product with constant composition is required. This led to the development of granulated fertilizers.

FUNDAMENTALS OF FERTILIZER AGGLOMERATION[1]

The granulation by agglomeration of single or multi-component fertilizers began approx. 35 years ago, although a few granulated fertilizers were known even before. Only since about 25 years granulation has, in many cases, become the rule.

"Conventional" fertilizer granulation processes use wet or melt agglomeration technologies (Figure 1) whereby the finely divided solid (2) is mixed with relatively large amounts of a liquid (1) and agglomerated in a moving bed by aggregation. Binding may be due to anyone or several of the mechanisms a.1 to a.4 shown on the left hand side of Figure 2. The liquid can be plain water, a solution containing dissolved nutrients or a melt (e.g. urea). The moving bed—in which the solid particles move turbulently, are wetted with the liquid, and coalesce to form agglomerates—is produced in rotating drums (Figure 1A), inclined rotating discs (Figure 1B), prilling towers (Figure 1C) or fluidized beds (Figure 1D), or in mixers such as pug mills (Figure 1E).

The "green" agglomerates which are still wet and/or hot need curing to gain final strength (right part of Figure 1). This is accomplished in large dryers (4) and/or coolers (5) in which water is evaporated and heat is removed. The cured material is screened (6) to eliminate undersized fines (3). Oversized lumps are crushed in a mill (7) and rescreened.

The majority of the product with a particle size of e.g. 1–3.3mm (6–16 mesh Tyler) is more or less spherical in shape. In some cases, it is further rounded in an abrasion drum and/or conditioned with, for example, anti-caking agents to avoid caking (8).

The undersized fines (3) are recirculated to the beginning of the process. Typically, the yield, i.e. the ratio between product from the screen and the feed [(1) + (2) + (3)] to the system, is 0.25 to 0.3. The rest must be rewetted for agglomeration, redried and recooled. Therefore, with today's high cost of energy these technologies are only economical if large amounts of material are being processed in a continuous operation where heat recovery from hot off-gases is performed.

An alternative group of granulation processes utilizes the application of force for agglomeration. These "pressure agglomeration" technologies make use of the mechanisms on the right hand side of Figure 2 (b.1 to b.4). Binding is chiefly accomplished by the effects of attraction (molecular, van-der-Waals, and valence) forces. Since these forces are only effective over short distances (they are of almost no consequence at a distance of only a few Ångström), the largest possible area of the solid particles must be approximated closely to each other to achieve sufficient agglomerate strength.

The above is only possible if (sometimes considerable) forces are applied to the particulate solids. Materials which deform plastically under the effect of pressure permit high van-der-Waals forces. Brittle particles are crushed, reoriented and bound together by van-der-Waals and valence forces (recombination of free chemical bonds produced during crushing). In both cases, in addition, material bridges due to partial melting (caused by high energy concentrations

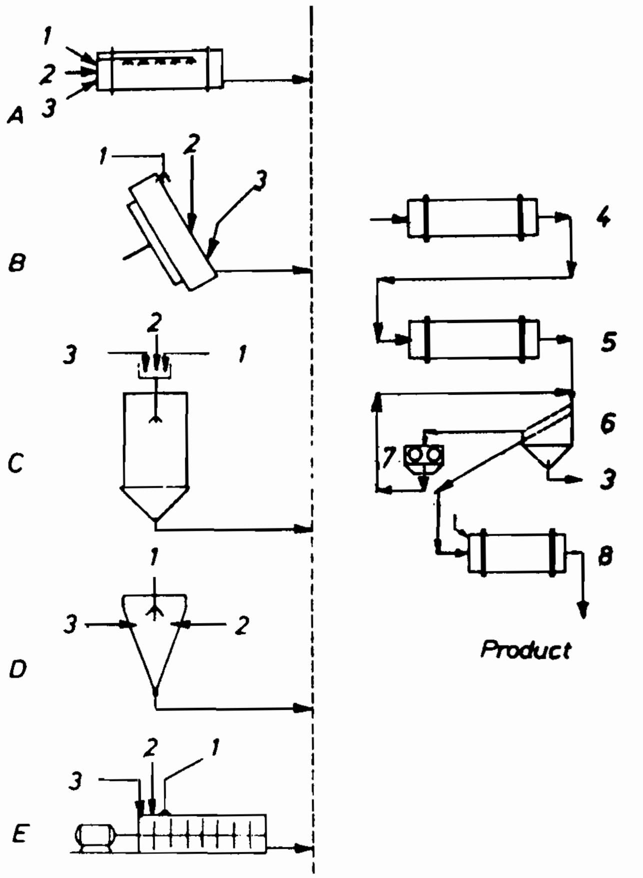


Figure 1: Schematic representation of the most common "conventional" fertilizer granulation processes.

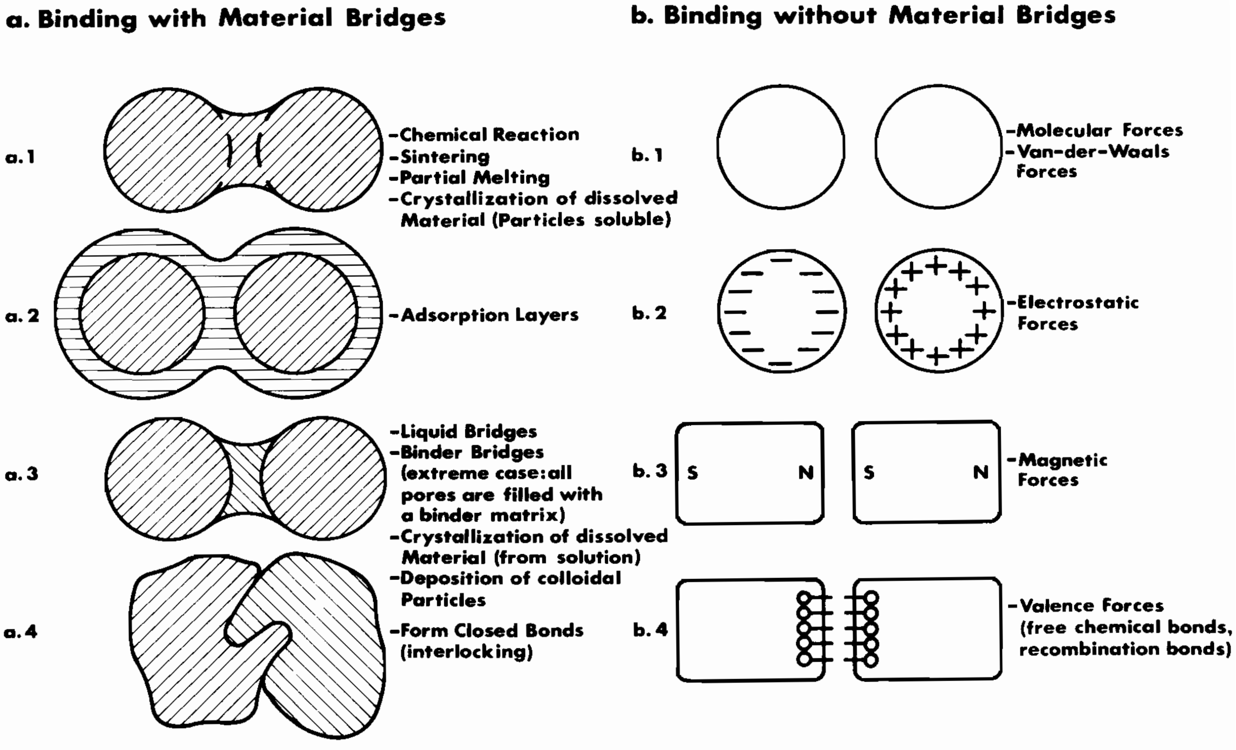


Figure 2: Binding mechanisms of agglomeration.

at the roughness peaks), chemical reactions, adsorption layers, recrystallization and interlocking participate in bonding.

Pressure agglomeration technologies typically produce strong agglomerates without the need for further curing. However, it is uneconomical to directly produce agglomerates of the size distribution required for fertilizer applications. In such cases, a simple system, such as shown schematically in Figure 3, is being used. Fresh feed (2), recirculating material (3), and, optionally, a liquid or solid binder are fed to the pressure agglomeration equipment (4). The agglomerated material is screened (5). Oversized particles are crushed in a mill (6) and returned to the screen. Undersized fines (3) are recirculated to the pressure agglomeration equipment.

The product with a particle size of e.g. 1–3.3mm (6–16 mesh Tyler) is irregular in shape. It can be rounded to some extent in an abrasion drum and/or conditioned with, for example, anti-caking agents to avoid caking. Depending on the strength of the agglomerate prior to crushing, the type of crusher used for disintegration, and the width of the product particle size distribution, the yield, i.e. the ratio between product from the screen and the feed [(1) + (2) + (3)] to the system, is between 0.3 and 0.6. Although, in many cases, the yield may not be substantially higher than that of the previously described "conventional" fertilizer granulation processes, the energy required for handling and processing of the recirculating fines is much lower. The fertilizer granulation systems using pressure agglomeration also lend themselves to small capacities and to shift operation.

PRESSURE AGGLOMERATION EQUIPMENT[2,3]

Pressure agglomeration can be divided into low to medium force and high force applications.

The low to medium force technology is often called "pelleting". In the equipment belonging to this group (Figure 4), materials with sufficient binding tendency or those containing binders are forced through open dies or holes in dies of different shape. Wall friction produces the resistance which defines the force available for densification. In some cases, the column of already finished extrudates provides an additional back pressure.

Pelleting does not generally impart much strength and often relies on subsequent curing steps to produce an acceptable product. The highest density and, therefore, strength is obtained where the material slides along the die walls. The product, which is typically cylindrical in shape, is strong and dense at its periphery but soft and weak in the center of the pellet. If such pellets are crushed the resulting granular material contains large amounts of soft, insufficiently abrasion-resistant particles. On the other hand, the equipment is also sensitive to high wear and relatively small overloads may cause breakage of the delicate (because perforated) die.

High force pressure agglomeration equipment is more rugged and the technology is more versatile. Figure 5 shows schematically the different methods. (a) and (b), the reciprocating piston and rotary table briquetting or tabletting presses, can be disregarded in this context. These machines are widely used in the pharmaceutical industry but do not offer sufficient capacity for bulk applications.

Figure 5 (c) and (d) show schematically roller presses for compacting (c) and briquetting (d). These machines are designed for heavy duty and are highly reliable. Their particular merit lies in the capability to compact large quantities of material at low cost. Other considerations may be the ease with which the equipment can be made dust-tight for the processing of toxic chemicals and explosive dusts as well as for odour control, or the variety of materials from which the rollers can be constructed for those cases where corrosive and/or abrasive resistance is of importance.

Figure 6 shows the principle of roller compaction. Compaction is achieved by squeezing material between two rollers, much in the same manner of a rolling mill. If matching pockets are cut into both rollers and their centerline distance is set such that only a narrow gap exists in the nip area, briquets are formed. The land area around the pockets produces a flashing or web on the briquets that usually breaks off during handling. If smooth or shallow profiliations are used on the roller surfaces and a relatively wide gap is present between the rollers, a continuous dense sheet or flake is produced. The latter is the technology used in fertilizer compaction.

The process occurring during compaction of particulate matters in roller presses is described and interpreted by different authors in a rather similar way. The feed mechanism is characterized by the pressure caused by gravity or a force feed system and the friction between material and roller surface. Compaction between two rollers may be explained by dividing the nip area into two zones: the feed zone and the compaction zone.

In the feed zone, the material is drawn into the nip by friction on the roller surface. Densification is solely due to the rearrangement of particles. In the compaction zone, the press force becomes effective and the powder particles deform plastically and/or break.

Figure 7 shows one of the largest available fertilizer compaction machines in the assembly bay of KÖPPERN, one of the leading manufacturers of roller briquetting and compacting equipment. With a roller diameter of 1,000 mm, a roller width of 1,250mm, five screw feeders, a force between the rollers of e.g. 6,900 kN (10,400 kN max.) and a roller speed of 12 rpm, this machine is capable of compacting between 60 and 100 t/h of fertilizer material by producing a

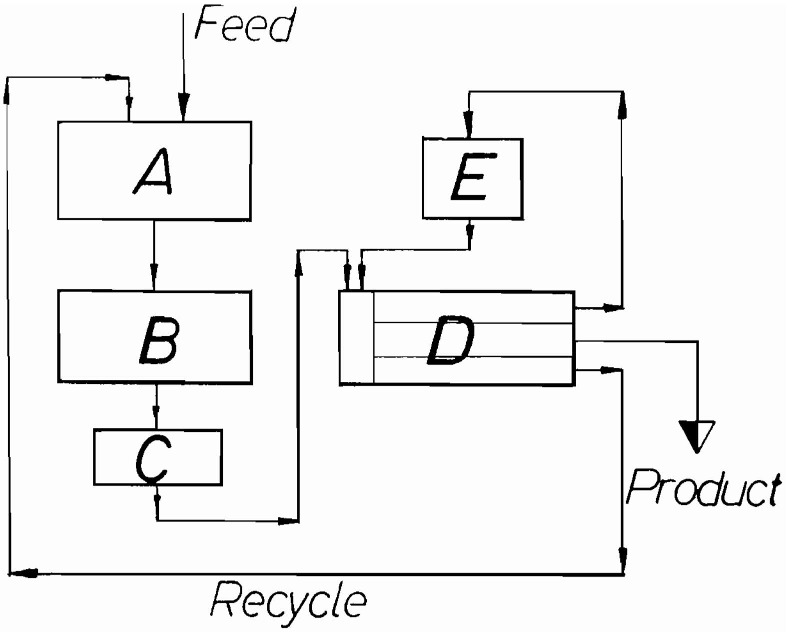


Figure 3: Simplified flow-sheet of a pressure agglomeration/granulation system.
A: Mixer, B: Compactor, C: Flake-Breaker,
D: Screen, E: Crusher.

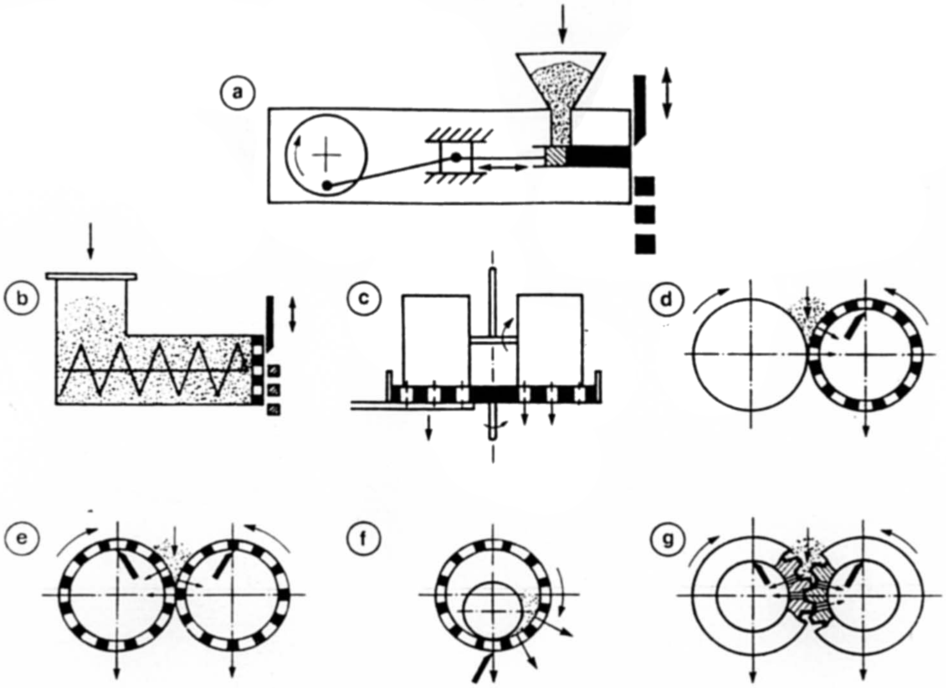


Figure 4: Schematic representation of pelleting equipment (low to medium pressure agglomeration).
a: reciprocating piston extrusion press
b: screw extruder
c: flat die pelleting machine
d-f: roller pelleting machines
g: gear pelleter

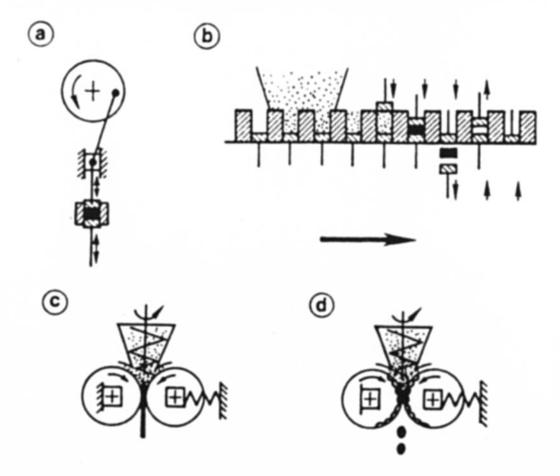


Figure 5: Schematic representation of high force pressure agglomeration equipment.

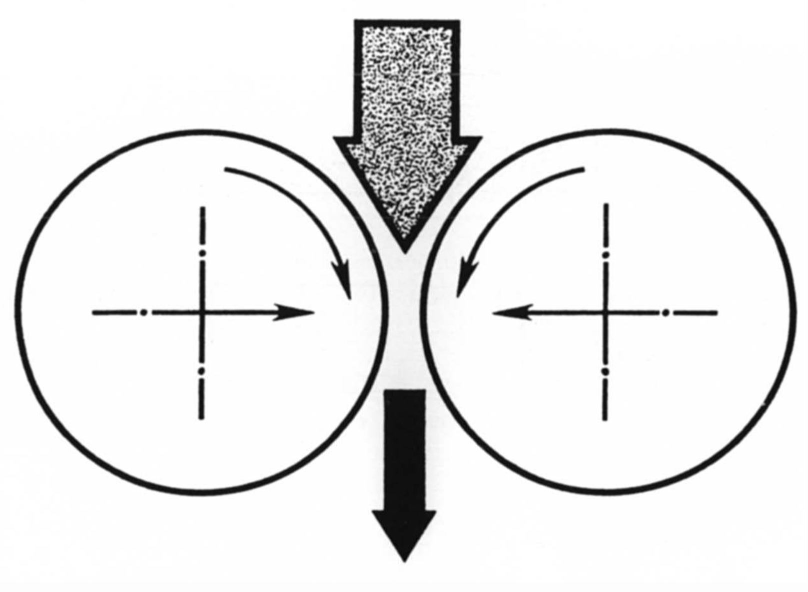


Figure 6: The principle of roller compaction.

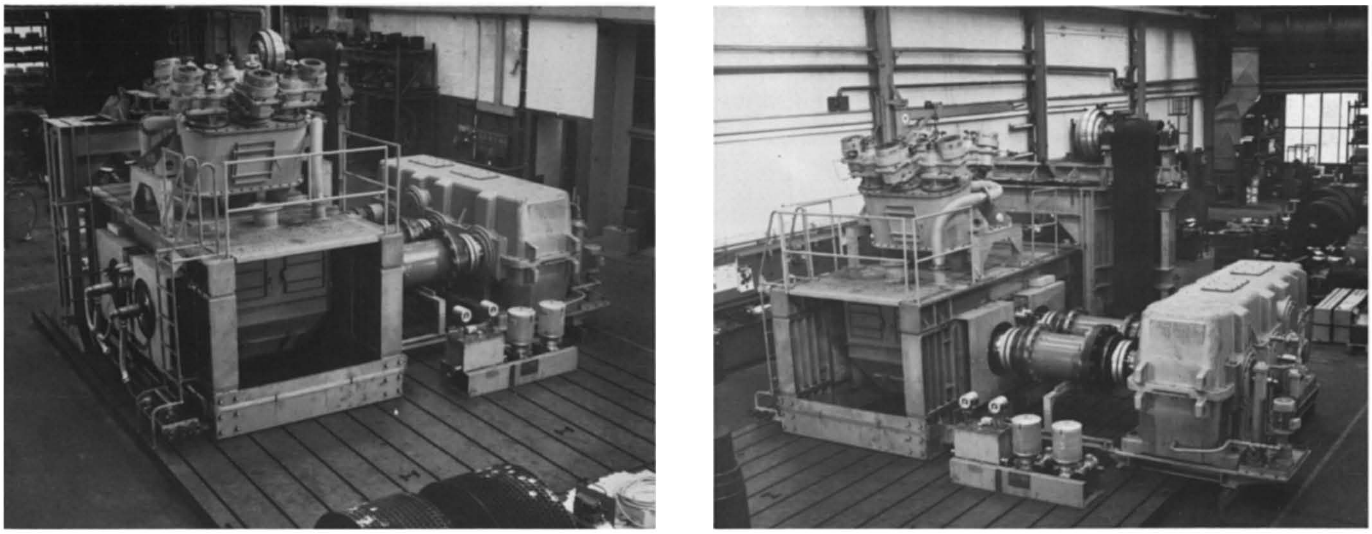


Figure 7: Photographs of one of the largest available roller presses for fertilizer compaction in the assembly bay of Maschinenfabrik KÖPPERN, Hattingen|Ruhr, W.-Germany.

waffled sheet 14 to 16mm thick. The actual capacity depends on the characteristics of the material to be compacted. For example, this machine can handle more than 100 t/h[4] of potash, while in the case of urea based mixed fertilizers a typical throughput would be 60 t/h.

Of course, machines with rollers of smaller diameter and width, at least one screw or a gravity feeder, varying force ratings, as well as adjustable roller speed and sheet thickness, are available for lower plant capacities. However, they all use the same modern design principles which include heavy, fabricated frames of proprietory design incorporating a hydraulic pressurizing system for the floating roller, self-aligning roller bearings with automatic grease lubrication, double output shaft gear reducer, and flexible geartooth couplings with spacers to allow horizontal displacement of the rollers in the frame. The roller cores with integral bearing and drive shaft journals are machined from high strength steel forgings. The pressing tools, rings or segments, are fastened to the cores by different methods which include shrink fit or clamp rings with and without keys. The moulds are machined into the pressing tools by cutting, milling, grinding or ECM (electrochemical milling). Optional machine features include water cooling of the rollers and of other vital parts of the press, roller housings e.g. for dust containment, and electrical control units designed for different operating conditions.

GRANULATING EQUIPMENT

In the present context, granulation means the production of granular material by crushing and grinding. The compacted material is broken by suitable equipment, whereby the yield of material in a particular size range is of utmost importance because, in most cases, the percentage of granular product within specification determines whether or not such a plant is a commercial success.

Crushing and grinding of an agglomerated (compacted) material and its optimization is different from the size reduction of a uniform solid. By nature, the compacted sheet has differently densified zones with variable strength. Also, depending on the material, it may have different characteristics. Some products, like potash, feature high strength and brittle behaviour almost instantaneously, while many other fertilizers, like NPK formulations containing phosphates, urea or organic components, form soft and plastic sheets which harden during storage. Therefore, to obtain the highest possible yield of a narrow product size distribution (e.g. 1 – 3.3mm) different crushing methods and equipment must be selected.

Since, at the same time, the granular fertilizer must not produce excessive fines during multiple handling, storage, and shipping, as well as during the application in the field, in all those cases where the compacted sheet exhibits high strength and brittle behaviour, a severe stressing should be applied which destroys all softer parts of the agglomerate. This is accomplished by impact crushing. If the compacted material is soft and/or plastic, other mill designs must be used as roller mills with fluted rollers, matching or staggered discs, and pins of different shape and distribution. Because during crushing and grinding, the amount of fines which must be recirculated should be as small as possible and the shape of the product particles should be spherical or cubic as nearly as practicable, the selection and optimization of the granulating equipment is very critical for each fertilizer compaction/granulation plant. To improve the yield, in most cases, two or more stages of granulation are being employed.

ASSOCIATED PLANT EQUIPMENT

Among the associated plant equipment, the screens are of particular importance, because they do, to a large extent, determine the actual yield and the quality of the product. Screens must be selected such that they separate as accurately as possible with virtually no product left in the screen oversize and no fines remaining in the product. To accomplish this, multistage screening is often applied and screens with vibrating frames or housings have recently been replaced by equipment in which the screen cloth is directly excited by high frequency vibrators. A large amount of the high energy input during compaction is converted into latent heat which causes many fertilizers to become plastic and sticky. These materials clog screens, stick to material handling equipment, and exhibit extremely unfavourable flow characteristics. Such properties or other problem conditions must be recognized and considered during plant design. Because, in most of these cases, a complete theoretical treatment of the process related problems is not possible, they can only be solved by suitable test or pilot work and/or through experience. The latter also teaches that each individual plant design must be adapted to the particular fertilizer composition and the local conditions. However, it is a particular advantage of fertilizer compaction/granulation systems that a large number of parameters can be altered thus allowing successful treatment of a wide variety of mixtures.

PLANT FLOW-SHEETS

Because a generalized recommendation for the optimal flow-sheet of fertilizer compaction/granulation plants is not possible, two examples shall be presented. Figure 8 is a typical flowsheet of compaction/granulation plants for materials which reach almost final strength instantaneously such as potash. In this case impact mills destroy all softer parts of the compacted material and a strong, highly abrasion resistant product is obtained.

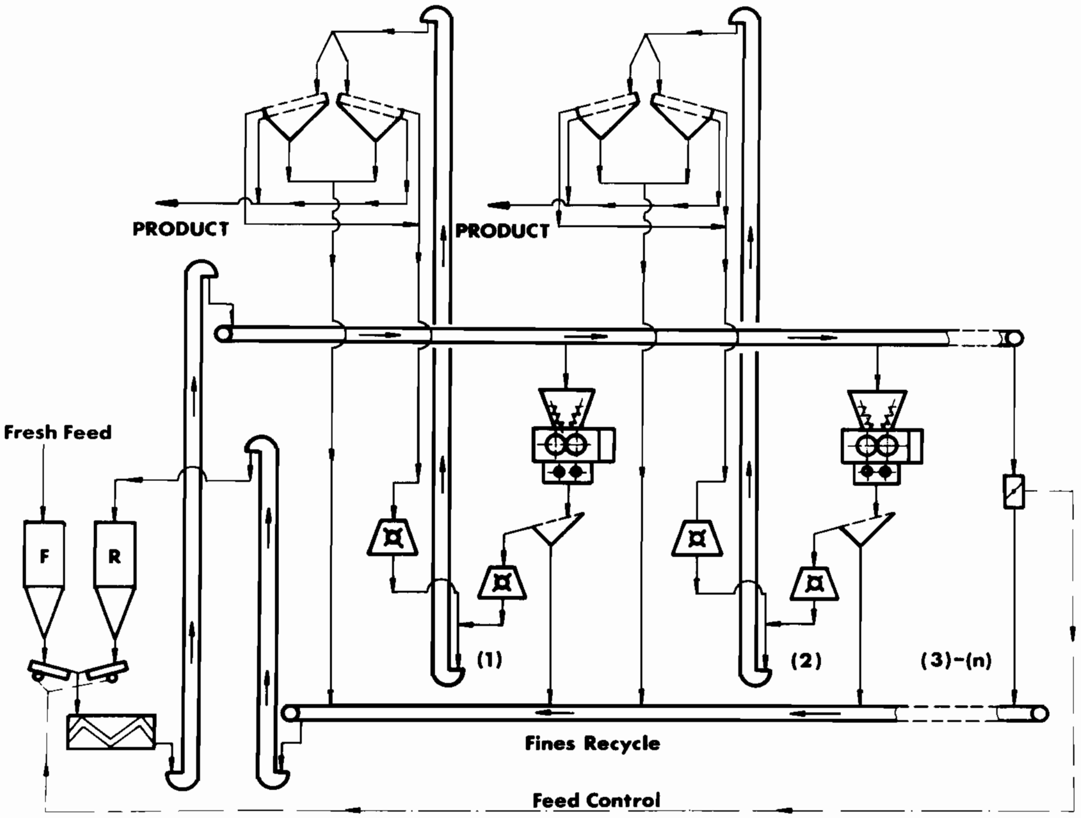


Figure 8: Typical flow-sheet of a potash compaction|granulation plant.

Figure 9, on the other hand, depicts the flow-sheet of a plant for the compaction/granulation of fertilizer mixtures producing soft sheets which must be broken and handled delicately to obtain an acceptable yield of granular product. Such materials gain final strength during a subsequent curing operation or during storage. The granulators in such plants are usually disc type mills which cut, bend or shear the sheets rather than stress them at high energy levels.

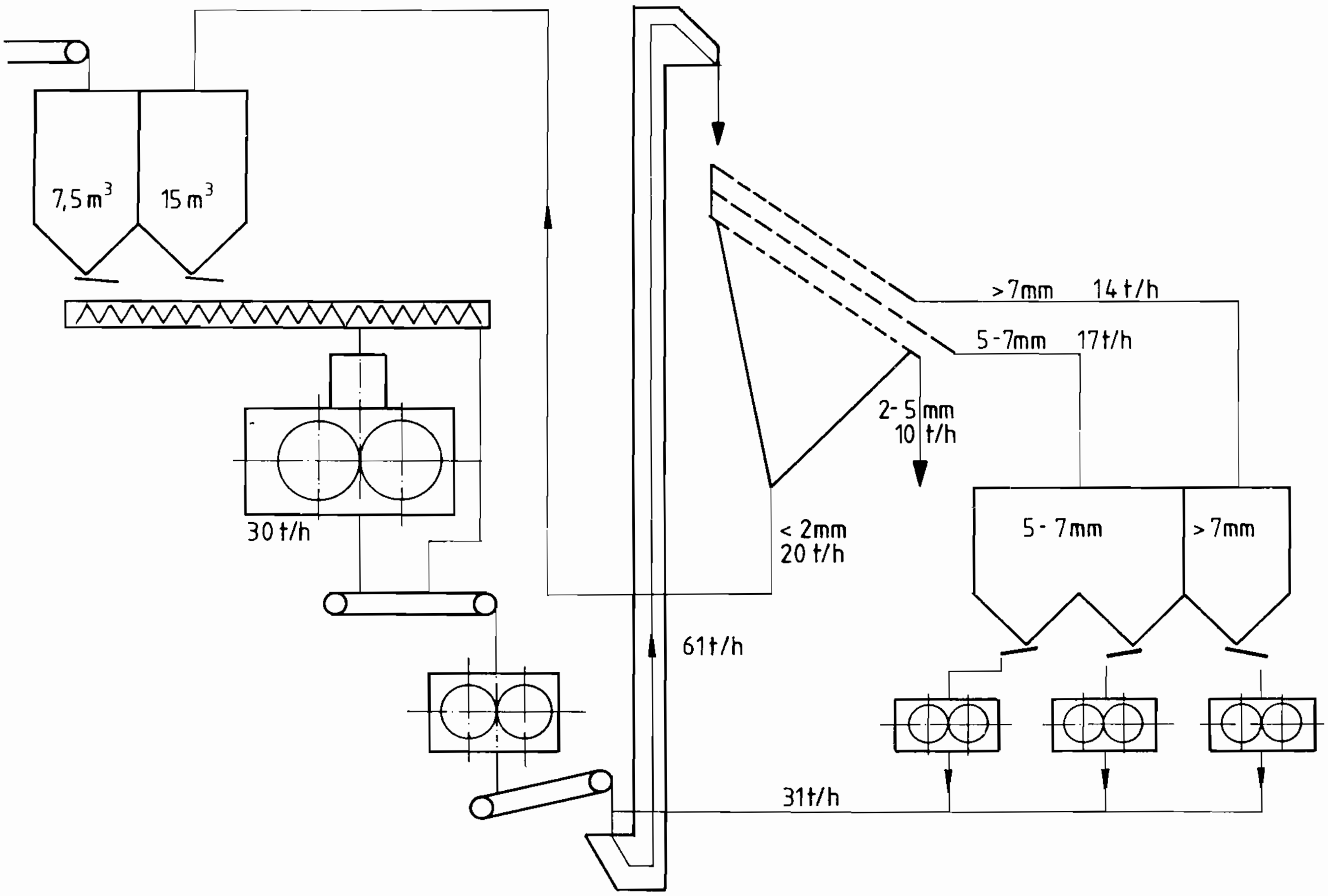
Figure 10 is reproduced with the friendly permission of Südchemie AG, München, W.-Germany. It shows an installation at their Kehlheim/Donau works corresponding essentially to the flow sheet in Figure 9. The plant is located in the fertilizer storage shed (left). In the foreground the roller type compactor is visible which is fed from the surge bin on the extreme right receiving freshly mixed and recirculating undersized materials. The crushing, screening, and material handling parts of the system are located in the center background.

APPLICATIONS

The compaction of fertilizers can be applied in a number of ways. Figure 11 depicts schematically the simplified flow-sheets of the most important applications.

Figure 11 A represents compaction/granulation as a separate system (see also Fig. 3). It can be designed as a small regional facility for the production of, say, 5 to 50 t/d of special granular mixed fertilizers, operating during one or more shifts, and supplying a wide variety of formulations. An example would be the plant shown in Figures 9 and 10 which is capable of producing up to 10 t/h of granular multicomponent fertilizers. The system can also be designed as a large central facility with, potentially, several parallel trains, each incorporating large equipment, multi-stage crushing and screening having a production capability of up to 50 t/h of granular fertilizers. For example, using the equipment shown in Figure 7 and the flow-sheet of Figure 8, each train

Figure 9: Flow-sheet of a mixed fertilizer compaction/granulation plant.



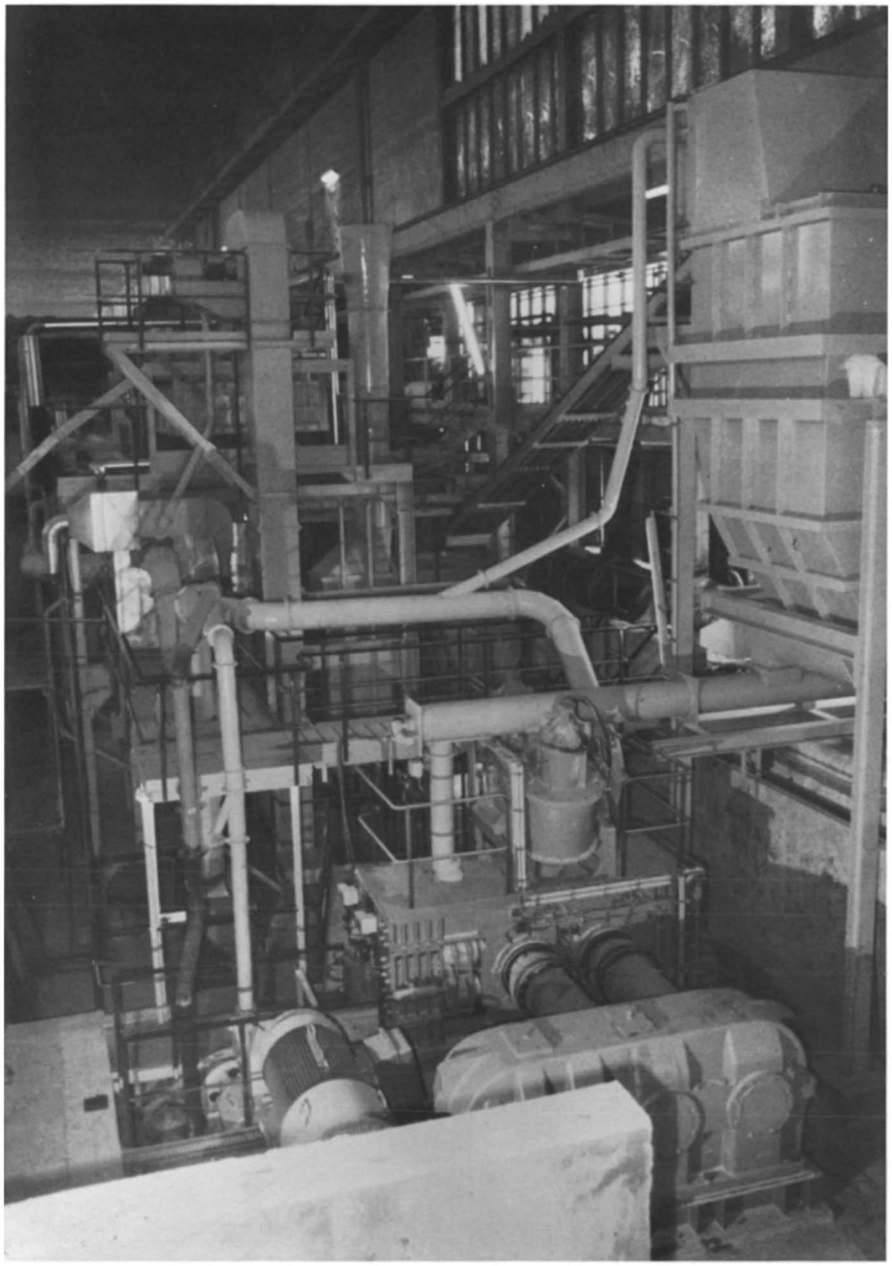


Figure 10: Photograph of a mixed fertilizer compaction|granulation plant (Courtesy of Südchemie AG, München|Kehlheim, W.-Germany).

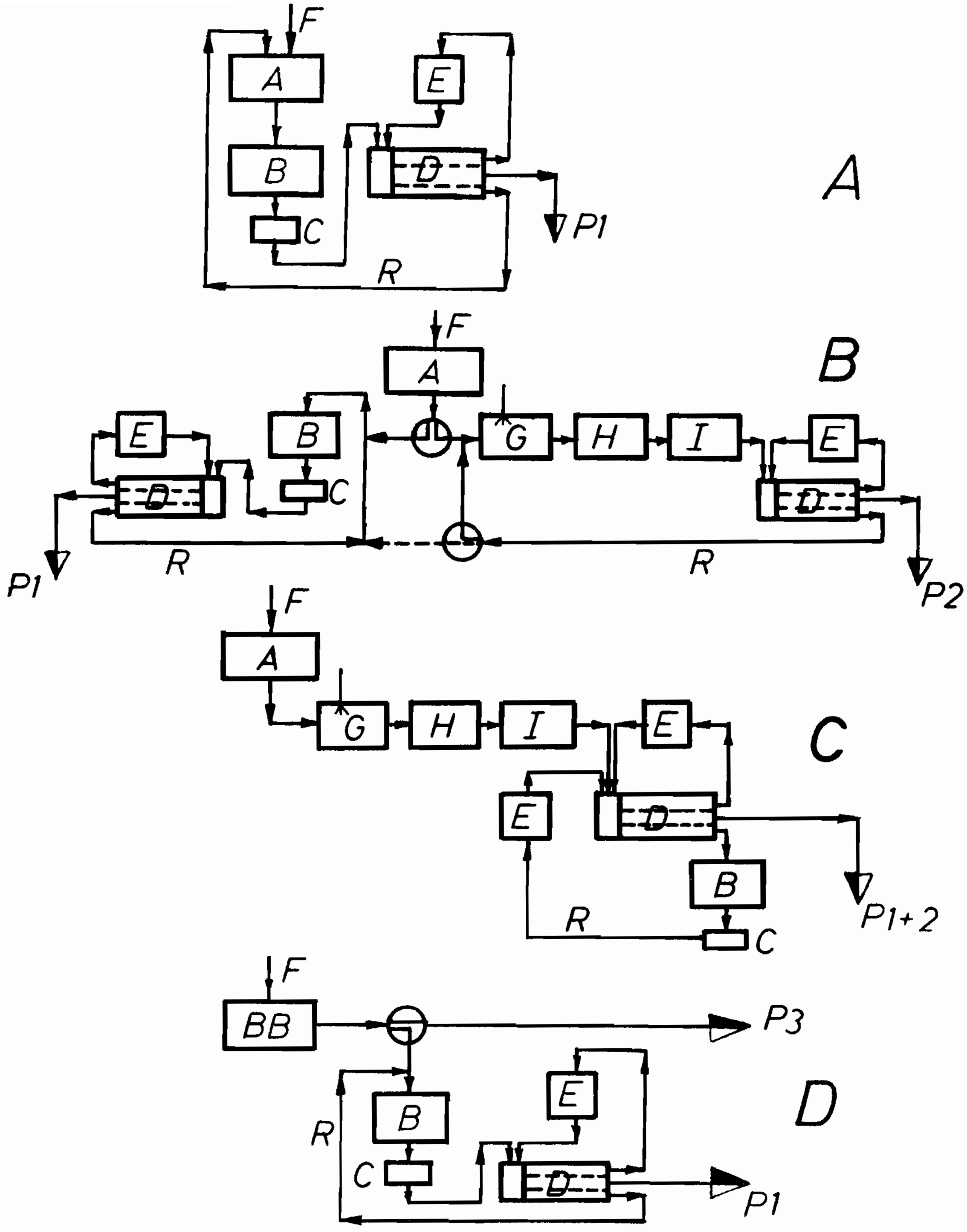


Figure 11: Schematic representation of different applications of fertilizer compaction|granulation.
A: Mixer, B: Compactor, C: Flake-Breaker, D: Screen(s),
E: Crusher(s), G: Wet Granulator, H: Dryer, I: Cooler,

F: Feed-Materials, P: Product(s), R: Recycle,
BB: Bulk-Blending.

can produce up to 60 t/h of granular potash, while the same system using narrower rollers (e.g. 900 – 1,000mm, four screw feeders) to allow the use of higher specific pressing forces (which are required for some fertilizer components) and a modified flow-sheet (as compared with Figures 8 and 9) may produce up to 40 t/h of granular mixed fertilizer.

With the exception of a few theoretically interesting fertilizer formulations which must be excluded because the components react chemically if brought in intimate contact, almost all combinations of nutrient, micronutrient, and filler/conditioner raw materials can be compacted. Some components, which tend to softening and sticking if used in too large amounts, must be limited to an acceptable level. For example, urea should be maintained below 30-40 percent in most formulations to avoid handling problems and produce a product with good physical characteristics. Even fertilizer raw materials such as ground basic (Thomas) slag can be compacted with e.g. 30 percent of potash as a "binder" and dried digested municipal sludge can be converted into a high quality granular product suitable for fertilizer applications.

Figures 11 B, C and D show applications of compaction in connection with other fertilizer technologies. Figure 11 B indicates that, by adding a compaction/granulation system to an existing "conventional" wet granulation plant and connecting it after the raw material mixer, the operator can choose to use either system, depending on the material characteristics and the energy requirements. If no waste energy is available for use in the wet granulation plant, in most cases, compaction/granulation would be the preferred route from a cost point of view. The dotted line indicates the possibility shown simplified in Figure 11 C whereby the recirculating fines from the wet granulation plant are fed into a suitably sized compaction/granulation system for granulation at lower energy levels. Experience showed that the recycle from a wet granulation plant is an excellent feed for compaction producing a high quality granular product. While the flow-sheet of Figure 11 B (dotted line) produces two products of identical formulation but slightly different shape (Product 2 also contains crushed and, therefore, irregular particles), due to the common use of the product screen C, the product from the plant depicted in Figure 11 C is a mixture from both agglomeration systems. Finally, Figure 11 D shows a compaction/granulation system connected with a bulk blending facility whereby those fertilizers which tend to segregation after bulk blending can be "fixed" by low cost agglomeration.

CONCLUSION

While most operating fertilizer granulation plants still use wet agglomeration methods for the production of more or less spherical particles, the compaction/granulation process offers a number of advantages. The most important are:

—Low energy consumption

—No liquid binder required

—Applicable for a wide range of feed particle sizes

—Flexibility regarding composition of feed

—Applicability for all capacities, large and small

—Possibility to operate shifts.

While, often, the users of granulated fertilizers express concern about the irregular particle shape of compacted fertilizers, a comprehensive study[5] showed that granular fertilizers fulfilling the requirements of:

—sufficient strength

—no caking

—large enough particle size with little or no dust

—free flow

—narrow particle size distribution

can be distributed uniformly over a wide distance by conventional rotary disc spreaders. Particle shape did not have an influence on these results.

For these reasons, the compaction/granulation technology for fertilizers attract considerable interest for a large number of new plants in many countries.

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Nitrophosphate—Technology and Economics

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INTRODUCTION

The nitrophosphate—or Odda process—is a process where nitric acid is used exclusively for the dissolution of the phosphate rock in order to produce a complex fertilizer (NP/NPK).

A characteristic feature of the process is the removal of calcium by crystallization of calcium nitrate tetrahydrate.

From its inception in the thirties, the process has gained wide-spread acceptance, particularly in Europe. In the U.S., surprisingly, it has never attained much popularity.

Norsk Hydro has become a technology leader in this field. The company operates three plants in Norway and its technology has during the last 15 years been included in a total of 13 other plants located in different parts of the world.

With these plants in full operation, the total production volume would be about 10 mill. tons per year complex fertilizer or 1.35 mill. tons expressed as P_2O_5. This corresponds to about 11% of the estimated world production of complex fertilizer. This is a remarkable increase from the figure of 1.5% in 1967, when the licensing activity started.

There are several reasons for this substantial gain of market share by the nitrophosphate technology:

—Independence of sulphur.

—High raw materials flexibility and efficiency.

—High energy efficiency

—A process adapted to to-day's strict environmental requirements (a "closed loop" process).

—A process without by-product deposition problems.

With increasing concern about pollution all over the world, and with increasing demand on raw materials utilization to meet the increasing need for fertilizer, these features will certainly be in focus also in the future.

Thus, it may be of interest to review the technological and economic status of the Odda process.

PROCESS PRINCIPLES

Phosphate rock is reacted with nitric acid to form phosphoric acid and soluble calcium nitrate:

$$3\ Ca_3(PO_4)_2 \cdot CaF_2 + (20 \quad + X)HNO_3 \rightarrow$$
$$6\ H_3PO_4 + 10\ Ca(NO_3)_2 + 2HF + XHNO_3$$

Other cations in the rock, such as aluminum, iron and magnesium, are also converted to nitrates.

After removing the major part of the calcium (about 85%) as calcium nitrate tetrahydrate by crystallization/filtration, the remaining solution (mother liquor) is neutralized with ammonia.

The main reactions are:

$$HNO_3 + NH_3 \rightarrow NH_4NO_3$$
$$H_3PO_4 + NH_3 \rightarrow NH_4H_2PO_4$$
$$H_3PO_4 + 2NH_3 \rightarrow (NH_4)_2HPO_4$$
$$Ca(NO_3)_2 + 2H_3PO_4 + 2HN_3 \rightarrow Ca(H_2PO_4)_2 + 2NH_4NO_3$$
$$Ca(NO_3)_2 + H_3PO_4 + 2NH_3 \rightarrow CaHPO_4 + 2NH_4NO_3$$

One of the misconceptions prevailing about the nitrophosphate process is that calcium nitrate is present in the products. As shown by the equations, any calcium iones present in the mother liquor will be completely converted into mono- and dicalcium phosphates.

The calcium nitrate tetrahydrate filtered off may be converted to ammonium nitrate with ammonia and carbon dioxide from an adjacent ammonia plant.

Through a first stage where ammonium carbonate is formed:

$$CO_{2(g)} + 2\ NH_{3(g)} + H_2O_{(liq)} \rightarrow (NH_4)_2CO_{3(aq)}$$

The second step completes the conversion:

$$Ca(NO_3)_{2(aq)} + (NH_4)_2\ CO_{3(aq)} \rightarrow$$
$$CaCO_{3(s)} + 2\ NH_4NO_{3(aq)}$$

Any free nitric acid in the calcium nitrate will be reacted to ammonium nitrate.

Thus, by reacting phosphate rock with nitric acid, and using ammonia and carbon dioxide, the major products from the nitrophosphate process are ammonium phosphates, ammonium nitrate and some calcium phosophates.

Instead of the phosphogypsum as by-product, this process will give calcium carbonate which has many applications.

The nitrophosphate route will have an overall output of about twice as much nitrogen as of P_2O_5. This means, if all ammonium nitrate from the conversion of calcium nitrate is included in the NP product, the resulting grade would be 28-14.

NORSK HYDRO'S NITROPHOSPHATE PROCESS

Process Description

A simplified process scheme is shown in Appendix 1. In the digestion step 60% nitric acid is used to dissolve phosphate rock. If wet rock is used, a concentration of about 65% nitric acid is needed. This concentration can be obtained at a marginal increase in investment in a nitric acid plant.

The digestion takes place at 55-65°C and the rate of dissolution is high. Additional grinding of commercial rocks is not necessary.

Only small amounts of fluorine (1-2% of the amount present in the rock) is released during digestion and can easily be absorbed in a conventional packed scrubber.

The NOX-fume can be treated in two or more consecutive scrubbers to meet required pollution levels. The scrubbing equipment can be simplified significantly if urea is added to the digestion step, thus suppressing the formation of nitrogen oxides (Ref. 1).

Essentially all P_2O_5 in the rock is dissolved in the digestion liquor.

The digestion liquor normally passes directly to the crystallization step. If the rock contains large amounts of acid insoluble materials, these may, if desired, be removed by installing hydro-cyclones. The underflow from these cyclones is washed with water in a simple wash drum. The sand is discharged as essentially dry material containing only traces of nutrients.

By cooling of the digestion liquor, the calcium nitrate tetrahydrate crystallizes out and is subsequently filtered off. By cooling to a temperature of about -5°C, approximately 85% of the calcium is removed.

The cooling medium is a 20% ammonia-water solution. This solution is cooled by ammonia evaporation. The gaseous ammonia is utilized to neutralize the mother liquor and as feed to the conversion unit.

Thus, about 75% of the regular cooling requirement can be supplied directly by ammonia evaporation, leaving some 25% to be covered by an additional cooling unit.

Norsk Hydro uses batch type crystallizers with indirect cooling. This design gives large and uniform crystals in the cooled suspension. The batches are operated sequentially to meet the otherwise continuous process.

The cooling medium flows from the refrigeration unit to the one crystallizer being in the most advanced stage of cooling and then successively through each crystallizer towards the warmest unit.

The filling/dumping of each batch as well as the on/off-control of the cooling medium are completely automatic.

The calcium nitrate tetrahydrate is separated employing two-stage rotating drum filters. The mother liquor is sucked off from the first stage and the crystal cake washed with nitric acid and water in the second stage. These filters are robust and sturdy equipment not exposed to the erosion problems experienced when using centrifuges for the same service. The filters can tolerate that phosphates with (at least) 5-6% acid insoluble material is processed without sand separation equipment installed.

The mother liquor, being essentially phosphoric acid plus small amounts of free nitric acid and calcium nitrate, is neutralized with gaseous ammonia.

The heat of neutralization results in a substantial evaporation of water. The addition of ammonia is controlled by automatic pH-measurement.

The water content of the neutralized liquor is further reduced to 0.5% by evaporation. Removal of water from a liquid phase requires much less input of energy than if the same amount of water is to be removed by drying of solid granules. Norsk Hydro does not use the air-swept-type evaporators, and subsequent treatment of the ammonia-containing vapors can be made at low investment cost.

The essentially water-free melt is mixed with potassium salt (and micronutrients) in a specifically constructed mixer where recycle material is also introduced. The suspension is fed to a perforated rotating basket located on top of the prill tower. The droplets solidify in the counter-current flow of air in the tower. This process gives prills with an average diameter of approx. 2.5 mm. More than 90% of the prills are within the product size range of 1.4-4.0 mm. Thus only 10% needs to be recycled to the mixer.

No further drying of the prills is needed. From the tower they pass through screening (with crushing of oversize), before the on-size material is cooled and coated.

