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ROUND TABLE
1985

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Table of Contents

Tuesday, October 29, 1985
Morning Session
Moderators
John L. Medberry
Rodger C. Smith

Tuesday, October 29, 1985
Afternoon Session
Moderator
Douglas Caine

Wednesday, October 30, 1985
Morning Session
Moderator
Dr. Ole Lie

Wednesday, October 30, 1985
Afternoon Session
Moderator
James C. Brown

Thursday, October 31, 1985
Final Session
Moderators
Cecil F. Nichols
Paul J. Prosser, Jr.

INDEX OF PARTICIPANTS

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Tuesday, October 29, 1985

Morning Session Moderators:

John L. Medberry
Rodger C. Smith

Opening Remarks—Chairman

John L. Medberry

Welcome to the 35th Annual Meeting of the Fertilizer Industry Round Table. The Round Table is the only organization holding annual meetings that address the complete spectrum of the fertilizer industry.

The main purpose of the Round Table is to exchange technical information for the purpose of improving fertilizer products and manufacturing and distribution methods. The scope has become worldwide through the participation and attendance of fertilizer industry scientists and executives from many other countries.

I also wish to welcome you to Atlanta and the state of Georgia. Atlanta has been a major rail center and commercial hub for the southeastern United States for over 140 years. It is only natural that a thriving fertilizer industry would spring up in this city about 100 years ago when the farmers of this region first began to use chemical fertilizers. Rail access made this city the most efficient distribution and production center.

Some of the companies that operated manufacturing plants in Atlanta were:

Adair-McCarty
Swift Chemical
The F. S. Royster Guano Co.
Tennessee Corporation
Schoen Brothers
Furman Fertilizer Works
Virginia-Carolina Corporation
Armour and Company
American Agricultural Co.
Atlanta Chemical Co.
Southern Cotton Oil Co.
Morris Fertilizer Co.

and International Agricultural Corporation, the company that I work for, which was renamed International Minerals and Chemical Corporation in 1942.

Although there are no fertilizer plants still operating in Atlanta today, many such plants did exist, some as recently as the 1960's. Georgia is an important agricultural state, and fertilizer consumption is currently higher than at any time in the past. Marketing and distribution patterns are much different now, and the fertilizer is presently marketed through many small local outlets and a few regional granulation plants. All of these are located in the principal agricultural sections of the state.

This year we are fortunate to have, as attendees at our conference, members of the technical committee of the International Fertilizer Association. They represent countries from Europe, Africa and Asia, as well as the U.S.A. We have prepared a large poster which is at the entryway to this meeting room which lists the country, names and company affiliations of these honored guests of the round table. The flags of their nations are displayed on this table. They are arranged in alphabetical order:

Algeria
Belgium
Denmark
Fed. Rep. of Germany
Finland
France
Greece
India
Italy
Jordan
Morocco
Netherlands
Nigeria
Norway
Spain
Sweden
Switzerland
Togo
Tunisia
United Kingdom
United States

Thank you for being here, and an especially warm welcome to all of our friends from outside the U.S.A. There will be a cocktail reception at 6:00 this evening in the Atlanta Room. During that enjoyable interlude, I hope to meet each of you and get to know you better.

Keynote Speaker

William W. Gaston
Chief Executive Officer
Gold Kist Inc.

I would like to welcome all of you who are not from the Atlanta area to our city. Gold Kist has been in and around Atlanta for its 52 years and we are proud of our city and region.

No doubt many of you have visited Atlanta before, at least as close as going through the airport. In this part of the country it's said that everyone will eventually have to go through the Atlanta airport, even if it's only to change planes on the way to Heaven or ......

It is not very often that a keynote speaker starts out by telling you what he will *not* talk about. That's what I'm doing.

As your keynoter, I do not intend to deal with a technical or detailed analysis of the fertilizer industry. You have experts from around the world who will dissect the fertilizer industry in the next three days.

Instead, what I want to look at are some of the fundamental changes which are confronting business executives here and around the world. Time was we in the U.S. could deal with national issues and ignore their global impact. Today, the opposite is true—the global issues are what create the national issues in all industries.

I think many managers still think of their industry as an end unto itself. They analyze issues on the basis of the impact on the fertilizer industry or steel industry or the automobile industry or computers or whatever. But an industry is only a component of an activity which satisfies a human need.

Fertilizer is a component of agricultural production. It is an element of the petro-chemical industry, a user of natural resources. It is part of many other industries, including engineering, construction, transportation, finance and retailing. Furthermore, it is a global international industry woven into the fabric of many nations' economies.

But fertilizer's function is to increase production of food and fiber for humans, not to drive the other industries. Hopefully, the various branches of government are also working in cooperation with the heads of major corporations in the U.S. toward mutually beneficial goals. I *underline hopefully*.

At the CEO level, there is much concern for where we are headed with our U.S. industrial base—questions about the extent to which industry and government are working together to determine the course of future events.

There is no question about the fact that U.S. industry is under seige from all sides. We are losing jobs and whole industries to other countries. We seem to have lost our competitive edge abroad and even here at home—i.e., steel, autos, ship building, etc.

The U.S. trade deficit was $36 billion in 1983; it rose to $123 billion in 1984 and seems to be headed for about $150 billion this year—*$36* to *$123* to *$150* billion. And the story is worse in manufactured products.

I am sure that Dean Bill Flatt will cover the agricultural outlook in some detail in his presentation this afternoon. You are familiar with the numbers. Net farm income for 1985 is forecast at $23 to $27 billion, down from $34.5 billion last year.

As of mid-August, U.S. farm exports for fiscal 1985 were forecast