Some NPK-product compositions require more potassium salt than can be accepted in order to keep the fluidity of the melt at a level which permits prilling. For such products granulation will be chosen. The pug-mill version is favored. The water content in the melt entering the granulator may be as low as about 1.5%, substantially reducing the recycle requirement in the process.

The calcium nitrate tetrahydrate is in most cases converted to calcium carbonate and ammonium nitrate solution.

The calcium carbonate is filtered off and washed with water using conventional filters.

The 60% ammonium nitrate solution is evaporated in multiple-effect evaporators.

Part of the evaporated ammonium nitrate solution may be returned to the neutralization section to increase the N/P_2O_5-ratio in the complex fertilizer.

Any excess ammonium nitrate can be processed into solid granules. Norsk Hydro has developed its own granulation process—the Norsk Hydro high temperature pan granulation process. (Ref. 2). A simplified process diagram is shown in Appendix 2.

Product Description

The major components in the product are:

—Mono Ammonium Phosphate

—Diammonium Phosphate

—Mono Calcium Phosphate

—Dicalcium Phosphate

—Ammonium Nitrate

—Calcium Fluoride

—Iron/Aluminium/Magnesium Phosphates

The water-solubility of the P_2O_5 in the product will be in the range of 85-90%, while the citrate solubility will be essentially 100%.

Using the regular nitrophosphate route, the lowest possible N/P_2O_5-ratio obtainable, is about 0.5, corresponding to a 16-32-0-grade. There are no limitations as to high N/P_2O_5-ratios. Above a ratio of 2, ammonium nitrate from external sources must be added.

Distribution of fertilizers in bulk has increased dramatically in the last 10 years (Ref. 3).

For such transportation, the following product properties are of particular importance:

—Mechanical strength

—Caking tendency

—Hygroscopicity

—Dusting tendency

The mechanical strength of the prilled NP/NPK, as shown in Appendix 3, is well above 3 kg. Dust formation would thus be minimal, even if the granules absorb up to 1% moisture.

Efficient anti-cake materials, Appendix 4, ensure free-flowing conditions in the bulk storage areas.

These anti-caking materials give low dust levels, Appendix 5, and bulk handling can thus be accepted by port authorities.

AGRONOMIC CHARACTERISTICS OF NITROPHOSPHATE FERTILIZERS

The nitrophosphate fertilizer has typically 55% of the nitrogen as NH_4-N and 45% as NO_3-N. Such a split is preferable to a pure ammoniacal N-component whenever the fertilizer is applied on the surface in the field. Due to fixation by the soil, NH_4 becomes resistant to leaching even under heavy rainfall or irrigation. Through the process of nitrification in the soil, it becomes available as plantfood later in the growing season. Thus NH_4 takes over after NO_3 in plant-feeding and an important "longer term" nitrogen requirement of many crops is satisfied.

It has been fairly well established that the efficiency of the two nitrogen forms are more or less equal when the fertilizer material is mixed with well-drained soil.

The NO_3-content of the split component is advantageous in fertilizing systems involving top dressing and especially on grassland and soils with rather high pH, because the volatilization loss of nitrogen from a split component is lower than from a pure ammoniacal component. This is of particular importance under dry weather conditions.

All P_2O_5 in the nitrophosphate fertilizer is citrate soluble, and between 85-90% is water soluble. The fertilizer will therefore have a definite advantage in soils with a high pH, where water soluble phosphates perform better than non-water soluble phosphates. It appears to be a general agreement among research workers as to the superiority of high water soluble P_2O_5 on soils with a high pH, low P_2O_5-content and when short duration crops are grown.

When soil pH decreases, the difference in agronomic effectiveness between phosphates of varying water solubility tends to be less noticeable. Increasing phosphorus content in the soil will have the same effect. On very acid soils, and especially where long duration crops are grown, the citrate soluble phosphate sources may be as good as the water soluble ones.

The two universally used potassium forms are muriate of potash (KC1) and sulphate of potash (K_2SO_4) and these are also the forms of potash added to the nitrophosphate fertilizer. Whichever NP or NPK ratio chosen, it is easy to meet soil and crop requirements.

The agronomic aspects of nitrophosphate fertilizers are described in detail in Ref. 4.

RECENT CHALLENGES TO THE NITROPHOSPHATE TECHNOLOGY

Conversion of calcium nitrate

Until the early sixties, the calcium nitrate tetrahydrate was processed into nitrate of lime fertilizer. Due to lower demand for this product, Norsk Hydro developed its own process for converting the calcium nitrate to ammonium nitrate and calcium carbonate.

Contrary to other versions of this process, (Ref. 5) the reaction of ammonia and carbon dioxide to ammonia carbonate, and the subsequent precipitation of calcium carbonate, take place in two different units (Appendix 1). In this way, scaling problems, with frequent need for cleaning, are avoided.

The by-product calcium carbonate is a product with many applications. At our plant site in Porsgrunn, it is picked up by the farmers in the region and used as a soil improvement agent. Compared to natural limestone, dustfree handling is obtained, because the carbonate is transported and spread on the farmland while containing about 10% moisture ("snowball-consistency"). It also dissolves rapidly due to the fineness (50-80 micron) and loose crystal structure of the particles.

Tests have shown that $CaCO_3$ by-product can be utilized as neutralizing agent for the pulp industry and as supplementary feed to the cement industry.

Through additional processing, phosphorous and fluorine in the calcium nitrate tetrahydrate can be precipitated and removed. From this refined calcium nitrate, calcium carbonate of high quality can be made.

After grinded to a size range of 1-5 micron, its use as filler in areas like plastics and rubber, and as a paper coating agent, has been demonstrated (Ref. 6).

The calcium carbonate can also be dried and mixed with the ammonium nitrate to produce ammonium nitrate of lime fertilizer. In Hungary (Norsk Hydro technology) a 1200 MTPD plant producing 27% N CAN is in operation.

Phosphate Rock Flexibility

For a long period of time, the indigenous Kola rock was almost exclusively the raw material for the Norsk Hydro Nitrophosphate Process.

In later years, Kola rock has become scarce, and the process has been adapted to a variety of commercial rocks.

The following rocks have been used in our plants:

—Calcined/Uncalcined Florida Rocks from different mines

—Calcined/Uncalcined Morocco

—Calcined/Uncalcined Israel

—Calcined Texas Gulf Sulphur

—Gränges and LKAB Rock from Sweden

—Taiba and Togo Rock

—Algerian Rock

Other commercial grades have been tested in our pilot unit and have given satisfactory results:

—Jordanian Rock

—Tunisian Rock

—Brasilian Rocks (Araxa, Goyas)

A wide range of non-commercial rocks have also been tested and found acceptable. Some of these are listed below:

—Chinese Rocks from the Hubei and Yunnan provinces.

—Rajasthan Rock from a pilot plant benefication plant operated by Rajasthan State Mines and Minerals Ltd.

—Egyptian Rock.

—Indigenous Kovdor Rock from USSR.

The analyses of these rocks are listed in Appendix 6.

As can be seen from the Appendix 6, some rocks are of rather low grade quality. However, the impurities have not shown to influence most of the key process steps. The complete dissolution of P_2O_5 through use of nitric acid has been observed for all types of rock and the subsequent calcium nitrate crystallization behaviour and filtration rate are only influenced to a small degree.

The key process step for a phosphate rock with respect to its applicability is neutralization of the mother liquor. Here, a high content of magnesium, often combined with a high R203-level, can result in an unacceptable viscosity of the neutralized liquor.

Emission to Air and Water

Great efforts have been made to improve the abatement systems to meet increasingly stricter pollution regulations.

In the digestion step, addition of urea gives a drastic reduction in the NOX-level. As a result, the plant would release much less nitrous oxides than set forth as emission requirement for a nitric acid plant.

With the low level of fluorine release (1-2% of fluorine in the rock), a relatively simple scrubber installation brings the stack concentration well below normally required levels. The absorbed fluorine can also be conveniently returned to the process and follow the NPK-product as precipitated calcium fluoride.

With respect to air pollution, there is a quite different situation when prilling NP or NPK compared to prilling straight nitrogen fertilizers. The main difference is that the NPK, (which contains ammonium nitrate), is prilled at 140-150°C. Thus, the problem of haze formation is eliminated, and the particulate concentration in prill tower exhaust air is below 10 mg/Nm3.

Thus, no installation of fiber filter or other scrubbing devices is needed.

Through experience with equipment for recovery of dust as dry material, we have experienced a total particulate emission (including the prill tower), from the NPK-plant of less than 1 lb/ton product.

In the middle of 1970, the allowable figure for P_2O_5 in liquid effluents from Porsgrunn Works was drastically lowered. This meant an improved system had to be developed and installed in our largest nitrophosphate plant at that site. This system had to eliminate the liquid effluents coming from spills, leakages, floor washing, overflow etc.

Through a sump collection system combined with treatment of the collected flows, it is now possible to completely return the collected nutrients to the process (Appendix 7). The system produces its own "water" (e.g. a 7-8% ammonium nitrate solution) which is used as internal wash water in the plant. A bleed can be maintained since this "water" substitutes the regular process water previously used in different process steps.

At the Porsgrunn NPK-plant, the dry section of a plant can be incorporated in this system if necessary. This meant a separate collection system for an area with chlorine. The water containing chlorine is then bled into the chlorine-free system at a low rate controlled by automatic chlorine analysis.

The only liquid effluent from the plant would then be in the form of stripped condensate. This condensate, free of P_2O_5, would contain 100-200 ppm ammonia, which would normally be an acceptable level.

Energy Savings

Savings, particularly on steam requirement but also on electricity, have been essential parts of all fertilizer process news since the first energy crisis of 73/74.

In this area, the improvements in the nitrophosphate process have been significant.

The steam consumption in to-days process is only 75% of the previous level. One main contributor to this gain is the development of multiple effect ammonium nitrate evaporators for concentrating the solution from 60% up to 92%.

Another major reduction is obtained through the use of pressurized neutralization of the mother liquor. In this design, the released steam could be used to substitute process steam.

A lower water content is obtained in the neutralized liquor and is thus reducing the steam requirement. On electricity consumption, the prilling process presents very favourable figures due to the low recycle ratio and because scrubbing of prill tower air is not necessary. A consumption of 15-20 kWh/ton is typical.

NEW DEVELOPMENTS

Traditionally, the nitrophosphate has been a process for products high in nitrogen. However, through the systematic development, modifications have been obtained which give a new and broader range.

The development of the deep-cooling crystallization process gave, in particular, new opportunities to utilize the Odda-process for production of phosphoric acid and phosphate (Ref. 6).

The new process may conveniently be divided into two parts:

- —Production of Ca-containing phosphoric acid from mother liquor.
- —Production of calcium phosphates (animal feed grade quality) from Ca-containing phosphoric acid and $CaCO_3$.

The calcium-containing phosphoric acid is a suitable raw material to NPK products with N/P_2O_5-ratios lower than the 0.5 obtained from the straight nitrophosphate process route.

In the production of animal feed grade phosphates, it is necessary to remove practically all the nitrates and fluorides in the mother liquor. Thus, process steps have been developed for:

- —Removal of F-containing sludge by centrifugation.
- —Removal of nitrates and fluorides by evaporation.
- —Recovery and concentration of nitric acid (which then is returned to the front end of the nitrophosphate process).

Norsk Hydro has demonstrated these processes in semi-works built in conjunction with one of the NPK-plants at Porsgrunn works.

Furthermore, the granulation where Ca-containing phosphoric acid is reacted with finely ground $CaCO_3$ from the conversion to yield mono- or dicalcium phosphate has been demonstrated.

Thus, a process route has been established for the production of feed-grade phosphates which is independent on the sulphur-based production of phosphoric acid.

NORSK HYDRO'S NITROPHOSPHATE KNOW-HOW

Norsk Hydro started licensing of the nitrophosphate technology in 1967. Plants based on Norsk Hydro know-how are shown in Appendix 8.

PRODUCTION ECONOMICS

In the following, we have compared the cost of producing fertilizers via two different process routes. Appendix 9 and 10 show alternative routes to produce the same amount of P_2O_5, either via the nitrophosphate or via the urea ammonium phosphate route. In addition, the same amount of by-product nitrogen is also produced, either as ammonium nitrate in the nitrophosphate case, or as urea.

Energy Utilization

The single production units within such complexes should be integrated in a reasonable manner to allow for a maximum utilization of the combustion energies in raw materials (Ref. 7). The basis for the calculations are given in Appendix 11.

Such integration has been undertaken for the complexes described above, and the result is shown in Appendices 12 and 13. When these complexes generate their own steam and electricity demand within the battery limits, the total energy requirement, including the raw materials as energy carriers, would be 105.8 GJ per MT P_2O_5 for the nitrophosphate and 121.6 GJ per MT P_2O_5 for the sulphur based urea-ammoniumphosphate.

The difference in energy requirement is caused by two major reasons:

- —The lack of adequate utilization of low grade energy in the sulphuric acid plant leaves the combustion of sulphur as a process with non-optimal energy efficiency.
- —The requirement of high pressure steam in the urea process reduces possible electricity production and calls for additional natural gas input.

Variable Production Cost

Appendices 12 and 13 show the main components in the variable production costs for the two routes. (It should be recalled that each route produces the same amount of P_2O_5 and the same amount of by-product-nitrogen per ton P_2O_5):

NITROPHSOPHATE + AMMONIUM NITRATE BY-PRODUCT

	Consumption per MT P_2O_5	Unit Cost US $/MT	Cost US $/MT P_2O_5
Natural Gas	2182 Nm3 or 79.8 GJ	4 $/GJ	319.1
Phosphate Rock	3.32	25	83
Potassium Chloride	1.68	65	109.2
Platinum (for HNO3)		12	4.4
	Sum Main Variable Costs		515.7

UREA AMMONIUM PHOSPHATE + UREA BY-PRODUCT

	Consumption per MT P_2O_5	Unit Cost US $/MT	Cost US$/MT P_2O_5
Natural Gas	2282 Nm3 or 83.5 GJ	4 $/GJ	334
Sulphur	0.93	125	116.3
Phosphate Rock	3.58	25	89.5
Potassium Chloride	1.68	65	109.2
	Sum Main Variable Costs		649.0

Manpower requirements have been assumed to be the same in the two production routes.

Transportation Costs

Adjustments must be considered due to the difference in energy/cost for transportation of additional raw materials and increased amounts of products in the two process routes.

This has been done in Ref. 8. One finds, however, that these differences roughly balance each other out.

Investment Cost and Total Production Cost

Both schemes would require the same size ammonia plant of about 1000 MTPD.

A battery limit budget price estimate, including the ammonia plant, is approximately 180 mill. US$ for both complexes.

Thus, the capital-related interest, depreciation and maintenance costs would not influence the previously calculated 130 US$/MT P_2O_5 in lower production cost for the nitrophosphate route.

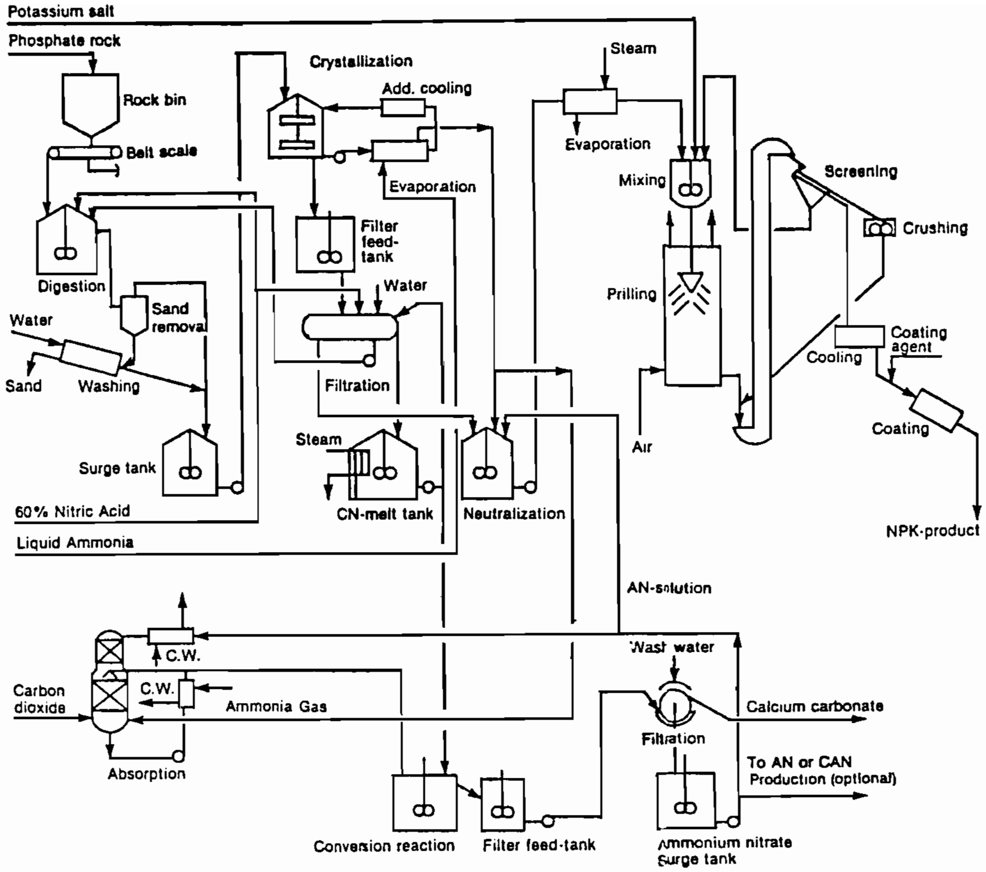
CONCLUSION

Through the development in recent years, the nitrophosphate process to-day is very competitive in the fertilizer production technology market.

The process has advantages in many areas, such as raw-material flexibility and efficiency, energy efficiency, its adaption to increasingly stricter environmental requirements and as a process without by-product disposal problems.

Being a process independent of sulphur, the production cost for the nitrophosophate products is considerably lower than for an alternative sulphur complex.

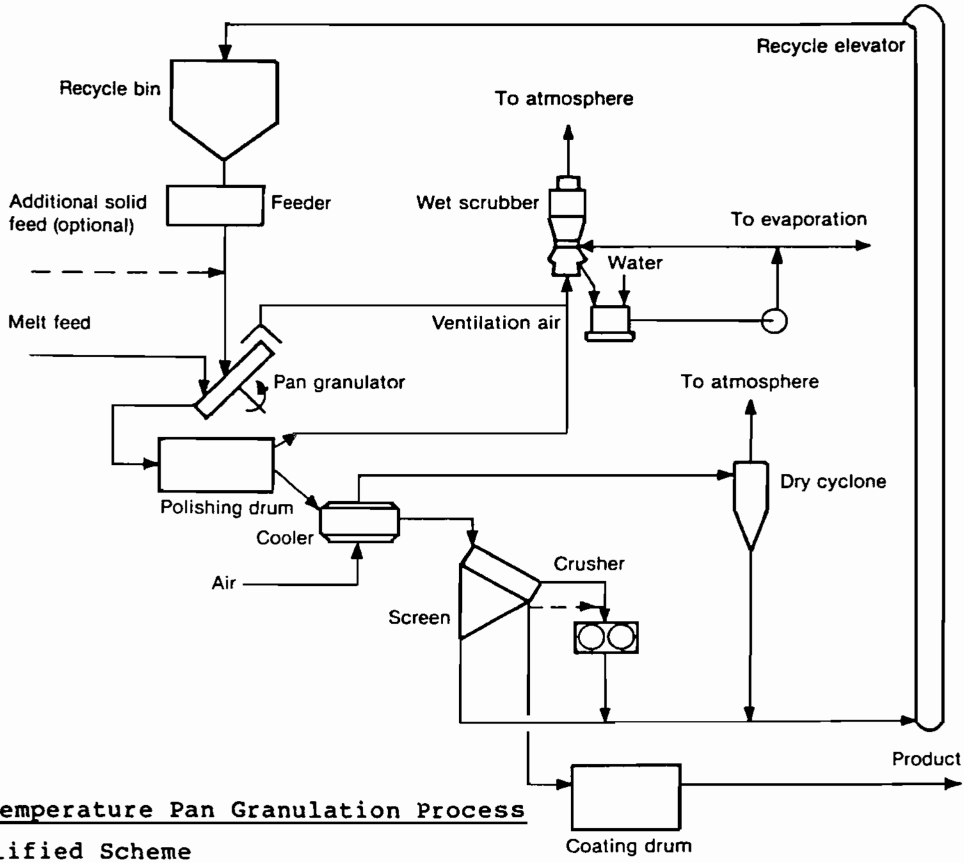
These factors, in my opinion, will lead to an increased use of the nitrophosphate technology in the future.



Norsk Hydro Nitrophosphate Process

Simplified Scheme

Appendix 1



Norsk Hydro High Temperature Pan Granulation Process

Simplified Scheme

Appendix 2

Appendix 3

Nitrophosphate Products

Particle strength of prilled NPK fertilizers

Fertilizer N-P_2O_5-K_2O	Crushing strength, kg.		Remarks
	With normal moisture content	After about 1% moisture absorption	
16-16-16	6.3	4.9	KCl-based
20-11-11	5.6	4.4	
21-9-12	3.9	3.1	
25-7-11	3.2	3.1	
14-9-9	6.9	5.7	
15-15-15	7.0	6.3	
15-9-15	6.0	5.6	K_2SO_4-based
21-16-17	5.6	4.0	
20-20	8.2	8.2	
23-23	7.4	7.3	
26-14	6.0	6.0	

The measurements are according to TVA's Special Report No. S-444, Sept. 1970, and measured for 2.5 mm diameter particles.

Appendix 4

Nitrophosphate Products

Caking Index for NPK with 0.5% H_2O

Anti-caking agent	Caking Index
Untreated product	1000
0.5% fatty amine	950
0.4% Kieselguhr	650
0.4% Kieselguhr + 0.05% fatty amine	300
0.4% Amorphous SiO_2	360
0.4% Amorphous SiO_2 + 0.05% fatty amine	170

Appendix 5

Nitrophosphate Products

Adherence Properties of different anticaking Agents

Powder	Dust—mg per kg NPK	
	Quantity 0.4%	Quantity 0.8%
Amorphous SiO_2	64	353
Kaolin	1790	5000
Kieselguhr	2730	5080
Talc 0000	1700	6550
Danish powdering chalk	1627	2135
Attacote	2680	4120

These results are from newly produced, prilled and dust-free NPK treated with 0.4% and 0.8% of some common anticaking powders.

Appendix 6

Analysis of Different Rocks Tested in Norsk Hydro Nitrophosphate Pilot Plant

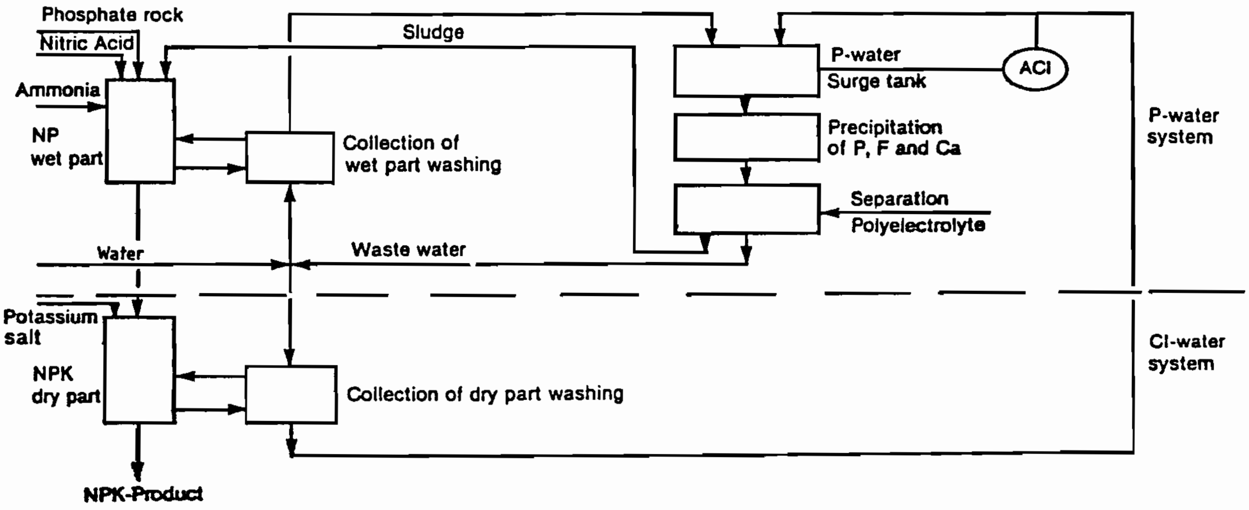
Chemical Composition on Dry Basis (% – w/w)

	China (Hubei)	China (Yunnan)	Rajasthan	Kovdor	Egypt El Sebaiya East
P_2O_5	31.8	31.1	35.6	39.2	23.8
CaO	45.2	45.5	51.1	54.3	43.1
Fe_2O_3	0.63	1.14	0.95	0.24	2.15
Al_2O_3	0.53	0.91	1.02	0.10	0.91
MgO	1.69	2.34	0.74	2.50	0.42
CO_2	3.7	4.7	2.60	1.94	7.9
Cl^-	0.02	0.02	0.008	0.015	0.14
F	2.92	3.00	3.24	1.02	2.57
Acid insoluble (in HNO_3)	11.4	7.9	6.8	1.4	14.0
Loss of ignition (800°C)	4.2	6.6	2.7	1.4	9.82

Norsk Hydro Nitrophosphate Process

Collection and Treatment System for Liquid Effluents

Principle Diagram



Appendix 8

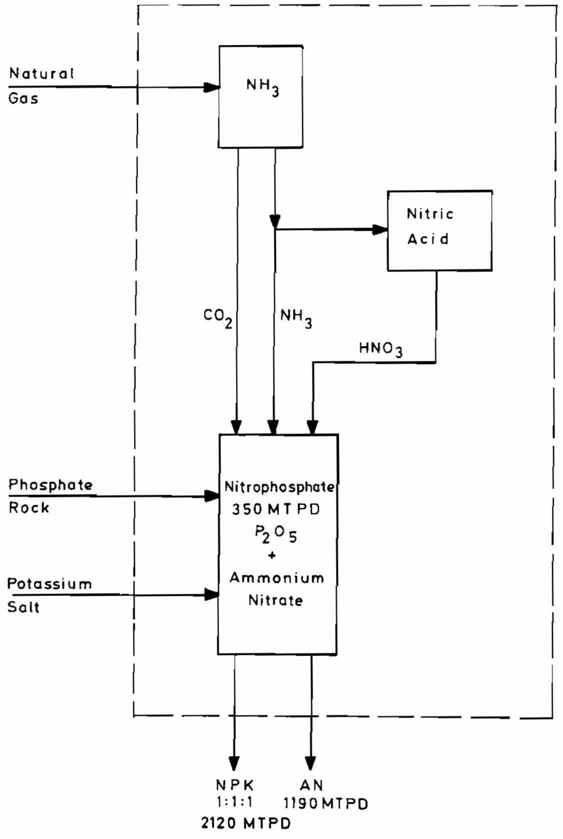
Complex Fertilizer Plants Using Norsk Hydro Technology

Country	Client	Location	Start up	Design capacity (product)	Finishing	Design formulation*	Products water sol.
Norway	Norsk Hydro	Porsgrunn	1967	2500 t/d	Prilling	22-11-11	80-85%
	Norsk Hydro	Porsgrunn	1970	1200 t/d	Prilling	22-11-11	80-85%
	Norsk Hydro	Glomfjord	1970	2000 t/d	Granulation	22-11-11	80-85%
U.S.	Farmers Chemical	North Carolina	1969	820 t/d	Prilling	15-15-15	60%
Hungary	Chemokomplex	Petfürdo	1976	2200 t/d	Prilling	22-11-11	85%
Romania	Romchim	Tirgu Mures	1975	2700 t/d	Prilling	22-11-11	85%
	Romchim	Craiova	1976	2700 t/d	Prilling	22-11-11	85%
	Romchim	Turnu Magurele	1976	2700 t/d	Prilling	22-11-11	85%
	Romchim	Arad	1977	2700 t/d	Prilling	22-11-11	85%
USSR	Techmashimport	Novgorod	1982	1850 t/d	Prilling	16.5-16.5-16.5	85%
	Techmashimport	Novgorod	1983	1850 t/d	Prilling	16.5-16.5-16.5	85%
	Techmashimport	Dorgobuzh	1984	1850 t/d	Prilling	16.5-16.5-16.5	85%
	Techmashimport	Pridonsk	1984	1850 t/d	Prilling	16.5-16.5-16.5	85%
	Techmashimport	Pridonsk	1984	1850 t/d	Prilling	16.5-16.5-16.5	85%
China	China National Technical Import Corp. (CNTIC)		1987	2970 t/d	Granulation	27-13-0	70%

*Most plants can produce other formulations as well as 16.5-16.5-16.5, etc.

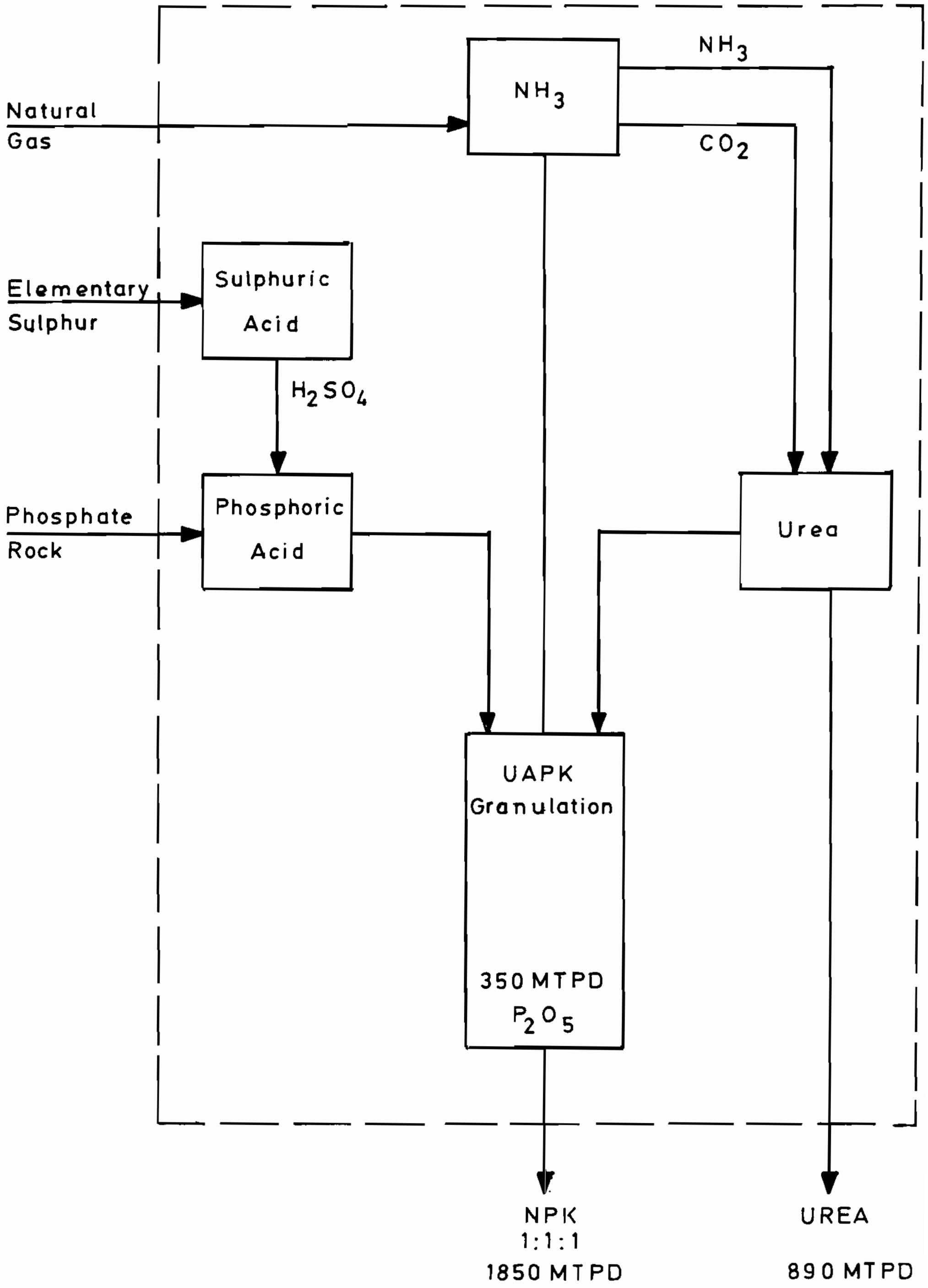
APPENDIX 9

NPK-COMPLEX
Nitrophosphate Process



APPENDIX 10

NPK - COMPLEX
Urea-Ammonium-Phosphate Process



Basis for Energy Integration

The following consumption figures for raw materials and utilities are used for the various process plants in the comparison between the two production complexes. All plant sizes are assumed to balance a 350 MTPD P_2O_5 production and approx. 410 MTPD nitrogen as ammonium nitrate or urea.

Ammonia Plant:

We have here assumed a natural gas based unit with the following figures per MT NH_3:

Gas consumption:	Feedstock	616 Nm^3
	Fuel	172 Nm^3
	Total	788 Nm^3
Electricity consumption:		100.8 kWh
Steam export, 46 bar		668 kg

Nitric Acid Plant:

The choice is a dual medium pressure process with the following consumption figures:

Ammonia, feedstock	0.29 MT
Electricity	1.1 kWh
Steam credit, 46 bar	0.8 MT

Figures are per 1 MT 100% HNO_3.

Sulphuric Acid Plant:

A double catalyst absorption unit is regarded as an advantage for the total sulphur based complex (. . .).

Sulphur	0.34 MT
Electricity	56 kWh
Steam export, 46 bar	1.25 MT

All consumption figures are per 1 MT 100% H_2SO_4.

Nitrophosphate Plant:

The data refers to a 2120 t/d complex fertilizer production and 1190 t/d pan granulated ammonium nitrate (34,5% N) fertilizer.

Figures are per 1 MT P_2O_5 in 1-1-1 grade:

Phosphate rock (30.4% P_2O_5)	3.32 MT
Nitric acid (as 100%)	4.43 MT
Ammonia	1.44 MT
Potassium chloride	1.68 MT
Carbon dioxide	1.21 MT
Electricity	470 kWh
Steam (20 bar and 5 bar)	3.30 MT
Fuel (Natural gas)	12 Nm^3
Export: By-product AN (34.5%)	3.4 MT

Phosphoric Acid Plant:

The hemihydrate phosphoric acid process is chosen. Figures per 1 MT P_2O_5 are presented:

Phosphate rock (30.4% P_2O_5)	3.58 MT
Sulphuric acid	2.73 MT
Electricity	100 kWh
Steam (5 bar)	0.2 MT

Urea Plant:

With Urea ammonium phosphate production, the total quantity of urea will be 3.96 MT/MT P_2O_5. Part of this (1.36 MT) is used to produce UAPK and the balance is produced as granular urea.

Consumption figures per 1 MT of product:

Urea Synthesis + Evaporation	
Ammonia	0.58 MT
Steam (12 bar)	0.73 MT
Steam (5 bar)	0.15 MT
Electricity	118 kWh
Granulation	
Steam	0.07 MT
Electricity	22 kWh

UAPK-Granulation Plant:

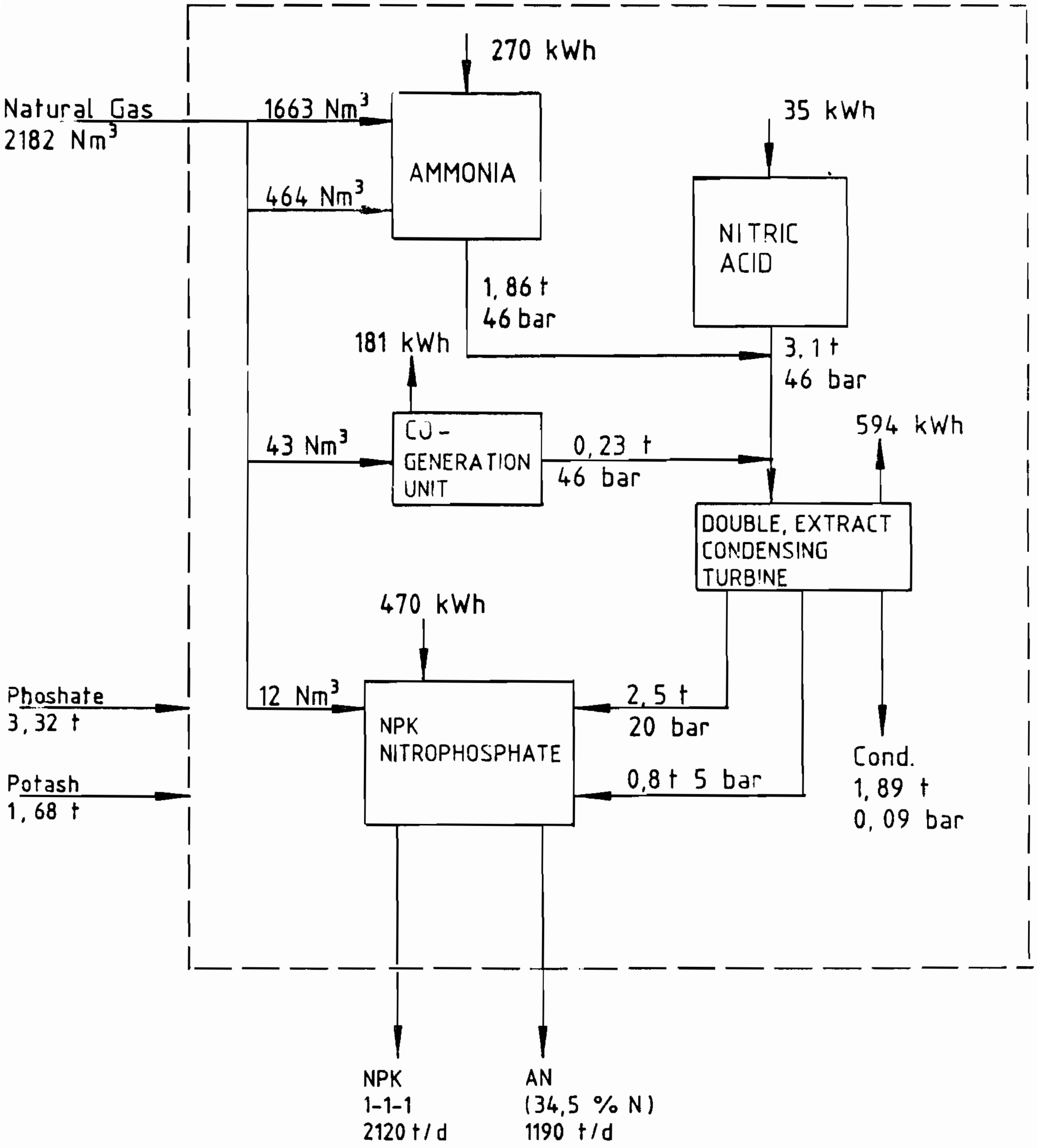
Phosphoric acid is neutralized and mixed with urea to produce UAPK complex fertilizer.

Consumption figures per 1 MT P_2O_5 in the product are:

Phosphoric acid (as P_2O_5)	1.00 MT
Ammonia	0.47 MT
Urea	1.36 MT
Steam (5 bar)	0.12 MT
Electricity	242 kWh
Fuel (Natural gas)	21 Nm^3

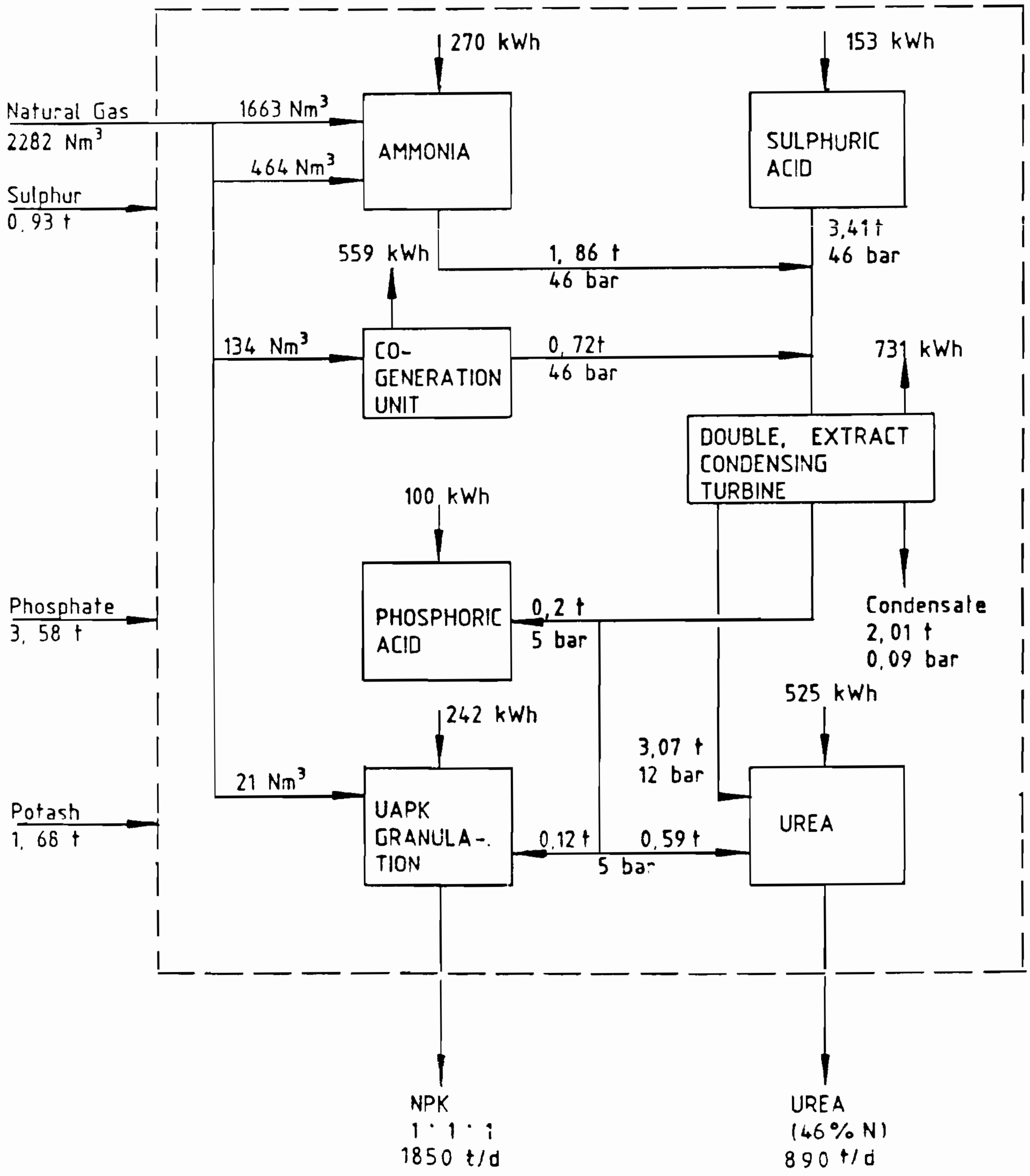
NPK—COMPLEX WITH NITROPHOSPHATE PROCESS INTEGRATED ENERGY SCHEME

Figures are per 1t P_2O_5



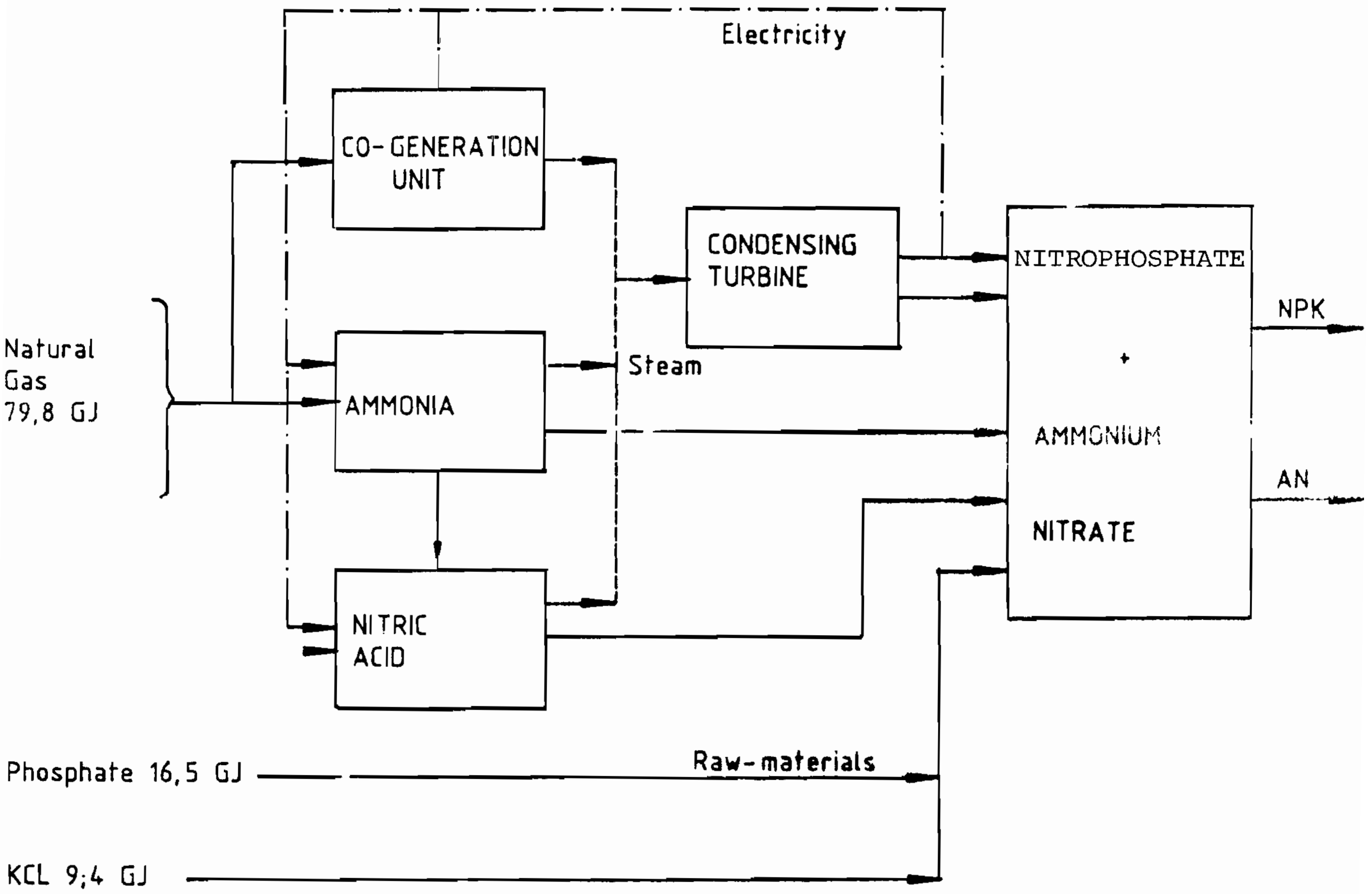
SULPHUR-BASED NPK-COMPLEX with UREA production INTEGRATED ENERGY SCHEME

Figures are per 1 t P_2O_5



NITROPHOSPHATE COMPLEX

ENERGY INTEGRATION SCHEME

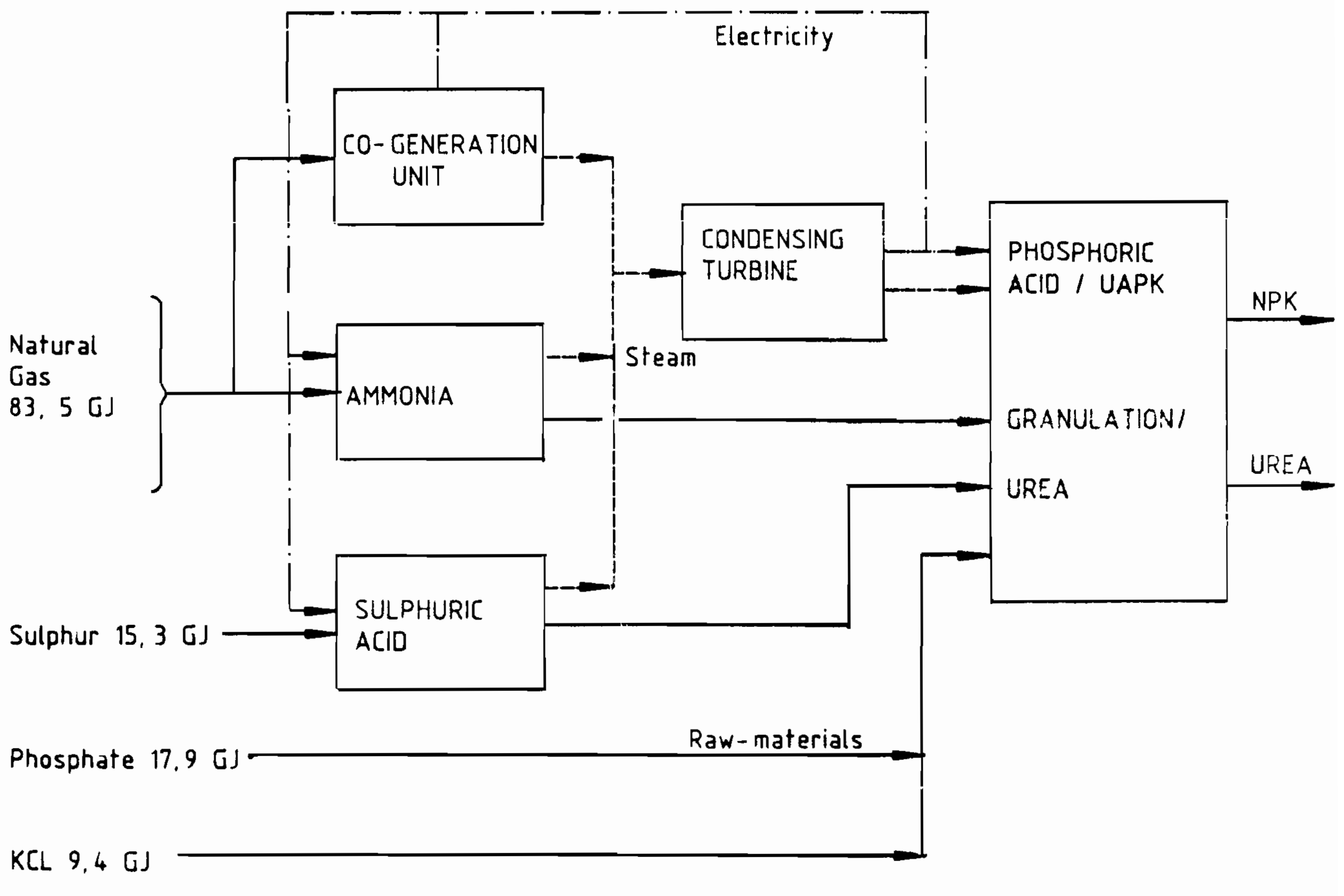


Figures are per. 1 MT P_2O_5

Appendix 14 b

UREA-AMMONIUMPHOSPHATE COMPLEX

ENERGY INTEGRATION SCHEME



Figures are per. 1 MT P_2O_5

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Experience With the Pipe Reactor in the Manufacture of Diammonium Phosphate and Ammonium Sulfate

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SUMMARY

This paper discusses the techniques which have been developed at Incitec for the granulation of ammonium phosphates and ammonium sulfate using a pipe reactor as a means of feeding into an otherwise conventional granulation plant.

INTRODUCTION

At the Fertilizer Industry Round Table held in Washington in 1977, Incitec Ltd (then Consolidated Fertilizers Limited) presented a paper outlining experiences in developing and operating a pipe reactor process for production of diammonium phosphate. At that time, the process was operated on a fully commercial basis for production of DAP and it has continued in use with only minor changes to operating procedures in the years since then. It has been interesting to note the increasing number of references to the use of pipe reactors in the literature but it has been somewhat surprising to see continued comment, and some of it quite recent, that the process has not been commercially used for DAP. The process has been commercial since 1975, has been used to produce more than 1,000,000 tonnes of products, and, as time has passed, it has been refined until it is a completely reliable, easily controlled and very flexible operation. In addition to producing DAP and MAP, a process for the granulation of ammonium sulfate has been developed and fully commercialized.

DESIGN FEATURES

The plant is a conventional drum granulation process as shown in Fig. 1 with the exception that the preneutraliser is replaced by a Tee reactor. Scrubber liquor is mixed with acid and fed to the Tee where the first stage of ammoniation takes place. The slurry is discharged to the granulator bed where further ammoniation takes place. Flashed steam and ammonia slip are exhausted to the scrubbers and the product is fed to the drying, screening and recycle system. Notice that there is no recycle hopper. The original design was for 15 tonnes/hr but plant rates have since been raised to 25-30 tonnes/hr without change in the reactor size.

REACTOR DESIGN

Ammonium Phosphates

The Tee reactor is constructed of 316L stainless steel and is a small compact unit which can be located at any convenient point close to the granulator. Fig. 2 shows the design and dimensions. The reactor feeds into a 316L stainless steel pipe which discharges through a slot onto the granulator bed; Fig. 3 sets out the configuration of the pipe used in the Incitec plant.

Provision has been made for the injection of steam into the ammonia and slurry lines for preheating the reactor, prevention of backflow on startup and cleaning of the system after shutdown.

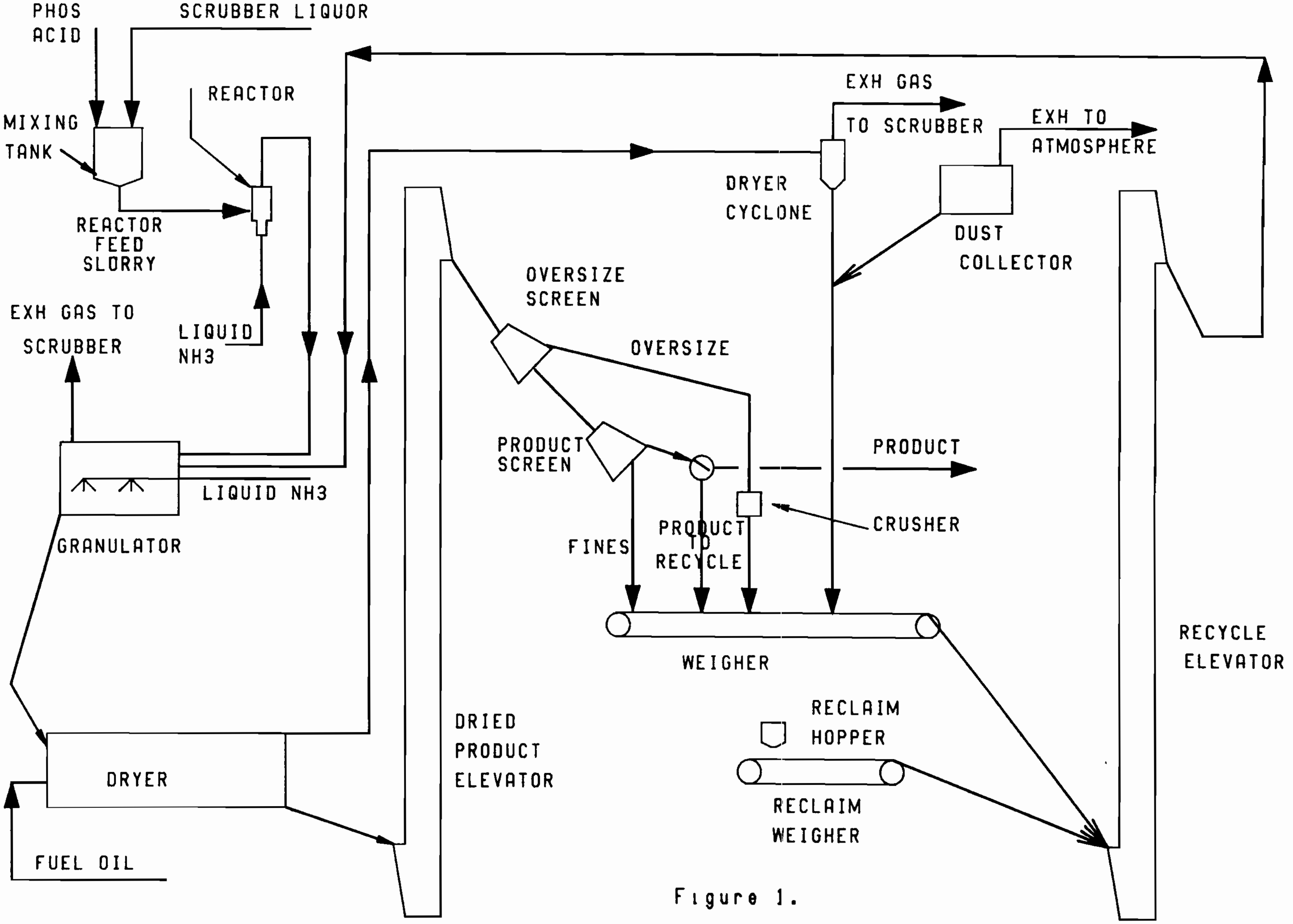

Figure 1.

PROCESS FLOWSHEET FOR DAP.

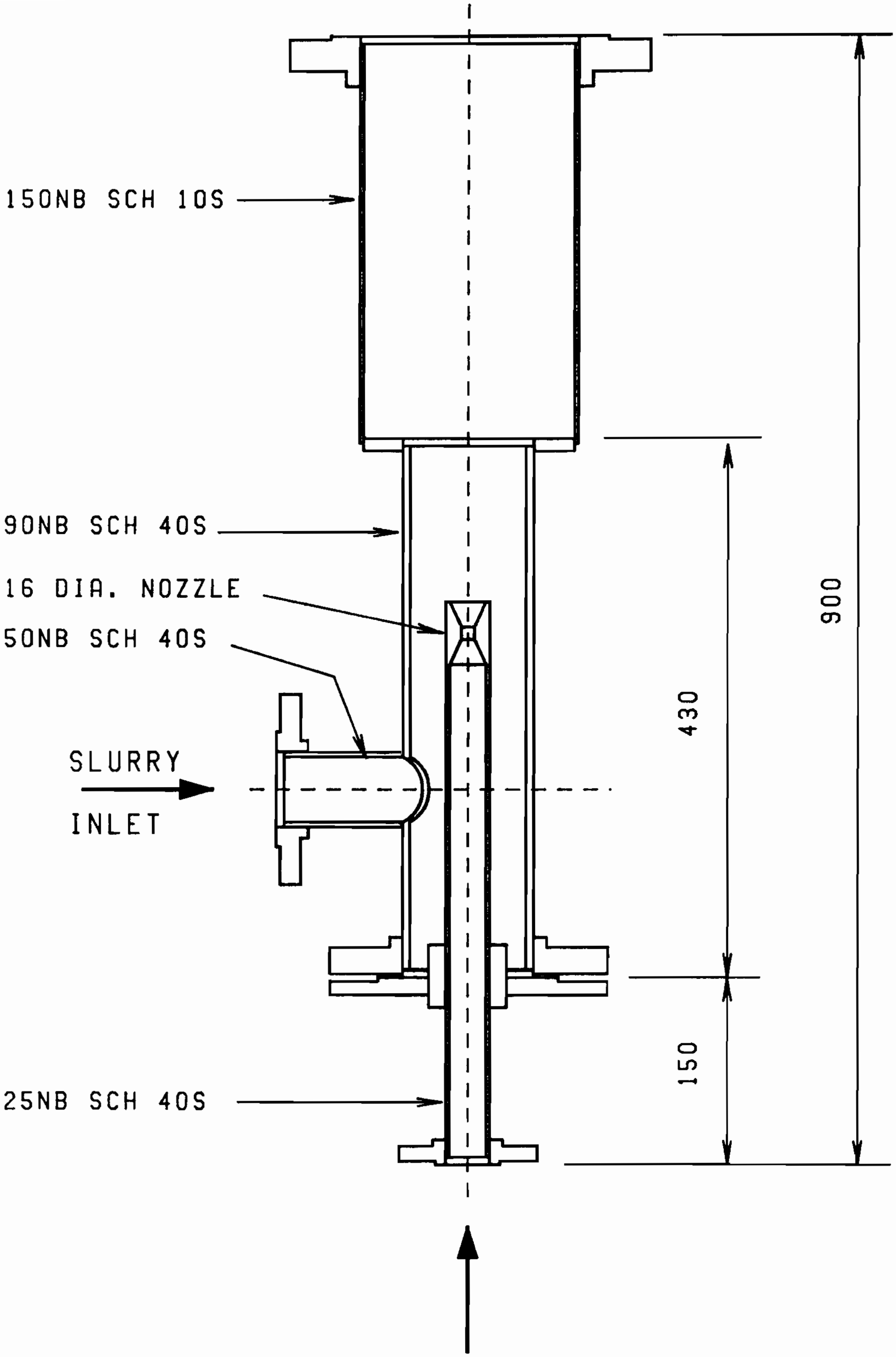

Figure 2.

REACTION TEE

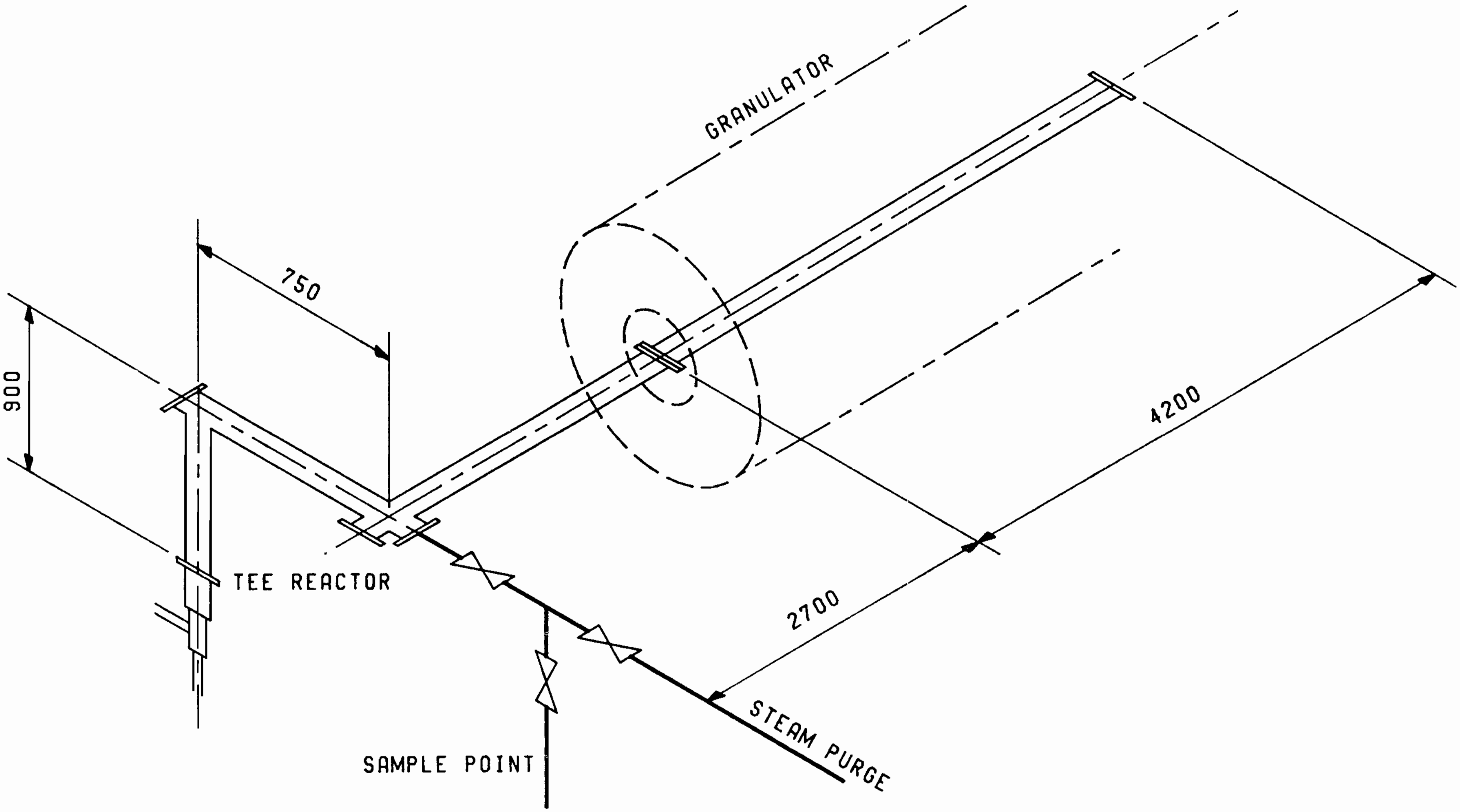

Figure 3

CONFIGURATION OF
PIPE REACTOR

A recirculation system has been provided on all flows to the Tee reactor so that flows can be stabilized before startup and introduced simultaneously to the reactor.

Ammonium Sulfate

For production of ammonium sulfate, a new reactor of similar dimensions to the DAP reactor but with different materials of construction was developed. Anhydrous ammonia and scrubber liquor are mixed and then reacted with sulfuric acid in the Tee. The resulting slurry is again fed to the granulator bed and ammoniated. The high temperature/corrosion areas of the Reaction Tee and pipe are constructed of either Teflon lined mild steel or Hastelloy C276 with the balance of the system being 316 L stainless steel.

SCRUBBERS

The scrubber system consists of a venturi scrubber on each of the granulator and dryer exhausts. The scrubbing liquor is recirculated over the venturi scrubbers via a common recirculation tank from which feed is bled to the Tee reactor.

PROCESS CONTROL (Figs. 4a and 4b)

When producing diammonium phosophate, the N/P mole ratio and moisture content of the scrubber liquor is frequently checked and adjusted to an N/P mole ratio of 1.2 to 1.4 and a moisture content of 35-40% by adjusting phosphoric acid and water flows to the recirculating tank. A constant flow of slurry is taken off via the mixing tank as feed to the tee. Any changes in ammonia slip in the granulation system are thus absorbed as surges in the scrubber recirculation tank and are prevented from passing through and affecting the reactor.

Total flow of phosphoric acid is used to set the production rate on the plant and the balance of the phosphoric acid not used in the scrubbers is fed into the system via the mixing tank.

Control of the scrubber system is critical when operating on DAP. Operation on MAP and ammonium sulfate is much less sensitive to changes within the scrubber system because ammonia slip levels are much lower.

The slurry flow rate required to achieve the desired production rate is fed to the reactor Tee for the first stage of ammoniation and then distributed on the granulator bed where it is further ammoniated to the final product. The recycle rate is set and not altered. Changes to plant control are made by minor changes to feeds to the reaction Tee and the ammonia sparger, and, under normal conditions, recycle ratios are of the order of 3:1 to 4:1.

This approach differs from the conventional "control by recycle" method and can be implemented because—

(i) accurate and reliable metering and controlling systems have been installed on all flows to the reactor.

(ii) residence time in the reactor is very short and hence any changes are transferred immediately to the granulator and have an immediate effect on control.

The result is a very flexible and responsive system which allows adjustment to control chemical and physical quality, to adjust plant rate, and to allow very fast shutdown and startup.

It is interesting to note that with this method of control it has been possible to totally enclose the granulator and make fine adjustments to control by watching instrumentation and by intermittent visual inspection of the ex granulator product falling through the chute to the dryer.

OPERATING EXPERIENCE

The process as it is operated at present is substantially the same as it was when installed and commissioned in 1975. There have been a series of minor changes to the internal configuration of the granulator and a refinement of the techniques of controlling granulation using reactor and sparger feeds rather than recycle control.

Several different designs of reaction Tee were tried for reaction of ammonium phosphates but there has been no significant change in performance associated with change in design. The first reaction Tees and pipes that were installed for ammonium sulfate were subject to severe corrosion and this led to the development of the current Teflon-lined pipe. There is still occasional cracking of the Teflon liner and further development work is taking place to eliminate this minor problem.

During the early years of operation, slurry was distributed to the granulator bed by a series of nozzles. Problems with blockage, and hence changing distribution pattern to the bed, led to the testing of a series of nozzle sizes and designs. The most effective system has been found to be a simple slot cut into the reactor pipe.

D.A.P.

Two types of phosphoric acid feed have been used: Nauru acid produced in a Nissan phosphoric acid plant and Gardinier acid produced from Florida rock. During the early stages of production using Nauru acid, blockage of the reactor with a magnesium ammonium phosphate was a problem although there was a far less significant problem when using Gardinier acid. In the last five years, there has been no problem with reactor blockage. The change co-

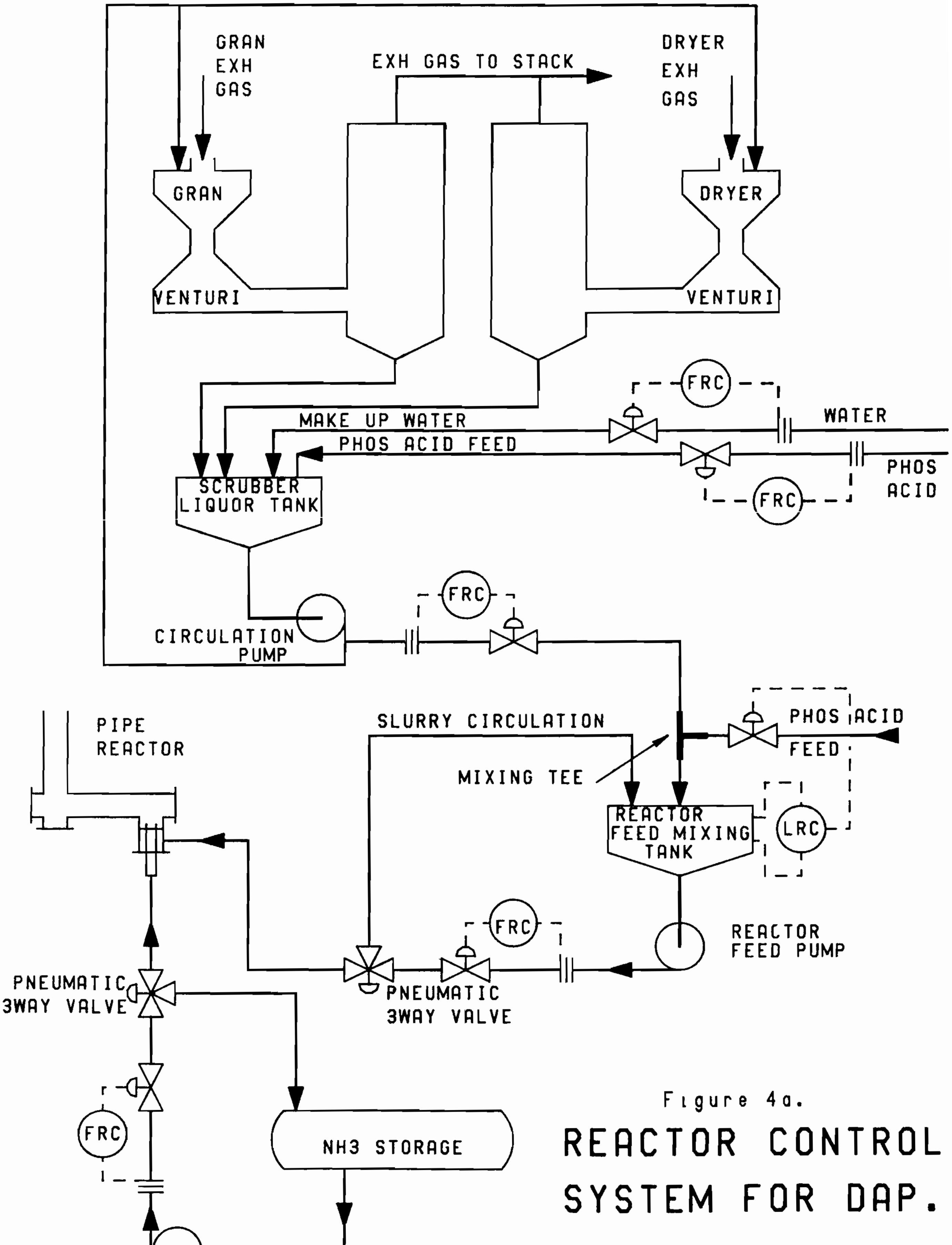

Figure 4a.

REACTOR CONTROL SYSTEM FOR DAP.

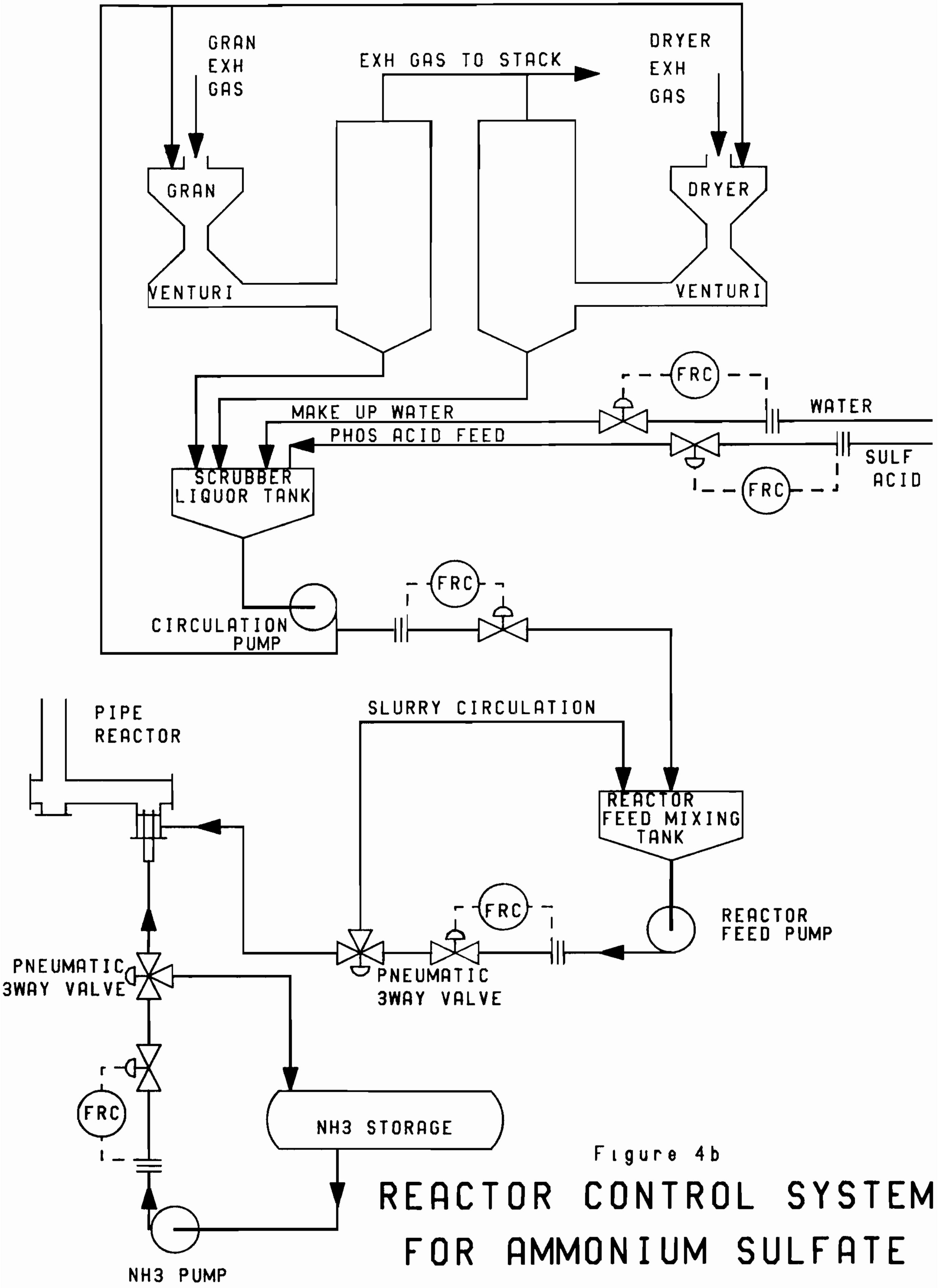

Figure 4b

REACTOR CONTROL SYSTEM
FOR AMMONIUM SULFATE

incided with changes made to operation of the phosphoric acid plant and could be related to minor changes in the ratios of magnesium, iron, aluminium and fluorine etc. There is now no downtime caused by reactor blockage.

The usual practice is to operate the scrubbing system at N/P mole ratios of 1.2-1.3. An attempt was made to operate at mole ratios of 0.4-0.6; however, this resulted in a series of serious scrubber blockages causing considerable downtime and the practice was discontinued.

M.A.P.

The scrubbers are operated at N/P mole ratios of less than 0.4 and the liquor is sent to the Tee reactor for ammoniation to N/P mole ratio 0.7. This slurry is then fed to the granulator bed and ammoniated to MAP.

Very little water is added during steady operation and about an hour after startup the dryer burner is turned off and the dryer used as a recycle cooler. Production rates of 35 tonne/hr have been achieved.

AMMONIUM SULFATE

The granulation of ammonium sulfate is a docile, easily-controlled operation. It is necessary to add a granulation additive and to control granulator conditions within a specified parameters. If control moves outside this specific range, one of two conditions will occur.

(i) The plant will fill with dust and in this situation it may be necessary to dump the plant contents and start again.
(ii) A hard good-looking product will be produced but on storage it will set rock hard.

In all cases of upsets of this type which occurred during commissioning, the product was reclaimed through the plant.

The important thing to note about the granular ammonium sulfate is the physical product quality. It is a hard well-rounded product with moisture of approx. 0.2%, and does not set under any conditions of storage, either when stored alone or when blended with other materials.

ADVANTAGES

The advantages of the Tee reactor system as designed and operated at Incitec can be listed as follows:

1. A small simple reactor with low capital and maintenance costs.
2. The short residence time in the reactor and precise control of reactants allows—
   (i) control by adjustment of feeds rather than recycle which, in turn, allows optimization of plant performance and product quality.
   (ii) instantaneous change and/or control of plant rates.
   (iii) Very fast startup and shutdown of the plant. When the plant is started from cold, the reactor is brought on at full rate as soon as the plant is loaded with recycle. Normal control conditions can be established within 1 hour. For a 'hot start' after a minor shutdown, normal control conditions at full rate can be reestablished within minutes.
3. The simplicity of the reactor allows the granulation plant to be used as a multi-product plant capable of producing ammonium phosphates and ammonium sulfate.
4. The simplicity of the reaction system allows it to be retrofitted to an existing conventional granulation plant.

CONCLUSION

Pipe reactors have been successfully used on Incitec's granulation plant for 9 years to produce DAP, MAP and ammonium sulfate at annual rates of 150,000 tonnes/year.

Because of their simplicity, they are inexpensive to construct and very flexible in operation.

The key to successful operation is the high reliability achieved by adopting control techniques which are particularly suited to a pipe reactor operation.

The Impact of the Regulatory Process on the Economics of Cogeneration

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Energy & Regulatory Consultant

Presented by
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The potential cogenerator first discovers the impact of the regulation process on the economics of cogeneration the day he begins to seriously talk contract with the local utility. Until that day, his source of information has been the popular press, technical journals, promotional literature and the visits from companies eager to sell anything from T/G sets to turnkey installations. Figures ranging from 5¢ to 9¢ per kwh have been sprinkled about like flowers in Spring. These seeming miracles (our potential cogenerator has been paying a little over 4¢ per kwh for the electricity he purchases) have been easily explained as being the result of "avoided fuel costs" and "avoided capital costs." A very logical explanation; everyone knows the utility would reduce the consumption of their most expensive fuel and that the latest facility built must be the most expensive.

So, what is cogenerated electricity worth? Our cogenerator finds that actual fuel costs make up about half or less of his present electric bill and, except under most unusual circumstances, the avoided fuel costs aren't that much greater than the average fuel costs. As for avoided capital costs, there really aren't any, at least not now. The utility obviously cannot abandon its work in progress and is willing to postpone the unit that has already been approved by the Public Service Commission and is in design. And they have only the most tenuous plans for future expansion. However, they do admit that added capacity does have some intrinsic value and "we'll do whatever the Public Service Commission tells us."

Although I have presented this in a rather flippant manner, this probably represents the experience of many cogenerators. I know it represents our experience at IMC. A brief relating of IMC's experience might form an instructive backdrop to further discussion of the impact of the regulatory process.

When IMC was planning its last major expansion at its New Wales facility, the proposed design for the two new sulfuric acid plants recovered more of the heat as steam than did the three original units. Initially, it was decided to use this steam to provide motive force for some of the large pumps and fans in the facility. However, it didn't take long to realize that the best way to deliver this energy more than a few hundred feet was to convert it to electricity and feed it into the electrical distribution system within the Plant. With the concept set, the design went forward with waste heat recovery, steam superheating and a back pressure steam turbogenerator, all sized to produce up to 8 megawatts (MW) (later expanded to 10 MW).

Construction was nearing completion when I joined IMC at New Wales. I was disappointed that New Wales was planning to "just" use the electricity internally. Fresh from California, I "knew" that selling to the utility at avoided fuel costs plus avoided capital costs offered the best return. We explored the possibility with our utility and were encouraged. Florida had a brand new rule covering cogenerators which had been developed by the utilities working with the Florida Public Service Commission (FPSC). The rule directed the utility to "purchase energy from qualifying facilities (QF's) at rates which reflect the utility's avoided costs," provided the utility with guidelines for determining these costs and directed the utilities to file a tariff "which reflects the full decremental fuel costs." The numbers developed by the utilities did not look like California, but they looked definitely better than "just" using the electricity internally. The published avoided fuel cost was less than (but close to) the average cost of electricity to New Wales. With a capacity payment, the final figure should be attractive. Thus encouraged, we rolled up our sleeves and sat down to serious negotiation.

The three main contract areas for negotiation (in addition to the usual questions of term, escape clauses, renewal provisions, etc., common to every contract) were: Interconnection hardware, metering and controls, and payment terms. Interconnection hardware was no problem; this had already been worked out with the utility as part of the design. We were amazed at the metering and controls required by the utility. Telemetry would keep the utility aware of our instantaneous megawatt and VAR output. All cumulative meters would be able to be read by telephone. The utility's System Dispatcher could reach out and remotely open the generator breaker in an emergency. Communication between our cogeneration operator and the utility's Systems Operation Dispatcher would be by dedicated telephone—a hot line! We did not care for the intrusion into our operation but the utility eventually convinced us this was not frivolous. It paralleled, to some extent, the control the utility exercised over its own facilities and over the inter-ties to other utilities. We also began to appreciate the unique problems of an electric utility who has to manufacture and deliver its product to the customer at the rate the customer is using it at the moment. Imagine if you can, the problems we would face if we had to manufacture fertilizer ingredients, blend them and deliver to the farmer at the rate and at the moment he is applying the product in his field—and without any intervening storage!!

When we came to payment details, we found that when forecasting the avoided energy cost we are dealing with a number that is far less predictable than the expected average price of electricity—and each time the utility made a new prediction, it seemed to be less than the last! Furthermore, the FPSC rule, although it gave guidelines for evaluating the cogenerator for receiving capacity payments, did not provide for the utility to recapture these payments. Without this assurance, the utility would not consider paying for capacity.

While all this was going on, the 8 MW T/G had started up. We were using the electricity internally and paying the utility for our "net" consumption. In other words, we were simply slowing down the meter. Incidently, "netting" was not permitted in the cogeneration rules, but it wasn't prohibited either. After some further conversation with our utility, we agreed to shelve the agreement and continue to net until the rule was clarified. The rule was seven months old at this time and it was another seven months before the Final Order was issued. In the Final Order, the question of capacity payments was handled by one sentence which said, in part: "Capacity payments . . . that we find to be reasonable, and prudent expenditures will be recovered . . . ." Naturally, this invitation to play roulette with the stockholders' money did not appeal to any utility in the state and served only as a deterrent to cogeneration contracts.

In the meantime, with the assistance of Monsanto Enviro Chem (MEC), we had made a detailed engineering study of the potential for cogeneration at New Wales. The results exceeded all of our expectations. Depending on the extent to which we would be willing to install retrofit heat recovery and energy enhancement items, we could conceivably generate significantly more electricity than we use internally to operate the Plant. We knew that this was technically feasible but was it economic? We were back to our original question, "What is cogenerated electricity worth?" The difference was that we now knew that we didn't know the answer to the question. To evaluate the economics, we made an end run by using the following strategy:

1. We broke the opportunities down into a "shopping list" of stand-alone energy enhancement items.
2. The contribution of the steam made available by each item was expressed in KW's.
3. The capital cost of each item was estimated, including an incremental turbogenerator cost, and expressed as $/KW.
4. Screening criteria of $1,080/KW and $1,800/KW were developed. $1,080/KW corresponds to a 15% DCF return (corporate guidelines) at 3¢/kwh (our best estimate of the minimum value of avoided energy at start-up) and $1,080/KW at 5¢/kwh (our best estimate of the maximum value of avoided energy at start-up).

Applying these criteria to our shopping list produced two project proposals differing by the degree of uncertainty in the economic forecast.

As a result of this study, we went with the more conservative approach and selected a retrofit energy enhancement project (REEP) which added about 40 MW to the existing 10 MW for further consideration. This kept our generation less than our internal use. Also as a result of these experiences, it was decided that we, as cogenerators, should take an active role in the rule making process under the FPSC. We had a glimpse of the impact the regulatory process has on us, not only in setting rates and defining what has value, but also in many ways that are not immediately obvious at first glance. So we, and a few other cogenerators and potential cogenerators, hired an attorney and entered into the new, and often wondrous, world of the regulation of public services. Telling you what we did, how we did it, and what we accomplished is best done by our guide in the new land, our attorney.

(The following portion of the paper is by Mr. Zambo)

INTRODUCTION

I appreciate being given the opportunity to discuss the subject of cogeneration. It is a topic which I believe is important to industry and especially the fertilizer industry. What I intend to cover in my discussion can be broken down into two components. First, is to provide a brief review of recent Federal legislation and regulations aimed at encouraging and stimulating cogeneration development in the United States. I will define basic terminology, describe some of the mechanisms employed, and discuss a few major highlights. Second, is to furnish you with an overview of how IMC and a group of Florida industrial cogenerators approached various cogeneration issues and the overall results of their participation in the regulatory process with myself, in the words of Dr. Hirsch, as their "guide."

To keep from getting ahead of myself, let me define what is meant by the term "cogeneration." Cogeneration is the combined production of power (mechanical or electrical) and useful thermal energy (heat or steam) through the sequential use of energy from a single fuel source. That is, the reject heat energy of one process becomes the energy input to a subsequent process. Cogeneration requires significantly less fuel to produce electricity and thermal energy than would be needed to produce the two separately. Now that we have defined what Congress sought to encourage, let's look at the mechanism chosen to accomplish their objectives, identify those areas which may still present obstacles to cogeneration development, and analyze the impact of this new body of law on the cogenerator.

FEDERAL INTEREST IN COGENERATION

In the past, developers of cogeneration facilities were faced with a number of regulatory, institutional, and economic obstacles. For example, utilities were not required to interconnect with cogenerators; a cogenerator might find standby service unavailable or available only at discriminatory rates; utilities were not required or willing to purchase electric power from cogenerators; and, even if these problems were resolved, a cogenerator selling power to an electric utility could find himself subjected to the burden of state and federal regulations as an electric utility. All of these factors contributed to a less than encouraging climate for the development of cogeneration in the United States.

The "energy crisis" of the 1970's focused attention on and breathed new life into cogeneration—a technology which dates back to the turn of the century but which declined into obscurity in the face of cheap fuel and cheap electricity, at least until the time of the "oil shocks" of the seventies. The United States Congress began to view cogeneration as a technology whose time had come again, one which, if adequately encouraged, could reduce the country's growing dependence on and appetite for imported fuels. In 1978, as part of a package of laws broadly referred to as the National Energy Act, Congress enacted the Public Utility Regulatory Policies Act or PURPA as it is often referred to. PURPA sought to remove or neutralize previous obstacles to cogeneration as well as provide incentives to foster the development of cogeneration.

PURPA declared that it would be in the national interest to encourage cogeneration and sought to foster its development by mandating the Federal Energy Regulatory Commission, or FERC as it is referred to, to provide the appropriate regulatory framework in which to provide incentives and remove existing barriers. PURPA and the FERC's rules which followed contained several major provisions:

1. Electric utilities are required to interconnect with cogenerators.
2. Electric utilities are required to purchase energy and capacity from cogenerators at the utility's avoided cost.
3. Electric utilities are required to provide back-up power to cogenerators at non-discriminatory rates.
4. Cogenerators are exempted from certain State and Federal regulations applicable to electric utilities.

In addition, each state's agency vested with regulatory authority over electric utilities, such as the state public service commission, was required to implement regulations on a state level which would, in essence, be equivalent to or better than the FERC regulations in terms of fostering cogeneration development. The states accepted their tasks with varying degrees of enthusiasm ranging from excitement at the prospect to a more reluctant response to the federal mandate. Utilities likewise responded quite differently—some openly soliciting cogeneration development and others challenging the legality of PURPA and the FERC's rules.

Most notably, there are two instances of legal challenge, one by the State of Mississippi and the other by the American Electric Power Corporation. The State of Mississippi and the Mississippi Public Service Commission challenged the constitutionality of PURPA. The Supreme Court of the United States reversed the decision of a lower Federal Court and held PURPA to be a valid, constitutionally permissible exercise of federal power. That case was decided in June, 1982. American Electric Power Corporation (AEP) challenged not PURPA, but rather the FERC's regulations, which were adopted pursuant to PURPA. Specifically, the AEP took issue with FERC's mandate that utilities be required to pay full avoided costs to cogenerators for their energy and capacity. Secondarily, AEP challenged certain aspects of the interconnection provisions. The United States Supreme Court again reversed a lower court's decision and found FERC's regulations to be appropriate. That decision was rendered in May, 1983. Once the Supreme Court had spoken on both the constitutionality issue and the propriety of the FERC's regulations, much of the cloud of uncertainty lifted from the future of cogeneration.

STATE IMPLEMENTATION OF PURPA

The legal challenges to PURPA and the FERC rules provided justification for some states to delay implementation of cogeneration rules while others rushed forward to develop early momentum in the reborn cogeneration industry. Although it was fairly simple to establish procedures for interconnection and for the provision of back-up power services, it was quite another story when it came to calculating the utility's "avoided cost" for purposes of energy and capacity payments to cogenerators.

Avoided costs were defined as costs the utility would otherwise incur had it generated the electricity itself or purchased the electricity from other sources. There were indeed a number of costs a utility could avoid by purchasing from a cogenerator. "Avoided energy cost" is essentially the cost of the fuel the utility would otherwise consume to produce the same amount of electric energy. This is a variable cost, expressed in terms of ¢/kwh. "Avoided capacity cost" represents the revenue requirements associated with the investment of capital in generating plant. This is a fixed cost measured in terms of $/kw/year. "Avoided operating and maintenance (O&M) costs" are a combination of fixed and variable costs attributable to normal payroll; use-related replacements; maintenance; and so forth, some or all of which would be avoided by purchases from a cogenerator. "Avoided transmission and distribution (T&D) costs" also represent a combination of fixed and variable costs related to the maintenance, repair, and replacement of existing T&D systems as well as the revenue requirements associated with the investment of capital in new T&D facilities. Purchases from cogenerators, depending on their location on the utility's system and the delivery voltages, could allow a utility to avoid T&D related costs.

The determination of the "avoided energy cost" can be accomplished by computer simulations to calculate the incremental fuel savings due to "blocks" of cogeneration on a utility system. "Avoided O&M costs" can be derived using the utility's average costs on a KWH or KW basis as an approximation. Similarly, "avoided T&D costs" can be approximated by adjusting deliverd KWH's and KW's to reflect avoided losses due to transformation and transmission. The more problematic of the avoided costs is the "capacity" components. This component involves not only the capital investment revenue requirements aspect, but also raises issues of when is additional capacity needed by a utility?—remember, if it is not needed, it may not be worth paying for; and, when is a cogenerator's capacity equivalent to utility capacity?—If a utility is in need of capacity and the cogenerator is an acceptable substitute or equivalent to utility capacity, then a cogenerator would allow a utility to avoid capacity costs.

The derivation of the value of capacity is complex and difficult. As a result, many avoided capacity cost methodologies were advanced. Among those proposed were short-run marginal costs; peaker cost based on gas turbine capacity cost; the system planning approach, where cogeneration was used in lieu of utility units and utility unit pricing was the basis for avoided cost calculations; long-run differential revenue requirements approach and shared savings approach. As you can imagine, the divergence among these methods in terms of payments to cogenerators was substantial, and, depending on the method selected, would provide varying degrees of encouragement to cogenerators.

Many utilities were and are reluctant to embrace cogeneration—partly because it represents a degree of competition in a historically monopoly market, and, partly because it is new—they are not quite sure how to handle it or how it might affect them. In some instances, the state utility commissions share the concerns of the utilities and as a result, implement rules which are designed to minimize or avoid the unknown risks and pitfalls of cogeneration.

An interesting phenomenon occurred at the state level. Remember that PURPA and the FERC rules were intended to revive, rejuvenate, and encourage an old technology—cogeneration. Yet, when the law went into effect, it was not obvious who the potential cogenerators were (even to the potential cogenerators themselves) or from which industries they would come. There was a problem of "which comes first—the chicken or the egg". Until a state's cogeneration rules defining operating parameters, payment rates, and other economic factors were in place, many potential cogenerators could not know whether cogeneration would be attractive to them. As a result, many states adopted rules absent input from the very industry (cogenerators) they were seeking to encourage. The utilities and state regulatory commissions debated the issues and developed regulations without industry participation.

In Florida, for example, a "split the savings" approach for payments to cogenerators was proposed—that is, the average of the utility's cost and the cogenerator's cost. Presumably, under that method, a cogenerator which used waste heat for generation and had no fuel cost, *per se*, would be paid 1/2 of the utility's cost. Florida rejected that notion for failing to provide the proper incentives. Florida subsequently adopted rules which required utilities to pay the equivalent of their marginal fuel cost to cogenerators for energy delivered, but left capacity payments to be negotiated between utility and cogenerator. The rules did provide, however, that a cogenerator willing and able to perform at a 70% capacity factor would be entitled to a capacity payment. The Florida Commission has since amended its rules—this time with the substantial participation of the cogeneration industry. The following comments will describe industry's interest and participation in the amendment process as well as briefly describe the results.

INDUSTRY'S ROLE IN THE REGULATORY PROCESS

As industry began to evaluate the potential for cogeneration in their various manufacturing operations, and, as they became aware of cogeneration regulatory activity in the state, an organizational process of sorts began. An *ad hoc* group of Florida Industrial Cogenerators developed, comprised of a large segment of the Florida phosphate industry, and the cement, lime, and aggregate interests as well as agricultural (sugar cane) interests. It is through the representation of this group over the past several years in the ongoing proceedings which affect cogenerators' interests, and in power sales contract negotiations, that I gained a good deal of the experience necessary to prepare this paper.

The obvious interest of cogenerators in the regulatory process is to maximize their revenues as cogenerators supplying electric power to their facilities or in sales to utilities. If however, the cogenerator is also a large purchaser of electric power, there is a potential for conflict between the maximization of cogeneration revenues on the one hand, and the minimizing of electric power purchase costs on the other. This potential for conflict can be largely, though not completely, resolved by applying cost of service principals to both cogeneration pricing and electric rate setting. The Florida industries which participated actively in the cogeneration regulation development were, for the most part, large users of electric energy and were careful to apply consistent reasoning in the development of cogeneration pricing proposals. Through the application of cost of service principals, a balance between purchase power costs and electric power sales prices should result.

Let's take a look at the factors which can affect the level of benefits associated with cogeneration and briefly discuss each of them.

—Price for the purchase of electric energy (kwh).

—Price for the purchase of electric capacity (kw).

—Cost of interconnection.

—Cost of back-up service.

—Ability to wheel power.

Energy: Looking first at the price for electric energy (the kwhs), recall that the FERC rules require utilities to pay full avoided (or "incremental") cost. Accordingly, the price of energy should be based on the cost of fuel the utility *would have used* had it not purchased from the cogenerator. Industry recognized the varying avoided energy costs among utilities—relatively low for those utilities with significant increments of nuclear, coal or hydropower generation and relatively high for those with significant increments of oil and gas generation. Therefore, an ability to sell cogenerated power to any utility (in the state) could substantially improve revenue prospects for potential cogenerators depending on their location. For example, a cogenerator located in the service territory of a utility totally dependent on nuclear energy would face very low avoided energy payments. However, if that cogenerator were able to sell electricity to another utility, perhaps one that used significant amounts of oil fuel, the avoided energy payment could be many times greater. This flexibility benefits all parties—the cogenerator, the utilities, and the ratepayers. It benefits the cogenerator since his economics are no longer determined by the fortune or misfortune of the utility service area in which he falls. It benefits the utilities in the sense that those utilities most in need of alternative energy sources can attract them from outside the confines of the service territory. It benefits ratepayers by encouraging further cogeneration development than may otherwise have occurred, thus avoiding utility generation. The Florida cogeneration rules offer such flexibility through the availability of wheeling services.

Capacity: Concerning capacity payments, the FERC rules also provide for payment of full avoided cost. This issue has perhaps spawned more controversy than any other PURPA related issue. As mentioned earlier, since many cogenerators are also large users of electric energy, a logical and consistent application of cost of service principals is mandatory if the proper balance between payments to cogenerators and retail electric rates is to be maintained. This is especially true with respect to capacity payments. If a utility has no need for capacity but is nevertheless forced to purchase it, an unnecessary increase in the purchasing utility's retail rates could occur. Also, if greater than the avoided cost is paid, a further unnecessary increase in retail rates could occur. In each of these instances, the cogenerator would benefit in terms of the sales price he receives for his power—conversely, however, users of electric energy would be adversely affected through increases in retail rates. Accordingly, the Florida cogenerators supported positions consistent with cost of service principals, annd linked to the avoidance or deferral of a base load coal fired unit—the only type of units currently being planned by Florida utilities. The "avoided unit" eventually became the basis for the Florida capacity payment rules which identify planned future units capable of being avoided through the substitution of cogeneration capacity. Payments for avoided capacity are based on the utilities' projected revenue requirements associated with the capital investment in the avoided unit. The revenue requirements are adjusted on a present value basis for variations in cogenerator-utility contract length, in-service date, and various other factors.

The Florida rules recognize that unit avoidance and unit planning is a dynamic process. Accordingly, annual proceedings are held for purposes of maintaining current pricing and parameters for the benefit of the cogenerators and retail customers.

Interconnection: An often overlooked aspect of cogeneration is the physical interconnection of the facility with the electric utility. Such interconnection is necessary in each instance in which a cogenerator seeks to operate in parallel with the utility. Depending on the size, location and characteristics of the cogeneration facility, interconnection costs and operational requirements can substantially impact cogeneration economics. Not only from a direct cost standpoint, but also from a "timing" standpoint in terms of arriving at an agreed upon arrangement with the electric utility. The Florida industrial cogenerators recognized the potential for controversy in this area and favored standards for regulating interconnection requirements. The Florida rules provide for interconnection standards, assign responsibilities and liabilities, and otherwise "standardize" the operations of interconnected utilities and cogenerators. The rules also recognize that situations may differ, providing for deviation from the standards on a case by case basis. The existence of such standards provide cogenerators with a basis from which interconnection costs and lead times can be estimated—both important factors in cogeneration planning.

Back-up Power: Although the Florida rules provide numerous alternatives to a cogenerator in terms of the use and/or sale of electricity, several of those alternatives will require that the cogenerator rely on the utility for back-up power during those times the cogeneration facilities are not in operation. Depending on the "design" of back-up power rates, a cogenerator which experiences a short duration outage in a billing period could be subject to substantial demand charge assessments. The Florida rules provide for back-up service under normal retail rate schedules, do not include demand charge ratchets, and in the case of certain time of use rates, do not include demand charges at all. The specific back-up rate issues of cogenerators' diversity, cogenerators' contribution to peak demand, and other factors, have not yet been generically addressed in Florida. As cogeneration continues to develop in the state, specially designed back-up rates will almost certainly be developed. Such rates should result in lower back-up costs to cogenerators, reflective of their reliability and diversity.

Wheeling: The last and perhaps one of the most important factors I will address today, is that of wheeling. I mentioned earlier under the discussion of avoided energy costs that cogenerators in Florida are able to sell to any utility in the state. The mechanism which makes those sales possible is the "wheeling" of electricity over intervening utility lines from the cogenerator to the purchasing utility. Aside from selling and wheeling to another purchasing utility, there are two other wheeling transactions of interest to cogenerators—wheeling to "retail" users of electricity, and wheeling to "other facilities" owned by the cogenerator.

The first of those transactions, wheeling to "retail" customers, poses a number of potential problems including the questions of whether a cogenerator would then become a public utility; infringement of utility franchise rights, if any (Florida has none, *per se*); as well as the certainty of formidable resistance by electric utilities. In spite of those potential difficulties, such sales may one day be routine if deregulation of the industry should occur.

The second of those transactions, wheeling to "other facilities" owned by the cogenerator is much more a current possibility in Florida. Florida cogenerators view such transactions as an extension of the "self-generation" concept. No one argues that a cogenerator may not choose to serve himself in terms of providing its own electrical needs—why not then, at more than one location? In the fertilizer industry, for example, the chemical complex is often remote from the mining site. Excess electrical generation at the chemical complex where the cogeneration would take place could then be transmitted over electric utility lines to serve the remote load. Although this type of transaction has not yet occurred in Florida, there are several cogenerators who have made requests to their utility for wheeling services to accommodate such a transaction. Furthermore, several attempts by the electric utility industry to literally outlaw such transactions have been turned back, perhaps indicating that they may eventually be permitted and encouraged. The benefits of such wheeling are two-fold. From the cogenerators' standpoint, they would increase revenues since the purchased power displaced by wheeling is typically more valuable on a per kwh basis than sales of excess power to the utility. From the utilities and ratepayer's standpoint, the increased revenues would encourage further cogeneration development and thereby allow the avoidance of utility capacity construction. The current policy in Florida is to allow such transactions to occur on a negotiated basis with utilities. Disputes, if they arise, will be resolved on a case by case basis.

CONCLUSION

Although there are a number of other issues I could address, time constraints dictate that I only discuss the major areas of interest as I have done here. The IMC experience and the experience of the Florida industrial cogenerators indicates that it makes good sense to participate in the cogeneration regulatory process. The Florida Cogeneration Rules in their present form represent a sharp contrast to initial proposals on the subject. Through industry's intervention and participation, the decision-makers were educated as to the identity, viability, potential, and most importantly, the needs of a fledgling cogeneration industry. The resulting Florida rules offer substantial flexibilities to cogenerators while also providing certainty with respect to factors such as pricing and interconnection, and, are designed to accomodate changes in a dynamic process.

Based on our experiences, I highly recommend that those of you involved in, or considering cogeneration, take an active role in the regulatory and legislative processes in your state which will impact cogeneration. Otherwise, decisions which will ultimately have a direct bearing on cogeneration economics and indirectly on retail electric rates are likely to be made without industry's valuable input.

Wednesday, October 31, 1984

Morning Session
Moderator:
Thomas L. Howe

Comparison of Hygroscopic Properties of Mixtures of Granular Materials (Bulk Blends) and Granulated Mixtures

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Introduction

It has been demonstrated that mixtures of fertilizer materials are more hygroscopic than the individual materials. For example, a granulated mixture of urea and ammonium polyphosphate (28-28-0) has a critical relative humidity (CRH) of 55%, whereas its individual components—urea and ammonium polyphosphate—have CRHs of about 70% (*1, 2*). It is evident that this lowering of the CRH is due to chemical and/or physical characteristics of the materials that are manifested when they are brought together. Thus, it may be logical to assume that if the surface contact between the different components in a fertilizer were decreased, the hygroscopic properties would be improved.

Components in granulated mixtures and bulk blends have different degrees of surface contact. The components in a granulated mixture have a much larger surface contact area than the components in a bulk blend where contact only occurs between the relatively large granules. On the basis of surface contact, it could be assumed that the physical properties of bulk blends would be superior to those of the equivalent grades of granulated mixtures.

To study the effect of surface area contact, determinations were made of the CRH, moisture absorption-penetration characteristics, and caking tendency of bulk blends and granulated mixtures of three grades. Two of the grades were tested with and without conditioners.

MATERIALS

The three N-P_2O_5-K_2O fertilizer grades that were used in the tests were: 28-28-0, 19-19-19, and 17-17-17.

The bulk-blend versions of these grades were prepared using granular materials: urea, crystalline ammonium sulfate, potassium chloride, ammonium polyphosphate (APP), monoammonium phosphate (MAP), and diammonium phosphate (DAP). The formulations for each grade are shown in Table 1.

The granulated mixture versions of these grades were prepared by conventional granulation techniques. The composition of these products is shown in Table 2.

Urea was selected as the major source of nitrogen because of its increased use in preparing multinutrient fertilizers in the United States and worldwide. Additionally, urea-based fertilizers are known to be hygroscopic and prone to caking, especially during long-term storage.

The 28-28-0 and 17-17-17 grades were also evaluated to determine the effect of using a conditioning agent. These fertilizers were conditioned by spraying them with 0.5% motor oil (SAE 20) and dusting them with 2.0% kaolin. A duplicate set of samples was sprayed with 0.5% amine and dusted with 2.0% kaolin.

TEST PROCEDURES AND RESULTS

In order to evaluate the performance of the fertilizer mixtures, three aspects of their behavior were observed: the condition under which they absorbed significant amounts of moisture from the air; the severity and consequences of moisture absorption; and their ability to withstand simulated warehouse storage conditions. To observe these three behavioral aspects, three standard tests were performed: CRH, moisture absorption-penetration, and small-bag storage (caking tendency).

Critical Relative Humidity

The CRH of a fertilizer material or a mixture of materials is defined as the relative humidity at which it will begin to absorb a significant amount of moisture from the atmosphere and below which it will not. The CRH values reported here were determined at 30°C (86°F) by the procedure described in TVA's Special Report No. S-444 (3). This method involves exposing a sample to various controlled humidities

Table 1. COMPOSITION OF BULK-BLEND GRADES[a]

Grade	Urea (46-0-0)[b]	Ammonium Sulfate (21-0-0)	Ammonium Polyphosphate (11-55-0)	Monoammonium Phosphate (11-55-0)	Diammonium Phosphate (18-46-0)	Potassium Chloride (0-60-0)
	(% by weight)					
28-28-0	49		51			
28-28-0	49			51		
28-28-0	38				62	
19-19-19	33		35			32
19-19-19	33			35		32
19-19-19	26				42	32
17-17-17	20	21		31		28

a. Moisture contents of the individual bulk-blend ingredients: urea (0.1%), ammonium sulfate (0.1%), ammonium polyphosphate (1.1%), monoammonium phosphate (1.4%), diammonium phosphate (2.0%), and potassium chloride (0.2%).
b. Conditioned with 0.4% of a 37.0% formaldehyde solution.

Table 2. COMPOSITION OF GRANULATED MIXTURES

Grade	Major Source of Nutrients		
	Nitrogen	Phosphorus	Potassium
28-28-0	Molten urea	Molten APP[a]	—
19-19-19	Solid urea	Molten APP	KCl
17-17-17	Solid urea	MAP[b] slurry AS[c] slurry	KCl

a. APP = Ammonium polyphosphate.
b. MAP = Monoammonium phosphate.
c. AS = Ammonium sulfate.

at a constant temperature in a standard laboratory environmental chamber.

The CRH values of the granulated mixtures without conditioning were all at least 5 percentage points below those of the equivalent bulk blends (Table 3); therefore, the bulk blends were rated as slightly superior to the corresponding granulated mixtures with respect to CRH (Figure 1). The addition of a conditioner did not improve the CRH of any samples (Table 4).

The fact that bulk blends have higher CRH values than granulated mixtures may possibly be due to the decreased contact area between the components in bulk blends.

For comparison the CRH values of the commercial fertilizer materials that were used in the blends and their corresponding pure salts (reagent-grade materials) were determined (Table 5). Also included are CRH values calculated from vapor pressures of saturated solutions (*4*). It should be noted that the fertilizer-grade materials have lower CRHs than the pure materials. This is assumed to be dependent upon the amount and nature of the impurities. An exception to this generalization is the CRH of urea, which is the same for pure- and fertilizer-grade materials.

Moisture Absorption-Penetration Characteristics

To determine physical quality after exposure to humid conditions, moisture absorption-penetration tests were made by two methods. The first method was a laboratory absorption-penetration test described in the previously mentioned TVA special report (*3*). The second method was an IFDC procedure, similar in purpose to the TVA small-pile storage test (*3*). In both methods the samples were exposed in a chamber where the temperature and humidity were controlled.

In the laboratory procedure (TVA), the values determined were: moisture absorption, moisture penetration, and moisture-holding capacity. The granule integrity was also determined qualitatively by handling the moist sample and rating the granule strength as excellent, good, fair, or poor. In these tests, two sets of conditions were used for the 72-hour exposure period: 30°C and 65% relative humidity and 30°C and 80% relative humidity.

The moisture absorption of the 28-28-0 and 19-19-19 unconditioned granulated mixtures and bulk blends at 65% and 80% relative humidity showed no significant differences. The unconditioned 17-17-17 granulated mixture had a significantly higher moisture absorption than the equivalent bulk blend at both 65% and 80% relative humidity (Table 3). The addition of a conditioner did not decrease the moisture absorption of any samples (Table 4).

The difference in moisture penetration between unconditioned granulated mixtures and bulk blends of the 28-28-0 and 19-19-19 grades was not significant at 65% relative humidity. However, the unconditioned 17-17-17 bulk blend had a significantly higher moisture penetration than the unconditioned 17-17-17 granulated mixture at 65% relative humidity. At 80% relative humidity the moisture penetration with all the unconditioned bulk blends was considerably

TABLE 3
Hygroscopic and Storage Properties of Mixtures of Granular Materials (Bulk Blends) and Granulated Mixtures[a]

Grade[b]	28-28-0				19-19-19				17-17-17	
Type[c]	GM	BB			GM	BB			GM	BB
P_2O_5 source[d]	APP	APP	MAP	DAP	APP	APP	MAP	DAP	MAP	MAP
Moisture, %[e]	1.4	0.6	0.8	1.4	2.3	0.5	0.6	1.0	0.8	0.7
Critical relative humidity, %[f]	55–65	65–70	65–70	65–70	50–60	55–65	55–65	55–65	50–55	55–60
Laboratory absorption-penetration test (30°C, 65% relative humidity for 72 hours)										
Moisture absorption, mg/cm^2	62	46	56	—[g]	166	102	113	—	303	177
Moisture penetration, cm	1.5	0	2.3	—	5.1	6.1	5.9	—	4.8	10.1
Moisture-holding capacity, mg/cm^3	41	—[h]	24	—	33	17	19	—	63	18
Moisture-holding capacity, %	5.0	—[h]	3.0	—	4.6	2.1	2.2	—	8.1	2.0
Granule integrity[i]	Poor	Good	Good	—	Poor	Good	Good	—	Poor	Good
Laboratory absorption-penetration test (30°C, 80% relative humidity for 72 hours)										
Moisture absorption, mg/cm^2	370	421	394	381	483	359	391	467	576	410
Moisture penetration, cm	2.9	14.4	12.1	14.0	9.1	17.1	20.0	20.0	6.0	14.0
Moisture-holding capacity, mg/cm^3	128	29	33	27	53	21	20	23	96	29
Moisture-holding capacity, %	15.1	3.8	3.9	3.0	7.3	2.6	2.3	2.6	11.7	3.2
Granule integrity[i]	Poor	Good	Good	Good	Poor	Good	Good	Good	Poor	Good
Small-Bag Storage Test										
Percent + 12.7-mm lumps/hardness[j]										
1 month	0.1/L	0/—	0/—	0.5/L	38.1/L	0/—	0/—	0.5/L	30.2/M	0/—
3 months	15.0/M	0/—	0/—	12.5/M	44.2/H	0/—	3.5/L	19.4/L	55.3/M	10.0/L

a. All tests were performed according to TVA procedures (Special Report No. S-444).
b. The nitrogen source for all grades was urea, except 17-17-17 which contained urea and ammonium sulfate. Where potassium was used, potassium chloride was the source of K_2O.
c. BB = bulk blend; GM = granulated mixture.
d. APP = ammonium polyphosphate; MAP = monoammonium phosphate; DAP = diammonium phosphate.
e. Determined by vacuum desiccation (*Official Methods of Analysis*, 13th Edition [1980], AOAC, 2.013).
f. Measured at 30°C (86°F).
g. Not determined.
h. Moisture-holding capacity was calculated using moisture penetration.
i. Granule integrity is a qualitative observation based on the strength of the surface granules after exposure for 72 hours.
j. H = hard; M = medium; L = light.

deeper than with the equivalent granulated mixtures (Table 3 and Figure 2). The addition of a conditioner did not decrease the moisture penetration in any samples (Table 4 and Figure 3).

Moisture-holding capacity is described as the maximum amount of moisture that a granule will absorb before moisture is transferred to adjacent granules. The moisture-holding capacities of all unconditioned granulated mixtures were significantly higher than the equivalent bulk blends at 65% and 80% relative humidity (Table 3). A high moisture-holding capacity is considered a desirable characteristic if it does not adversely affect the granule integrity. The addition of a conditioner did not affect the moisture-holding capacity of any samples (Table 4).

The granule integrity of all the unconditioned bulk blends was much better than that of the equivalent granulated mixtures at 65% and 80% relative humidity (Table 3). Again, the addition of a conditioner did not affect the granule integrity of any samples (Table 4).

The second procedure (IFDC moisture penetration method) was devised to determine (1) whether moisture would continue to penetrate a material for

TABLE 4
Hygroscopic and Storage Properties of Mixtures of Granular Materials (Bulk Blends) and Granulated Mixtures Conditioned With 2% Kaolin[a]

Grade[b]	**28-28-0**				**17-17-17**			
Type[c]	**GM (APP)**		**BB (MAP)**		**GM (MAP)**		**BB (MAP)**	
Binder[d]	**AF**	**MO**	**AF**	**MO**	**AF**	**MO**	**AF**	**MO**
Moisture, %[e]	**1.4**	**1.4**	**0.8**	**0.8**	**0.8**	**0.8**	**0.7**	**0.7**
Critical relative humidity, %[f]	**55-65**	**55-65**	**65-70**	**65-70**	**50-55**	**50-55**	**55-60**	**55-60**
Laboratory absorption-penetration test (30°C, 65% relative humidity for 72 hours)								
Moisture absorption, mg/cm²	75	80	24	31	252	239	153	174
Moisture penetration, cm	1.5	1.7	0	0	3.3	3.6	6.0	7.4
Moisture-holding capacity, mg/cm³	50	47	—[g]	—	76	66	26	24
Moisture-holding capacity, %	6.2	5.9	—	—	9.5	8.6	2.9	2.7
Granule integrity[h]	Poor	Poor	Good	Good	Poor	Poor	Good	Good
Laboratory absorption-penetration test (30°C, 80% relative humidity for 72 hours)								
Moisture absorption, mg/cm²	332	349	306	346	512	555	410	585
Moisture penetration, cm	3.7	3.8	10.0	11.0	5.4	5.4	11.0	15.5
Moisture-holding capacity, mg/cm³	90	92	31	31	95	103	37	38
Moisture-holding capacity, %	10.9	11.7	3.7	3.8	11.7	13.1	4.2	4.4
Granule integrity[h]	Poor	Poor	Good	Good	Poor	Poor	Good	Good
Small-Bag Storage Test Percent + 12.7-mm lumps/hardness[i]								
1 month	0/-	0/-	0/-	0/-	0/-	0/-	1.0/L	1.0/L
3 months	0/-	0/-	0.1/L	0.1/L	0/-	0/-	7.2/L	6.7/L

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a. All tests were performed according to TVA procedures (Special Report No. S-444).
b. The 28-28-0 samples contained urea; the 17-17-17 samples contained urea, amonium sulfate, and potassium chloride.
c. GM (APP) = granulated mixture containing ammonium polyphosphate; BB (MAP) = bulk blend containing monoammonium phosphate; GM (MAP) = granulated mixture containing monoammonium phosphate.
d. AF = amine (Armoflo L-15, Armak Industrial Chemicals Division, Chicago, Illinois); MO = motor oil (SAE 20, Keystone Penwalt, Philadelphia, Pennsylvania); 2% kaolin was added as a conditioner.
e. Determined by vacuum desiccation (*Official Methods of Analysis*, 13th Edition [1980], AOAC, 2.013).
f. Measured at 30°C (86°F).
g. Moisture-holding capacity was calculated using moisture penetration.
h. Granule integrity is a qualitative observation based on the strength of the surface granules after exposure for 72 hours.
i. H = hard; M = medium; L = light.

TABLE 5
Percent Critical Relative Humidity (at 30°C)—Pure Salts Compared With Commercial Fertilizers

Material	**Method**	**Urea**	**Monoammonium Phosphate**	**Diammonium Phosphate**	**Potassium Chloride**	**Ammonium Sulfate**
Fertilizer grade	TVA procedure	70-75	70-80	70-75	70-80	75-85
Pure salt[a]	TVA procedure	70-75	90-95	80-85	80-85	80-85
Pure salt[a]	Vapor pressure	72.5	91.6	82.5	84.0	79.2

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a. Reagent-grade material.

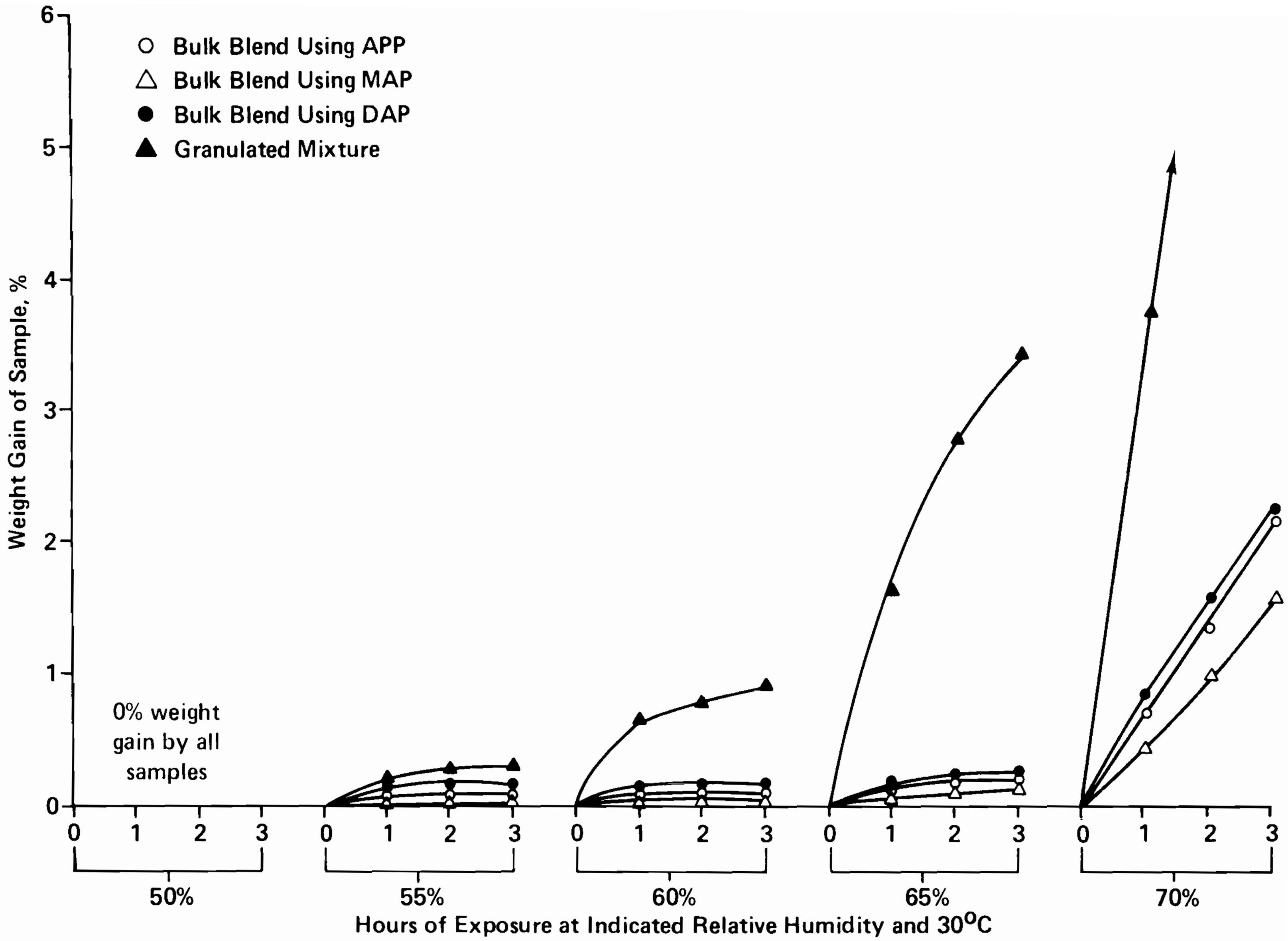

Figure 1. Critical Relative Humidity Data for Bulk Blends and a Granulated Mixture of 28-28-0.

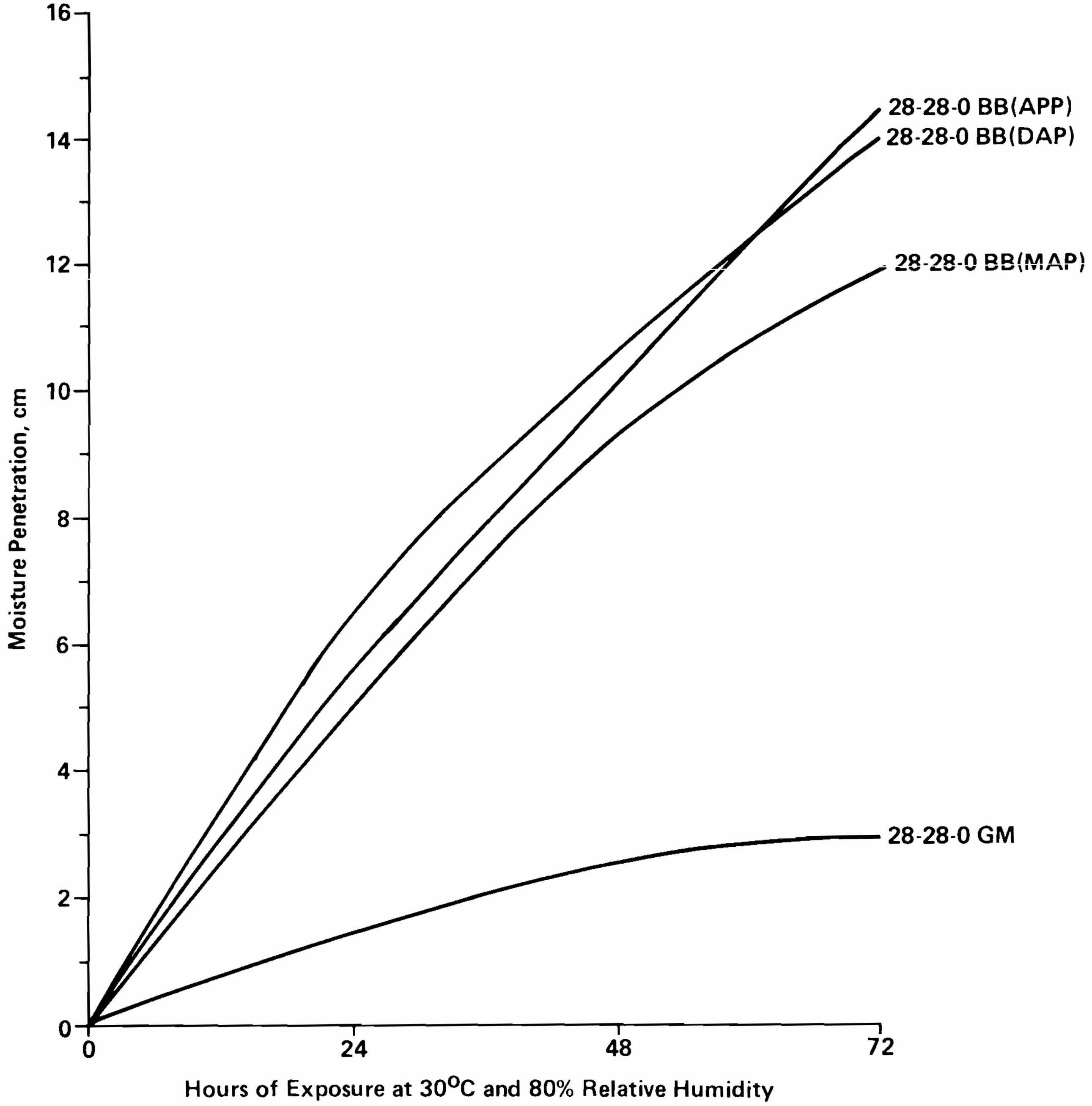

Figure 2. Moisture Penetration Into Bulk Blends (BB) and Granulated Mixture (GM) of 28-28-0.

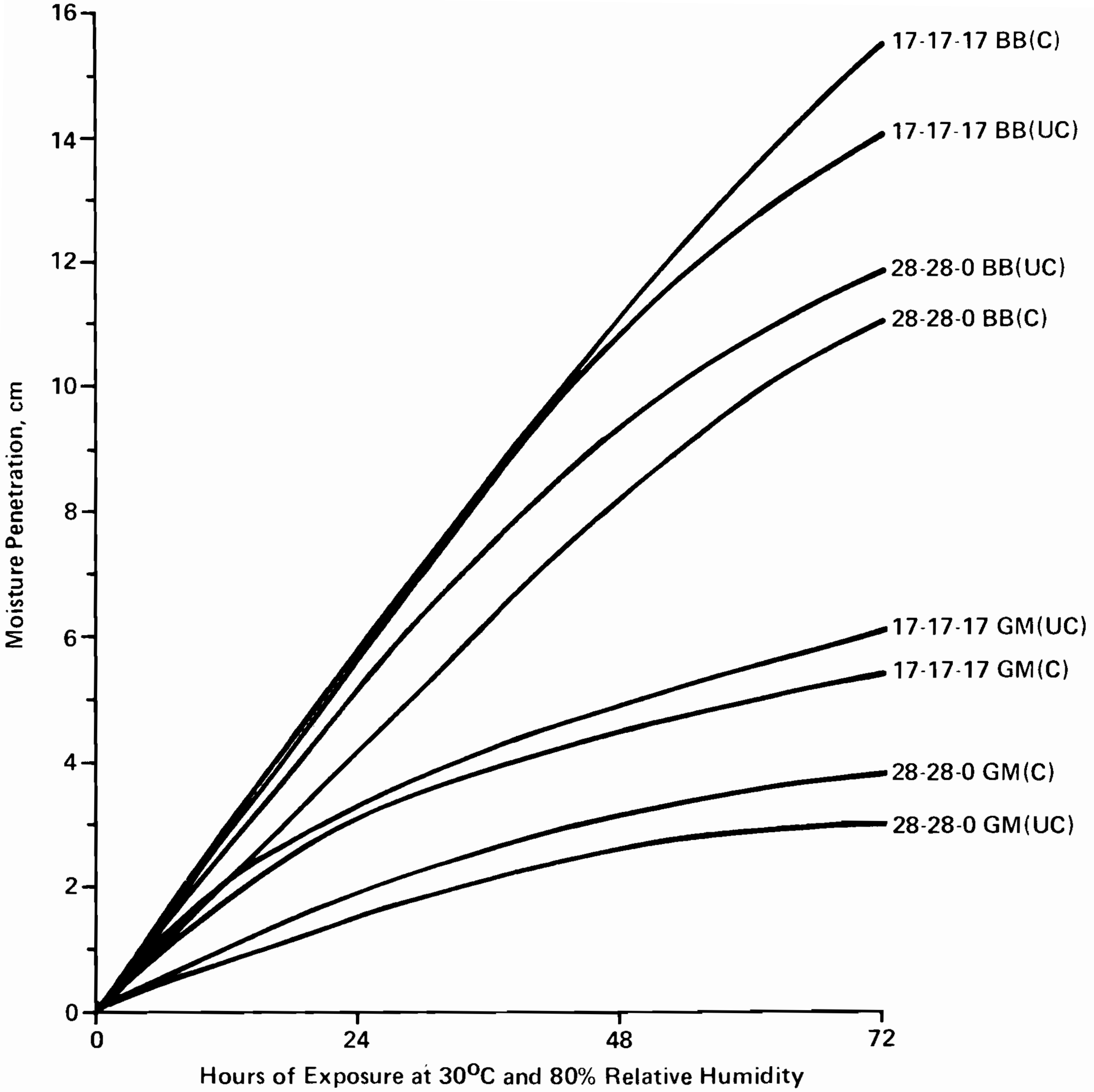

Figure 3. Moisture Penetration Into Conditioned (C) and Unconditioned (UC) Bulk Blends and Granulated Mixtures of 28-28-0 and 17-17-17.

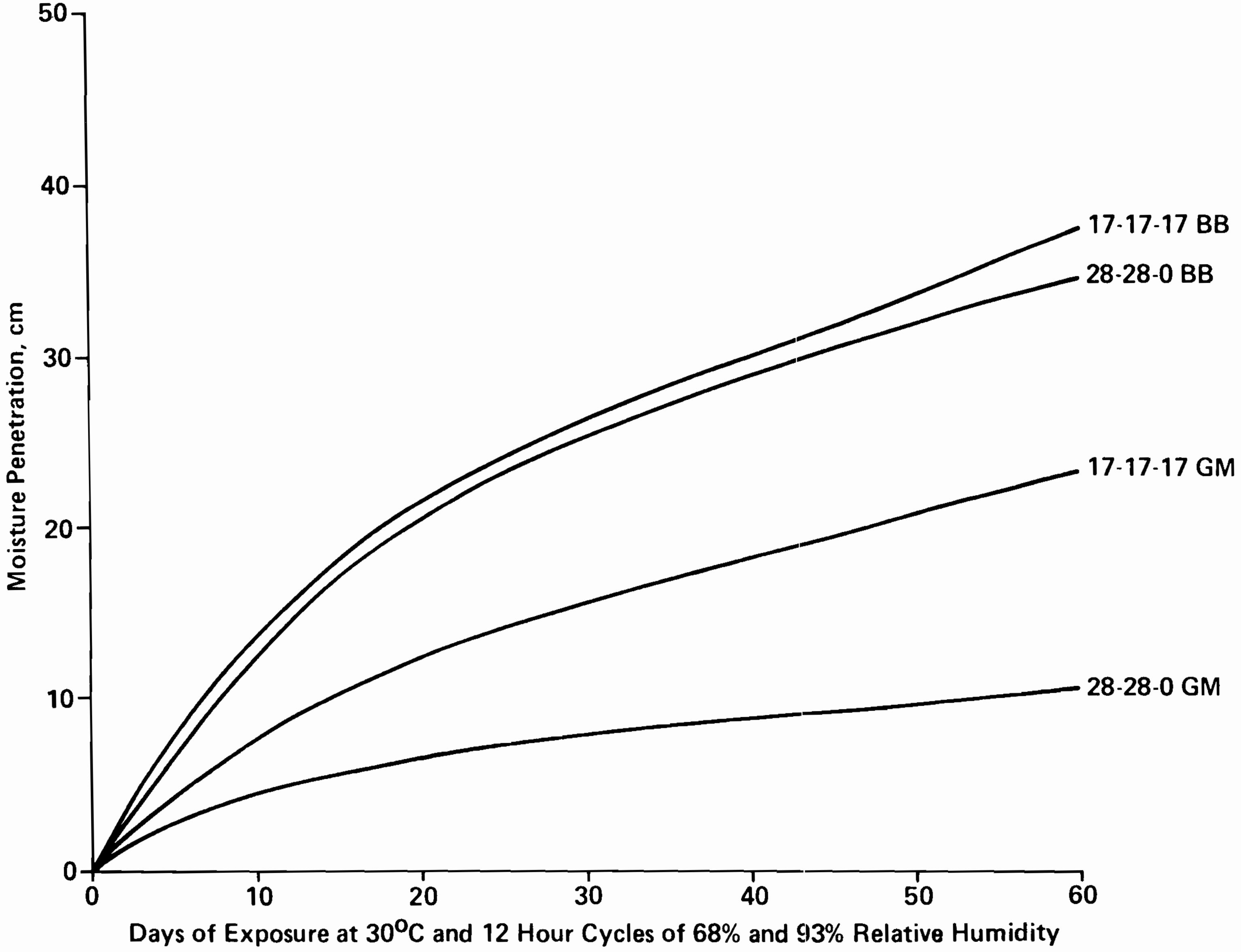

Figure 4. Moisture Penetration Into Bulk Blends (BB) and Granulated Mixtures (GM) of 28-28-0 and 17-17-17.

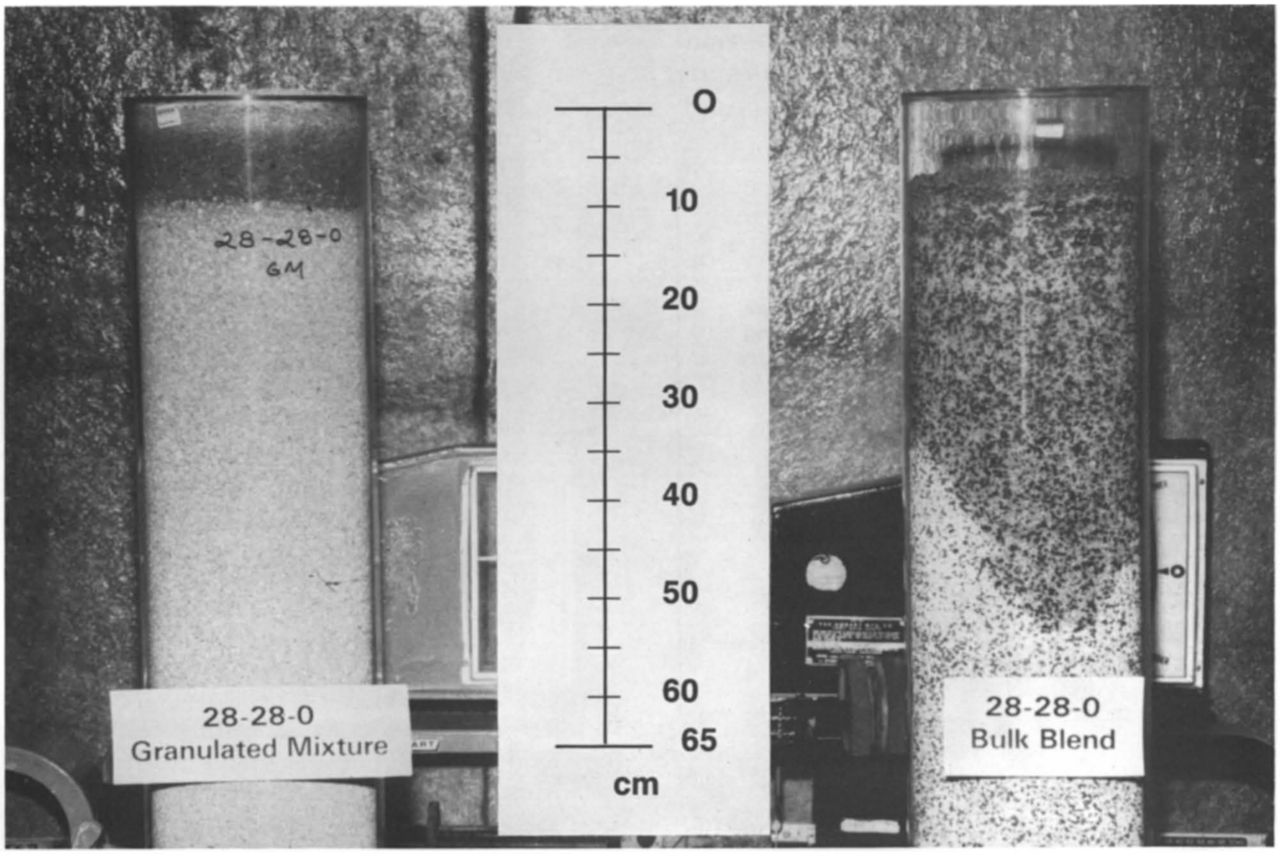

Figure 5. IFDC 60-Day Moisture Penetration Test.

an extended period of time under cycling humidities or (2) whether a crust would form on the material that would effectively stop moisture penetration.

With the IFDC procedure, samples were exposed to a constant temperature (30°C), but cycling relative humidities (12 hours at 68% followed by 12 hours at 93%) in open-top, clear plastic cylinders (20 cm [8 inch] in diameter by 152 cm [5 feet] in depth) for a period of 60 days.

Moisture penetration was observed and measured through the wall of the cylinders. Attempts were made to measure the amount of moisture absorbed by placing the cylinders on platform scales, but the gain in weight was too small to measure accurately. Therefore, the moisture-holding capacities of the samples could not be determined because these are calculated from the moisture absorption (weight) data.

Four samples were subjected to the IFDC moisture penetration test. These were the 28-28-0 and 17-17-17 granulated mixtures and the 28-28-0 and 17-17-17 bulk blends.

The moisture penetration into the bulk blends was considerably deeper than that of the equivalent granulated mixtures (Figures 4 and 5). "Crusting-over" of the samples did not occur. Therefore, the penetration of moisture into the sample never stopped although after approximately 3-4 weeks the rate of penetration decreased considerably.

In both of these procedures, the most striking difference between the bulk blends and the granulated mixtures was the lower moisture-holding capacity of bulk blends, which resulted in a deeper penetration of moisture into the bulk blends. A probable reason for the lower penetration of moisture into the granulated mixtures is the greater porosity of the granulated mixtures caused by the evaporation of water during the drying process. This greater porosity gives the material a higher moisture-holding capacity, which results in a lower moisture penetration. The bulk-blend ingredients, on the other hand, especially granular urea and crystalline potassium chloride, are much less porous; thus a deeper penetration of moisture is encouraged.

The strength or hardness of the individual granules is usually a good indicator of porosity. For example, granules that are relatively porous usually have a relatively low crushing strength. Such granules are also usually characterized by a high moisture-holding capacity. This relationship between crushing strength and moisture-holding capacity is illustrated in Table 6. Materials with low porosity, such as granular urea and crystalline potassium chloride, have a relatively high crushing strength even after they have been exposed to humid conditions. The reason for this is that the structure of the granules is not weakened by the absorption of moisture; hence, a strong granule remains even after exposure to a moist atmosphere.

TABLE 6
Relationship Between Granule Strength and Moisture-Holding Capacity of Selected Fertilizers[a]

Material	Granule Crushing Strength (kg/granule)	Moisture-Holding Capacity (%)
17-17-17 (granulated mixture)	1.7	11.7
28-28-0 (granulated mixture)	2.5	15.1
Urea (granular)	3.8	3.8
DAP (granular)	4.1	11-18[b]
KCl (crystalline)	4.1	3.0

a. All tests were performed according to TVA procedures (Special Report No. S-444).
b. The moisture-holding capacity of DAP is largely dependent on the type and amount of impurities in the product.

Caking Tendency

The caking tendencies of all samples were determined using a small-bag storage test (3). Samples of 1,800 ml (110 in^2) were subjected to a pressure of 0.25 kg/cm^2 (3.5 lb/in^2) at 30°C for a period of 1 month and 3 months.

The caking tendencies of all unconditioned granulated mixtures were quite high. The caking tendencies of the DAP-based unconditioned 28-28-0 and 19-19-19 bulk blends were also quite high. The caking tendency of all other unconditioned bulk blends not containing DAP was low (Table 3).

The addition of a conditioner to the granulated mixtures completely prevented caking. With the exception of the DAP-based bulk blends, the tendency of unconditioned bulk blends to cake was much less than that of the unconditioned granulated mixtures. The caking of the DAP-based bulk blends could probably be attributed to the fact that they contained approximately twice as much moisture as the other bulk blends (Table 3 and 4).

CONCLUSION

The following major differences were noted in these comparative studies:

1. The CRH values of the bulk blends were higher than those of the granulated mixtures. This is probably true because of the lower surface area contact between the components of the bulk blends.
2. The penetration of moisture into the bulk blends was much deeper than that into the granulated mixtures. This result probably occurred because of the lower moisture-holding capacity of the bulk blends.
3. The integrity of the moist granules of the bulk blends was much better than that of the moist granules of the granulated mixtures. This finding, also, probably resulted from the low moisture-holding capacity of the bulk blends.
4. The presence of a conditioner was necessary to prevent caking in the granulated mixtures. Most of the bulk blends did not cake even when no conditioner was used. The absence of caking in the bulk blends could probably be attributed to a low moisture content, low surface area contact between the ingredients of the blend, and hard, nonporous granules. Where caking did occur in the bulk blends, the moisture content was about twice that of the noncaking blends.

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Application of SGN to Analysis or How to Cut Cost and Improve Quality - Both at the Same Time!

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Three years ago, at the thirty first meeting of the Round Table, I had the privilege to present my view on "Quality Control in Bulk Blending".

Today, it is my pleasure to share with you the experience gained since 1981 and to expand on the application of SGN and other concepts.

May I begin by repeating some of the information given in the earlier paper?

In Canada, fertilizers are monitored at the federal level. Sampling is done by inspectors of the Plant Products Branch of Agriculture Canada. Most blend samples are taken at the blenders, although some are collected on the way to, or at the farm. Results are tabulated and sent several times a year to each company. Area and national averages are also released to industry organizations.

Table 1 lists the tolerance levels for Nitrogen, P_2O_5 and K_2O. If the actual (found) value for one of these plant foods is below the applicable tolerance level, the sample is reported deficient for that plant food.

To insure that the customers get full commercial value, a tighter tolerance is imposed on the combined nutrient level (CNL). A sample is reported deficient if its CNL is less than 98%. Most blenders overformulate. In Canada, the national average for CNL has always been over 100% in the last 15 years and over 102% in at least 6 of those 15 years.

The point must be made that CNL is a good indicator of formulation overage, at least on groups of samples, and we know that the deficiency rate is strongly dependent on formulation overages. As one would expect, there exists a logarithmic relationship between deficiencies and CNL averages. When the data are plotted on semi-log paper the logarithmic curve is converted to a straight line. The dotted line here is the line of best fit for the four years 1969 to 1972. The line of best fit for the next seven years is practically the same, and it seems to fit also the four years 1980 to 1983.

It should be no surprise to find that the UCO data points for the three "PRE SGN" years 1978 to 1980, lie on a line almost exactly parallel to the line shown on the previous graph. In those years we tried to control deficiencies by adjusting formulation overages, and the 1980 deficiency rate had been accurately predicted a year earlier when the decision was made to increase overages to 4%.

At that point in time, we convinced ourselves that, maybe, there was a better way. We wanted both lower costs and less deficiencies, and we got them, both, in 1981. All we had to do was to mix granular and coarse potash 50/50. This mixture had an SGN of 220. The premium on granular potash cost an average of $.20 per ton of blend but the overage contributed $2.00 for a net saving of $1.80 per ton, and deficiencies were lower too.

When the only thing changing is overage, one can expect the data point to move on a line parallel to the line shown on the previous graph. So, in 1982, we kept everything the same except for a significant reduction in overages, and the deficiency rate moved exactly where we expected it to move.

TABLE 1
Tolerance Levels in Canada

Nutrient Guarantee	**Found Value Must Be At Least**	
	N	**P_2O_5 or K_2O**
3 or less	Guarantee—0.3	Guarantee—0.3
4	3.3	3.3
5	4.2	4.2
6	5.1	5.1
7	6.0	6.0
8	7.0	6.9
9	8.0	7.8
10	9.0	8.7
11	10.0	9.6
12	11.0	10.5
13	12.0	11.4
14	13.0	12.3
15	14.0	13.2
16	15.0	14.1
17	16.0	15.0
18	17.0	16.0
19	18.0	17.0
20 or more	Guarantee—1.0	Guarantee—2.0

Combined Nutrient Level

$$\frac{2.5\,N_A + 2\,P_2O_{5_A} + K_2O_A}{2.5\,N_G + 2\,P_2O_{5_G} + K_2O_G} \geqslant .98$$

Where the Subscript A stands for "Actual"
and the Subscript G stands for "Guaranteed"

Since that time we have "polished" the control we have over material sizes. Indeed, we found a predictable improvement in our results when potash producers made available to us a material of SGN 210. This material matches well the granular urea (SGN 215) and the phosphates (SGN 205) we use.

It is now possible to calculate the probability of deficiency, with a fair degree of confidence, when the SGN's of materials used and the formulated overage are known.

I have repeatedly mentioned SGN in the course of this paper. An explanation is overdue. SGN, or Size Guide Number in layman's language is "Average Particle Size." SGN 210 means that the average particle measures 2.10 mm in diameter. That would go through an 8 mesh screen but would be retained on a 9 mesh.

The blender operator can do everything right, from formulation, to weighing and mixing, and still get a deficient sample. That will happen when his materials are not size compatible.

He can now take most of the element of chance out. To remain uniformly mixed, and therefore give a good representative sample, blend materials must have almost identical SGN's. The closer the SGN's, the better the quality control and that means lower overages too.

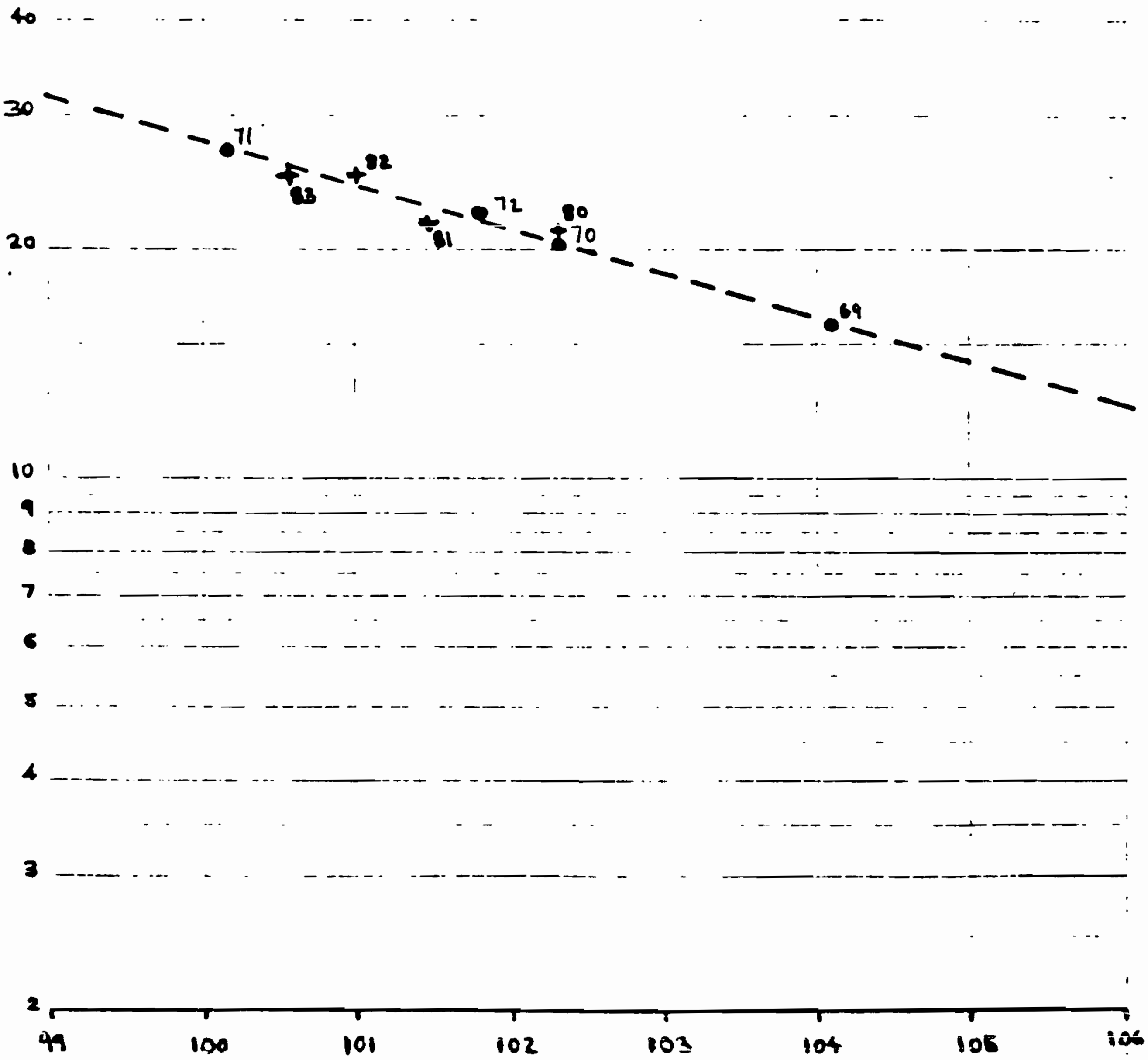

FIG. 1
CANADA
69 - 72 ●
80 - 83 +

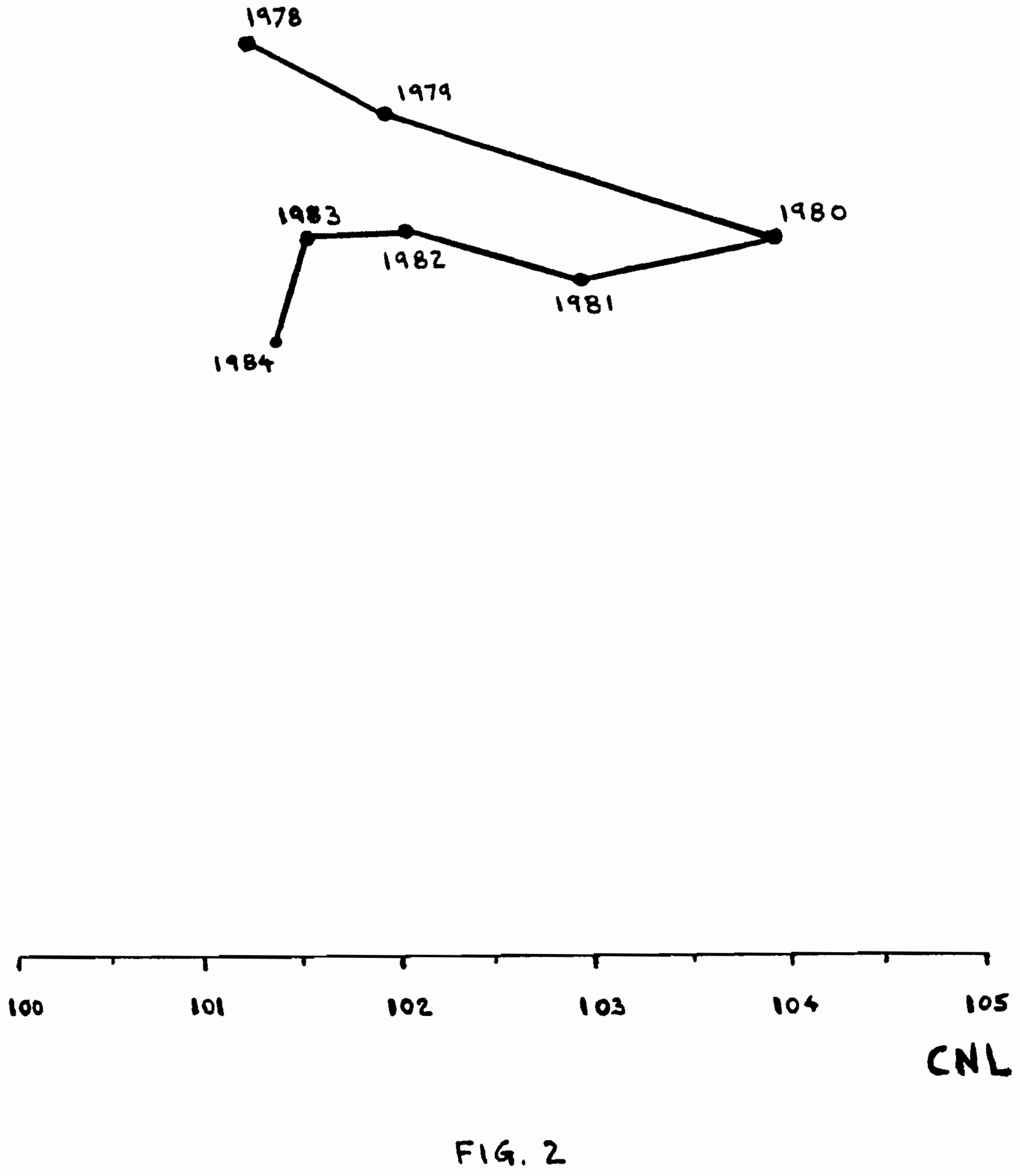

FIG. 2

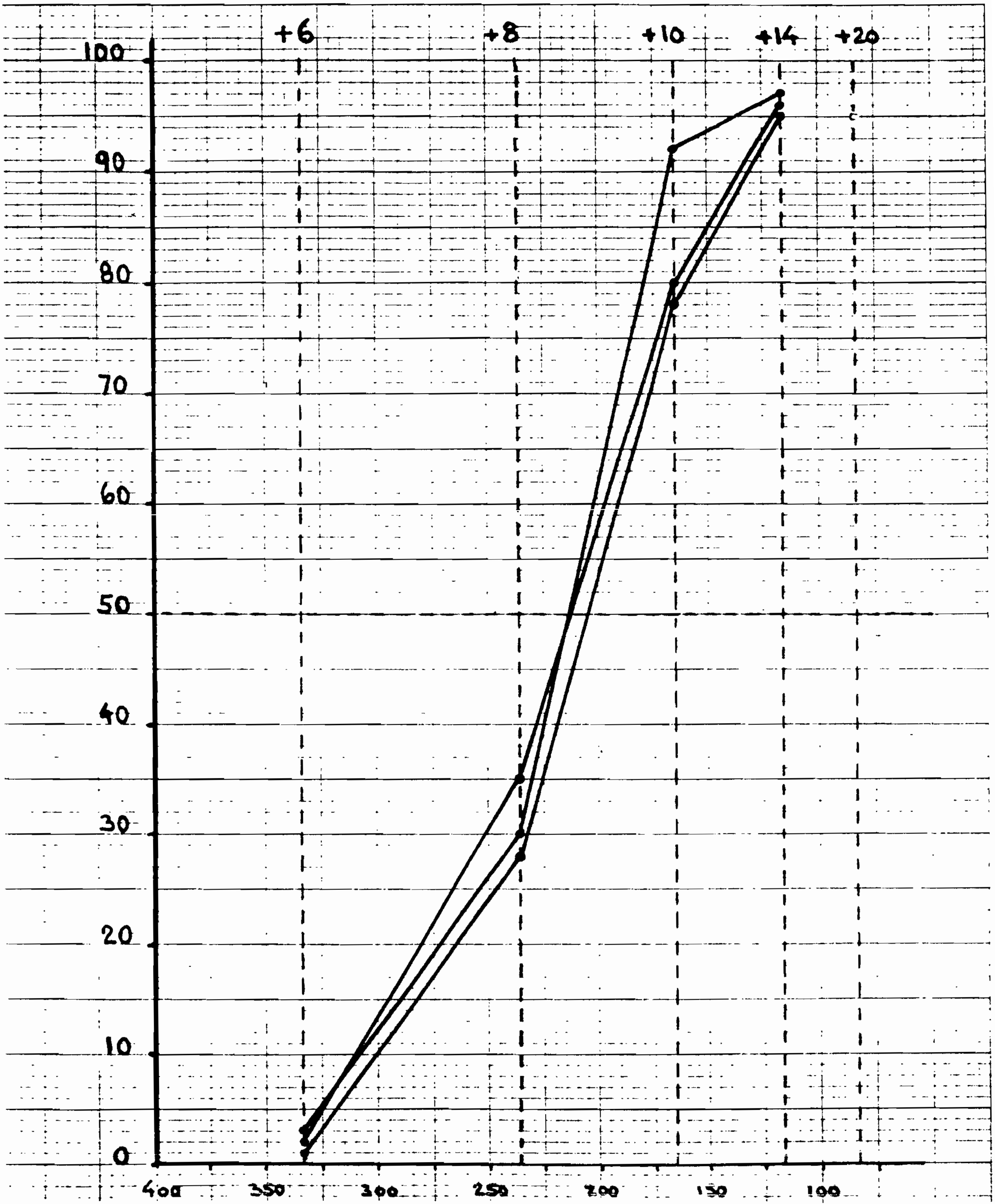

FIG. 3 – MATCHED MATERIALS

SGN 205 - 215

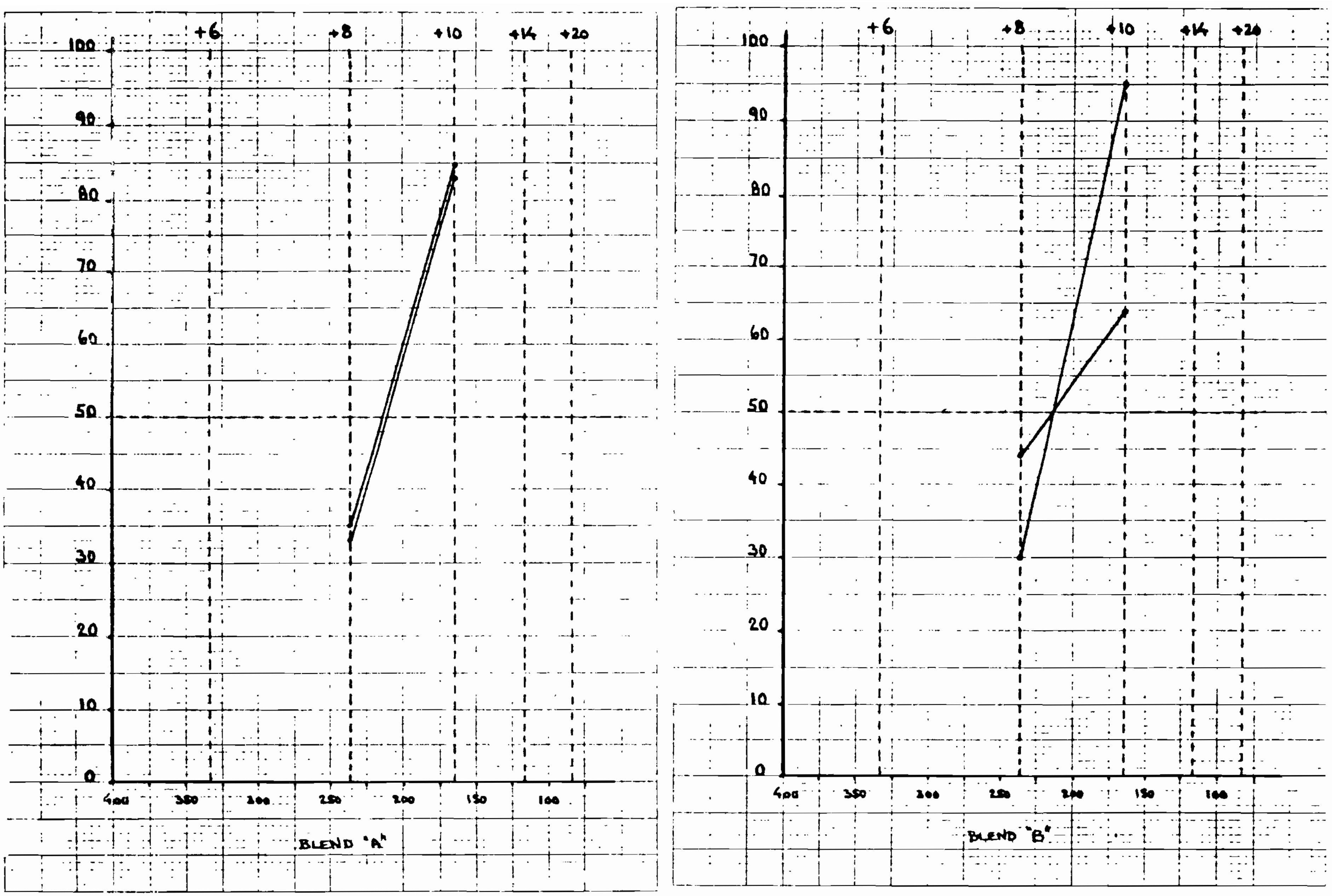
+6
+8
+10
+14
+20
100
90
80
70
60
50
40
30
20
10
0
400
350
300
250
200
150
100
BLEND "A"
+6
+8
+10
+14
+20
100
90
80
70
60
50
40
30
20
10
0
400
350
300
250
200
150
100
BLEND "B"

FIG. 4

Now let us look at two different situations: Will the materials in Blend "A" mix better than those in Blend "B"? Note that the two materials in Blend "B" have exactly the same SGN, yet most of us would expect Blend "A" to perform better. So, in addition to SGN we may need another index, to tell us something about the slope of those lines. I will call it Uniformity Coefficient and you would want your materials to have, not only almost identical SGN's, but also similar Uniformity Coefficients.

To obtain the uniformity coefficient we will determine the particle size passing 80% and the particle size passing 20%—divide the first by the second. This number will be less than unity. The closer it is to unity, the more uniform the product.

And eventually, we will combine SGN's and uniformity coefficients of our materials to get one single number which I would call "Mixing Quality Ratio".

A first approximation, I would suggest that the Mixing Quality Ratio be defined as:

$$MQR = 1 - CV_{SGN} - CV_{UC}$$

Where CV_{SGN} = Coefficient of variation of SGN's

CV_{UC} = Coefficient of variation of UC's

It is conceivable that a mixing quality ratio of, say, .98 would mean practically no deficiencies even when formulating "Flat" (exactly meeting guarantee).

Sooner or later a very large blender will study this approach. The support staff will collect screen samples of the materials used every day and will correlate SGN's and UC's to the analysis of the mixes.

In the concluding paragraph of my 1981 paper I said: "I strongly believe in the power of the blender operator to improve quality. Faced with an excessive number of deficiencies the operator will try the "quick" fix first. That is—increase overages. And I have shown the limits of that approach. He may try next change in procedures, change in equipment, change in people. It is far more effective (and generally more economical) to do something about particle size matching. With the continued help from producers, I am convinced that quality control can be improved significantly over a relatively short time."

I am pleased to report that the quality control record of Ontario blenders improved significantly in the last year and I do know that the producers helped, particularly those potash producers who brought out the new "Blender Grade-SGN 210" material. I must acknowledge, here and now, their outstanding contribution to our efforts to achieve excellence.

For UCO the application of SGN to analysis has worked. A perfect record may never be reached. But, at least, the Ontario blending industry can now look at the TFIO goal of 10% deficiencies with 101% CNL as a reasonable and attainable target.

Important Happenings at the International Technical Level

Robert C. Rund
Office of the Indiana State Chemist
Purdue University

It is highly unlikely that many in this audience today are fully cognizant, or even slightly aware, of the activities being conducted by a group of fertilizer chemists at the international level which may play a major role and have a significant impact upon the financial return of a future fertilizer shipment abroad. The reference being made here is to a committee of the International Organization for Standardization (ISO). The ISO is a Geneva, Switzerland based organization operating through a network of national standards making bodies since 1970 to standardize methods of analysis, sampling and description of fertilizers and soil conditioners on an international scale.

It may come as a surprise to some of you to learn that the standard analytical method, or sampling procedure, for a given plant nutrient is not necessarily the same from one country to another. It is these national idiosyncracies that create differences in analysis of nutrient content to such an extent as to cause delay in unloading ocean going vessels, resulting in extreme and unanticipated demurrage charges, unfavorable settlements, or possibly, actual refusal of a shipment.

The purpose of this presentation is to direct your attention toward an international liaison which has as its goal the removal of these idosyncrasies and, at the same time, the barriers to international trade created by them. On the surface, at least, this appears to be a worthwhile endeavor unless the standardization results in an economic disadvantage for one or more parties. It is this potential that each participating national delegation tries to avoid without sacrificing scientific truth.

Membership within the International Organization for Standardization consists of the national standards making bodies of 87 countries representing 95% of the world's industrial production. Input by any national interest anywhere is through one's national standards organization. As an example, the USA member body is the American National Standards Institute (ANSI).

In 1970, at the instigation of several European members, ISO authorized the creation of a technical committee, known appropriately as Technical Committee 134 (TC 134), and charged it with developing methods of analysis and allied technical matters for fertilizers and soil conditioners. The secretariat, for administrative purposes, was secured by the French. TC 134 was promptly organized and agreed to initiate studies into terminology, sampling, physical properties and chemical analysis. The present organization of TC 134 appears in Table 1.

TABLE 1
Structure of ISO/TC 134—Secretariat held by France

SC(1)	WG(2)	Title	Secretariat
1		Terminology and Labeling	France
2		Sampling	United Kingdom
3		Physical Properties	West Germany
4		Chemical Analysis	United Kingdom
	1	Determination of Nitrogen	United Kingdom
	2	Determination of Phosphorus	France
	3	Determination of Potassium	Netherlands
	4	Determination of Water	Portugal
	5	Determination of Ca, Mg, S	Netherlands

(1) Subcommittee
(2) Working Group

Early on, the Association of Official Analytical Chemists (AOAC) became aware of these actions. Inasmuch as AOAC methods of analysis are respected worldwide and prescribed by law in North America for fertilizer regulatory purposes and have been and are in vogue when prospecting for phosphate and used in controlling quality of processed fertilizer in North America and elsewhere, and because AOAC methods have been collaboratively studied and developed by many laboratories over a long period of time to insure scientific worth, it seemed critical to those of us close to this matter to be in position to influence the adoption of methods for international use which would be at least as scientifically sound as AOAC methods.

Accordingly, the AOAC organized a Technical Advisory Group (TAG) in 1980 and agreed with ANSI to provide administration for the TAG. Ten different organizations (U.S. governmental and industrial concerns) were invited to join in the formation of the U.S. TAG. Only two, the National Fertilizer Development Center (NFDC) and The Fertilizer Institute (TFI) responded affirmatively and have worked cooperatively with AOAC in this endeavor since. The organization of the U.S. TAG is depicted in Table 2.

Purposes of the TAG include: (1) Establishing the U.S. position on documentation arising from TC 134 and its subsidiary groups; (2) Initiating U.S. technical proposals for consideration by TC 134 and subsidiary bodies; (3) Appoint U.S. technical experts to serve on TC 134 and subsidiary groups; (4) Provide representation for TC 134 and Subcommittee meetings; (5) Obtain financial support to meet costs of technical participation; and (6) Seek resolution of differences of opinion within the U.S. TAG.

TABLE 2
Structure of U.S. TAG—Administered by AOAC
TAG Chairperson—R. C. Rund, Purdue University

SC(1)	WG(2)	Leader	Organization
1		J.P. Minyard, Jr.	AAPFCO(3), MSU(4)
2		D. Caine	AOAC, Estech
3		G. Hoffmeister	TVA
4		R.C. Rund	Purdue University
		F.J. Johnson	TVA
	1	P.R. Rexroad	AOAC, Univ. of Missouri
	2	F.J. Johnson	TVA
	3	P. Kane	AOAC, Purdue Univ.
	4	R.D. Duncan	TVA
5		C. McBride	USS AgriChem

(1) Subcommittee
(2) Working Group
(3) Association of American Plant Food Control Officials
(4) Mississippi State University

Proposals for study can be generated at any level within the Technical Committee and, if accepted, are referred to a subcommittee or working group for consideration and action. Following development and determination of a possible solution to the problem and providing evidence of reliability and accuracy, the method under study is submitted as a Draft Proposal (DP) to the participating subcommittee members. If accepted, the proposed method then becomes a Draft International Standard (DIS) and must survive a vote by the participating members of the Technical Committee to become a full fledged International Standard subject to review every five years for revision, rejection or continuation.

During the fourteen years of existence for the Technical Committee, ten International Standards have been adopted and published. A listing of these appears in Table 3. Copies are available and can be purchased from ANSI or any other national standards body. Of the ten referred to here, three are standards concerned with labeling and classification, one deals with physical handling of the gross sample,

TABLE 3
International Standards

Number	Title
5306	Presentation of Sampling Reports
5311	Determination of Bulk Density (Tapped)
5317	Determination of Water Soluble Potassium—Dissolution of the Test Portion
5318	Determination of Potassium Content—Potassium Tetraphenylborate Gravimetric
7407	Determination of Acid Soluble Potassium—Dissolution of the Test Portion
7408	Determination of Ammoniacal Nitrogen Content—Titrimetric
7409	Marking—Presentation and Declarations
7410	Final Samples—Practical Arrangements
7837	Determination of Bulk Density (Loose) of Fine-Grained Fertilizers
7851	Classification

two standards are concerned with the determination of bulk density and four refer to methods of analyses. One should not assume that these standards have been adopted unanimously. Of the ten noted, four were disapproved by one or more country and these include two in which the U.S. was the only dissenting party.

Work continues within Technical Committee 134 on agreement of the contents of a fertilizer glossary, sampling plans for bulk and bagged fertilizer, including procedures for sample reduction, development of means to evaluate the performance of mechanical sampling devices for bulk fertilizer moving on a conveyer belt, preparation of the test sample for chemical analysis and physical testing, sieve testing, determination of oil retention in ammonium nitrate, determination of the angle of repose for bulk storage of dry fertilizer, determination of total nitrogen and phosphorus, extraction procedures for acid soluble and available phosphorus, and determination of moisture, calcium, magnesium and sulfur.

Perhaps the most time, effort and expense in the last two years by the U.S. TAG has been expended in gathering data to convince other members of Working Group 2 Phosphorus that a marked discrepancy exists between results obtained using the AOAC method and the method of the European Economic Community (EEC) for extraction of available phosphoric acid, especially when applied to certain fertilizers produced in America.

The difference in the analytical methods themselves appears inconsequential on the surface—the AOAC method requires a prior extraction with water before treatment with neutral ammonium citrate solution, the EEC method ignores the water extraction. However, we of the U.S. TAG recognized early on that the exchange capacity of the quantity of neutral ammonium citrate solution used in both methods was limited and, if mono calcium phosphate present was not all solubilized with a prior water wash, the citrate solution alone would not be sufficient to solubilize all the remaining phosphatic compounds remaining when certain phosphate sources were used.

F. J. Johnson and K. L. Parks (1), through a series of three well conducted collaborative studies, verified these concerns. Table 4 notes the results obtained upon 7 samples by 5 laboratories and the differences between the two methods in the first of the three studies. The differences ranged as high as 2.92 percentage units in favor of the AOAC method when the sample compared was triple superphosphate.

Expanding the first study to include more laboratories and fertilizers with phosphorus sources from different areas of the U.S., two additional studies were conducted by Johnson and Parks and reported in the same paper noted before. A summation of their findings in this second and third round robin is given in Tables 5 and 6. Note that the greatest discrepancies occur in TSP and, according to the original paper of Johnson's and Park's, in products whose phosphorus originated in eastern U.S. locations. It is worthy to note that the lone GTSP sample reported in Table 5 was made with western phosphate rock.

While the latter two studies discussed above did not show the gross differences between methods as did the first, it is evident from examination of the tables that a definite bias exists.

TABLE 4

Fertilizer	Percent APA		
	EEC	AOAC	Diff
DAP	46.18	46.05	−0.03
MAP	49.65	49.55	−0.10
GTSP	44.14	46.33	2.19
GTSP	42.41	45.33	2.92
GTSP	43.63	45.03	1.40
GTSP	44.99	45.86	0.87
N-Super	17.72	18.01	0.29

TABLE 5

Fertilizer	Percent APA		
	EEC	AOAC	Diff
6-24-24	24.53	24.57	0.04
20-10-10	10.29	10.29	—
15-15-15	14.16	14.61	0.45
ROP-TSP	37.26	37.59	0.33
ROP-TSP	46.78	46.78	—
GTSP	43.97	43.99	0.02
DAP	45.80	45.85	0.05
DAP	46.58	46.66	0.08

TABLE 6

Fertilizer	Percent APA		
	EEC	AOAC	Diff
GTSP	45.27	45.96	0.69
GTSP	44.38	45.96	1.58
GTSP	45.32	46.13	0.81
ROP-TSP	46.93	47.12	0.19
ROP-TSP	46.26	46.57	0.31
0-10-30	11.19	11.24	0.05
0-15-40	15.49	15.62	0.13
10-20-20	17.17	17.20	0.03
15-5-16	5.23	5.26	0.03

In May 1983 the working group (WG2) on phosphorus met and the results of an earlier international study were released (2). Table 7 is a summation of that report.

TABLE 7

Fertilizer	Percent APA		
	EEC	AOAC	Diff
MAP	52.28	52.32	0.04
TSP	47.56	47.56	0.00
20-20-0	21.16	21.06	−0.10
N-Super	19.52	19.80	0.28
15-15-15	15.23	15.28	0.05
Ammoniated Super	14.97	15.17	0.20
0-15-20	9.83	10.61	0.78

While support for the EEC method for available phosphoric acid has been severely degraded, the final chapter of this confrontation has yet to be written. It is hoped the AOAC method will prevail. If not, U.S. producers of triple superphosphate will surely find their calculated available phosphoric acid levels a unit or more short when marketing abroad. If the AOAC method does prevail, a small group of chemists who foresaw this problem several years ago and became directly involved with ISO will have saved the backsides of several phosphate producers.

Many other unsatisfactory methods of analysis and of sampling are being debated currently. It is hoped that more industrial concerns will take note of this and lend their support, both in terms of financial aid and technical expertise, to the U.S. TAG, administered by the AOAC.

REFERENCES

1. Frank J. Johnson and Parks, Kenneth L. (1984) J. Assoc. Off. Anal. Chem. *67*, 594–596.
2. ISO/TC 134/SC 4/WG 2N47.

Programs of the Florida Institute of Phosphate Research

G. Michael Lloyd, Jr.
Research Director—Chemical Processing
The Florida Institute of Phosphate Research

I would like to take this opportunity to acquaint you with the Florida Institute of Phosphate Research and the work that we are doing. The Institute was created in 1978 by an act of the Florida Legislature. Research responsibilities were specified by empowering the Institute:

(a) To conduct or cause to be conducted such environmental studies related to radiation and water consumption, or other environmental effects of phosphate mining and reclamation, as may from time to time be deemed reasonably necessary for the health, safety and welfare of the citizens of the regions where phosphate mining or processing occurs.
(b) To conduct or cause to be conducted a thorough and comprehensive study of reclamation alternatives and technologies in the phosphate mining or processing industry, including wetlands reclamation.
(c) To conduct or cause to be conducted a thorough and comprehensive study of phosphatic clay disposal and utilization as a part of phosphate mining, together with all environmental or land use related thereto.
(d) To establish methods for better and more efficient phosphate recovery mining and processing in this state as it may determine most beneficial to the economy, environment, and way of life of the citizens of the state.

The law also instructs that "emphasis shall be given to applied research which tends to solve real problems of the industry in which the public has a substantial interest".

As you can see, this Legislative Act authorizes the Institute to conduct research related to all aspects of the Florida phosphate industry.

Funding for the Institute's programs was provided by allocating 5% of the severance tax on solids minerals for research purposes.

The Institute is structured so that a Board of Directors, appointed by the Governor, exercises control over the research effort, having sole authority to grant or deny funding for each research proposal. There are five directors serving staggered three year terms. The law requires that two directors will be from the phosphate industry, one from state government, one from the academic community and one to represent environmental interests.

The day-to-day operation of the institute is the responsibility of the Executive Director, Dr. David Borris, who is assisted by five Research Directors who are responsible for research in the areas of:

Mining: This area oversees research into all phases of mining and pre-mining activities. A typical project would be reduction of power consumption in the pumping of the matrix slurry from the dragline to the plant.

Beneficiation: While the primary emphasis for this area is to seek solutions to the phosphatic clay problem, this director is also involved with proposals to achieve improved flotation, reduction of the MgO content of south Florida phosphate rock, and the characterization of the various mineral components making up the matrix. A typical project would involve increasing the rate of settling of the clays and/or increasing the load bearing capabilities of the settled clays.

Chemical Processing: This director is interested in all aspects of the chemical treatment of phosphate rock. While priority projects address the large volume uses of phosphogypsum, projects to conserve energy or to improve the efficiency of any phase of chemical plant operation are encouraged. There is increasing interest in the fate of the radionuclides entering the chemical plant and this subject will undoubtedly receive a much higher level of attention in the future.

Reclamation: This area is concerned with all aspects of the restoration of the land after mining with particular emphasis on the development of techniques to reduce the time needed to achieve stabilized environmental conditions. Projects to restore specific pre-mining land features such as wetlands, upland hardwood forests, etc. are common.

Environmental Services: Projects in this area address all of the environmental effects of mining and chemical processing of phosphate rock. A major interest today is the determination of any radiation problems that might be faced if phosphogypsum is used in construction. The fate of all chemical or radionuclides pollutants introduced into the environment will undoubtedly be studied in even greater detail in the future.

Research proposals may originate from any source and to date almost all the research projects funded have originated under the Applied Research Proposals Program. The Applied Research Proposals Program defines general areas of interest that the Institute would like to investigate, but does not attempt to define or limit the research approach to be used. We will have a Request for Proposal Program in operation in the near future where the Institute will outline a research idea and advertise for bids to perform the work. We are particularly interested in utilizing the Request for Proposal procedure where the originator of a good idea is unable or unwilling to do the work himself.

The Institute is required by law to "carry out or cause to be carried out" research programs. Our long range plans call for the Institute to utilize up to one third of the research funds available for "in-house" research. This will require additional personnel and facilities but it will enable us to conduct more research programs with the same expenditure of funds.

All research proposals, whether in-house, request for proposal, or Applied Research, are subjected to the same technical evaluation procedures. In addition to an in-house evaluation, each research proposal is sent to at least three outside reviewers for evaluation, with at least one of the reviewers selected from a list provided by the originator of the proposal. The reviewers are selected for their technical expertise in the subject area and are requested to comment primarily on the technical aspects of the proposal, but are given the freedom to comment on any and all other aspects of the proposal also.

After the proposal reviews are completed, a verbatim summary of the reviews is forwarded to the originator of the proposal in order that he may comment on or rebut the views expressed by the reviewers. The review process is not intended to generate criticism of a project; it is intended to critique the project and develop constructive suggestions for improvement.

The total package of proposal, reviews and staff analysis is forwarded to the individual Board members prior to the monthly meeting where funding will be approved or denied. The Board relies heavily on the evaluations by the technical reviewers to determine the technical soundness of the proposal, but they are also required to make the determination that the project will satisfy the guidelines prescribed by the law that define the limits for the Institute's activities.

If the Board approves funding for a proposal, the investigator is required to file quarterly progress reports over the life of the project. The final report, due within thirty days after the project is completed, is also sent out for peer review before copies are made available to the general public. However, in all cases, the report will be available at the Institute for public review and study while the peer review is underway. It is the Institute's policy to disclose and circulate all information promptly, but we do try to insure that the information contained in the reports on the projects we have funded is as accurate as it is humanly possible to make it.

Now that you know how we came to be and how we function, let's take a look at some of the work we have done and are doing.

In the mining area, we have funded a project "Articulated Cutterhead Ladder for Phosphate Pit Car Operation" by Circle J Dredging. This project was basically an energy conservation approach to matrix slurry pumping from the dragline to the plant. The idea was to use a dredge type pickup for the matrix in order to increase the percent solids in the slurry pumped to the plant. A completely different type project, "Ground Penetrating Radar System for Detecting Sub-surface Anomalies" by the Bureau of Mines was an attempt to locate sinkholes that could pose a hazard for future phosphatic clay settling area dams. We are also interested in pre-mining activities and have funded Seaburn and Robertson's "Inventory and Presentation of Environmental Quality Monitoring Locations in the Central Florida Phosphate District" to locate and catalog all the air and water monitoring activities carried out by both phosphate and other companies, local governments, state government, environmental groups, federal agencies, etc. in order that everyone will know where to go to obtain existing data and avoid setting up programs that would only duplicate results from an existing system.

One of the research areas that generates a great deal of interest is Beneficiation. There has been a major emphasis in Florida during the past ten or so years on treating the phosphatic clays in order to eliminate the above ground settling areas. The Institute is conducting an in-house basic research project, "Physico-Chemical Stabilization of Phosphatic Clays," in an attempt to determine how to increase the bearing strength of the phosphatic clays in order that they could adequately support any and all types of construction. "Physico-Chemical Characteristics of Florida Phosphate Clays" by Bromwell Engineering, a proposal to classify the various types of clays, was one of the first projects funded by the Institute.

Through August of this year, we have funded six proposals to evaluate and/or field test methods that would enable the industry to return all phosphatic clays generated to below ground storage. The problem with the clays is that they occupy a volume approximately three times greater after mining than they did before they were disturbed by the mining activities. If we assume that our phosphate matrix is one-third phosphate rock, one-third sand and one-third clay, it is obvious that the sand plus the expanded clay volume cannot be returned to below ground storage without special treatment, mixing or processing. Much research is being carried out to devise ways to mix the sand and clay to obtain a stable land form that would not be restricted to agricultural uses only, but would have sufficient load bearing strength to adequately support roads, housing, commercial building, etc.

We have sponsored research in a freeze-thaw method to dewater phosphatic clays, utilization of the phosphatic clays as a raw material for ceramic building materials, methods to recover the phosphate values in the phosphatic clays, autoclave acidulation of phosphatic clays, computer modeling of the flow characteristics of thickened phosphatic clays in the event of a settling pond dam break, as well as a number of proposals to investigate methods of reducing the higher dolomite-magnesium-content of the south Florida ores.

The need to return the land disturbed by mining to its pre-mining condition has been of paramount importance to Florida. The tremendous interest in this subject has resulted in numerous funded proposals for the development of better and faster ways to revegetate the reclaimed land. This interest in reclamation has not been limited only to land forms. A two-year study by Environmental Science and Engineering "Ecological Considerations in Lake Reclamation Design For Florida Phosphate Region" has been completed and is ready for publication. The information gained in the study will provide valuable information on what can be done to create lakes for recreation, fishing or other uses.

Of course, all of this interest in the water used during mining and found in the lakes after reclamation does generate intense interest in a Florida native, the mosquito. In the study "Investigations of Mosquito Populations in Phosphate Mining Areas," it was demonstrated that different types of mosquito prefer water discharged from specific parts of the mining operation, and perhaps more important that the larvae of at least two types of quite active mosquitos grow well only when attached to vegetation growing in the water. As a result of this piece of information, Polk County has embarked on a program to eliminate the water lettuce in lakes in and near the cities in the county.

In the environmental area, radiation is the big question mark and public concern that radiation associated with phosphate mining could represent a danger has been expressed often. In order to answer some of the questions raised, we have sponsored research to determine the fate of radioactive elements present in the soil after mining and reclamation. These programs are looking at both birds and animals and a recent proposal will determine if the radionuclides from the soil will accumulate in the fruits and vegetables that would enter the human food chain. We are also working to encourage home building utilizing all the newest techniques to reduce radon entry into homes in order to demonstrate that it is not necessary to experience a radiation problem in homes built on reclaimed lands. Since there is natural radiation in many wells in Florida, we have also been involved in studies to define the nature and extent of this problem in the phosphate regions of the state. Interestingly enough, the average level of radioactive elements in the water in the central Florida phosphate district is less than the level found in many other parts of the state.

When it comes to Chemical Processing, it might be more appropriate to call it phosphogypsum utilization. There is a tremendous interest in finding uses for this material and eliminating the approximately 400 million tons stored in central Florida piles. Our Board recently contracted with the Bureau of Economics and Business Research at the University of Florida to develop priorities for the Institute's research program. "Productive Uses for Phosphogypsum" was selected as the highest priority research goal by a group representing the industry, environmental community, state and local government agencies.

One of the Institute's first phosphogypsum projects was an "International Symposium on Phosphogypsum" sponsored by the University of Central Florida and held at Lake Buena Vista November 5–7, 1980. This symposium was attended by people from most of the countries producing phosphoric acid and the papers presented described the most recent experiences with phosphogypsum as a chemical raw material and in construction purposes and agricultural applications. A second symposium is in the planning stages and is tentatively scheduled for Miami in December 1986.

Perhaps everyone who has ever been associated with a wet process phosphoric acid plant has had the idea at one time or another of recovering the sulfur in the phosphogypsum and achieving a closed circuit where sulfur purchases would no longer be necessary. This idea was addressed in one of the first proposals funded by the Institute. Zellars-Williams, in a proposal entitled "Gypsum By-Product Exploitation", planned to evaluate the various routes for converting phosphogypsum to sulfuric acid and determine if any of these routes would have an economic advantage. The Iowa State University thermal process utilizing fluid bed technology developed by Dr. Wheelock was selected as the most promising processing alternative.

The logical next step in this investigation was a second proposal from Zellars-Williams, "Gypsum By-Product Exploitation, Phase II Technical Development of the ISU Process." This project enlisted Dr. Wheelock and Iowa State University to make both bench and pilot scale tests to demonstrate that phosphogypsum could be thermally treated to yield SO_2 and lime in an economical manner. The fuel source was high sulfur coal.

The processing steps were:

(1) Clean up the phosphogypsum by washing and sizing.
(2) Granulate the phosphogypsum or the phosphogypsum coal mixture.
(3) Dry the granules.
(4) Fluid bed calcination of the granules.
(5) Heat recovery from both the lime and the SO_2 gas stream.
(6) Gas stream clean up to remove dust and fluorine.

The gas stream exiting the gas cleaning step would go to a metallurgical type sulfuric acid plant.

Economic analysis of the results demonstrated that the process would be practical only if all the lime could be disposed of at a relatively high price. The economic analysis did reveal one very interesting fact—fuel cost is not as critical as the capital cost and even if the fuel were free, the economic viability of the process would remain marginal.

Shortly after the Zellars-Williams study was completed, Davy McKee requested funding to thermally treat phosphogypsum in a circular grate system. "A Proposal for the Recovery of By-Product Gypsum" demonstrated that the capital cost of the plant could be reduced by the elimination of the clean up step and by achieving a higher SO_2 content in the gases exiting the circular grate. All the results were encouraging but the results obtained during the final series of pilot runs appeared to point the way to achieving a major capital cost reduction.

A second Davy McKee proposal, "Phosphogypsum Conversion via Circular Grate Technology" was a direct result of the original Davy effort. This project is to refine the results of the first study and is going on at this time. It has been demonstrated that, with the proper techniques, it is not necessary to have a drying step before the gypsum-coal pellets are calcined and that an SO_2 content of at least 9% in the exhaust gases is feasible. This project is still going on at this time and we are encouraged by the results obtained to date. This project has looked at producing an aggregate as a by-product rather than lime.

The second phase of the Davy project is to prepare accurate, detailed capital and operating cost estimates. The decision to go ahead with these estimates will be dependent upon the results obtained in the first phase of the project. It is felt that the results from the second phase of the Davy study will provide an economic yardstick that can be used in the preliminary evaluation of future phosphogypsum thermal processing proposals.

Science Applications, Inc. has taken a different approach in their proposal "Conceptual Design and Testing of a Phosphogypsum Reactor." The first phase of this study will consist of laboratory experimentation and numerical analysis to provide a more detailed understanding of reaction chemistry and kinetics for the thermal decomposition of phosphogypsum. The second phase will utilize the information developed in Phase I to design a bench scale reactor and test program. This investigation will address reactor retention times, operating pressure, oxygen enrichment, etc. if the Phase I data indicates that any of these approaches has the potential for improving the thermal conversion process.

It may be of interest that we have a proposal under review from the Bureau of Mines that will look at the conversion of phosphogypsum to sulfur by thermal methods. This project would be funded jointly by the Bureau and the Institute and is a three-phase effort consisting of laboratory testing, piloting of the process developed and operation of a large scale pilot plant that would provide design data for commercial units.

"A Study to Produce Alite Cement and SO_2 from By-Product Gypsum" did not achieve its goal of producing this high quality cement product. Cement and SO_2 were produced easily but the speciality material sought could not be routinely obtained.

One of our most interesting projects, "Reclamation, Reconstitution and Reuse of Phosphogypsum Wastes for Building Materials" by Dr. Chang of the University of Miami, has generated a tremendous amount of interest in utilizing phosphogypsum for both structural purposes and road building. Dr. Chang has worked with cement phosphogypsum mixtures to produce numerous building materials. There has been no attempt made to fit phosphogypsum into the niche occupied by natural gypsum in regular wallboard. Instead, the idea has been to develop material formulations that are uniquely suited to phosphogypsum. One of the products that is being actively studied is a sandwich panel that could be used for either interior or exterior walls. The panel consists of wire mesh reinforced outer layers of phosphogypsum cement with an inner layer of foamed insulating material. Dr. Chang envisions building modules that would be factory produced and hauled to the building site for installation. A prototype room has been constructed at the University and is being used in tests to evaluate the potential applications for this type construction. One of the exciting things about this panel is that it can be used as a load bearing wall.

Another area that is under very active investigation is phosphogypsum for road construction. While phosphogypsum can be substituted for the limestone commonly used for road base in Florida, it has not been widely used except for private roads and parking lots. Phosphogypsum and fly ash mixtures have been used in Texas as a road base, but high lime content fly ash is not readily available in Central Florida. A cement-phosphogypsum-sand mixture has been prepared in the laboratory and tested on a small scale and this material may well be suited for all types of highway construction in central Florida.

There are also many miles of unimproved roads—dirt roads—in Polk County, Florida. It has been the practice to add clay and mix it with the sand to obtain a road that is superior to a sand only road. It has been demonstrated that a phosphogypsum sand mixture produces a superior road and a full scale field test is in the planning stage. Dr. Chang has been working on methods for "water proofing" this phosphogypsum sand mixture. One of the primary causes of failure in these unimproved roads is potholing caused by water standing on the road long enough to penetrate the road surface, soften the clay or phosphogypsum sand mixture, and allow the surface to be worn away at an accelerated rate by the tires of the vehicles using the road. If this "water proofing" treatment is successful, the technique can also be applied to road bases and will provide a much longer useful life for all types of roads constructed where soil water levels may be a problem.

We also have a memorandum of agreement with the Bureau of Mines to "Identify and Determine High Volume End Uses for Phosphogypsum." These jointly funded efforts have looked at substituting raw phosphogypsum for part of the aggregate used in asphalt formulations for road surfaces, making aggregates from phosphogypsum fly ash mixtures, and calcining phosphogypsum mixtures to produce light weight aggregates.

In the agricultural area we have two recently signed contracts with the University of Georgia to investigate "Use of Gypsum to Improve Properties of Southeastern Soils" and "Gypsum as an Ameliorant for Subsoil Acidity." Both of these proposals addressed problems that are common to soils in the southeastern part of the country and are intended to promote chemical and/or physical changes in the soil itself. We are also extremely interested in developing programs that would test phosphogypsum as a fertilizer source for both sulfur and calcium and expect to have some proposals funded for this type research in the near future.

One of the more recent proposals we have funded, "Evaluation of Waste Management for the Florida Phosphate Processing Industry" by PEDCo, will address the question of ground water contamination associated with phosphogypsum storage. The information developed by this study will be used by EPA to develop standards for the phosphate industry under the Resource Conservation and Recovery Act. The project will consider four locations in Florida and is scheduled to be completed in 15 months time or by August, 1985.

As you might imagine, there has been a great deal of interest in this study and because of the nature of the study, we have worked with PEDCo to develop a peer review committee that will review all phases of this study, evaluating both procedures and results. This peer review committee is composed of representatives of the industry, consultants and representatives from both state and federal agencies. By utilizing such a group, we expect to insure that the data collected will be adequate for all interested parties and that there will be few, if any, questions as to the validity of procedures used to collect the data and the accuracy of the data and its interpretation.

In closing, I would like to take this opportunity to encourage you to make the universities and other researchers in your area aware of our work and the fact that we are able to fund research to investigate many facets of the phosphate industry and are always willing to work with them to develop proposals to study our problem areas. I know that most of your are very much aware that both phosphogypsum and phosphatic clays have been well and frequently investigated and this does make potential new and unique solutions to these problems more difficult to come by, but who knows, the answer to our problems may come as a result of your actions.

Fertilizer Distribution Trends in the U.S.

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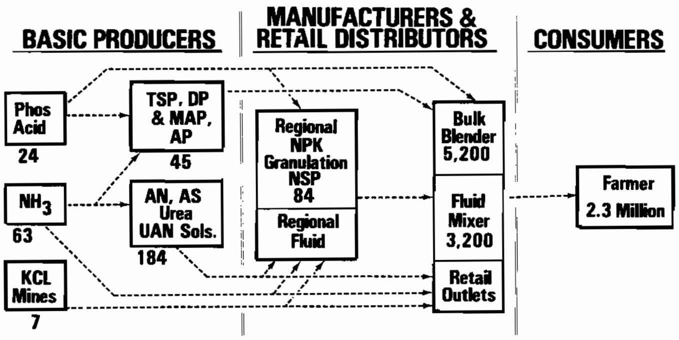
Introduction

The U.S. fertilizer industry is big business. About 50 million tons of fertilizer worth 9.5 billion dollars is sold each year to 2.3 million American farmers. At the core of the industry are 12,000–15,000 bulk blenders, fluid mixers, ammoniation-granulation plants, and retail stores providing a vital link between producers and farmers. Retail fertilizer outlets receive fertilizer materials from basic producers of ammonia, phosphoric acid, diammonium phosphate, triple superphosphate, and potash which they then mix, blend, suspend, or granulate, possibly adding micronutrients and pesticides. The product is then sold to farmers either directly or through other retail outlets or distributors. Figure 1 is a diagram of the U.S. fertilizer production and distribution flow.

Figure 1

SIMPLIFIED FLOW OF U.S. FERTILIZER PRODUCTION & DISTRIBUTION



Figures indicate number of operating plants – FY 1984
Total retail outlets: 12,000–14,000
AAPFCO Survey – 1984 MDES TVA

Today's fertilizer marketing pattern contrasts with the one thirty-five years ago when basic producers supplied materials to regional wholesale mixing plants which combined a few grades for distribution to retail outlets which then sold to farmers.

In contrast, today's basic producers provide materials to large-scale ammoniation-granulation plants, dry bulk blenders, and liquid and suspension mix plants where the materials are combined to form hundreds of fertilizer mixtures to meet individual farmer requests.

TVA, cooperating with the Association of American Plant Food Control Officials, periodically surveys the retail segment of the U.S. fertilizer market. Information from the survey is used in publishing the "Directory of Fertilizer Plants in the U.S." and in structuring a profile of the retail market.

Survey of the Fertilizer Industry

Since 1973–74, the Association of American Plant Food Control Officials (AAPFCO) and the National Fertilizer Development Center (NFDC) have conducted four surveys of U.S. fertilizer distributors. Results each time were presented at The Fertilizer Industry Round Table annual meeting. The latest survey is still being processed.

Preliminary results of the 1983–84 survey presented in this paper are based on 3,289 early responses from bulk blenders, fluid mixers, granulation plants, and a few basic producers. Of these plants, 81 percent had bulk blending facilities, 27 percent had liquid, 15 percent had suspension and 30 percent had both liquid and suspension.

Distribution by class indicates that 45 percent of all fertilizer was dry bulk or bagged blends. Fluid fertilizers (including mixtures, anhydrous ammonia, nitrogen solutions, and other direct application materials) account for 30 percent; granulation materials account for almost 16 percent; with the remaining 9 percent consisting of dry direct application materials such as ammonium nitrate (33.5-0-0), and diammonium phosphate (18-46-0). Percentages of materials distributed by all plants are shown in table 2. Applying these percentages to the 48 million tons of materials distributed in fiscal year 1984 indicates that 21.7 million tons of dry blends (both bulk and bagged), 7.6 million tons of granular NPK mixtures, and 4.7 million tons of fluid mixtures were used. Previous AAPFCO surveys indicated similar distribution patterns.

Granulation Plants

Granular homogeneous complete mixtures continue to be a major marketing channel for N, P, and K. However, conventional ammoniation-granulation plants have changed. Many have increased production by installing pipe-cross reactors. They now use large quantities of phosphoric and sulfuric acid, anhydrous ammonia, and other fluids to produce granular NPK fertilizers, while their use of run-of-pile triple superphosphate, normal superphosphate, and ammoniating solutions is decreasing. Diammonium phosphate (18-46-0) is also a popular source of both nitrogen and phosphate for granulating complete mixtures. Granulation provides an excellent means for incorporating micronutrients into mixed grades and for using byproduct materials.

Supplementary data indicate that 84 ammoniation-granulation plants are operating, compared to the 118 plants shown in the 1974 AAPFCO survey. Total tonnage of NPK mixtures from the 84 operating plants is estimated to be 7.6 million tons—including both large plants who primarily produce for the farm market, and smaller plants who produce primarily for the lawn and garden market. Leading grades pro-

TABLE 1
Summary of Directory Listings—1984[a]

Region	Total Listing[b]	Bulk Blend		Fluid					
		All	BB Only	All	Liq	Liq Only	Sus	Sus Only	Ls Only
New England	86	15	11	8	7	4	4	—	1
Middle Atlantic	390	34	28	11	11	5	3	—	1
South Atlantic	856	230	211	80	78	36	39	3	27
East North Cent.	2,935	866	761	205	191	32	119	6	67
West North Cent.	4,502	665	510	376	337	79	191	23	114
East South Cent.	517	224	205	55	27	7	44	20	14
West South Cent.	1,665	91	83	30	24	14	11	2	4
Mountain	519	129	86	68	68	22	13	—	3
Pacific	661	40	28	23	23	11	—	—	—
Total	12,131	2,294	1,923	856	766	210	424	54	231

Region	Granulation		All Plants	Total Questionnaires	Questionnaires As % of Total[b]
	All	Gran Only			
New England	1	—	20	23	26.7
Middle Atlantic	2	1	43	74	19.0
South Atlantic	10	5	303	334	39.0
East North Central	12	6	994	1,082	36.9
West North Central	5	1	888	1,024	22.7
East South Central	8	3	270	288	55.7
West South Central	2	1	116	129	7.7
Mountain	—	—	156	252	48.6
Pacific	—	—	52	83	12.6
Total	40	17	2,842	3,289	27.1

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a. Types of plants determined by AAPFCO survey—preliminary data
b. Based on 1980 listings of registrants and licensees
0541i

TABLE 2
Distribution of Fertilizer Materials in the U.S. By Class—1984

Class	Percent of Total Fertilizer[a]				Total Material			
	1974	1976	1979	1984	1974	1976	1979	1984
	%				Million Tons			
Dry Bulk Blends	33.3	33.7	35.8	36.7	15.7	16.5	18.3	17.6
Dry Bagged Blends	9.2	6.4	5.7	8.5	4.3	3.1	2.9	4.1
Bulk Granulation	4.9	9.9	9.9	11.0	2.3	4.9	5.1	5.3
Bagged Granulation	6.2	9.0	6.3	4.7	2.9	4.4	3.2	2.3
Fluid Mixtures (Liq & Sus)	9.7	9.6	10.1	9.8	4.6	4.7	5.2	4.7
Anhydrous Ammonia	7.2	9.5	9.2	7.6	3.4	4.7	4.7	3.7
Nitrogen Solutions	7.1	9.4	10.8	11.4	3.3	4.6	5.5	5.5
Dry Direct Appli. Malt.	19.7	9.5	10.4	8.9	9.3	4.7	5.3	4.3
Liq. Direct Appli. Malt.	2.7	3.0	1.8	1.3	0.7	1.5	0.9	0.6
Total	100.0	100.0	100.0	100.0	47.1	49.1	51.1	48.1

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a Preliminary AAPFCO-Fertilizer Plant Surveys duced at granulation plants are 10-10-10, 5-10-15, 3-9-18, 5-10-10, 6-24-24, 10-20-20, 3-9-9, 13-13-13, 12-12-12, and 6-12-18. Average analysis of all grades produced by granulation plants is 35.1 percent.

The average granulation plant produces 102,375 tons of material annually. Of this, 33 percent is sold to blenders for use in their plants or to retailers for resale. Raw material and finished product storage amounts to 41 percent of total annual distribution (table 3). Six percent of the plants add pesticides to mixtures while 82 percent add micronutrients. Fifty percent of these granulation plants are in the Atlantic Coast States and 40 percent are in the Midwest.

Bulk Blend Plants

Bulk blending became prominent in the middle 1950's when granular diammonium phosphate was introduced. Because the manufacture and distribution of blends was simpler and more economical than traditional methods, bulk blending grew rapidly. Today it is the largest system for manufacturing and distributing fertilizer mixtures. A primary reason for the rapid growth in bulk blending is the ability of dealers to provide farmers with needed services such as custom mixing and spreading at attractive prices.

Bulk blending works best with well-granulated, closely sized, dry materials that do not deteriorate in storage. Bulk blending and granulating have complemented each other because blenders have motivated manufacturers of granular materials to provide more materials with improved physical properties. Materials most commonly used for bulk blending are diammonium phosphate, urea, triple superphosphate, potassium chloride, ammonium nitrate, and ammonium sulfate. Most plants report using urea, more than any other material, as a nitrogen source. Ammonium nitrate is the second favorite source of nitrogen. Diammonium phosphate and triple superphosphate are the main sources of P_2O_5 (table 4). Other materials used include normal superphosphate; MAP (11-52-0); ammonium phosphate grades, such as 16-20-0, 27-14-0, and 11-48-0; and complete mixtures, such as 6-24-24.

A typical bulk blend plant has a total annual throughput of 4,757 tons of all materials. Of this total, 2,715 tons are dry bulk blend mixtures. Average analysis of the 10 leading grades is 53.5 percent, which is considerably higher than grades produced in other types of fertilizer mix plants. The average bulk blend plant also distributes 1,272 tons of dry direct application materials, primarily ammonium nitrate and diammonium phosphate. A typical plant distributes 807 tons of anhydrous ammonia and 632 tons of nitrogen solutions. Average tonnages are only for plants handling these products and therefore are not additive (table 5).

Although the average annual distribution of a bulk blend plant is 4,757 tons, the greatest number of plants are in the 1,000–2,000 ton range. The mode–1,669 tons—is the value occurring most frequently. The median—2,883 tons—represents the middle value of all bulk blend plants considered for this presentation. Eighty-one percent of these respondents show distribution between 1,000 and 4,000 tons.

Storage capacity for raw materials and finished products average 46 percent of the total annual distribution. Storage is an important aspect of the retailer because it allows basic producers to maintain monthly production levels despite a highly seasonal

TABLE 3
Storage Capacity of Bulk Blend, Fluid, and Granulation Plants[a]

Region	Bulk Blend	Liquid	Suspension	All Fluid	Granulation	All Plants
	(% of Total Fertilizer Distribution)					
New England	79.6	14.1	—	12.7	—	52.1
Middle Atlantic	42.8	64.5	—	47.0	91.3	50.0
South Atlantic	32.8	29.2	12.4	29.7	24.0	33.6
East North Central	51.0	36.2	31.6	44.3	39.9	47.7
West North Central	52.9	32.7	34.4	77.6	28.3	58.8
East South Central	51.3	26.0	36.9	33.8	50.0	52.8
West South Central	35.4	26.4	—	27.2	36.8	35.2
Mountain	47.6	24.8	—	41.9	—	43.8
Pacific	42.5	8.5	—	46.5	—	44.3
Average	46.4	29.2	33.0	51.0	41.3	46.9
# Plants Reporting	1,610	171	53	715	17	2,372

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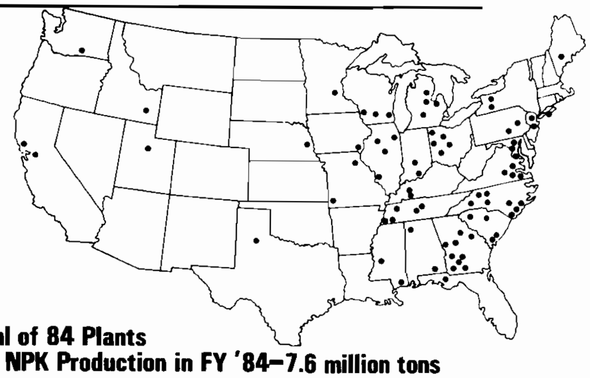
a Preliminary AAPFCO Fertilizer Plant Survey—1984
0544i

Figure 2

AMMONIATION-GRANULATION PLANTS IN THE U.S.



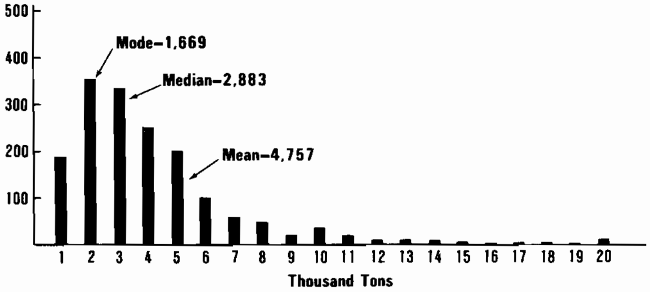
Total of 84 Plants

Est. NPK Production in FY '84–7.6 million tons

AAPFCO Survey – 1984 MDES TVA

Figure 3

FREQUENCY DISTRIBUTION FOR U.S. BULK BLENDS FERTILIZER PLANTS



AAPFCO Survey – 1984 MDES TVA

Based on 1,618 Bulk Blend Plants

TABLE 4

Types of Materials Used in Bulk Blend, Fluid, and Granulation Plants[a]

Materials	Bulk Blend	Liquid	Suspension	Granulation
		(% of Plants)		
Ammonium Nitrate	29.8	—	—	—
Ammonium Sulfate	25.6	11.3	—	82.4
Urea	81.3	16.9	—	17.6
Urea (soluble)	—	7.2	18.2	—
DAP (18-46-0)	94.7	4.1	3.6	64.7
MAP (11-52-0, etc)	15.0	5.6	25.5	64.7
Normal Superphosphate	2.5	—	—	47.1
Triple Superphosphate	75.7	—	—	70.6
Nitrogen Solutions	57.3	75.9	78.2	—
Anhydrous Ammonia	50.1	12.8	18.2	100.0
10-34-0	—	74.4	56.4	—
Phosphoric Acid	—	11.8	1.8	88.2
Superphosphoric Acid	—	7.2	—	—
Ammoniating Solutions	—	—	—	88.2
Sulfuric Acid	—	—	—	88.2
Dry Clay	—	6.2	36.4	—
Fluid Clay	—	6.2	20.0	—
Potassium Chloride (STD)	95.2	12.3	9.1	94.1
Potassium Chloride (SOL)	—	43.6	49.1	—
By-Products	—	7.7	14.5	—
Other	41.4	—	—	—
Number of Plants Reporting	1,912	195	55	17

a. Preliminary AAPFCO Fertilizer Plant Survey—1984

market. A comparison with the previous survey shows that bulk blend plants have not increased their storage capacity relative to total distribution. In the current survey, bulk blenders indicate that 60 percent of their storage was filled as of December 31, 1983, and 20 percent as of June 30, 1984.

The survey reveals that bulk blenders have increased farmer services. In 1984, 38 percent of the fertilizer was custom applied by blenders and 33 percent was spread by the farmer with rental equipment (table 6). In contrast, in 1974 and 1976, 30 percent and 25 percent, respectively, of the fertilizer distributed by blenders was custom applied. Data on custom application of bulk blends indicate that more material is being applied by farmers (59 percent) than is being custom applied by blenders. However, deal-

TABLE 5
Average Throughput for Bulk Blend, Liquid Mix, and Suspension Fertilizer Plants 1984[a]

Class	Bulk Blend Only		Liquid Only		Suspension Only	
	Plants	Tons	Plants	Tons	Plants	Tons
Dry Bulk Blend Mixtures	1,560	2,715	11	1,014	4	925
Dry Bagged Blend Mixtures	721	1,344	11	483	5	153
Granulation Bulk Mixtures	198	853	8	706	4	925
Granulation Bagged Mixtures	375	362	16	103	5	135
Liquid Mixtures	163	363	146	1,884	4	186
Suspension Mixtures	24	483	23	956	51	1,718
Anydrous Ammonia	763	807	50	881	16	650
Nitrogen Solutions	888	632	112	1,116	44	830
Direct Application, Dry	656	1,272	19	485	1	360
Direct Application, Liq.	170	260	70	371	10	270
Total Plants	1,618		177		54	
Average Throughput		4,757		2,980		2,772

a. Preliminary AAPFCO Fertilizer Plant Survey—1984
0559i

ers often provide rental application equipment to farmers.

Complimentary services continue to be a vital part of the bulk blender's fertilizer marketing program. Almost 77 percent of all bulk blend plants add micronutrients, 58 percent add herbicides, 35 percent add insecticides, 57 percent add seed to their dry bulk blend, and 16 percent have bagging facilities (table 6).

Data relating to type of business reveal that 7.0 percent of bulk blend plants are sole proprietorships, 4.3 percent partnerships, 45.7 percent corporations, and 44 percent cooperatives (table 7).

Fluid Fertilizer Plants

The number of fluid-fertilizer-mix plants has grown at a remarkable rate during the past 20 years. As with dry bulk blending, little investment is required for establishing a fluid mix fertilizer unit. Higher analysis grades are possible with suspensions, at a lower cost, than with liquids. Fluids continue to expand in the fertilizer market. Both bulk blend and fluid mix fertilizer systems can economically combine intermediate fertilizer materials produced at widely dispersed production points. They also serve as storage facilities in the market area and are points of contact between dealers and farmers.

Fluid fertilizers, including liquids and suspensions are considered in this analysis. In the 1950's, more elemental phosphorus and furnace phosphoric acid was available than was needed for the industrial market. This surplus was neutralized with low-cost ammonia to produce liquids 11-37-0 or 10-34-0. Production of high-nitrogen, nonpressure urea-ammonium nitrate solutions further promoted liquid fertilizers, since these solutions can be used as a material in producing fluid mixtures or as direct application material. Advantages of fluid fertilizers include ease of mixing, ease of incorporating additives while achieving mixture homogeneity, convenience of mechanical handling, and high reliability of fluid application systems.

Suspension fertilizers are liquids in which salts are suspended by the incorporation of a suspending agent. Complete solubility of phosphate is not required in suspensions. This allows a wider range of phosphate materials to be used. Mono-ammonium phosphates (MAP) have become a primary source of P_2O_5 for suspension manufacture (table 4). Higher analysis grades can be formed with suspensions than is possible with conventional liquids. Consumption of all fluid mixtures (liquids and suspensions) for fertilizer year 1984 is estimated at 4.7 million tons. In 1984, five States—Georgia, Illinois, Indiana, Iowa, and Texas, accounted for half of all fluid mixtures used. Based on the AAPFCO survey, suspensions now comprise an estimated 45 percent of all fluid mixtures, up from 25 percent in 1974, 33 percent in 1976 and 40 percent in 1980.

The AAPFCO survey shows an average throughput of 2,980 tons for the 177 plants listing only liquid mix facilities. A typical fluid plant distributes 1,884 tons of liquid mixtures, 881 tons of anhydrous ammonia, 1,116 tons of nitrogen solutions, and 375 tons of liquid direct application materials, such as 10-34-0 and 8-24-0 (table 5). The ten leading liquid grades reported are: 20-10-0, 4-10-10, 7-21-7, 2-6-12, 7-22-5, 5-10-10, 6-18-6, 4-8-12, 10-34-0, and 16-20-0. These grades have an average 30.2 percent nutrient content. Fluid plants also distribute significant tonnages of

TABLE 6
Other Services Offered[a]

Service	Bulk Blend	Liq	Sus	All Fluid	Gran	All Plants
Adding Herbicides to Mixtures	57.5	61.9	84.5	80.9	5.9	63.7
Adding Insecticides to Mixtures	34.7	39.5	44.8	53.1	5.9	39.7
Adding Micronutrients to Mixtures	77.0	67.1	79.3	83.4	82.4	78.6
Adding Seeds to Mixtures	56.8	19.5	25.9	42.5	—	51.7
Bagging Equipment	16.3	—	—	—	76.5	14.2
Soil Testing	86.6	71.4	74.1	85.4	35.3	85.2
Consultation Service	72.9	61.0	50.0	68.1	41.2	70.9
Custom Application (% of tonnage)	37.9	35.2	75.9	52.1	—	38.5
Number of Plants	1,923	210	58	859	17	2,842

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a. Preliminary AAPFCO Fertilizer Plant Survey—1984

TABLE 7
Form of Business[a]

Form	Bulk Blend	Liquid	Suspension	All Fluid	Granulation	Retail Outlets	Plants
				(% of Plants)			
Sole Proprietor	6.6	15.8	18.8	16.5	—	14.4	9.4
Partnership	4.3	4.9	6.0	4.7	—	6.3	4.6
Corporation	45.7	60.1	63.4	59.7	80.0	56.0	49.3
Cooperative	44.0	20.3	13.8	20.0	17.5	24.1	37.3
Number Reporting	2,275	755	415	847	40	432	2,813

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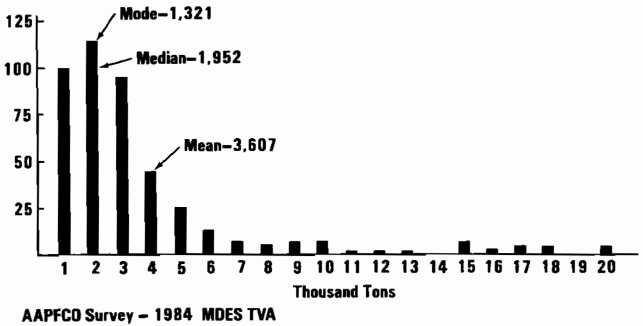
a. Preliminary AAPFCO Fertilizer Plant Survey—1984
0560i

Figure 4
FREQUENCY DISTRIBUTION FOR U.S. FLUID ONLY FERTILIZER PLANTS



AAPFCO Survey - 1984 MDES TVA
Based on 435 Plants

bulk and bagged dry mixtures and materials, such as ammonium nitrate and diammonium phosphate.

Comparable data for suspension fertilizer plants show an average annual throughput of 2,772 tons including 1,718 tons of suspension mixtures, 650 tons of anhydrous ammonia, 830 tons of nitrogen solutions, and 630 tons of dry and liquid direct application materials (table 5). The ten leading suspension grades produced by these suspension plants are: 3-10-30, 4-12-24, 3-9-27, 6-18-18, 13-13-13, 3-9-18, 10-30-0, 5-10-15, 20-5-10, and 5-15-30. Average analysis for these grades is 39.3 percent compared to 30.2 percent for liquids. Similar to the liquid plants, these suspension plants also distribute significant tonnages of dry complete mixtures. A frequency distribution of all fluid plants (both liquids and suspensions) indicates the greatest number of plants in the 1,000- to 2,000-ton range (figure 4). Compared to bulk blend plants, fluid facilities tend to be smaller. The mode for fluids is 1,321 tons compared to 1,669 tons for bulk blending. The median for fluids is 1,952 tons while for bulk blends it is 2,883 tons.

Storage capacity for liquid fertilizer plants surveyed amounts to 29 percent of the total annual distribution. Suspension plants have a storage capacity of 33 percent of the total annual distribution. Both liquid and suspension plants show increases in their storage capacities in the past several years. In December 1983, 48 percent of the storage facilities for liquids was filled, with 30 percent filled as of June 30, 1984. Suspension plants report 46 and 22 percent for the same periods, respectively. Storage capacity by region and type of fertilizers is shown in table 3.

A total of 35 percent of the liquid fertilizer tonnage is custom applied with 33 percent of the tonnage applied by the dealer and 2 percent by application contractors. The farmer applies 44 percent using his own equipment and 19 percent using rental equipment. Similar to the bulk blenders, farmer application of liquid fertilizers is far greater than custom application by the dealers, although dealers provide the rental equipment for farmers to apply 19 percent of the fertilizer.

The percentage of custom applied suspension fertilizers is higher than that for both bulk blends and liquids. Almost 76 percent of suspension mixes are custom applied and, unlike bulk blend and liquid plants, suspension dealers custom apply 69 percent of the fertilizer. The higher percentage is because suspensions generally require more sophisticated application equipment (table 6).

Ownership data relating to all fluid fertilizer plants show that 17 percent of these plants are sole proprietorships, 5 percent partnerships, 60 percent corporations, and 20 percent cooperatives (table 7).

National Market Patterns

Other services—The survey also provides a composite description of the U.S. fertilizer market system. Of the 3,289 respondents, 2,842 have manufacturing facilities such as bulk blending, liquid and suspension mixing, and granulation or basic production units. Almost 48 percent offer anhydrous ammonia, 39 percent provide custom application services, 34 percent add insecticides, 55 percent add herbicides to their fertilizer mixtures, and 68 percent add micronutrients. Consultation service is offered by 39 percent of the manufacturing plants.

Non-farm use—The survey shows that 2.4 percent of total tonnage for all respondents is for non-farm use. Granulators sell 2.7 percent of their annual tonnage for non-farm use; bulk blenders, 2.9 percent; and fluid mixtures, 2.8 percent.

Types of plants—About 81 percent of all manufacturing plants have bulk blend facilities and 30 percent have fluid mix facilities. Twenty-seven percent of the fluid mixers have both liquid and suspension facilities.

Ownership patterns—Nine percent of all manufacturing plants indicate their form of business as sole proprietorships; 5 percent as partnerships; 49 percent as corporations; and 37 percent as cooperatives (table 7).

Directory of Fertilizer Manufacturers

A 1984 edition of the "Directory of Fertilizer Plants in the U.S.," based on respondents to the AAPFCO survey, is available through the Association of American Control Officials (AAPFCO). The directory lists plant location, plant type (bulk blend, fluid mix, or granulation), plant owner's or manager's name, telephone number, storage capacity, and related services offered by each plant. Requests, including prepayment of $12 per copy, should be directed to:

Mr. Penn Zentmeyer, AAPFCO
Virginia Department of Agriculture
and Consumer Services
Fertilizer, Lime, Motor Fuel Section
203 North Governor Street, Room 304
Richmond, Virginia 23219

Use of Phosphogypsum in Production of Gypsum Flakeboard

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Introduction

In Germany, a novel type of gypsum board has been developed for the building industry; the so-called gypsum flakeboard. Nearly all its properties are better than those of gypsum wallboard. The gypsum flakeboard also has advantages compared to the gypsum fibreboard which has been produced in Germany for about 10 years as a competitive product to the gypsum wallboard.

Despite its better properties, the gypsum flakeboard will not be more expensive regarding manufacturing costs than the usual gypsum wallboard, and is even considerably cheaper compared to a gypsum fibreboard. The basic materials for the production of gypsum flakeboards are plaster and wood flakes. Plaster can be manufactured from natural or chemical gypsum; a processing plant in Finland is using phosphogypsum as raw material.

Properties of Phosphogypsum

As its name implies, phosphogypsum is a by-product arising from the production of phosphoric acid by the "wet" method; by this method, the rock phosphate is digested by means of sulphuric acid.

The quantity of phosphogypsum that is produced in this way amounts to approx. 4 to 5 tons per ton of P_2O_5.

The essential difference between phosphogypsum and natural gypsum consists in the specific additions contained in phosphogypsum, and in the different grain sizes. Though the proportion of specific additions or impurities contained in phosphogypsum is relatively small, they exert an influence on the characteristics of the calcined product. The crystal structure of phosphogypsum is governed by the type of rock phosphate used and the related reaction conditions. The crystal growth is influenced by various factors such as

—the specific surface of the rock phosphates

—inorganic impurities

—the conditions of reaction.

It is simply impossible to list all the different impurities that are found in phosphogypsum.

It is no exaggeration to say that each individual phosphoric acid production plant yields a specific type of phosphogypsum that has specific properties and composition, even when using exactly the same type of rock phosphate.

Roughly the impurities may be subdivided into two groups according to their solubility:

—soluble impurities

—insoluble impurities

The soluble impurities are salts or acids that are not removed during the washing process. The proportion of such materials is governed by the gypsum's filtering property.

Usually the total content of impurities in phosphogypsum is over 5%, and the larger proportion of them is of the insoluble type. Some of the insoluble impurities derive from the rock phosphate, such as:

—quartz

—non-digested apatite

—organic carbon.

In addition, there are compounds that arise during the digestion process and result from secondary reactions. These compounds include:

—insoluble P_2O_5 as complex phosphates formed together with metals

—co-crystalline P_2O_5

—fluorine as CaF_2, Ca_2SiF_6, Na_3AlF_3 and other complex compounds

—metals such as Fe, Mg and the like, as complex phosphates and sulphates.

A purely chemical analysis of the phosphogypsum, however, merely gives a first indication with regard to the utilization of phosphogypsum. This does not suffice as a basis for an extensive evaluation since these impurities can be acceptable depending upon their chemical composition and the intended application of the calcined phosphogypsum.

Salzgitter Technology for Refining of Phosphogypsum

Following extensive development work and the experience gained in practical situations, our technology has been designed in accordance with the following principles:

—transformation of harmful impurities into an inactive state and/or

—removal of harmful impurities.

The necessary process steps are performed during or before calcination and depend on the specific characteristics of the phosphogypsum and on the required qualities of the final product.

In the Finland plant, phosphogypsum resulting from Kola rock phosphate (Prayon dihydrate phosphoric acid process) is used. The refining technology comprises two main sections that are as follows:

Section 210: Dewatering and Scrubbing

The reduction of the free moisture in the phosphogypsum as much as possible before calcination represents an important economic factor. At the same time, this reduction of the free moisture causes a fundamental decrease in the amount of water-soluble impurities.

In section 210, the phosphogypsum, which is delivered in the form of a slurry, is dewatered and scrubbed on a vacuum filter. The water used to wash the filter cake is heated to about 80°C by scrubbing the off-gas from calcination section 220 in a gas scrubber. Due to the warm washing water, the dewatering effect of the vacuum filter is considerably improved and the filter cake pre-heated to 50–60°C. The dewatered and washed phosphogypsum is sent to the calcination section 220 for the next stage of the process.

Section 220: Calcination

The production of plaster from phosphogypsum, according to the Salzgitter technology, under controlled conditions is characterized by the following factors:

—exact and constant product temperature during drying and calcination,

—the aging effect due to the high steam content of the conveying gases,

—the stabilizing period (hot pit) before the plaster goes into final storage.

Our calcining system combines elements from a flash calciner and a centrifugal sifter.

The phosphogypsum to be dried or calcined enters the respective cyclone chamber in a flow parallel to the hot gas. The forced rotational flow of the product, caused by the high velocity of the hot gas entering at a tangent, results in the centrifugal forces separating out all particles whose diameter exceeds a characteristic limit value. These particles form a rotating ring at the wall of the chamber and the rotational velocity of this ring lies considerably below the velocity of the gas. The relative velocities at this stage encourage the material and heat exchange in such a way that high capacities can be achieved with relatively small drying and calcining chambers.

The sifting effect of the chambers results in differing residence times depending on the particle size of the phosphogypsum. Material flows in continuously, forcing the dried or calcined particles to the centre where they leave the respective chamber together with the off-gas through the central discharge opening.

The off-gas from the calcination chamber serves to dry the moist phosphogypsum in the drying chamber. For the production of one tonne of plaster, 35 kg of bunker C fuel oil are required.

Dry Technology for the Production of Gypsum Flakeboard

The dry technology is basically the result of research and development done by Prof. Dr. Kossatz of the Wilhelm-Klauditz-Institut, Braunschweig. The machine company Bison Werke of Springe has developed the machinery for the production plant. Dry technology means, the quantity of water added lies at a level just barely higher than the quantity required for hydration of the plaster.

The Process

In the manufacture of gypsum flakeboard, the wood flakes serve as a source of water, as reinforcement for the gypsum matrix and as a means of reducing the overall bulk density of the board. Plaster from refined phosphogypsum will be delivered to the plant in bulk and stored in a silo.

Round timber is made into flat flakes in a chipping machine.

These are then conveyed via an intermediate bin to a mill where they are reduced further in size. The resulting fine flakes are transported pneumatically to a dosing bin.

The dosing and mixing station operates automatically. The moisture in the flakes is registered continuously. A computer controls the amount of make-up water needed to maintain the level of moisture in the wood and the constant plaster-to-wood ratio. The standard formulation is based on a ratio of absolutely dry wood to gypsum of 30 : 100.

The mixture is produced in batches. After weighing the flakes, the make-up water is mixed in intensively together with accelerating solutions, if required. Thanks to the intensive mixing program, it only takes a few seconds to moisten the flakes evenly. Following this, the dry plaster is added. After a few more seconds, the mixing process is complete. The free-flowing mix, with a moisture level of 20–30% dependent on the water-to-plaster ratio, is discharged and fed via conveyor belts to the moulding machine.

The fresh mix is distributed with the aid of a proven pneumatic spreader which has only been modified slightly to cope with the mixture of plaster and flakes.

After the moulding station, the process resembles that used to produce cement boards. The sheets, on which the material is spread out like mats, are stacked on top of each other in a clamping frame. The loaded frame enters the press. The mats in the stack are compressed to the final board thickness at a specific pressure of approximately 25 bars. The frame is locked and placed on a siding track during which time hydration can take place. A heated setting chamber, as used in the production of cement boards, is not required in this process.

After hydration, the boards have now reached a strength which will allow them to be removed from the sheets.

In contrast to cement boards, the gypsum flakeboards can now be dried immediately and they are ready for dispatch after trimming and being cut to size.

Drying takes place in multi-tier roller or belt driers, or by feeding the boards through a drier after stacking them on rack carriages.

Properties of Gypsum Flakeboard

Gypsum flakeboard will be produced with a size of 1.25 m in width and a length up to 3 m. The normal board thicknesses lie between 8 and 28 mm. Even thinner boards of 6 mm or thicker ones of 32 mm can be manufactured in one plant. The specific weight of the boards is variable between 1.0 kg/m^3 and 1.3 kg/m^3. The gypsum flakeboard is characterized by the following main properties.

Modules of rupture: (in all directions)	7–9.5 N/mm^2
Modulus of elasticity:	2000–4000 N/mm^2
Withdrawal strength:	0.25–0.35 N/mm^2
Impact strength:	100–125 mm
Screw extraction resistance:	up to 700 N/cm
Linear expansion: (20°C/30%–20°C/85%)	0.05–0.06%

Wednesday, October 31, 1984

Afternoon Session
Moderator:

Dean R. Sanders

Some Agronomic Aspects of Nitrogen Management Under No-Tillage

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Introduction

Acceptance of no-tillage and reduced tillage crop production methods, often collectively referred to as conservation tillage, has expanded rapidly in many parts of the U.S. in recent years, particularly in the Mid-Atlantic region. For instance, from less than 10,000 acres in 1970, the extent of no-tillage and reduced tillage corn grown in Maryland increased to more than 350,000 acres by 1978 (1). A 1983 county-by-county Maryland survey showed that even in a year when the Federal Government's PIK (Payment in Kind) program encouraged an overall reduction in corn acreage, over 400,000 acres of corn were nevertheless attributed to conservation tillage methods (10). Similar trends have also been reported in other Mid-Atlantic states where, on the average, conservation tillage corn acreage increased from less than 5% in 1970 to almost 30% in 1978 (1).

Once growers and scientists recognized that no-tillage systems for growing row crops such as corn, could function in a practical manner, it became apparent that traditional lime and fertilizer application methods might not be suitable or even possible. With the introduction of improved no-tillage planters, farmers found that they could establish excellent corn stands without prior soil tillage. It also became obvious that traditional rates and methods of nitrogen application did not always result in expected high yields and acceptable nitrogen efficiency (3).

Some nitrogen management problems have also resulted from the fertilizer industry trend away from ammonium nitrate and toward urea (7). Indications are that increased use of surface applied urea or urea-based fertilizers in conservation tillage systems often present agronomic and subsequent economic problems for the farmer (2,11). It is well known that under favorable conditions, significant quantities of nitrogen can be lost to the atmosphere from surface applied urea due to ammonia volitilization (5,8,12). The "bottom line" is that where urea or urea-based fertilizers are surface applied, particularly in the presence of organic residues, crop yields are often reduced (2,6,9,11). Considerably improved N efficiency can be obtained by proper fertilizer placement (2,11), or if sufficient rainfall occurs at a fortuitous time. According to Fox and Hoffman (6), there is an apparent relationship between timeliness of rainfall after N application and possible N volatilization losses. They have suggested the following relationships: "(1) there was insignificant ammonia volatilization loss from unincorporated urea fertilizers if at least 10 mm (0.4 in.) of rain fell within 48 hours after fertilizer application; (2) if 10 mm or more fell 3 days after the urea was applied, volatilization losses were slight (<10%); (3) if 3 to 5 mm (0.1 to 0.2 in.) of rain fell within 5 days, or 7 to 9 mm (0.3 to 0.4 in.) within 9 days, volatilization losses could be moderate (10% to 30%); and (4) if no rain fell within 6 days, the loss could be more substantial (>30%)."

According to the 1982 FERTILIZER SUMMARY DATA published by the Tennessee Valley Authority (7), of the direct applied nitrogen materials utilized on U.S. farms, 11.5% was attributed to urea and 25.1% to UAN solution. In Maryland, where no-tillage crop production has gained rapid popularity, 6.1% of the direct applied nitrogen came from urea, and 62.4% came from UAN solution. The relatively high popularity of UAN solutions in recent years is probably related to the fact that many herbicides and other pesticides can be tank-mixed with UAN, thus saving one or more extra trips across the field. The potential problems associated with surface applied urea and other urea-based fertilizers is already widespread, and will continue to grow as acreage of reduced tillage and no-tillage corn increases. Other problem areas related to no-tillage N management besides N source, include N rate, N placement and time of N application. These topics will be discussed in greater detail in the following sections.

Nitrogen Rate for Maximum Yields

As no-tillage corn gained in popularity during the 1970's, one difference observed between no-tillage and conventional tillage was the "apparent" need for higher nitrogen levels in no-tillage fields. Unfortunately, some have incorrectly interpreted this difference to mean that no-tillage corn is a less efficient utilizer of fertilizer N than conventional tillage corn. But, when properly managed, no-tillage corn actually provides a much MORE EFFICIENT vehicle for fertilizer N utilization than does conventional tillage.

Long-term N rate by tillage experiments conducted in Maryland since 1973 have provided useful data relative to the nitrogen requirements of the two tillage systems. These tests substantiated that at sub-optimal N rates, N deficiency symptoms were more pronounced in no-tillage than in conventional tillage corn. Some of this work illustrated the major differences in N requirements between the two tillage systems. In these tests, N was applied to both no-tillage and conventional tillage corn at rates of 0, 80, 120, 160 and 240 lb/A. Yield data from one typical location-year are presented in Table 1.

TABLE 1. GRAIN YIELDS FOR CONVENTIONAL TILLAGE AND NO-TILLAGE CORN FOLLOWING VARIABLE NITROGEN RATES. POPLAR HILL RESEARCH FARM. 1981.

Tillage	N (lb/A)**					Mean
	0	80	120	160	240	
			bu/A			
No-Tillage	27.5	122.5	173.1	197.6	181.2	140.4
Conv. Tillage	72.6	142.1	156.7	161.6	162.2	139.0
Mean	50.1	132.3	164.9	179.6	171.7	139.7

NOTE: LSD/.05:N Rate = 21.7 bu/A.
**40 lb N/A applied 4-30-81, remainder applied 6-16-81.

From the response curves in Table 1, it would appear that the 160 lb/A N rate resulted in highest yields for both tillage systems. However, neither of these curves actually "peaked" at 160 lb N/A. Using a statistical technique known as curvilinear regression, best fitting curved lines were selected for these data points. These lines showed that grain yields for both tillage systems continued to increase to some N rate(s) between 160 and 240 lb/A. Maximum yields should have occurred at approximately 196 lb N/A for no-tillage and at 177 lb N/A for conventional tillage corn—approximately 19 lb/A more N for the no-tillage than for the conventional tillage. These values illustrate typical differences in N requirements between the two tillage systems. Experience has shown that diffferences in maximum yield N requirements between typical no-tillage and conventional tillage corn systems average about 30 to 40 lb N/A more for no-tillage, but may vary from 0 to more than 60 lb N/A. The magnitude of these differences depends upon many factors, such as soil type, past cropping history, seasonal rainfall and temperature, soil pH, etc. These all are factors which directly or indirectly influence the level of residual soil N available to the growing crop.

Despite no-tillage corn often requiring a higher fertilizer N rate than conventional tillage corn, the higher N level is usually justified under Maryland conditions by higher yields. For instance, in Table 1, no-tillage corn yields exceeded those from conventional tillage by approximately 16 to 36 bu/A at the more optimal N fertilization rates. When the amounts of fertilizer N required to produce a bushel of corn were calculated (Table 2), it was apparent that at N rates of less than 120 lb/A, no-tillage corn required the same amount of N/bu as conventional tillage. But, at N rates of 120 lb/A or more, no-tillage corn required LESS N/bu than conventional tillage. For instance, at N rates of 120, 160 and 240 lb/A, each bushel of conventionally tilled corn required 0.8, 1.0 and 1.6 lb N/bu respectively compared to 0.7, 0.8 and 1.3 lb N/bu for no-tillage corn. At these higher N rates, conventional tillage corn required 1.1, 1.2 and 1.2 times more N respectively than similarly treated no-tillage corn. N efficiency relative to grain yields declined for both tillage systems as N rates increased. But N efficiency for no-tillage corn was always higher than that for conventional tillage corn at N rates of 120 lb/A or more.

Summarizing yield data collected over an 11-year period from as many as five Maryland locations (Table 3), showed that at sub-optimal N rates (below 80 lb N/A), conventional tillage corn out-yielded no-tillage corn 64% to 69% of the time. At the 80 lb N/A rate, the odds were about even that either tillage system would result in highest yields. But, at more optimal N rates (120 lb N/A or more), the odds were reversed,

TABLE 2. RATIOS OF FERTILIZER N TO GRAIN YIELD FOR CONVENTIONAL TILLAGE AND NO-TILLAGE CORN FOLLOWING VARIABLE NITROGEN RATES. POPLAR HILL RESEARCH FARM. 1981.

Tillage	N (lb/A)					Mean
	0	80	120	160	240	
	lb. N/bu					
No-Tillage	0.0	0.6	0.7	0.8	1.3	0.7
Conv. Tillage	0.0	0.6	0.8	1.0	1.6	0.8
Mean	0.0	0.6	0.7	0.9	1.4	—
Ratio: Conv. Till/No-Tillage	—	1.0	1.1	1.2	1.2	—

NOTE: Ratios calculated from points on best-fitting curvilinear regressions.

TABLE 3. INFLUENCE OF TILLAGE ON PROBABILITY OF OBTAINING MAXIMUM CORN YIELDS FROM VARIABLE NITROGEN RATES AT FIVE MARYLAND LOCATIONS. 1973–1984.

Nitrogen Rate lb/A	No-Tillage/1		Plow Tillage/2		Total Tests
	No. Tests	%	No. Tests	%	
0	15	31	34	69	49
40	9	36	16	64	25
80	24	49	25	51	49
120	32	65	17	35	49
160	35	71	14	29	49
240	18	75	6	25	24

1/Number of tests and percent of time in which no-tillage corn out-yielded conventional tillage corn.
2/Number of tests and percent of time in which conventional tillage corn out-yielded no-tillage corn.

and no-tillage corn OUT-YIELDED conventional tillage corn 65% to 75% of the time.

Obviously, when managed properly and fertilized at the optimal N rate, no-tillage corn can be expected to deliver more efficient use of fertilizer N than conventionally tilled corn. No-tillage corn can thus be expected to normally return more profit per acre from properly applied N fertilizers than its conventionally tilled counterpart.

Nitrogen Source

As discussed briefly in the INTRODUCTION, N fertilizers containing urea frequently are not as efficiently utilized when surface applied as ammonium nitrate or other materials less sensitive to volatilization losses. In a series of Maryland tests conducted from 1976 to 1979 at three locations, ammonium nitrate resulted in the highest and urea the lowest average no-tillage corn yields (2). Yields from UAN solution were intermediate between ammonium nitrate and urea (Table 4). Calculating from response curves fitted to a summation of this data covering 12 location-years, it was estimated that at the 160 lb N/A rate, urea utilization by no-tillage corn was 61% as efficient as ammonium nitrate, and 80% as efficient as UAN. Broadcast UAN solution was 75% as efficient as ammonium nitrate, and 125% as efficient as urea in these tests.

In spite of the frequently erratic behavior of urea under no-tillage conditions, the importance of urea to agriculture cannot be discounted. Urea has the highest N content of any solid N fertilizer on the market. And because of more favorable economics in manufacturing, as well as the lack of many government restrictions on transportation and storage that have been imposed upon ammonium nitrate, urea has the potential to become a very important dry nitrogen material. Therefore, it becomes extremely important that more efficient methods of utilizing urea and UAN solutions continue to be investigated and refined.

If the cost per unit of N were the same for all N sources, obviously, ammonium nitrate would appear to be a better buy than either UAN or urea for surface application on no-tillage fields. UAN would also appear to be more economical than urea under no-tillage conditions. However, any cost differential between these matierals must be taken into account when determining application rates. If the cost per unit of N from urea or UAN is significantly lower than that of ammonium nitrate, then it may be economically sound to increase the rate of application for urea or UAN to compensate for the lower efficiency of these materials. But since any nitrogen fertilizer should be considered as a valuable resource to be conserved and also as a potential pollutant of lakes, streams, rivers and ground water, a more practical approach to improve N efficiency might be to modify the application method or time of application.

Nitrogen Fertilizer Placement

One proven technique for increased efficiency of urea-based fertilizers is soil incorporation. Since this technique requires special equipment if applied under no-tillage conditions, a research project was initiated

TABLE 4. INFLUENCE OF NITROGEN RATE AND SOURCE ON NO-TILLAGE CORN GRAIN YIELDS AT 3 LOCATIONS. 1976 TO 1979.

N Source	N (lb/A)					Mean
	0	40	80	120	160	
	bu/A					
Ammonium Nitrate	85.6	107.0	130.5	141.4	147.7	122.4
Urea	85.6	100.6	119.6	126.9	135.8	113.7
UAN	85.6	97.3	120.7	134.3	141.9	115.9
Mean	85.6	101.4	122.6	132.4	140.3	117.4

NOTE: LSD/.05: N Source = 3.2 bu/A, N Rate = 3.2 bu/A,
N Source × N Rate = 6.4 bu/A

in 1979 at the University of Maryland in cooperation with the Tennessee Valley Authority to develop and test the effectiveness of an experimental apparatus for soil injection of liquid fertilizers under no-tillage field conditions. Subsequently, a tractor-mounted three-point-hitch soil injector was developed for use on small plots. Solutions of ammonium nitrate, urea or UAN were placed between the rows about 15 inches from the plant, and about 4 to 6 inches deep. A plow coulter in front of the injection knife cut through plant residues. Results from some of this research are presented in Table 5 (4).

TABLE 5. FOUR-YEAR SUMMARY OF THE INFLUENCE OF N SOURCE AND N PLACEMENT ON NO-TILLAGE CORN YIELDS. POPLAR HILL RESEARCH FARM. 1979 TO 1982.

Nitrogen Placement	N Source 1			Mean
	Ammonium Nitrate	Urea	UAN	
	bu/A			
Broadcast	153.9	127.0	142.7	141.2
Injection	155.1	152.8	158.1	155.4
Mean	154.5	139.9	150.4	148.3

NOTE: N placement means significant at 5% level. 1/ N applied at 120 lb/A.
LSD/.05: N source = 4.2 bu/A, N source by N placement = 6.0 bu/A.

Over the four-year duration of this experiment, it was obvious that surface broadcast N resulted in large yield differences between N sources. Ammonium nitrate resulted in the highest yields, and broadcast urea resulted in the lowest. Broadcast UAN resulted in yields intermediate between those from ammonium nitrate and urea. Corn grain yields from broadcast urea averaged 26.8 bu/A less than those from ammonium nitrate. For individual years, this difference ranged from 13.4 to 36.5 bu/A. Grain yields from broadcast UAN averaged 11.2 bu/A less than those from broadcast ammonium nitrate. Over the four-year duration of the test, yields after UAN were 8.4 to 15.9 bu/A lower than yields from ammonium nitrate. But, in those cases where all three N fertilizers were soil injected, no statistically significant grain yield differences occurred between N sources.

Soil injection improves N fertilizer efficiency under no-tillage conditions. Considering only the N, injection is obviously the most efficient method available. But, there are also some disadvantages with this technique. For instance, there is currently no satisfactory method for prilled or granular nitrogen products to be injected into no-tillage soils. Injection of N solutions works well, but injection is not as rapidly accomplished as other methods of fertilizer spreading. Soil injection requires more energy than surface application. Most farmers already own, or have access to, a sprayer. But many do not have access to an injection apparatus. Thus, injection may not be as convenient as other techniques. Another potentially serious problem is that the traditional anhydrous ammonia type knife often used for injection causes soil disturbances which may create an erosion problem on more rolling topography. High pressure injection, or use of a soil stream nozzle behind a straight plow coulter may remove some of these disadvantages. Field testing of some of these innovative techniques, in cooperation with the Tennessee Valley Authority, USDA and the Arcadian Corporation, is still in its infancy. Some preliminary results obtained at five Maryland locations in 1984 are presented in Table 6. It must be recognized that the very timely spacing of rainfall events at most locations in 1984 probably was a major reason why larger differences did not occur more frequently between application methods or materials. This research will be continued for several more years.

With proper equipment, soil injection of N solutions works very well, usually with a yield advantage. But, until significant improvements in machine availability occur, it is doubtful that many farmers will have injection available as a practical option. But, since most growers either own or have access to a sprayer that could be used to apply fertilizer solutions, another application technique known as "dribbling," or surface banding, should be considered.

TABLE 6. INFLUENCE OF N SOURCE AND PLACEMENT ON NO-TILLAGE CORN GRAIN YIELDS AT SEVERAL LOCATIONS. 1984.

N Treatment	Poplar Hill	Wye Res. Center	Belts-ville	Forage Farm	Sharps-burg	Mean
			bu/A			
Check	49.4	51.2	82.0	144.9	109.6	87.4
Ammonium Nitrate	170.4	173.3	150.7	195.9	146.3	167.3
UAN Broadcast	140.6	135.1	143.5	197.3	146.0	152.5
UAN Dribbled	143.8	158.5	141.2	184.2	142.2	154.0
UAN Injected 1/	182.0	156.4	162.6	198.7	141.7	168.3
UAN Injected 2/	165.0	155.0	154.4	200.3	144.6	163.9
UAN Injected 3/	161.9	155.4	145.6	177.1	146.8	157.4
Urea Broadcast	—	115.8	123.1	163.1	148.6	137.6
LSD.05	12.1	26.0	21.1	25.4	16.7	

NOTE: 120 lb N/A applied near planting time. UAN injected by 1/ anhydrous ammonia knife, 2/ low pressure solid stream nozzle into plow coulter slot, or 3/ high pressure NUTRI-BLAST 2000.

"Dribbling" of N solutions is a simple, low-cost procedure that can easily be accomplished by attaching a length of hose over the sprayer nozzle. This technique is effective for improving the efficiency of surface applied UAN under most normal growing conditions. Results from tests conducted at several Maryland locations in 1982 are presented in Table 7.

In all 4 comparisons in Table 7, dribbled UAN was statistically superior to broadcast UAN. Yield differences between dribble and broadcast ranged from 12.6 to 36.7 bu/A in favor of the dribble technique (9.2% to 30.6%). Even when corn is priced at only $2.00/bu, improved N efficiency from dribbling translated into $25.20 to $73.40/A additional income. Essentially, the only additional cost to this practice is for the purchase of a few lengths of hose, plus possibly driving an extra trip over the field if the grower had normally been following the traditional practice of tank-mixing pesticides with UAN for simultaneous application. It would appear that surface banding (dribbling) UAN solutions on no-tillage corn is a reasonable alternative to the apparently large N losses otherwise experienced when broadcast application methods are employed.

TABLE 7. INFLUENCE OF N SOURCE AND PLACEMENT ON NO-TILLAGE CORN GRAIN YIELDS AT WYE RESEARCH AND EDUCATION CENTER AND POPLAR HILL. 1982.

N Treatment	Wye/1	Poplar Hill/1	Poplar Hill/1	Poplar Hill/2
		bu/A		
Check	33.3	31.1	42.3	42.3
Ammonium Nitrate	112.4	155.1	141.9	163.6
UAN Broadcast	99.0	119.9	136.3	159.0
UAN Dribbled	119.9	156.6	148.9	176.0
UAN Injected	124.2	167.2	156.2	178.4

NOTE: 1/ N rate = 120 lb/A, 2/ N rate = 160 lb/A.

Timing Nitrogen Applications

Proper timing of N applications on any crop is extremely important. But, it is doubtful that there has ever been a crop where proper N timing is more critical than it is for no-tillage corn. Proper N timing is particularly critical because of the many ways in which fertilizer N can be lost under no-tillage, many of which are not a serious concern under conventional tillage. A good "rule of thumb" is to "apply N fertilizer as near as possible to the time of plant need." N leaching losses can be a problem on light textured sandy soils regardless of the tillage system. But where no-tillage is practiced, a number of other factors may also significantly influence N use efficiency if abused or ignored.

Under no-tillage management, N fertilizers may be lost from the soil by ammonia volatilization and/or by denitrification. Or N may be biologically immobilized. Two of the more important of these N "loss" mechanisms include ammonia volatilization from surface applied urea or urea-based fertilizers, and denitrification, a process by which readily available nitrate N is chemically reduced (oxygen removed), until it is converted to a gas. Denitrification is believed to be a major source of fertilizer N losses from no-tillage soils and is most often a problem in wet soils where oxygen availability is limited. Denitrification can be serious during growing seasons in which wet soils are a problem, particularly when nitrogen was applied at times not coinciding closely with plant needs.

Another important mechanism that reduces fertilizer N availability is microbial immobilization, a process in which certain soil microbes decompose plant residues and convert them into soil organic matter (humus). Crop residues, such as old corn stalks, leaves, cobs, roots, etc. are relatively high in carbon and low in nitrogen. For soil microbes to convert such residues into protein relatively high in N, a readily available N source is necessary. Fertilizer N applied before needed by the crop could be consumed by microbes (immobilized), rendering it temporarily unavailable to plants. Most immobilized N remains unavailable to plants until the newly formed soil humus is broken down by oxidation (mineralized), releasing the immobilized nutrients. Cultivation, for instance, encourages mineralization by aerating the soil, allowing oxygen to react with the organic matter.

No-tillage corn production is an excellent example of a cropping environment in which N immobilization could be a serious problem. If N fertilizers are applied too early in the growing season, when N requirements of corn are minimal, then more biological N immobilization could occur than if N fertilizers were applied in a more timely manner. Corn requires very little N during its first 25 to 30 days. N applied during this period would not be in heavy demand by the crop. But, as plant dry matter increases, the crop's need for N also increases. N applied during this latter period could also be immobilized, but not likely to as great an extent as the early applied N because there would be more intense competition for it by the rapidly growing plants. A good example of the possible combined effects of ammonia volatilization, denitrification and immobilization on corn grain yields, and the extent to which these effects can be minimized by N placement and timing of application is presented in Table 8.

In all cases, grain yields tended to be highest following the delayed N application, particularly where UAN was broadcast. Injecting UAN 4 to 6 inches deep tended to reduce the importance of time of application. Over the three-year period from 1980 to 1982, delaying the N application by about 30 days from the time of planting increased no-tillage corn yields by 17.0 bu/A, about a 14.4% increase where UAN was surface broadcast. Yields were increased by 7.8 bu/A, or by about 5.7% where injection was the application technique. Obviously, proper timing of N applications is much more critical for broadcast than for injected UAN applications. Delayed N applications have not always resulted in yield benefits compared to N applications near planting time. But when yield differences have occurred, they have almost always always favored the delayed timing, especially for surface applications. Leaf analyses have almost always indicated improved N efficiency from the delayed N application.

Summary

An attempt has been made to demonstrate the importance of more careful nitrogen management on no-tillage corn. Factors that were of minimal importance under conventional tillage require more intensive management under no-tillage conditions. Special consideration must be given to N source, time of N application and N placement. Based upon current research and experience, a suggested fertilization program for no-tillage corn might then be as follows:

—Use a starter fertilizer in a band near the row to supply 20 to 40 lb/A of N. Ideally, this fertilizer should also include P205 and K20 in a 1:2:1, 1:3:1, or one of many other widely recommended ratios for starter fertilizers.

—Broadcast according to soil test any remaining P205 and K20 requirements. Timing is not as critical for this operation as long as leaching and erosion are not problems. It is preferable that application be made sometime before planting.

TABLE 8. INFLUENCE OF APPLICATION TIME AND PLACEMENT OF UAN SOLUTION ON NO-TILLAGE CORN GRAIN YIELDS. WYE RESEARCH AND EDUCATION CENTER. 1980 TO 1982.

Method/1	Time/2	Year			Mean
		1980	1981	1982	
		bu/A			
Broadcast	Early	104.5	134.4	116.0	118.3
Broadcast	Late	114.5	167.0	124.5	135.3
Difference		+10.5	+32.6	+8.5	+17.0
Injection	Early	102.9	164.9	143.6	137.1
Injection	Late	111.1	176.0	147.7	144.9
Difference		+8.2	+11.1	+4.1	+7.8

NOTE: 1/ UAN applied at a rate of 120 lb N.A.
2/ Early = UAN applied with 2 to 3 days of planting.
Late = UAN applied approximately 4 weeks after planting.

—Apply the remaining N requirement about 4 to 6 weeks after planting, or when the corn has attained a height of 12 to 18 inches. If UAN solution is utilized, dribble (surface band) or inject between the rows.

—On the average, approximately 30 to 40 lb/A more N may be required on no-tillage than on conventional tillage corn. But, the amount may vary considerably from soil to soil, possibly from 0 to 60 lb/A or more. The difference in N requirement between the two tillage systems will depend upon soil conditions and past cropping history. But, under Maryland conditions, any extra N required is usually justified by the higher yield potential of no-tillage corn.

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Agronomic Programs for Maximum Yields

Dr. Roy L. Flannery
Specialist in Soils
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Part I. Maximum Yield Corn Experiment in 1982
Soils and Crops Research Center, Rutgers University
Adelphia, New Jersey

Experiment Conducted By: Roy L. Flannery, Specialist in Soils.

Experimental Variables Employed:

Corn hybrids (2): Agway 849X and O's Gold SX5509.

Plant populations (2), ppa: High population (37,337 ppa)—single rows 14″ apart, plants spaced 12″ in row; Low population (32,670 ppa)—double rows 8″ apart on 32″ centers, plants spaced 12″ in row.

Macronutrient rates (2), Lb./A.	N	P_2O_5	K_2O
(See accompanying table for sources,	300	175	175
time and methods of application)	500	350	350

Irrigation levels (2): None and 12.25″ (See accompanying table for timing, rates and method of application)

Soils Information

Soil type used: Experiment was conducted on a well drained Freehold sandy loam soil containing approximately 70% sand, 23% silt, 7% clay, 1.3% organic matter and having a cation exchange capacity (CEC) of 8–9 meq./100 g.

SOIL TEST RESULTS FOLLOWING 1981 SOYBEAN CROP AND BEFORE FERTILIZING AND PLANTING 1982 CORN CROP

1981 Fertilization			Soil Test Results[1]					1982 Fertilization		
N	P_2O_5 Lb./Acre	K_2O	pH	P	K Lb./Acre	Ca	Mg	N	P_2O_5 Lb./Acre	K_2O
50	100	125[2]	6.1	163	393	1540	172	300	175	175[2]
50	100	125[3]	5.9	160	297	1403	169	300	175	175[3]
100	200	250[2]	6.0	184	443	1572	149	500	350	350[2]
100	200	250[3]	5.7	185	341	1243	154	500	350	350[3]

[1] Melich 1 extraction method used for P, K, Ca and Mg.
[2] Nonirrigated plots.
[3] Irrigated plots.

Cultural Practices Employed:

Cropping history: Sweet corn 1978–79; Corn 1980; Soybean 1981; Corn 1982.

Winter cover crops: Rye each fall following cultivated crop.

Tillage: Soil was moldboard plowed and disked twice each year before planting either corn or soybeans. Land was subsoiled 18″ deep at 30″ intervals in fall of 1980.

Crop residue: Corn stover and soybean vines are returned to soil and disked in prior to seeding winter cover crop.

Liming: All plots were limed with 2000 lb./acre of dolomitic limestone in 1980, 1000 lb./acre in 1981, and with 1600 lb./acre of dolomitic limestone in 1982.

Macronutrient fertilization: See following table for sources, rates, methods and time of application.

Micronutrient fertilization, lb./acre: B—2, Cu—5, Mn—25, Zn—10. Half of the B and all the other micronutrients listed were broadcast and disked in on all plots before planting. Half of the B was applied through the irrigation system or topdressed at early tasseling on the nonirrigated plots.

Secondary nutrient fertilization: See following table for rates applied.

Manure applied: All plots were covered with dairy cattle manure (4.41 T/A of solids) supplying 150-100-100 lb./acre of N-P_2O_5-K_2O. Manure was broadcast over cover crop and plowed down.

Weed control, amount/acre: Bladex (1 qt.), Sutan+ (2 qt.), and Atrazine (0.6 qt.) preplant incorporated.

Planting:

Seed treatment—Diazinon and Captan.

Date—May 1.

Method—Hand.

Spacing—Rows 14″, in row 12″ (37,337 ppa) Double rows 8″ on 32″ centers, in row 12″ (33,670 ppa).

Soil temperature—62° F (3″ depth)

Air temperature—70° F (high); 34° F (low).

Soil moisture—70% of field capacity (0–6″).

Insect control: Furadan granules—25 lb./acre; Dyfonate granules—25 lb./acre preplant incorporated. Dyfonate granules, 10 lb./acre broadcast over corn plants when 2½–3″ tall.

Irrigation: Irrigated plots were watered with a low pressure trickle irrigation system, one drip irrigation tubing for each pair of rows. Plots were watered to maintain soil moisture between 70–100% field capapcity from emergence to tasseling and between 80–100% field capacity from tasseling to early dent stage of grain.

Rainfall, irrigation and growing degree days:

Month[1]	Rainfall	Irrigation[2]	Total	No. Growing Degree Days[3]
	Inches			
May	2.69	0	2.69	267
June	3.93	1.75	5.68	411
July	4.19	3.50	7.69	666
August	2.05	7.00	9.05	534
Sept. (1–22)	1.34	0	1.34	330
Totals	14.20	12.25	26.45	2208

[1] Corn was planted May 1, plants emerged May 10, and were harvested September 23.
[2] Trickle irrigation with tubing on soil surface.
[3] Growing degree days: May 10 thru September 22.
Note: Average normal rainfall (May–Sept.)—20.72″, 1982 deficit—6.50″.

Harvesting: Whole plants were hand harvested and chopped through a field chopper and weighed for silage yields on September 16. Samples were taken for moisture determinations and tissue analysis at this time. Ears were harvested for grain yields on September 23.

Experimental Results:

Grain, silage and total dry matter production for each combination of the eight management variables employed in the experiment are reported in the attached tables. Grain yields ranged from 150 to 338 bushels per acre. Silage yields ranged from 23.5 to

Macronutrient fertilization:

Lb./Acre N	Lb./Acre P_2O_5	Lb./Acre K_2O	Source of Nutrients[1]	Method of Application[2]	Date of Application	Growth Stage of Corn
			Non-irrigated corn—Low fertilization			
150	100	100	Cow manure	Br. & P.D.	4/19	Preplant
50	50	50	AN-NS-KS	Br. & D.I.	4/23	Preplant
50	25	25	AN-NS-KS	T.D.	6/11	6 leaf
50	0	0	AN-------	T.D.	7/22	Early tasseling
300	175	175				
			Irrigated corn—Low fertilization			
150	100	100	Cow manure	Br. & P.D.	4/19	Preplant
50	50	50	AN-NS-KS	Br. & D.I.	4/23	Preplant
50	25	25	14-7-7	Fertigation	6/11	6 leaf
50	0	0	AN--------	Fertigation	7/22	Early tasseling
300	175	175				
			Non-irrigated corn—High fertilization			
150	100	100	Cow manure	Br. & P.D.	4/19	Preplant
50	75	50	AN-NS-KS	Br. & P.D.	4/20	Preplant
50	50	75	AN-NS-KS	Br. & D.I.	4/23	Preplant
50	25	25	AN-TS-KCl	T.D.	6/11	6 leaf
75	37.5	37.5	AN-TS-KCl	T.D.	6/28	12 leaf
75	37.5	37.5	AN-TS-KCl	T.D.	7/28	Early tasseling
50	25	25	AN-TS-KCl	T.D.	8/26	Early grain filling
500	350	350				
			Irrigated corn—High fertilization			
150	100	100	Cow manure	Br. & P.D.	4/19	Preplant
50	75	50	AN-NS-KS	Br. & P.D.	4/20	Preplant
50	50	75	AN-NS-KS	Br. & D.I.	4/23	Preplant
50	25	25	14-7-7	Fertigation	6/11	6 leaf
75	37.5	37.5	14-7-7	Fertigation	6/28	12 leaf
75	37.5	37.5	14-7-7	Fertigation	7/8	Early tasseling
50	25	25	14-7-7	Fertigation	8/26	Early grain filling
500	350	350				

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[1] AN = ammonium nitrate; NS = normal superphosphate; KS = potassium sulfate; TS = triple superphosphate; KCl = potassium chloride; 14-7-7 = clear liquid.

[2] Br. = broadcast; P.D. = plowed down; D.I. = disked in; T.D. = topdressed; fertigation = clear liquid applied thru drip irrigation system.

INFLUENCE OF CORN HYBRID, PLANT POPULATION, IRRIGATION AND MACRONUTRIENT (NPK) FERTILIZATION ON FIELD CORN GRAIN (BU./A) AND SILAGE YIELDS (T/A) IN 1982

Fertilization			Harvested Portion of Plant[2]	Agway 849X				O's Gold SX5509			
Lb./Acre				32,670 ppa[1]		37,337 ppa		32,670 ppa		37,337 ppa	
N	P_2O_5	K_2O		N.I.[3]	I.[4]	N.I.	I.	N.I.	I.	N.I.	I.
300	175	175	Grain	185.4	238.8	183.0	264.1	181.4	277.3	183.2	286.5
			Silage	23.7	32.9	23.8	35.9	24.6	34.4	23.5	39.6
500	350	350	Grain	183.5	257.9	174.8	302.8	159.8	289.6	149.9	337.8
			Silage	27.4	31.6	22.7	38.4	27.7	34.5	28.0	44.6

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[1] ppa = plants per acre.

[2] Grain—15.5% moisture; Silage—68% moisture.

[3] N.I. = not irrigated.

[4] I. = irrigated.

44.6 tons per acre. Total dry matter production (above ground portion of plant) ranged from 14,528 to 28,544 pounds per acre. Values reported in tables are average values for four replicated plots.

Below is a table showing the soil test results for the plots prior to fertilizing and planting the 1982 corn crop. Also listed below are tables showing the elemental concentration in the corn ear leaf at tasseling for selected treatments. Additional work on plant tissue analysis (ear leaf and silage) is being performed and the data will be made available at a later date.

INFLUENCE OF HYBRID, PLANT POPULATION, IRRIGATION AND MACRONUTRIENT FERTILIZATION ON DRY MATTER PRODUCTION (LB./A) OF FIELD CORN, ADELPHIA, N.J. 1982

Fertilization			Plant Part	Agway 849X				O's Gold SX5509			
Lb./Acre				32,670 ppa[1]		37,337 ppa		32,670 ppa		37,337 ppa	
N	P_2O_5	K_2O		N.I.[2]	I.[3]	N.I.	I.	N.I.	I.	N.I.	I.
300	175	175	Grain	8,773	11,300	8,660	12,497	8,584	13,122	8,669	13,557
			Stover	6,395	9,756	6,572	10,479	7,160	8,894	6,371	11,787
			Total	15,168	21,056	15,232	22,976	15,744	22,016	15,040	25,344
500	350	350	Grain	8,683	12,204	8,272	14,328	7,562	13,704	7,093	15,985
			Stover	8,853	8,020	6,256	10,248	10,166	8,376	10,827	12,559
			Total	17,536	20,224	14,528	24,576	17,728	22,080	17,920	28,544

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[1] ppa = plants per acre.
[2] N.I. = not irrigated.
[3] I. = irrigated.

SOIL TEST RESULTS, FERTILIZER AND WATER APPLIED AND CORN YIELDS FOR MAXIMUM YIELD CORN PLOTS, 1982.

pH	Soil Test Results[1]				Irrigation Water Inches[2]	Fertilization			Yield[3]	
	Lbs./Acre					Lbs./Acre			Grain	Silage
	P	K	Ca	Mg		N	P_2O_5	K_2O	Bu./A	T/A
6.1	163	393	1540	172	0	300	175	175	183	23.9
5.9	160	297	1403	169	12.25	300	175	175	267	35.7
6.0	184	443	1572	149	0	500	350	350	167	26.5
5.7	185	341	1243	154	12.25	500	350	350	297	37.3

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[1] Melich 1 soil extraction method used for P, K, Ca and Mg. Soil test results are for samples collected following 1981 soybean crop harvest and reflect previous fertilization and cropping.
[2] Plots received 14.2 inches of water from rainfall during growing season (May 1–Sept. 23).
[3] 1982 corn yields following 1981 soybean crop. Yields reported are averages for both

MACRONUTRIENT COMPOSITION OF CORN EAR LEAVES GROWN UNDER IRRIGATION, ADELPHIA, N.J., 1982.

Hybrid[1]	Plant Nutrients Applied			Elements in Ear Leaves[2]		
	Lbs./Acre			%		
	N	P_2O_5	K_2O	N	P	K
Agway	300	175	175	3.13	0.34	2.23
849X	500	350	350	3.24	0.37	2.20
O's Gold	300	175	175	3.34	0.31	2.20
SX5509	500	350	350	3.38	0.32	2.39

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[1] At 37,337 ppa.
[2] Sampled at early tasseling.

SECONDARY NUTRIENT COMPOSITION OF CORN EAR LEAVES GROWN UNDER IRRIGATION, ADELPHIA, N.J., 1982.

Hybrid[1]	Plant Nutrients Applied						Elements in Ear Leaves		
	Lbs./Acre						%		
	N	P_2O_5	K_2O	Ca	Mg[2]	S	Ca	Mg	S
Agway	300	175	175	594	230	106	0.43	0.13	0.18
849X	500	175	175	672[1]	255[2]	179[3]	0.45	0.13	0.17
O's Gold	300	175	175	594	230	106	0.56	0.17	0.25
SX5509	500	175	175	672	255	179	0.59	0.18	0.28

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[1] Calcium Sources and Supply: cow manure—201, limestone—341, superphosphate—130 = 672.

[2] Magnesium Sources and Supply: cow manure—38, limestone—192, magnesium sulfate—25 = 255.

[3] Sulfur Sources and Supply: cow manure—19, limestone—5, superphosphate—75, potassium sulfate—47, magnesium sulfate—33 =79.

MICRONUTRIENT COMPOSITION OF CORN EAR LEAVES IN HIGHEST YIELDING PLOTS, ADELPHIA, N.J., 1982.

Hybrid	Plant Nutrients Applied[1]				Elements in Ear Leaves			
	Lbs./Acre				ppm			
	Mn	Zn	Cu	B	Mn	Zn	Cu	B
Agway	26	12	5.2	2.1	36	29	9	32
O's Gold	26	12	5.2	2.1	41	28	10	21

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[1] Sources: Mn—25 lbs./A as manganese sulfate; Zn—10 lb./A as zinc sulfate; Cu—5 lbs./A as copper sulfate; B—2 lb./A one-half as Borate 40 and one-half as Solubor. Additional amounts listed in table were supplied in cow manure and superphosphate applications.

MACRONUTRIENT COMPOSITION OF CORN EAR LEAVES NEW JERSEY, 1982

Hybrid[1]	Yield Bu./Acre[2]	Plant Nutrients Applied			Elements in Ear Leaves[3]		
		Lb./Acre			%		
		N	P_2O_5	K_2O	N	P	K
O's Gold	338	500	350	350	3.38	0.32	2.39
Agway	303	500	350	350	3.24	0.37	2.20
O's Gold	287	300	175	175	3.34	0.31	2.20
Agway	264	300	175	175	3.13	0.34	2.23
Suggested Critical Levels					2.75	0.25	1.75

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[1] O's Gold SX5509; Agway 849X.

[2] At 37,337 ppa under irrigation.

[3] Sampled at early tasselng growth stage.

SECONDARY NUTRIENT COMPOSITION OF CORN EAR LEAVES NEW JERSEY, 1982

Hybrid[1]	Yield Bu./Acre[2]	Plant Nutrients Applied			Elements in Ear Leaves[3]		
		Lbs./Acre			%		
		N	P_2O_5	K_2O	Ca	Mg	S
O's Gold	338	500	350	350	0.59	0.18	0.28
Agway	303	500	350	350	0.45	0.12	0.17
O's Gold	287	300	175	175	0.56	0.17	0.25
Agway	264	300	175	175	0.43	0.12	0.18
Suggested Critical Levels					0.25	0.15	0.15

[1] O's Gold SX5509; Agway 849X.

[2] At 37,337 ppa under irrigation.

[3] Sampled at early tasseling growth stage.

INFLUENCE OF HYBRID, PLANT POPULATION AND MACRONUTRIENT FERTILIZATION ON WATER USE EFFICIENCY OF FIELD CORN, ADELPHIA, N.J., 1982.

Fertilization			Bushels Grain Produced Per Inch Water[1]							
Lb./Acre			Agway 849X				O's Gold SX5509			
N	P_2O_5	K_2O	32,670 paa		37,337 paa		32,670 paa		37,337 paa	
			N.I.	I.	N.I.	I.	N.I.	I.	N.I.	I.
300	175	175	13.1	9.0	12.9	10.0	12.8	10.5	12.9	10.8
500	350	350	12.9	9.8	12.3	11.4	11.3	10.9	10.6	12.8

[1] Nonirrigated corn received 14.2″ of water from rainfall. Irrigated corn received 14.2″ of water from rainfall plus 12.25″ of water from irrigation.

Part II. Maximum Yield Soybean Experiment in 1983 Soils and Crops Research Center, Rutgers University Adelphia, New Jersey

Experiment Conducted By: Roy L. Flannery, Specialist in Soils

Experimental Variables Employed:

Soybean Varieties (2): Asgrow A3127 and Sprite.

Plant Populations and Spacing (8): Two populations were used for each variety with and without irrigation.

Macronutrient Fertilization (4): Two fertilization rates were used with and without irrigation.

Micronutrient rates (2), Lb/A: None and B—1, Cu—5, Mn—25, and Zn—5. One-half of the B and all the Cu, Mn, and Zn were broadcast and disked in preplant. One-half of the B was applied thorugh the irrigation system at early flowering.

Irrigation Levels (2): None and 11.5 inches during the growing season. See Table 1.

Soils Information

Soil Type: Experiment was conducted on a well drained Freehold sandy loam soil containing approximately 70% sand, 23% silt, 7% clay, 1.30% organic matter and having a cation exchange capacity (CEC) of 8–9 meq./100 g.

Cultural Practices Employed:

Cropping History: Sweet corn 1978–79; Corn 1980 and 1982; Soybeans 1981–83.

Winter Cover Crops: Rye each fall following harvest of cultivated crop.

Tillage: Moldboard plowed and disked twice each year before planting either corn and soybeans. Experimental site was subsoiled 18″ deep at 30″ intervals in fall of 1980.

Crop Residue: Soybean vines or corn stover are returned to plots each year and disked in prior to seeding winter cover crops.

Liming: All plots are limed each spring to adjust soil pH to approximately 6.5.

Soybean Variety	Irrigated		Plant Spacing, Inches		Plant Population ppa
	No	Yes	Row Width	In Row	
Asgrow	X		6	8	130,680
A3127	X		6	6	174,240
		X	6	6	174,240
		X	6	4	261,360
Sprite	X		6	6	174,240
	X		6	4	261,360
		X	6	4	261,360
		X	6	3	348,480

TABLE 1.
RAINFALL, IRRIGATION AND HEAT UNITS FOR MAXIMUM YIELD SOYBEAN PLOTS, 1983

Month	Rainfall*	Irrigation	Total	Heat
		Inches		Units
May	5.44	0	5.44	327
June	4.21	1.0	5.21	497
July	2.11	5.0	7.11	697
August	5.02	3.5	8.52	662
September	3.12	2.0	5.12	511
Totals	19.90	11.5	31.40	2694

*Rainfall June 22–August 10 was only 3.45".

N	P_2O_5	K_2O	Source of Nutrients[1]	Method of Application[2]	Date of Application	Growth Stage of Soybeans
Lb/A						
			Nonirrigated—Low Fertilization			
25	50	75	AN-NS-KS	Br. & D.I.	5/10	Preplant
25	25	25	10-10-10	S.D.	6/10	Preplant
50	75	100				
			Nonirrigated—High Fertilization			
50	100	150	AN-NS-KS	Br. & D.I.	5/10	Preplant
50	50	50	10-10-10	T.D.	6/9	3 leaf
100	150	200				
			Irrigated—Low Fertilization			
25	50	100	AN-NS-KS	Br. & D.I.	5/10	Preplant
50	50	50	9-9-9	Fertigated	7/7	E. Bloom
50	50	50	9-9-9	Fertigated	7/26	E. Pod F.
125	150	200				
			Irrigated—High Fertilization			
25	75	150	AN-NS-KS	Br. & D.I.	5/10	Preplant
50	50	50	9-9-9	Fertigated	7/7	E. Bloom
50	50	50	9-9-9	Fertigated	7/26	E. Pod F.
50	50	50	9-9-9	Fertigated	8/20	Pods ½ F.
175	225	300				

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[1] AN = ammonium nitrate; NS = normal superphosphate; KS = potassium sulfate; 9-9-9 clear liquid.

[2] Br. = broadcast; P.D. = plow down; D.I. = disk in; T.D. = topdress; Fertigated = fertilizer applied through drip irrigation system.

SOIL TEST RESULTS FOLLOWING 1982 CORN CROP AND BEFORE FERTILIZING AND PLANTING 1983 SOYBEAN CROP

1982 Fertilization			Soil Test Results[1]					1983 Fertilization		
N	P_2O_5	K_2O	pH	P	K	Ca	Mg	N	P_2O_5	K_2O
	Lb/A				Lb/A				Lb/A	
300	175	175[2]	6.2	162	373	1622	234	50	75	100
300	175	175[3]	6.2	159	296	1573	233	125	150	200
500	350	350[2]	6.0	183	418	1756	209	100	150	200
500	350	350[3]	5.8	185	318	1354	223	175	225	300

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[1] Melich 1 extraction method used for P, K, Ca and Mg.

[2] Nonirrigated plots.

[3] Irrigated plots.

Weed Control: Three-way combination of Treflan (1 pt.), Vernam (3 pt.) and Sencor 6 oz. 4L per acre, preplant incorporated.

Planting: Seed was inoculated, treated with a Captan dust and ammonium molybdate (4 oz/bu). Seed was planted with a hand drill on May 12 in 6" rows. Plants were hand thinned to provide desired populations when 2 to 3" tall. Soil, at 2" depth, and air temperatures at planting time were 55 and 60° F, respectively. Soil moisture was at 68% of field capacity at 0–6" depth.

Insect Control: Furadan granules (925 lb/A) and Dyfonate granules (25 lb/A) were broadcast over the soil surface and preplant incorporated. Plants were sprayed twice with Sevin (1.2 lb/A) during August to control Japanese beetle and Mexican bean beetle.

Disease Control: Seed was treated with Captan and plants were sprayed twice with Benlate (½ lb/A of 50% WP) on August 18 and September 2.

Irrigation: Irrigated plots were watered with a low-pressure (5 lb. psi) trickle irrigation system, one double-wall drip irrigation tube for each pair of rows. Plots were watered to maintain soil moisture between 60 and 100% of field capacity from emergence to flowering and between 80–100% of field capacity in top 8 inches of soil from early flowering through pod filling.

Harvesting: The two center rows of 6 row plots, after removing 1 foot from each end of plot, were hand harvested and thrashed through a portable field plot thrasher on October 17.

Experimental Results:

Grain yields for each combination of sixty-four management variables employed in the experiment, are reported in Tables 2 and 3. All yields reported are averages for four replicated plots. Yields ranged from 54 to 118 bu/acre. The lowest yield recorded was for the Sprite variety grown at 174,240 plants per acre without irrigation and with the lower macronutrient and higher micronutrient fertilization rates. The highest yield was recorded with the Asgrow variety grown at 261,360 plants per acre with 11.5 inches of supplemental irrigation water and with the higher macronutrient and higher micronutrient fertilization rates.

The Asgrow variety yielded approximately 4 bu/acre more beans than the Sprite variety without irrigation and approximately 8 bu/acre more with irrigation. The average yield of the Sprite variety without and with irrigation was 60.8 and 103.9 bu/acre, respectively. The average yield of Asgrow variety without and with irrigation was 65.1 and 111.8 bu/acre, respectively.

The Sprite variety produced the highest yields at the higher plant populations with and without irrigation. The Asgrow variety produced higher yields at the lower plant population without irrigation, but the reverse was true with irrigation—the higher plant population produced the higher yield.

Fertilization rates had little or no influence on yield of the Sprite variety without irrigation. However, a yield response was obtained with the higher fertilization rate with irrigation. The Asgrow variety gave a positive yield response to increased fertilization only under irrigation.

Of all the management variables employed in this experiment, irrigation had the greatest influence on yields. Yields were increased by 43 and 47 bushels per acre with the Sprite and Asgrow varieties, respectively, with irrigation.

Micronutrient fertilization increased yields of the Sprite variety only under irrigation. Micronutrient fertilization increased the yield of the Asgrow variety with and without irrigation. The magnitude of the yield response with both varieties under irrigation was 5 to 6 bushels per acre.

Highest yields obtained in these maximum yield soybean experiments over the years have been 59, 61, 71, and 76 bushels per acre during 1980, 1981, 1982 and 1983, respectively, for nonirrigated plots. Top yields of 94, 93, 109, and 118 bushels per acre were obtained in irrigated plots over the same four years. Top yields on the nonirrigated plots have averaged 67 bushels per acre and top yields on the irrigated plots have averaged 104 bushels per acre over the first four years of the experiment. See Figure 1.

Figure 1.

HIGHEST YIELDS OBTAINED IN MAXIMUM YIELD SOYBEAN EXPERIMENTS, N.J., 1980–1983

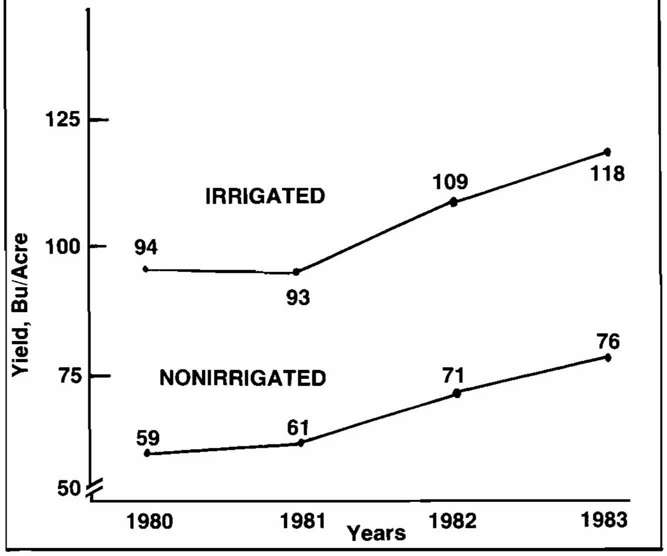


TABLE 1.
INFLUENCE OF FERTILIZATION, IRRIGATION AND PLANT POPULATIONS ON SOYBEAN YIELDS NEW JERSEY, 1983

Nutrients Applied			Yield, Bu/A, Asgrow A3127 Variety[1]			
N	P_2O_5	K_2O	Nonirrigated		Irrigated	
	Lb/A		130,680 ppa	174,240 ppa	174,240 ppa	261,360 ppa
50	75	100[2]	71.3	58.9	—	—
50	75	100[3]	76.2	60.1	—	—
100	150	200[2]	62.2	56.6	—	—
100	150	200[3]	74.3	60.8	—	—
125	150	200[2]	—	—	105.8	109.7
125	150	200[3]	—	—	110.2	113.8
175	225	300[2]	—	—	108.9	113.1
175	225	300[3]	—	—	114.8	118.4

---

[1] Yield standardized to 13% moisture.
[2] No micronutrients applied.
[3] Micronutrients applied, lb./A: B—1, Cu—5, Mn—25, and Zn—5.

TABLE 2.
INFLUENCE OF FERTILIZATION, IRRIGATION AND PLANT POPULATIONS ON SOYBEAN YIELDS NEW JERSEY, 1983

Nutrients Applied			Yield, Bu/A, Sprite Variety[1]			
N	P_2O_5	K_2O	Nonirrigated		Irrigated	
	Lb/A		174,240 ppa	261,360 ppa	261,360 ppa	348,480 ppa
50	75	100[2]	58.8	65.6	—	—
50	75	100[3]	54.4	63.6	—	—
100	150	200[2]	56.8	66.7	—	—
100	150	200[3]	55.2	65.4	—	—
125	150	200[2]	—	—	92.7	96.1
125	150	200[3]	—	—	103.6	107.5
175	225	300[2]	—	—	104.8	108.7
175	225	300[3]	—	—	107.4	110.3

---

[1] Yields standardized to 13% moisture.
[2] No micronutrients applied.
[3] Micronutrients applied, lb/A: B—1, Cu—5, Mn—25, and Zn—5.

Retail Fertilizer Marketing in the U.S.

Part I: David D. Hazen
Hazen Supply Corporation

Part II: Felton Coggins
Coggins Farm Supply

Part I.

Hazen Supply Corporation was created in 1956 (by a farmer named Dale Hazen) to offer products and services to local farmers because such products and services were not available.

Hazen Supply Corporation offers products and services such as:

1. An ACE HARDWARE franchise.
2. A large clothing line featuring brands such as Lee, Big Smith, Key, DuxbaK, Pioneer Wear, Justin, Texas County, Northern, LaCrosse, and Wolverine.
3. Shortline equipment from manufacturers such as Brady, Bush Hog, Parker, Brent, DMI, Mayrath, Feterl, Klein, Melroe Bobcat,Woods, Soilmover, Buckley & Busch, etc.

4. Grain storage and drying.

5. A fleet of trucks for hauling our customers products.

6. A line of Lawn and Garden equipment featuring Lawnboy, Dixon, Snapper, Bolen, and Homelite.

7. A service shop to repair our customers equipment and also our own.

8. Corn and Soybean seed from McCubbin, Riverside, Asgrow, Dekalb-Pfizer and PAG.

9. A complete line of feed from Ralston Purina.

10. A large warehouse for packaged chemicals and 22,000 gallons of bulk chemical storage to supply Ag Chemicals for sale to a majority of the farmers in Southeast Iowa.

11. A full service fertilizer department.

Hazen Supply Corporation currently has 15 full time employees and hires up to an additional 5 for part time work during Spring and Fall work.

Hazen Farms Corporation, which is a sister to Hazen Supply Corporation, farms approximately 1000 acres, where new products, equipment, and services are tested before they are offered to our customers.

Hazen Supply Corporation is located 20 miles West of the Mississippi River in southeast Iowa.

HAZEN SUPPLY CORPORATION FERTILIZER DEPARTMENT

Established 1960
Department Manager: David Hazen
Plant Manager: Allen Clark
Custom Applicators: Mike Oberman, Craig Jones, Floyd Conners
7000 Ton plus of fertilizer sold for the 1984 growing season

Storage Capacity:

2750 Ton of Dry Fertilizer
325 Ton of Liquid fertilizer
125 Ton of NH3

Fertilizer Equipment:

1-Full Flotation Dry and Liquid Applicator
1-Semi Flotation Dry Applicator
2-6 Ton Fertilizer Buggies
1-Dry Tender Truck
2-Dry Pull Type Tenders
2-DMI DRY FLOW Applicators
9-NH3 Preplant Applicators (9 thru 17 knife)
4-NH3 Sidedress Applicators
23-1000 gal. NH3 Nurse Tanks
4-1850 gal. NH3 Nurse Tanks
1-NH3 Semi Trailer
2-28% Sidedress Applicators
1-Liquid Nurse Truck
2-Liquid Nurse Trailors
1-Liquid Semi Trailor

Services Available:

Custom dry spreading of fertilizer
    (Small seeds mixed with fertilizer)
    (Fertilizer impregnate with chemicals)
Dry Delivery
Custom dry fertilizer injection with DRYFLOW
Custom spraying {Spring and Summer only}
    (Liquid fertilizer)
    (Chemicals)
    (Or both of above)
Custom Dry Blending
Soil Testing
Field Scouting

Products Available:

GRACE
5-30-35, 4-10-40, 7-28-28, 8-32-14-4-2
ORTHO
21-7-14
NH3
34-0-0
46-0-0
21-0-0-24S
28%
32%
18-46-0
0-0-60
0-0-50-18S
Zinc
Sulfur

EXAMPLE OF CROP REMOVAL

Farmer Jones wants to raise 160 bu. corn & 50 bu. soybeans (160 bu. corn and 50 bu. soybeans to 180 bu. corn and 60 bu. soybeans are profitable yields for our area.)

He has soil tests taken which show his phosphate in the medium to high range and potassium in the low to medium range. (This is typical for P & K levels in southeast Iowa.)

He knows that 160 bu. corn will remove 60# of P and 48# of K. He also knows that 50 bu. soybeans will remove 40# of P and 75# of K. Total food removal of these two crops is 100# of P and 123# of K.

Farmer Jones now knows:

1. That his phosphate is ok and all he has to apply is a maintenance level.

2. That he should apply extra K to the maintenance level.

3. What the total plant food removal will be.

Farmer Jones figures that he should apply 100# of P and 175# of K.

This corresponds with what his fertilizer dealer recommended.

NPK CROP REQUIREMENTS

	Yield			N	P	K
Corn	140 BU	Grain		120	52	42
		Stover		77	28	154
			Total	199	80	196
Corn	160 BU	Grain		136	60	48
		Stover		88	32	176
			Total	224	92	224
Corn	180 BU	Grain		153	68	54
		Stover		99	36	198
			Total	252	104	252
Corn	200 BU	Grain		170	75	60
		Stover		110	40	220
			Total	280	115	280
Soybeans	40 BU	Grain		160	32	60
		Stover		56	12	40
			Total	216	44	100
Soybeans	50 BU	Grain		200	40	75
		Stover		70	15	50
			Total	270	55	125
Soybeans	60 BU	Grain		240	48	90
		Stover		84	18	60
			Total	324	66	150
Soybeans	70 BU	Grain		280	56	105
		Stover		98	21	70
			Total	378	77	175

Farmer Jones only applies 60# of P and 100# of K because this is all he says he can afford. He cannot understand 2 years later when he only gets 35 bu. of soybeans after getting his 160 bu. of corn the year before.

What he did not remember was that he should have applied 100# of P and 175# of K and he only applied 60# of P and 100# of K. He was able to raise 160 bu. corn because the corn only removed 60# of P and 48# of K but this only left 0# of P and 52# of K for the soybeans. To raise 60 bu. of soybeans he needed 40# of P and 75# of K. When he did raise 35 bu. of beans he was mining the soil of 40# of P and 23# of K.

If he had only spent an additional $20 per acre he could have had an additional 15 bu. per acre or $100 profit.

REMOVAL OF PLANT FOOD

By a Corn/Soybean 2 year rotation

Corn	140 Bu		52	42
Soybeans	40 Bu		32	60
		Total	84	102
Corn	160 Bu		60	48
Soybeans	50 Bu		40	75
		Total	100	123
Corn	180 Bu		68	54
Soybeans	60 Bu		48	90
		Total	116	144
Corn	200 Bu		75	60
Soybeans	70 Bu		56	105
		Total	131	165

By a Corn/Corn/Soybean 3 year rotation

Corn	140 Bu		52	42
Corn	140 Bu		52	42
Soybeans	40 Bu		32	60
		Total	136	144
Corn	160 Bu		60	48
Corn	160 Bu		60	48
Soybeans	50 Bu		40	75
		Total	160	171
Corn	180 Bu		68	54
Corn	180 Bu		68	54
Soybeans	60 Bu		48	90
		Total	184	198
Corn	200 Bu		75	60
Corn	200 Bu		75	60
Soybeans	70 Bu		56	105
		Total	206	225

WHY FALL FERTILIZE

1. Fall fertilizer will cost less than or no more than spring fertilizer even after interest is added to the fall price.
2. By applying your fertilizer in the fall you save valuable spring time for planting. (Spring of 1984 is an excellent example)
3. By applying fertilizer in the fall you can greatly reduce soil compaction.
4. Fall application of fertilizer is easier than spring application due to better availability of equipment.
5. Fall application can help at income tax time.
6. Fall P&K fertilizer can now be applied on no-till or fields subject to eroison without loss of fertilizer with the DMI dryflow. (Potash is not recommended in the fall on sandy soils.)

7. Fall nitrogen can be applied with N-serve on most soils without loss when soil temperature reaches 60 degrees instead of waiting for 50 degrees and the bad weather that normally comes at the same time.

8. Eliminate some of your hard to control weeds (cocklebur, jimsonweed, annual morning glory, and velvetleaf) by impregnating your dry fertilizer going on corn ground with high rates of atrazine (rate depends on soil type and organic matter) without loss of yield in the following soybean crop.

9. If you do fall fertilize, do it early in September and October as soon as you take your crop instead of waiting and getting caught by bad weather which is sure to come.

NH3 PRICE HISTORY 1978–1984
PREPARED BY HAZEN SUPPLY CORPORATION
FALL 1984

Fall 1978 $148—Spring 1979 $160 $12 or 8% increase
200# Actual N Fall Cost $18.05
200# Actual N Spring Cost $19.51
Fall 1979 $177—Spring 1980 $230 $53 or 30% increase
200# Actual N Fall Cost $21.58
200# Actual N Spring Cost $28.05
Fall 1980 $202—Spring 1981 $230 $28 or 14% increase
200# Actual N Fall Cost $24.63
200# Actual N Spring Cost $28.05
Fall 1981 $200—Spring 1982 $220 $20 or 10% increase
200# Actual N Fall Cost $24.39
200# Actual N Spring Cost $26.83
Fall 1982 $185—Spring 1983 $210 $25 or 14% increase
200# Actual N Fall Cost $22.56
200# Actual N Sprng Cost $25.61
Fall 1983 $190—Spring 1984 $265 $75 or 40% increase
200# Actual N Fall Cost $23.17
200# Actual N Spring Cost $32.32

Average price increase per ton fall versus spring ((19%))

Average fall price per ton $183.66
Average spring price per ton $219.16
Average price increase per ton fall versus spring (($35.50))

Average fall price per acre $22.40
Average spring price per acre $26.73
Average price increase per acre fall versus spring (($4.33))

N-serve cost 1978 thru 1982 $5.00 per acre
N-serve cost 1983 $5.50 per acre
Average cost per acre 1978 thru 1983 $5.08

Loss in yield due to spring compaction at least 1 bu or $3.00

Loss in yield due to delayed planting at least 1 bu or $3.00

Interest rate as of 1-1-79 10%
Interest rate as of 1-1-80 15%
Interest rate as of 1-1-81 17%
Interest rate as of 1-1-82 17%
Interest rate as of 1-1-83 15%
Interest rate as of 1-1-84 14.5%
(Iowa National Bank furnished the above information)

Average interest rate of the above dates ((14.58%))

Fall NH3 cost per acre	$22.40	Spring NH3 cost per acre	$26.73
N-Serve	5.08	Compaction	3.0
Interest. (5 months)	1.67	Delayed planting	0
Fall total	$29.15	Spring total	$32.73

Fall application on NH3 can save you 12% or $3.58 per acre

DRY FERTILIZER PRICE HISTORY 1978–1984
PREPARED BY HAZEN SUPPLY CORPORATION

5-20-35
Fall 1979 $198—Spring 1980 $210 $12 or 6% increase
Fall 1980 $190—Spring 1981 $210 $20 or 11% increase
Fall 1981 $200—Spring 1982 $214 $14 or 7% increase
Fall 1982 $185—Spring 1983 $186 $ 1 or 1% increase
Fall 1983 $170—Spring 1984 $210 $40 or 24% increase

Average fall price $188.60
Average spring price $206.00
Average price increase fall versus spring 9.23%

21-7-14
Fall 1978 $146—Spring 1979 $148 $2 or 1% increase
Fall 1979 $165—Spring 1980 $190 $25 or 15% increase
Fall 1980 $180—Spring 1981 $190 $10 or 6% increase
Fall 1981 $200—Spring 1982 $200 $0 or 0% increase
Fall 1982 $172—Spring 1983 $177 $5 or 3% increase
Fall 1983 $158—Spring 1984 $200 $42 or 27% increase

Average fall price $170.17
Average spring price $184.17
Average price increase fall versus spring 8.23%

18-46-0
Fall 1980 $270—Spring 1981 $275 $5 or 2% increase
Fall 1981 $216—Spring 1982 $235 $53 or 9% increase
Fall 1982 $220—Spring 1983 $230 $10 or 5% increase
Fall 1983 $215—Spring 1984 $255 $40 or 19% increase

Average fall price $230.25
Average spring price $248.75
Average price increase fall versus spring 8.03%

0-0-60
Fall 1980 $140—Spring 1981 $155 $15 or 11% increase
Fall 1981 $153—Spring 1982 $151 $ − 2 or − 1% increase
Fall 1982 $140—Spring 1983 $140 $0 or 0% increase
Fall 1983 $125—Spring 1984 $150 $25 or 20% increase

Average fall price $139.50
Average spring price $149.00
Average price increase fall versus spring 6.8%

INJECTING OF DRY FERTILIZER USING THE DMI DRIFLO 2200

Save soil on soybean stubble ground by having fertilizer injected into the soil instead of working it in with a disc.

Save time by applying your NPK in one trip in the fall.

Save money by using NH3 and dry fertilizer.

Less compaction because of fewer trips over the field.

The DMI Driflo places fertilizer in 30 inch bands 6–9 inches deep.

Ground driven for accuracy.

+ or − 1% accuracy with stainless steel metering auger.

Use of coulters allows application on bean stubble, corn stubble, and alfalfa and pasture.

Part II:

Coggins Farm Supply is located near Lake Park, Georgia in Echols County. This is in the south central part of the state about 5 miles from the Florida line. We have a lot of hot weather in summer and an average annual rainfall of about 50 inches per year. The problem is that our rains are very erratic and usually deficient during the summer months.

The agriculture in our area is primarily row crops with the number one cash crop being flue cured tobacco with an average yield of 2500 pounds per acre. Cotton is increasing in acreage each year with the average yield being around 900 pounds of lint cotton per acre. Soybeans and corn are also grown in large acreages. Our geographical area is located below the fall line. Consequently, our soils are very sandy. The cation exchange capacity is between 3 and 5; therefore, our soil can't store a lot of nutrients. We have to fertilize each year. Our application rates vary from 500 pounds on soybeans to 2000 pounds on tobacco. The soil is low in sulfur, magnesium and minor elements. The extension service in the state of Georgia recognizes these problems and makes additional secondary and micro-nutrient recommendations for south Georgia crops.

After college, I managed a local farm supply store in Valdosta for several years. After 5 years at this job, I went back to my farming operation full time. Soon afterward, I began selling and custom-applying nitrogen for farmers in my area. In 1973, Coggins Farm Suppy became a reality. We now carry a full line of farm supplies such as feed, seed, chemicals, fertilizer, etc.

We also offer aerial application of chemicals.

Early in my business life, I made a decision to stress quality, service and dependability.

I have always tried to employ quality people to assist me in maintaining this business philosophy.

When I selected a fertilizer supplier, I choose IMC because of my previous association with them when I managed a farm supply store in Valdosta.

It was because of IMC's reputation for quality products and good service that I chose them as my fertilizer supplier.

At the time that I entered the farm supply business, my funds were very limited, so I chose the type of fertilizer that required the least capital investment. This was a homogeneous granular fertilizer.

Since the early years of my business, my primary marketing thrust has been to educate customers and potential customers in my area in the proper use of agronomic information in farming.

We hold 7 or 8 farmer meetings annually on various agricultural topics. At these meetings, most major chemical and seed companies are represented and they present information on application and use of their products. We hold at least one farmer meeting on crop fertilization each year.

Over the years, we have taken our customers and ourselves to Abraham Baldwin Agricultural College at Tifton, GA., which is about 60 miles away, to attend adult short courses on various agricultural topics.

This college ranks as one of the top colleges in adult education in the United States. We try to make good use of their efforts.

To better serve our customers, we installed a pH meter in our store for quick pH's for our customers.

We take soil samples for our customers each year, using local, IMC or state labs, depending upon the type of test and time desired.

We take approximately one thousand soil samples per year for customers and potential customers.

I take the results of these tests and sit down with the farmer and go over them with him.

Then, I make recommendations for each field.

We keep copies of these tests in our files as a reference. We employ extra people in the fall to help with the job of taking soil samples.

This is a big part of our customer addition and retention program.

We also do tissue testing and petiole analysis for our customers.

I make a lot of individual sales calls on farmers and I consider this to be another important marketing or selling aspect of our program. Back in the 70's, we ran a lot of test plots on customers' farms on various crops. But, today, the average farmer does not seem to have time to do this type testing.

We continue to test plots on our own farm and use them as a selling tool.

Also, a lot of testing is done at the Sunbelt Exposition at Moultrie, Ga. each year. Most farmers in my area visit these test plots during the year.

We buy some grain and have a partnership in a cotton gin. Farm credit is a treacherous item; but, with tobacco and some other specialty crops, we feel fairly positive about these farmers' futures.

We offer the full complement of agricultural products and services to the farmers in our area and it has definitely worked for us over the past years.

Over the years, I have attended many seminars provided by my supplier on credit, agronomy and marketing. Based on information from these and other seminars, I have stayed with my original decision on the type of fertilizer handled by Coggins Farm Supply and used on my own farm.

I have expanded my farm service operation to the point that we are now selling 6300 tons of premium granular fertilizer each year plus 4000 tons of nitrogen.

Also, we opened a new farm supply in Valdosta last year which moved about 1000 tons of premium fertilizer.

We expect to double this tonnage in 1985.

During the past few years, there has been an expansion of liquid or suspension dealers in South Georgia. This has been mainly due to improvements in technology concerning liquid fertilizers—mainly the use of high sheer mixers which allows the use of dry materials.

Also, because of increased costs, environmental controls, energy and reduced production, we have seen companies with granulation plants in our state, as well as in other states, make a decision to close their units.

In fact, nationwide from 1967 to 1983, the number of granulation units decreased from 250 to 84.

In the southeast, the number decreased during 1975 through 1983 from 62 to 45.

With these closings, plus low material prices, low commodity prices and the higher U.S. dollar, we have seen a lot of individually owned blender operations spring up in my general trade area and throughout the southeast. With low material prices, they are certainly tough competition on a basic N-P-K fertilizer.

However, I am premium minded and basically do not sell an N-P-K fertilizer but sell a premium homogeneous crop branded fertilizer. As I mentioned earlier, the soil in our area came from a basically infertile parent material. It will not store a high level of nutrients. Most of the fertilizers we sell is spread by truck or by our terragator. This fertilizer moves quickly through the soil.

It can't be applied in the fall because of our low cation exchange capacity soil. Therefore, logistics wise, it is much easier for me to use a manufactured homogeneous granular product because these grades are made and stored at my supplier's plant at Tifton, Ga. which is about 60 miles away from me.

I can supply myself with these grades as I need them or I can store them in my warehouse and they will remain in good condition. I don't have to worry about making each ton as the customer needs it.

Also, I can send my customers, who have their own trucks, to Tifton to pick up their own fertilizer. This saves handling and shrinkage costs.

In my selling, I have researched the advantages and disadvantages of dry blends and liquid blends in detail as a defense mechanism.

Because of the low cation exchange capacity of our soil, we can't build soil reserve fertility.

We have to supply crops with not only N-P-K but with calcium magnesium, sulfur, boron, zinc and other micro nutrients needed.

Our experience has proven that the plant gets a more complete feeding from granular fertilizer.

Based on 80 million granules per ton, we get 400 to 700 granules per square foot, depending upon the rate per acre.

Each of these granules contains all of the nutrients needed by the crop. Comparing this to the dry blender who has to blend each ingredient, including minor elements in small amounts, it is an almost impossible job for him to match the distribution of a granular product.

I know that in the state of Georgia last year, 51% of the samples pulled on dry blends were found to be deficient and on liquid blends, 31% were found to be deficient.

My supplier had the lowest number of penalties in the state with less than 7% of their samples being deficient. This is a fact that I can be proud of when I talk with my customers and try to sell the advantages of premium homogeneous granular fertilizer. I know that dry blends have a separation problem and I use this to my advantage in selling.

I feel I have an economic advantage in staying with a homogeneous premium granular fertilizer that is made with normal super phosphate. There may be times when I would make a little more money with a blend product, but year in and year out, I feel I will get a greater return on my investment from a premium granular fertilizer.

My fertilizer business has a lower overhead because I did not have to buy a blender, install a lot of unloading equipment or buy a sheer mixer. I can use less specialized labor because I don't have to formulate the various mixtures. Last year, the average blender in Georgia (liquid and dry) averaged selling 1500 tons per installation. Certainly, I can be more certain of the quality control I get in a granular product where a granular plant is making 180,000 tons per year compared to a blender making only 1500 tons per year. Each morning when I start my fertilizer day, I don't have to worry if the blender or mixer is going to operate properly. And, I don't have to guarantee analysis of my granular fertilizer. This is done by my supplier.

To summarize, I feel that a homogeneous granular product, in my area, will continue to be the correct route for me and my customers to take because we are in an inherently poor soil area. We have to continue to add the secondary and micro nutrients. We have to fertilize every year right before each crop.

Secondary and micro nutrients are recommended by the extension service.

So, until some revolutionary technology is developed for blends, we will continue to have a definite agronomic advantage on them in our area.

I feel that, in the future, for a farm supply to be successful, it must be an integrated operation which is basically tied to service. To maintain and increase my business, I feel I must continue to offer services that are needed by my customers and these will vary as time changes.

I will have to be forward minded enough to know of these changes ahead of time and be ready, willing and able to supply the help needed.

Experience With the Use of Big-Bags (FIBC) in Scandinavia

Odd Grønlie
Director, Raw Materials & Distribution,
Agricultural Division
Norsk Hydro a.s, (Norway)

As the main supplier of fertilizer to the Scandinavian market, Norsk Hydro a.s can today offer the farmers the choice between 50 kg bags shrink-wrapped on pallets, fertilizer in bulk or in one-way big-bags * (FIBC) in 500 kg to 1,000 kg sizes.

The development of the FIBC started in our company in 1971 when increased use of helicopters in forest-fertilization and the availability of cheap woven polypropylene gave us the idea to construct one of the first workable FIBC's in the world.

Although the costs of the bag and the handling of it was relatively expensive in the beginning, it could compete with other methods in the forest as the time for loading the costly helicopter was cut down considerably.

Later on we developed the FIBC further and it was then used for handling of calcium chloride which is known for its use as a dust-binding chemical on road surfaces.

The old well-known *reusable* big-bag could not any longer compete due to the purchasing price and due to the costs adhered to return and inspection.

Later we started to introduce the FIBC on the fertilizer market in Sweden, which, for several reasons, had been slow to change towards bulk distribution of fertilizer, and up until then preferred the 50 kg bag on pallets.

Today the FIBC is fairly popular and in use in several of our markets.

In 1984, the FIBC account for the following percentages of the fertilizer distribution of Norsk Hydro products:

TABLE A

Methods	Market			
	Norway	Denmark	Sweden	U.K.
FIBC (Portabulk)	8 %	0 %	25 %	15 %
50 kg bag	91 %	35 %	45 %	80 %
Bulk to farmers	1 %	65 %	30 %	5 %

(The main explanation for the zero percentage of FIBC in Denmark is that a highly developed bulk system existed *before* the introduction of the FIBC.

---

*FIBC = Flexible Intermediate Bulk Container.

The Danish farmer uses only a few different fertilizer grades and is mainly used to buying fertilizer in the spring time from storages near to his farm).

Altogether, Norsk Hydro a.s marketed, directly or through licenses/agents, a total of 2 million FIBC's (trade name "Portabulk") in 1984, mainly for fertilizers and in Europe. Only two years ago the quantity was 800,000 bags per year. With an average size of about 750 kg/bag, the total quantity of different commodities handled in FIBC is already significant.

In the first step of the development process, we mostly had the bag itself in mind and we constructed it to be handled by already existing equipment on the farm. Later on we improved the filling equipment and then the handling equipment at the factory/dealer before ending up on the farm again. Today the FIBC come along as part of a whole system from the filling station to the farmer's field.

Let us then look into why the FIBC-system in a few years' time has become rather popular and why it will continue to increase in use.

First of all the cost of delivering the fertilizer in FIBC is now on the same level as for other methods.

Today we prefer to fill the FIBC on the marketplace near to the farmer, utilizing already existing bulk storages by increasing throughput and obtaining low bulk freights from the factory to the bulk storage. The cost of fertilizers in FIBC will then be lower than 50 kg bags on pallets, and will also give other advantages to the farmers.

—High productivity, capacity, and saving of manual labour as like handling bulk fertilizer. (Table B).

—Avoidance of costly bulk storages and cleaning up operations usually connected with bulk handling. The farmer still can buy the fertilizer cheap in the autumn and by simple precautions keep the good quality until spreading season.

—The fertilizer in FIBC can, like the 50 kg bag on pallet, be stored through the winter out on the field ready to be spread.

TABLE B
TIME WORKED ON FARM
Minutes per tonne of fertilizer

	Pallets stored on field	FIBCs stored on field	Bulk delivered by lorry to field
Unloading	5	5	3
Filling of spreader	19	5	3
Spreading	22	22	22
Cleaning, etc.	10	7	4
	56	39	32

Also the fertilizer producer and dealer can see their own advantages besides giving a better service to the farmer: Fertilizer can continue to be distributed, bagged and stored on the market place in the off-season without constructing costly bulk storages with low throughput. Presenting the fertilizer to the farmer in FIBC's might also be better than gradually having to "give in" to demands for even smaller bags (35–40 kg) and on smaller pallets.

What will then in the end decide the percentage a new distribution method like the FIBC will cover of the whole market?

Here, of course, the policy pushed by the producer and by the dealer is of great importance.

Normally, costs are of great importance and we cannot only rely on average cost figures but have to more carefully study the actual case before choosing method. Local conditions can make the costs differ a lot from the average.

Table C shows some interesting parameters for four of our main markets in Europe.

TABLE C
FARM STRUCTURE

	Norway	Sweden	Denmark	U.K.
Population, millions	4	8	5	56
Total area of country				
1,000 sq. kilometres	324	487	43	244
No. of farms, 1000	95	120	120	240
Fertilizer consumption				
Mill. of tonnes/year	.5	1.5	1.5	5
Tonnes/farm	6	12	12	26
Tonnes/hectare	.6	.5	.5	.5
Average size of farms				
Hectares	10	25	24	51
Fertilizer handling				
Average man-hours per				
farm and year	5–10	10–20	10–20	25–35
(tonnes of solid materials)				

As you see, Denmark, in general, represents bigger farms than Norway where the farms also are scattered over a much bigger area and with a more complex distribution system.

Sweden is something in "between."

Besides more favourable conditions in Denmark for bulk distribution, the fertilizer producers and dealers have also heavily promoted bulk distribution in Denmark in order to stand up against competition from other mechanised systems (Liquid NH_3 + NPK) at a time when the FIBC did not exist.

The Norwegian and Swedish farmers have for many years been equipped with universal lifting devices on tractors and were already then "prepared" for the FIBC. They were also to a great extent motivated to buy and store much of their fertilizer from early autumn.

In these two countries we now have a strong development towards the FIBC.

In all three Scandinavian countries, part time farming is rather common and then the need for mechanised handling has increased.

The UK market should be ideally suited for a big percentage of bulk distribution, but are for the time being moving rapidly towards the use of the FIBC.

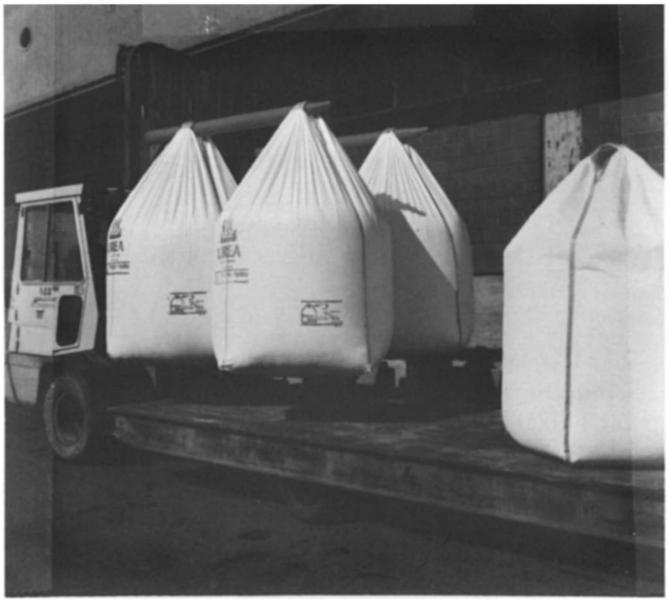
Reasons for this are that the producers lack the necessary storages for a shift towards bulk and the UK-market is known for its enormous number of different grades and qualities which hamper bulk-distribution. From time back the whole distribution chain has also been used to store much fertilizer near the farms long before the season starts.

Maybe the English also in this field are a little bit conservative?

We will then run quickly through the handling of FIBC's in different stages of the distribution chain.

Handling of "Portabulk" in the different stages is today characterized by:

1. Filling-station where two men and one fork-lift driver can fill and store away two bags per minute or about 100 MT per hour. A complete high-capacity filling-station will normally cost between US$35,000–US$75,000 which can justify installments also in small bulk storages near the farmer.
2. Fertilizer can be stored at the factory, at the dealer or on the farm under severe weather conditions.
3. Filled FIBC's are transported from the filling-station and on the dealer's premises 2 × 1 (or even 4 × 1) at a time using normal forklift trucks with a special attachment. (See picture below).



4. Filled FIBC's are normally transported to the farm using lorries equipped with a crane.
5. A variety of lifting devices are being used on the farm.

   In most cases the Scandinavian farmer will use his tractor equipped with a front loader to fill the spreader.

   Special equipment as a crane mounted on the fertilizer spreader makes the filling easy.
6. The emptying of the FIBC is being done by simply cutting a hole in the bottom or on the side of the FIBC. By using a sheet of metal or plastic, the flow of fertilizer can easily be regulated or stopped.

The intention with presenting the first section is to demonstrate how the FIBC now has been developed into an economical and fully usable distribution method for fertilizer.

The FIBC and the handling equipment will continue to be improved and the system will without doubt increase in use as a method for small and medium-sized farmers or for bigger farmers using several fertilizer grades.

Development of the Portabulk FIBC System for Cost-Effective Fertilizer Handling

Erik Myklebust
Manager, Packaging Dept.
Agricultural Division
Norsk Hydro a.s, (Norway)

1. GOAL

The Portabulk FIBC system was developed emphasizing that, to justify the introduction of a new transport system, it would have to:

- Meet a demand in the market.
- Be competitive in price, packing, handling, transport and discharge.
- Protect the product all the way to the end-user.
- Be compatible to commercially used handling equipment.

Ideas which did not comply with these requirements were rejected and explains why we went our own way in developing an FIBC system.

2. TECHNICAL DESCRIPTION

All the various types of Portabulk container available today are designed on the *same basic principle*, which is that *all its vertical fibres pass through the single lifting point*. This provides maximum strength with any weave quality and eliminates the need for additional lifting loops since the loop on the Portabulk container is integral to it.

The outer loadbearing bag is made of Polypropylene fabric, circular or flaw woven. It is fitted with a liner of the PE film to protect the contents from external contamination, e.g. rain, dust etc.

Norsk Hydro has always been a major user of its semi-bulk transportation system. This first hand knowledge of its performance has enabled us to stay ahead of the field in the continuous process of refining and further develop the bag and equipment associated with FIBC handling of fertilizer.

3. TEST OF THE FIBC

When Norsk Hydro started its development on FIBC, national and international performance requirements and corresponding test equipment were nonexistent.

To determine the container performance was essential and Norsk Hydro constructed an A-frame test rig for static top lift testing of filled FIBCs.

As the importance of the dynamic properties of the containers was disclosed, the test rig was modified also to test the dynamic performance under shock load conditions.

The lack of national and international rules in 1971 to determine FIBC strength performance made Norsk Hydro decide on a safety factor of 5:1. This requirement is today recognized world wide for standard duty single-trip FIBCs.

Norsk Hydro also initiated a research program carried out by the Swedish Packforsk Institute which confirmed the necessity to monitor the elastic properties of FIBCs.

4. UV-STABILIZATION

Polypropylene will be degraded when exposed to sunlight. Degradation leads to a loss of tensile strength.

To reduce the degradation of Polypropylene fabrics, UV-stabilizers are added to the propylene.

5. RULES AND REGULATIONS CERTIFICATES

The lack of national and international rules and regulations did not in any way impede the introduction of FIBCs. The high performance requirements and stringent codes of practice set by the industry were recognized and acknowledged by national authorities throughout Europe.

The first general regulations to be issued by a national authority were issued by the Dutch and Belgian Harbour Authorities. These regulations, valid for the port of Amsterdam, Rotterdam and Antwerp, appeared in 1979.

The British Standard no. 6382 was approved in 1983.

The first "international" standard to appear is the set of standards issued by the European Flexible Intermediate Bulk Container Association in 1984.

A typical additional requirement is that each individual FIBC shall be durably marked with the following data:

- Name and address of manufacturer/supplier.
- Safe working load (SWL).
- Safety factor (SF).
- Instructions on the methods of correct handling.
- Certificate no. and testing institution identification.

6. AUXILIARY EQUIPMENT

Parts of the Norsk Hydro development strategy for the Portabulk semibulk system called for:

- Competitiveness in packing, handling, transport and discharge.

This strategy required auxiliary equipment to be part of the system from the very beginning, and had to be developed in parallel to the container itself.

The two basic concepts of filling FIBCs today are:

- Filling of free-standing inflated FIBCs.
- Filling of suspended not-inflated FIBCs.

Today, Portabulk filling equipment is available from low-cost, low capacity to highly sophisticated, but cost-effective semiautomatic systems.

Norsk Hydro can supply their FIBC customers with complete installations, preferably on a consultancy basis, tailoring the equipment in close cooperation with the customer.

Compared with a bagging line for palletized shrink wrapped unit of 50 kg sacks, the investment for a high capacity FIBC packing line is modest with a manpower requirement of only 2 operators and a fork lift truck + driver for transportation and stacking.

Typical capacities (per filling spout) are:

- 120 units/hour of FIBCs for 600 kg fertilizer.
- 100 units/hour of FIBCs for 1000 kg fertilizer.

The latest creation is the development of a semiautomatic FIBC packing unit for fertilizer (600–1000 kg units), reducing the number of operators to only one. Expected bagging rates are:

140 units/hour of FIBCs for 600 kg
115 units/hour of FIBCs for 1000 kg

The introduction of the preformed lifting loop with a protective sleeve eliminates the need for handling accessories—except those designed for increased productivity.

Today Portabulk FIBCs can be handled directly on the tines of a fork lift truck, 2 at a time, and with simple accessories even 4 at a time.

Standard spreaders for 4 and 6 FIBCs per heave are available, but up to 20 containers have been unloaded in USA at the time.

Stored outside, the FIBC's containers should be stacked on a well drained surface. It is advisable to cover the stack with tarpaulins.

The bulk of all Portabulk FIBCs are single-trip containers and the easiest way to empty them is simply by slitting the base or sides.

Another Norsk Hydro invention is the pyramidic knife with only 2 cutting edges. Places in the top of a hopper, silo etc. 1000 kg containers can be emptied in 10 seconds.

7. ECONOMY

Price competitiveness of an FIBC transport system compared with that of palletized, shrinkwrapped unit loads of 50 kg sacks in 1974 and 1984:

— Packaging costs. The packaging costs per ton, initially higher, are today lower for FIBCs.
— Bagging costs. The bagging costs for FIBCs have been drastically reduced and the cost saving today can be substantial.
— Handling, storage, loading/unloading costs are reduced but still a little bit above similar cost for palletized cargoes.
— Transport costs, at the same level as palletized cargoes.
— Discharge costs. All handling at the farm gives advantages compared with palletized cargoes.
— Handling of empty packaging gives advantages compared with returnable pallets, empty 50 kg bags etc.

Conclusion

The Portabulk FIBC system of 1984 is a cost-effective transport system of bulk materials and the ambitious goals of the development strategy have been justified.

Impact of Biotechnology on Fertilizer Use

Dr. Ralph W. Hardy
Director of Life Sciences
E.I. DuPont de Nemours & Company, Inc.

(Paper Not Available)

Thursday, November 1, 1984

Final Session
Moderators:

Paul J. Prosser, Jr.
Bill E. Adams

Summary of Business Meeting:

1) The following Financial Statement was read to the membership:

FINANCIAL STATEMENT

October 25, 1983 to October 29, 1984

CASH BALANCE—October 25, 1983		$18,418.51
Income October 25, 1983 to October 29, 1984		
Registration Fees—1983 Meeting	$13,840.00	
Sale of Proceedings	3,905.34	
Registration Fees—1984 Meeting	12,900.00	
Cruise Fees	1,150.00	
Total Receipts October 25, 1983 to October 29, 1984		$31,795.34
Total Funds Available October 25, 1983 to October 29, 1984		$50,213.85
Disbursements October 25, 1983 to October 29, 1984		
1982 Proceedings, including postage, etc.	$16,932.54	
1983 Meeting Expenses	1,360.08	
Miscellaneous Expenses, including postage, stationary, etc.	439.22	
Directors Meetings	1,604.43	
1983 Proceedings, including postage, etc.	9,786.78	
1984 Meeting Expenses	2,015.09	
Cruise Expenses	5,798.72	
Disbursement—Cocktail Party Fund	101.05	
Total Disbursements October 25, 1983 to October 29, 1984		$38,037.91
CASH BALANCE—October 29, 1984		$12,175.94
Less Reserve for Cocktail Party Fund		331.69
Total Cash Available October 29, 1984		$11,844.25

Respectfully submitted,

PAUL J. PROSSER,JR.
Secretary-Treasurer

Mr. Prosser announced that the registration for the 1984 meeting was 235.

2) Mr. Tom Athey, Chairman of the Meeting Dates and Places Committee, as well as the Entertainment Committee, informed the membership that the 35th Annual Meeting of the Round Table is scheduled for October 29, 30 and 31, 1985 in Atlanta, Georgia at the Sheraton Hotel. He further thanked the following sponsors of the previous night's Harbor Cruise:

   ATLANTA UTILITY WORKS
   BIRD MACHINE COMPANY, INC.
   COMMONWEALTH LABORATORIES, INC.
   DAVY McKEE CORP.
   FEECO INTERNATIONAL, INC.
   HAVER FILLING SYSTEMS, INC.
   SUBSIDIARY OF HAVER & BOECKER, WEST GERMANY
   J&H EQUIPMENT, INC.
   JACOBS-DORRCO DIVISION
   KIERNAN-GREGORY CORP.
   THE PROSSER COMPANY, INC.
   RENNEBURG INTERNATIONAL, INC.
   THE A.J. SACKETT & SONS CO.
   STEDMAN FOUNDRY AND MACHINE CO., INC.
   ST. REGIS PAPER COMPANY
   D. M. WEATHERLY COMPANY
   WEBSTER INDUSTRIES, INC.

3) Mr. Walt Sackett, Jr., Chairman of the Public Relations Committee, acknowledged the cooperation of all publications in reporting the Round Table's schedule and program. Because of budgetary limits, no formal advertising was done in 1984.

   On behalf of the Membership, Mr. Sackett then presented a plaque to Mr. Tom Athey in appreciation of his many years of service as Chairman of the Committee for Meeting Dates and Places and as Chairman of the Entertainment Committee.

   Mr. Harold Blenkhorn was then presented a plaque by Mr. Sackett in recognition and appreciation of his service to the Round Table during the past two years as Chairman of the Board of Directors.

4) Mr. Joe Reynolds, Jr., Chairman of the Nominating Committee, placed in nomination Mr. John Medbery of I.M.C. Corporation as Chairman of the Board of Directors of The Fertilizer Industry Round Table for 1985 and Mr. Al Malone of Agway, Inc. as Vice Chairman. These gentlemen were unanimously elected, and each accepted the office.

Mr. Prosser then closed the Business Meeting.

Acid Fertilizers

Frank P. Achorn
Senior Scientist
Field Engineering Staff
Division of Agricultural Development
National Fertilizer Development Center
Tennessee Valley Authority

Acid Fertilizers

There has been a revived interest in production and use of acid fertilizers. These are fertilizers which usually have a pH of 1 to 3. They usually are formed by reacting urea in one or more of the following acids: nitric acid (HNO_3), sulfuric acid (H_2SO_4), and phosphoric acid (H_3PO_4).

Urea phosphate (UP) fertilizers are not new. In 1922 Clarkson and Braham patented a process for producing UP in which urea was reacted with phosphoric acid to produce a UP addition compound (1). Later the Germans (Gittenait), developed a process for producing reaction products from phosphoric acid, urea, and ammonia (2). They reported these results in 1969 and 1970.

Information concerning German and British patents for the production of UP were presented at the 1970 Technical Conference of the International Superphosphate Manufacturers Association in Norway. At this conference K. V. Nayer, et al. reported on their process for the manufacture of high analysis complex fertilizer through a UP route from wet-process phosphoric acid (3). The Russians (Beremzhanov, et al.) developed isotherms of solubility for the system urea-phosphoric acid-water at 0° and 10°C. In conducting this research during 1968, they produced liquid fertilizers containing UP based on their solubility studies (4).

Based on this earlier work TVA began its work on producing solid UP in the early 1970's. The decision was made to develop processes for producing solid UP, then convert it to other products at locations near the use area. Solid UP can also be used for direct application. The solid was selected because it could be delivered at a lower total freight cost than urea and phosphoric acid delivered separately.

Solid UP is produced by reacting solid urea with merchant-grade wet-process phosphoric acid (0-54-0). This work was shown at TVA's 9th demonstration "New Developments in Fertilizer Technology," October 1972 (5). Other information concerning its production and use in both fluids and solids was presented in the 1974, 1978, and 1980 TVA Technology Demonstrations (6, 7, 8). In some instances the UP is ammoniated to produce a granular or fluid urea-ammonium polyphosphate. In other work the UP is dissolved in hot water to produce a low-pH fluid usually referred to as acid solution fertilizer.

TVA has two processes for producing UP from urea and wet-process phosphoric acid. In one process, a high purity crystalline UP is produced which can be used to produce clear liquid fertilizers. The process also has a byproduct suspension which contains almost all of the impurities introduced by the wet-process phosphoric acid. For clarity, we have designated this as "TVA process 1" for production of crystalline urea phosphate.

In 1980 TVA began to develop a second process for producing UP from commercial wet-process acid. In this process the impurities are not separated from the crystals and the entire mass is granulated. This latter process has not been fully developed; however, for clarity we have designated it as "TVA process 2" for producing granular urea phosphate. In both TVA processes, the resulting UP product is a solid, either crystalline or granular, and has a pH of 1 to 3. Because it has the pH of a weak acid and has the characteristics of an acid, some TVA area directors have given it the nickname, "dry acid." Others have recently developed processes for producing solution fertilizers from urea, phosphoric acid and sulfuric acid (9, 10).

Chemistry of the Process

Urea has the ability to form adducts or additional compounds with many materials. A few are listed below:

Name	Chemical Formula
Urea nitrate	$CO(NH_2)_2 \cdot HNO_3$
Urea phosphate	$CO(NH_2)_2 \cdot H_3PO_4$
Urea sulfate	$CO(NH_2)_2 \cdot H_2SO_4$
Urea calcium nitrate	$4CO(NH_2)_2 \cdot Ca(NO_3)_2$
Urea calcium sulfate	$4CO(NH_2)_2 \cdot CaSO_4$
Urea monocalcuim phosphate	$CO(NH_2)_2 \cdot Ca(H_2PO_4)_2$
Urea zinc nitrate	$2CO(NH_2)_2 \cdot Zn(NO_3)_2 \cdot 4H_2O$

In these compounds, the components keep their identity and some of their characteristics. Therefore, the UP which is formed can react with other materials in the same way as urea and phosphoric acid would react with them; however, these reactions will also be affected by such environmental factors as pH and temperature. The chemical reaction for producing UP is as follows:

$$\underset{\underline{\text{Urea}}}{CO(NH_2)_2} + \underset{\underline{\text{Phosphoric acid}}}{H_3PO_4} \rightarrow \underset{\underline{\text{Urea phosphate}}}{CO(NH_2)_2 \cdot H_3PO_4}$$

Please note that the urea did not break down; it simply attached itself to a molecule of phosphoric acid. Thus it formed an adduct. The resulting crystalline product has a pH of 1 to 3. Fluid fertilizers produced from it also have low pH unless they are ammoniated. Urea phosphate can be ammoniated easily to produce a urea-ammonium polyphosphate material according to the following equation:

$$\underset{\underline{\text{Ammonia}}}{4NH_3} + \underset{\underline{\text{Urea phosphate}}}{10CO(NH_2)_2 \cdot H_3PO_4} \rightarrow$$

$$\underset{\underline{\text{Carbon dioxide}}}{3CO_2 \uparrow} + \underset{\underline{\text{Ammonium pyrophosphate}}}{3(NH_4)_2H_2P_2O_7} +$$

$$\underset{\underline{\text{Urea}}}{7(NH_2)_2CO} + \underset{\underline{\text{MAP}}}{4NH_4H_2PO_4}$$

Urea can form a compound with sulfuric acid according to the following chemical equation:

$$CO(NH_2)_2 + \underset{\underline{\text{Sulfuric acid}}}{H_2SO_4} \rightarrow \underset{\underline{\text{Urea sulfate}}}{CO(NH_2)_2 \cdot H_2SO_4}$$

Several patents describe processes for producing low pH solution fertilizers containing urea sulfate (9, 10) and/or UP. A review of the reference literature will give the details of these processes.

TVA Agronomic Tests

TVA has conducted some agronomic tests with low-pH fertilizers such as UP. Preliminary results show that UP is equivalent to the more conventional higher analysis fertilizers as a phosphate source. The UP is equivalent to urea as a nitrogen source under most conditions and probably is better than urea where nitrogen volatilization losses can occur, such as in topdressing of pastures.

Little research has been published on "acid-based" fertilizers because of their recent development as commercial products. Including acid-forming fertilizers with urea may decrease ammonia losses, especially on alkaline soils. Mixtures of superphosphate and urea resulted in decreased ammonia loss from surface-applications as compared with losses from urea alone (11). Nitrogen loss from surface-applications also was lower from acidic UP or urea-UP mixtures than from urea alone (12).

Enhanced micronutrient availability has been reported with band application of some acid-forming fertilizers. Manganese fertilizers are more effective if band applied with acid-forming fertilizers such as ammonium sulfate, and triple superphosphate and soil manganese may be made more available from band applications of these fertilizers (13). Availability of soil zinc and applied zinc sulfate was greater when the nitrogen fertilizer was ammonium sulfate than when it was sodium nitrate (14). Effect of the nitrogen source on soil pH was the reason for these results because ammonium sulfate is more acid forming than sodium nitrate. Band or spot applications of concentrated sulfuric acid also have resulted in increased availability of soil iron, but these results have not been demonstrated under field conditions (15). Crop response to ferrous sulfate cogranulated with acidic UP of pH 1 to 3 decreased with a decreased level of water-soluble iron in the fertilizer which was band applied in the greenhouse. Tests show that the hydrated form of ferrous sulfate will react with UP to form water-soluble iron compounds. Care must be taken in selecting iron sources that will not react with UP to form water-insoluble iron compounds. Greenhouse tests show that anhydrous ferrous sulfate is a good iron source for this purpose; however, more agronomic tests are needed to confirm these results (16). Other potentially beneficial uses of sulfuric acid are reclamation of sodic soils, increasing availability of soil phosphorus, and treating irrigation water (17). TVA is continuing its agronomic research using low-pH fertilizers.

Low-pH Fertilizer In Irrigation

Applying nitrogen fertilizers as solutions in irrigation water has been successful, even when the water was "hard" (of high calcuim and magnesium contents). But applying ammonium phosphate fertilizers, while generally satisfactory in "soft" irrigation water, is unsatisfactory in hard water because of formation of insoluble calcium and magnesium phosphates. Exploratory studies made by TVA several years ago on adding ammonium polyphosphate base solution to hard irrigation water showed that forming of insoluble calcium and magnesium phosphates could be avoided by adding phosphoric acid to decrease the pH of the base solution to 4 or lower. This experience later suggested the possibility that solid UP might be used successfully in irrigation systems using hard water, since base solutions made by adding UP to relatively small proportions of water have a low pH. For example, 8-20-0 grade base solution made from water and UP has a pH of 1.5.

For use in most irrigation systems, the solid should be predissolved. This will create a fertilizer solution that then can be conveniently transported in nurse tanks and metered by pumps into the irrigation system. Tests have shown that such solutions of 8-20-0 grade can be made by dissolving crystalline UP in water; however, heating of the water to at least 125°F is required to dissolve all of the impurities. Total dissolution time when the water is 125°F is 5 minutes and at 150°F it is 1 minute.

Studies have been conducted with two relatively hard irrigation waters—the Republican River near Culbertson, Nebraska, and the Colorado River in Colorado. Analyses of samples are shown in the following tabulation:

	Water analysis, ppm		
	$CaCO_3$	$MgCO_3$	pH
Republican River	310	229	7.55
Colorado River	265	104	7.80

In adding ammonium phosphate to such hard water, precipitation of impurities normally does not occur at low water: P_2O_5 ratios but does occur at high ratios required for practical application in irrigation systems. For typical irrigation systems, a practical ratio is considered to be about 800 gallons of water per pound of P_2O_5. At this dilution ratio, 1.5 inches of water would supply about 50 pounds of P_2O_5 per acre. The test shows that it is possible to add this amount of P_2O_5 to the Republican and Colorado River waters as 8-20-0 grade solution, made from UP (pH 1 to 2.0), without difficulties of precipitation. The pH of the irrigation waters after adding fertilizers was 7.0 and 6.8, respectively. In comparison, only 25 gallons of water per pound of P_2O_5 can be added without precipitation when 10-34-0 grade ammonium polyphosphate liquids (pH 6.2) are used.

"TVA Process 1"—Crystalline Urea Phosphate

Figure 1 shows a flow diagram of this process. Phosphoric acid is reacted with solid urea to produce UP crystals and a mother liquor which contains almost all of the impurities. The crystals are pure UP because the solids are crystallizing compounds. These crystals do contain a small amount of impurities because of traces of mother liquor which remain on their surfaces. These crystals are dried and can be granulated in an open-flame dryer. Granular product usually has a grade of 17-44-0. Phosphoric acid used to produce the UP is the conventional commercial acid containing 54 percent P_2O_5. It also contains from about 8 to 12 percent impurities. Pilot-plant studies show that in this process 80 percent of the P_2O_5 introduced by the wet-process phosphoric acid is recovered as UP crystals. The remaining P_2O_5 and the impurities are in the mother liquor which is separated from the crystals by centrifuging. It has a nominal grade of 9-22-0. This mother liquor can be coverted to a suspension by reacting it with ammonia and adding clay to suspend the impurities. The crystalline material can be dissolved and watered to produce a low-pH solution fertilizer with a grade of 8-20-0. It can be mixed with urea and water to make higher nitrogen grades of low pH (1 to 2.0).

Impurities removed during centrifuging and the remaining 15 to 20 percent of the total P_2O_5 are in a fluid form when they are discharged from the centrifuge. This slurry is converted into a suspension by reacting it with ammonia and adding a suspending clay. A typical suspension with the impurities and some of the P_2O_5 would have a grade of 13-20-0. This impure acid can also be used to produce granular MAP or granular N:P:K mixtures.

"TVA Process 2"—Granular Urea Phosphate

The main difference between this process and "TVA process 1" is that the final product contains not only the UP but also impurities introduced with the wet-process phosphoric acid. No attempt is made

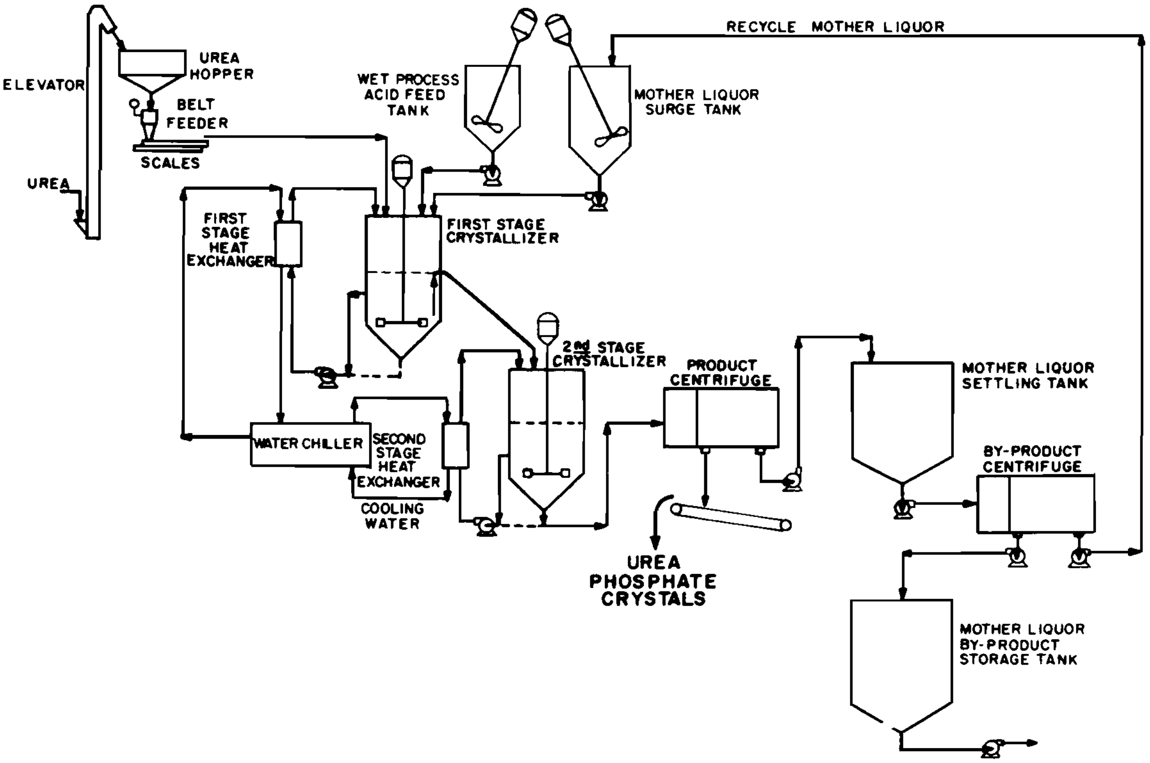


Figure 1
Flow Diagram for Pilot - Plant Production of 17-44-0 Urea Phosphate Crystals from Urea and Wet-Process Acid

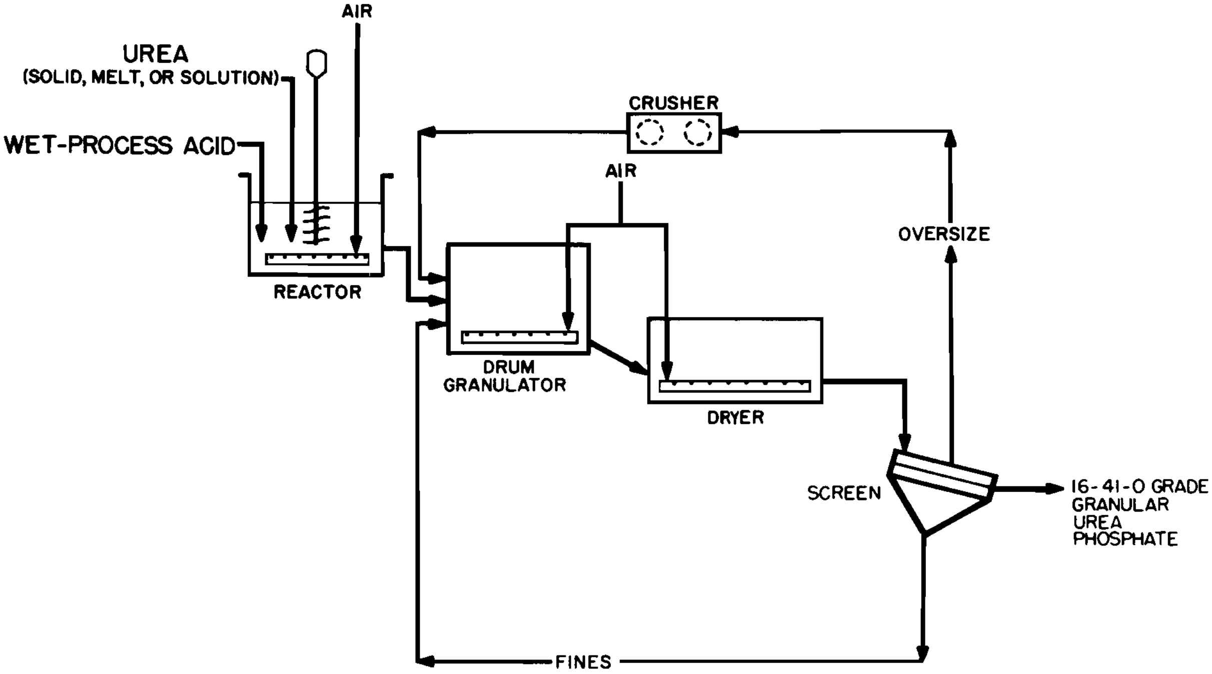


Figure 2
Direct Production of Granular Urea Phosphate from Urea and Wet-Process Phosphoric Acid

to separate impurities from the pure product. Also, the resulting product is a granular solid instead of a crystalline material. Figure 2 shows a flow diagram of this process. Urea and phosphoric acid are added to a mix tank and air is bubbled through the tank. This air is added to help remove some of the water introduced by the wet-process acid. After reaction is complete, the slurry is pumped into a rotary drum granulator where it is granulated with fines and crushed oversize from the product screening operation. Air is blown beneath the bed of material in the granulator during granulation to remove more of the water. Next, the product is dried in a rotary drum dryer. Air is also blown into the bed of material in this dryer. Material from the dryer is screened and product size (−6 +16 standard mesh) is removed.

Although the initial tests appear to be promising and an excellent 16-41-0 grade granular product is produced, there seem to be some problems concerning the total amount of air required in the process and the higher-than-usual recycle rate. However, we expect to solve these problems.

Commercial Processes

Stoller and Hartung of Stoller Enterprises have developed a process whereby high-analysis liquid fertilizers, comprising the reaction products of urea and phosphoric acid and having a pH between 1.5 and 4.0, are produced. This process is covered by U.S. Patent No. 4,315,763, February 16, 1982. They also have another option in the process whereby a solution product is produced from urea and sulfuric acid and trace elements, including those normally found as contaminants in wet-process phosphoric acid, and potash. They report fertilizers having a total analysis of N, P_2O_5, and K_2O of at least 25 percent by weight and preferably 30 percent or greater. Some grades shown are a 22-25-0, a 14-37-0, and an 8.6-44-0. Data presented in this patent indicate that the product would contain UP and the option would contain UP plus urea sulfate.

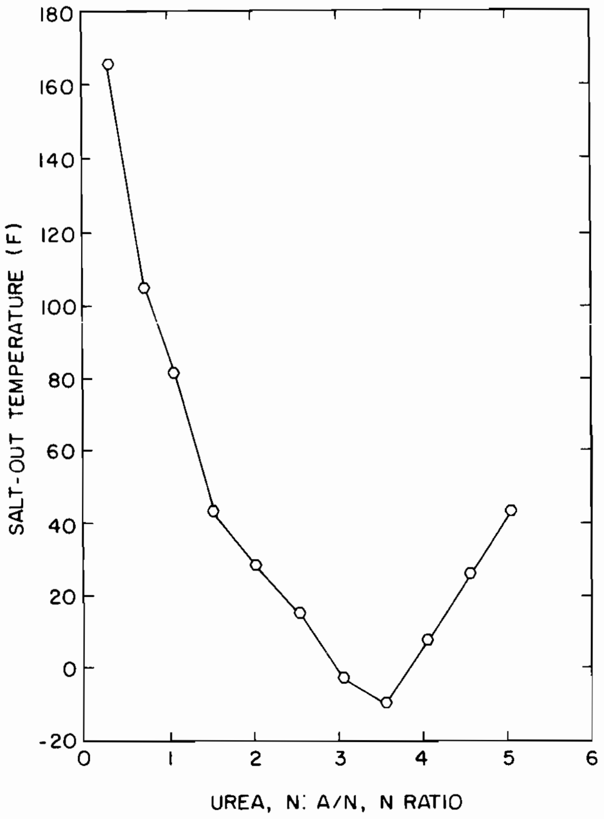
Leon Jones, Chandler, Arizona, developed a process in which urea and sulfuric acid were reacted to form a urea sulfate. This process is described in his U.S. Patent No. 4,116,664, September 26, 1978. This process has a method for controlling the reaction of urea with sulfuric acid to form a liquid nitrogen-sulfate fertilizer composition consisting of urea sulfate and liquified urea and which may include other nutrients. Some of the grades shown in the patent are a 28-0-0-8S, a 29-0-0-9S, and a 28-0-0-10S. Other data show that the total plant nutrient concentration (N + S) depends upon the amount of sulfuric acid used in the formulation. These tests show that the plant nutrient concentration is inversely proportional to the N:S weight ratio.

Recent Developments

In the past year TVA has completed enough laboratory tests to show that it is feasible to produce a solution product containing urea nitrate and ammonium phosphate. One of the products from this new invention will have a grade of 27-9-0 and a pH of 1 to 3.

FIGURE 3

SALT-OUT TEMPERATURES FOR 27-9-0 GRADE VERSUS UREA NITROGEN TO AMMONIUM NITRATE NITROGEN RATIOS



Tests show that by using combinations of urea and ammonium nitrates (as UAN solution, 35% $CO(NH_2)_2$ and 45% NH_4NO_3) the salting out temperature can be significantly lower than those solutions that do not contain ammonium nitrate. The salting out temperatures for solutions (27-9-0 grade) of urea N:ammonium nitrate N ratios are shown in figure 3. These data show that the solutions had a salting out temperature of less than 0 when its urea N:ammonium nitrate N ratio is between 3.0 and 3.8. The salting out temperature of a 27-9-0 solution that does not contain nitrate is 100°F. The pH of the liquid is about 2.0. The 27-9-0 can be mixed with potash to produce solution grades such as 15-5-5 and 12-4-8.

In another option to the process, a 25-0-0-5S grade is produced by mixing urea, nitrogen solution and sulfuric acid. This solution has a salt-out temperature of 15°F when its urea N:ammonium nitrate N ratio is 12.0. Some agronomists like the N:S ratio of this solution since, in most instances, they recommend that the N:S ratio be between 5 and 6. Preliminary field testing shows that the 27-9-0 grade will not cause germination damage when wheat seeds are soaked in it and then applied. Other tests show that when the seeds are soaked in a urea solution and then applied, germination damage does occur. Also, this urea-nitrate ammonium-phosphate solution may not cause burning of foliage; whereas, the straight urea solution does cause damage to foliage under certain conditions. More tests with this low-pH urea nitrate-ammonium phosphate solution are planned.

Summary

Probably the easiest way to produce these solutions is to use nitrogen solution, urea, and phosphoric or sulfuric acids. Preliminary agronomic data indicate that low-pH fertilizers such as UP, urea sulfate, and urea nitrate may have some good agronomic advantages when properly placed in appropriate soils. These fertilizers are of an entirely new type and their use opens a new area of research and development for new and improved fertilizers.

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Manufacturing Fluid Fertilizer in the Eastern United States

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From my viewpoint, manufacturing fluid fertilizer in the Eastern United States is really no different than any place else in this country. There could be as many differences within the state of Illinois, for instance, as there are differences between Maryland and Illinois. Some areas have better logistics for certain products than other areas; also different crops, cropping and tillage systems within various areas which could greatly vary the type of fluid fertilizer produced and how it is produced.

Some areas have water transportation available which naturally makes better logistics for certain materials within those areas. Other areas are blessed with unit train rates or a combination of unit trains and water systems. The closer one might be to one of these advantageous receiving points, the more dominant certain raw ingredients may be in a fluid fertilizer mix.

No till and minimum till have changed cultural practices in some areas and thereby greatly influenced the use of the type of fluid fertilizer to be used in that particular area.

I would now like to address some particulars with which I am familiar within the Mid-Atlantic States and, most particularly, the state of Maryland.

In my company's trade areas, direct application of ammonia is not much of a factor except on the Delmarva Peninsula. Most soils in the Mid-Atlantic, except the coastal plains, are too rocky and consist of a heavy clay-type soil which does not lend itself to the direct application of ammonia.

No tillage systems have become an important factor in the type of fertilizer used in this area. Since the early 70's, no till has grown like wildfire. 65% of the corn grown in Maryland is no till.

The main land or the Western shore, all of Maryland which is west of the Chesapeake Bay, today has 80% corn in no till.

No till is now starting to grow very fast on the Delmarva Peninsula and it is estimated in 1984 that 35% of the corn in this area is no till. No till has become popular because of the savings in trips over the field. This, of course, saves labor, fuel, and wear on equipment. Soil and moisture conservation has also been an important factor causing the growth of no till.

No till soybeans, wheat, barley, and alfalfa have also become very popular in the Mid-Atlantic States. Most of these systems use Paraquat as a "burn-down" herbicide. Paraquat is a contact herbicide and complete leaf coverage is necessary for it to be effective. 40 gallons per acre is a minimum fluid for good uniform coverage. The carrier for Paraquat can have no clay in the mixture as clay neutralizes Paraquat and makes it inactive. This has forced us in the heavy no till areas to continue with the use of clear liquids.

Our program would be a one shot application with 100–120 gallons of clear liquid per acre. Analysis such as 14-6-8, 16-6-8, spread at 100–120 gallons per acre gives 1000 to 1200 pounds of material per acre. As you can well imagine, with this high gallonage, we get tremendous coverage. Good total kills—all herbicides and insecticides are included in one mix in a one shot application. This mix would include Atrazine, Simazine, Dual or Lasso, 2,4-D, Toxaphene and Paraquat. The practice would be to spray either up to 10 days before planting or up to 10 days after planting. This is one trip to spray, one trip to plant, and one trip to harvest, giving you three trips over the field per year, total. The farmer makes two and the fertilizer/pesticide dealer makes one. This is very popular in our area.

This system has one problem when high amounts of potash are needed. As most of you know, to apply large quantities of potash, a suspension-type fluid fertilizer would be needed.

In recent years, we have done considerable work using Bladex as a "burn-down" herbicide in place of Paraquat. In many cases, Bladex can also well be utilized as a residual herbicide in the mix and it has a double advantage in these types of situations. Bladex can be used in suspensions, as clay does not deactivate Bladex as it does Paraquat.

When manufacturing fluid fertilizer, the main material we use in this area would be ammonia or aqua ammonia, UAN solution, sometimes dry urea, 54% phosphoric acid, spent phosphoric acid, 10-34-0 or 11-37-0, ammonium poly phosphate, DAP, or MAP, soluble or fine potash, ammonium sulfate, and more than likely a slew of other products with which I am not familiar.

In utilizing these various products, let's talk a bit about the manufacturing process. With clears, probably the most simple mix would be a clear fertilizer made with UAN solution, 10-34-0, or 11-37-0, soluble potash and water added in the proper ratio and a little mixing. This is a very simple mix to make with a minimum of necessary knowledge and equipment, resulting in a product that handles well, as long as the saltout temperatures are not exceeded, as easily as straight UAN solution or water itself.

Another procedure would be UAN solution, 54% phos acid, ammonia or aqua ammonia, soluble potash, and water. This mix is a little more sophisticated to manufacture than the first mentioned procedure, but can be manufactured when proper equipment is available and in place and with knowledgeable plant people.

A simple suspension can also be manufactured with UAN solution, some type of a phosphate base material, soluble potash, water and clay. In recent years, we've started using liquid clay and this type of clay has proven to be very practical for us.

As mentioned before, the clears handle almost like water. An analysis such as 5-10-10, 3-6-12, 10-8-8, have very low saltout temperatures and in the handling of these products, almost nothing can go wrong. They handle almost like water.

I would like to say that it is our company's policy to be very cautious about putting suspensions out in the hands of farmers. Whenever suspensions are utilized, we try to handle and apply them ourselves. We feel that the average farmer would not take the time and precautions necesssary to handle suspensions properly. It has been our policy to absolutely stay with clears for planter fertilizer and to utilize clears for our Paraquat no till which has made us remain heavily in clears.

We have gotten more into suspensions in the last few years, particularly with high potash grades and with the increased use of Bladex as a "burndown" material, we are getting more into suspensions and expect even more involvement in the future.

I'd like to tell you about some of our manufacturing experience with these various products and hopefully some of our experiences will be beneficial to you.

Our company started in the liquid fertilizer business in 1970 and our first mixer, which we still have, is a 6 ton mixer, 15 h.p. 4 x 3 pump, and a five h.p. agitator. We got along beautifully in the early years with this mixer, pump, and agitator in clears, but I'd have to say we had disasterous results with suspensions. In looking back, and the experience we've had since then, I think I now understand why. When trying to make 5 or 6 tons of suspension at one time with a 15 h.p. pump and a 5 h.p. agitator, not much happens in that mixer. Now we know that if we had worked with 2 or 3 ton batches our early experiences with suspensions would have been much better. 2 or 3 ton batches make many more passes through the pump in a short time. A few years ago our original 4 x 3, 15 h.p. pump was replaced with a 40 h.p. 6 x 4.

In direct relation to this, we are, at this time, building a new plant in Southern Pennsylvania which will have, instead of a 4 x 3 pump, a 6 x 4 pump and instead of having 15 h.p. it will have 75 h.p. This is the route I feel we need to take to manufacture a good quality suspension. Also, by pre-gelling our clay, mixing time is reduced and the fact that this clay has been wet for at least several hours, in many cases several days, we are getting much more efficiency out of our clay, 2 points—big, high H.P. pump & pre-gelled clay.

As a result of work done with our super phosphate supplier the past few years, it has been our experience that we make our best quality suspensions out of UAN solution, a *cold* phosohate base material, soluble potash, water and pre-gelled liquid clay. These suspension handle beautifully, transport, store, and flow well. 3 points—high H.P. pump, pre-gelled clay, cold mixing.

I'd like to speak for a moment about pre-gelled liquid clay and give you the procedures on how we handle it.

Our liquid clay is manufactured in a separate mixer from fertilizer. This is not an absolute necessity, but it is a great convenience because, if you were going to manufacture your liquid clay in a regular fertilizer mixer, you would need to take extreme precaution to make sure that all lines, pumps and the vat itself are absolutely free of any contaminating fertilizer material. Because of the necessity for thorough clean-up, we have chosen the route of having a separate, inexpensive mixer to manufacture our liquid clay. Clay is handled in paper bags. We are looking forward in the future to receiving this clay in one ton bags which we will handle with a fork lift. This will make handling clay very easy for us.

Water is brought in at a pre-determined level in our mixer; next clay is added (25%). There is a small quantity of TSPP (terra-sodium pyrophosate) added, 15 pounds per ton and the materials are thoroughly mixed and put in a tank for storage.

Various other mixing or suspending agents are utilized to make suspensions, but because of the economics, none are nearly as popular as attupulite clay.

The need for sulfur seems to increase in our area every year and sulfur can be added to fluids in many ways. Ammonia Thio is an easily handled product and can be readily added to both clears and suspensions. Due to our proximity to Hopewell, VA and the great amount of ammonia sulfate available from that facility, this material is also greatly utilized in the Mid-Atlantic States in both dry mixes and fluid fertilizers. Ammonia sulfate can readily be added to suspension fertilizers and small amounts can be added to clears.

I would like to spend a few moments talking about various types of equipment used in the manufacturing of fluid fertilizer. The number one item would have to be pumps. It has been interesting for me to observe, over the past 15 years that I have been in the fluid business, the size and horsepower of pumps gradually increase. 6 x 4 pumps are now rather commonplace for mixers with 40 to 80 H.P.

As pumps have increased in size and horsepower, plumbing has, of course, increased. In the late 60's and early 70's, 1½" and 2" plumbing was used and was rather common in the fluid fertilizers, and in those days 3" was considered a large line. Today, 3" is a small line and 4" and 6" is being used in many instances.

It is not uncommon at all to see a load-out terminal for fluids today having a 4 x 6 pump with 40-50 H.P. and a 6" suction line from the tank to the pump with a 4" loadout to the transport which will load a 24 ton trailer in just a few minutes.

Meters have also been increased in size as the pumps and plumbings were increased.

In the past 15 years, we have seen the manufacturing of 10-34-0 move from large central manufacturing facilities to more regional 10-34-0 manufacturing equipment with the event of the TVA-developed pipe reactor.

The advent of the flotation type applicator has revolutionized field application. Pesticide handling and application has also become an important item with most fluid fertilizer dealers. The event of "weed and feed" has made the incorporation of pesticides with fluid fertilizers popular in the eastern states just as it has over the rest of the country.

A critical factor facing retail dealers and manufacturers in recent years, and which will more than likely become more important in the coming years, is environmental requirements. It is important that all of us in the industry do everything possible to avoid having even more restrictions and restraints put on us in the future. Good stewardship by us in the industry is very important.

Whatever the manufacturing method which is used for fluids and no matter which materials are used, it is always our objective to manufacture a material that will handle easily, store well, and most important of all—be applied in the precise, uniform manner so as to maximize efficiency and profits for our farmer customers. For this reason, fluids have become popular in the East as they have in the rest of the country.

Nutri-Blast 2000—A New Concept for Clear Liquid Fertilizer Application

J. G. Clapp, Jr.

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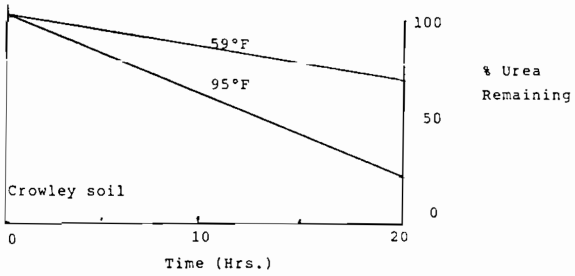
Applying urea or ammonium containing fertilizers on the soil surface without incorporation can result in considerable nitrogen loss to the atmosphere. This process, known as ammonium volatilization, can be influenced by such factors as soil pH, temperature, cation exchange capacity, soil texture, and soil moisture (Ernst and Massey, 1960. Finn and Kissel; 1973, 1974, 1976. Fenn and Escarzaga, 1976, 1977.). Volatilization losses of up to 50% of the applied nitrogen have been reported (Hargrove et al., 1977).

Higher losses are generally associated with calcareous, high pH soils. These losses increase as the soil temperature increases. Coarse-textured soils having a low CEC will lose more nitrogen by ammonium volatilization than fine-textured soils. In general, ammonia losses increase with increasing soil moisture.

The most severe losses can occur with surface-applied urea on both acid and alkaline soils and with surface-applied ammonium nitrogen sources on neutral to alkaline soils. These losses can be reduced to zero by incorporating urea two inches deep on acid soils and to near zero on alkaline soils (Terman, 1979). When urea was compared to UAN and ammonium nitrate surface applied, average volatile nitrogen losses were 25.0, 11.5, and 0.3%, respectively (Volk, 1959).

Urea placed on the soil surface and in the presence of water and the enzyme urease will hydrolyze, releasing ammonia and carbon dioxide. Unless this ammonia can equilibrate quickly to the soil, the nitrogen is lost to the atmosphere. Urea hydrolysis is temperature dependent, as illustrated in Figure 1; therefore, greater losses occur when applications are made in summer. Also, losses from surface-applied urea on no-till or minimum-till soil can be greater because of the old crop residue which provides increased moisture and urease for hydrolysis to take place (Moe, 1967).

Figure 1. Urea hydrolysis over time at two temperatures.



Vlek & Carter: IFDC

No-till or minimum-till cropping systems also have increased microbial levels near the soil surface, which may immobilize surface-applied nitrogen. The change in microbial populations for no-till vs. plowing are illustrated in Table 1.

TABLE 1.
Change in Microbial Population for No-Till Compared to Plowing.

Microbioal Group	No-Till compared to plowing	
	Soil depth, in inches	
Aerobes	0 - 3	3 - 6
Fungi	+57	-24
Bacteria	+41	-32
Nitrifiers	+ 3	-51
Anaerobes		
Bacteria	+59	+18
Dentrifiers	+170	+92

DORAN: University of Nebraska

Recent work at the University of Maryland indicates that placing UAN below the soil surface for no-till corn can be beneficial. Dribbling UAN was an improvement over broadcast applications and corn yields were increased by 23.4 bu/A in 1982, as noted in Table 2. An additional yield improvement was obtained by pulling a knife through the soil and placing the UAN behind this opening.

TABLE 2.
N-Source and Placement on No-Till Corn.

N Treatment 120 Lbs. N/A	Yield Bu/A*	
	1982	1983
Ammonium Nitrate	136.5	104.1
UAN—Broadcast	118.4	96.6
UAN—Dribbled	141.8	99.3
UAN—Subsurface	149.2	107.4

*Average of three locations

Bandel: University of Maryland

Research at Purdue University (Mengel, 1982) also verifies the need to place UAN below the soil surface for no-till conditions. Average corn yields were increased 17 bu/A for subsurface over broadcast surface application (Table 3).

On sloping land, the use of a knife or a tillage tool for no-till or minimum-till operations increases the risk of soil erosion and reduces conservation aspect of this method of crop production. Average soil loss on Southern Mississippi Valley silty uplands was found to be 22 times greater for conventional planted corn as compared to no-till (McGregor, K. C., and J. D. Greer, 1982).

TABLE 3.
N-Source and Placement on No-Till Corn.

N Treatment 147 lbs. N/A	Yield* bu/A
Urea—surface	123
UAN—surface	118
UAN—subsurface	135

*Average of 7 sites 1978–1980

Mengel: Purdue University

For these reasons, we decided in late 1982 to evaluate the potential of high pressure for placing nitrogen fertilizers below the soil surface. We theorized that with pressures of 1000+ psi, a clear liquid fertilizer would cut through any old crop residue and blast the liquid into the soil.

A small self-contained experimental unit was built at our Geismar, LA complex in early 1983 to evaluate the concept. This unit consisted of a positive displacement pump with a capacity of 4 GPM at 2000 psi. A 12-HP gasoline engine, a 8.7 gallon tank, two solid stream nozzles with a diameter of .033 inch and 100 mesh screens, a pulsation damper, pressure regulator, pressure gauge, cut-off valves and ⅜ inch hydraulic hoses with the required fittings were required to construct the unit.

This unit was successfully operated at pressures in excess of 2000 psi. We then decided to field test the method of application for no-till corn through a private agricultural research company near Cedar Falls, Iowa. The test site was on a Kenyon loam with 48% sand, 34% silt and 18% clay. Prior crops were sunflower (1982) and corn (1981).

Prior to planting, KCl at 167 lbs/A was broadcast. All remaining fertilizer was applied with the high pressure unit.

The unit was mounted on a 6-row John Deere 7100 Max-Emerge planter equipped for no-till planting. The four center rows were equipped for high-pressure application. At planting a clear liquid grade, 5-15-5-.33 Zn, made from POLY-N, KC1 and Liqui-Zn was applied 2 inches beside the row at 333 lbs/A. After planting, 50 lbs of N/A as URAN-28 was applied broadcast with Lasso and Bladex.

Nitrogen treatments were applied 6 weeks after planting. The high pressure unit was re-mounted on a cultivator frame for the initiation of these treatments. This method was compared to a surface dribble application. Both were placed approximately 6 inches to the side of the corn row. URAN-28 was applied at 83 and 133 lbs. N/A. Depth of penetration from the high pressure unit (operated at 1700 psi) was from ½ to 1 inch.

The highest corn yield (137.2 bu/A) was obtained from the high-pressure placement at 83 lbs N/A and 19.6 bu/A above the dribble placement (Table 4). Crop maturity was advanced by the high-pressure placement as indicated by the reduction in grain moisture at harvest.

TABLE 4.
N Rates and Placement on No-Till Corn.
Cedar Falls, Iowa—1983

N Rate (lbs/A)	Placement Type	Moisture (%)	Yield (bu/A)
83	H. Pressure	24.1	137.2
83	Dribble	25.2	117.6
133	H. Pressure	23.3	134.8
133	Dribble	24.3	130.9

Arcadian

These results encouraged us to build a self-contained unit, mounted on a standard three-point hitch for direct tractor attachment, whereby the tractor power take-off could be utilized for operating the pump. This new design also contains a shoe attachment for each nozzle which allows the liquid discharge to be at the soil surface. Previous tests indicated that the maximum penetration depth would occur if the nozzle was positioned within one inch of the soil surface. The shoe attachment also prevents soil and liquid particle from being thrown back into the air at the point of impact.

A second self-contained unit was built in early 1984. These units have been utilized by researchers at Kansas State University, University of Maryland, Purdue University, University of Nebraska and Southern Illinois University for nitrogen placement studies on wheat, pasture grasses, tomatoes and no-till corn. Additional university trials are being arranged.

Patent application covering this concept has been applied for by Arcadian and an agreement has been reached with the John Blue Company, Huntsville, Alabama, to produce complete self-contained units and components for the system. These units and components will be marketed under the trademark of Nutri-Blast and are expected to be available in 1985.

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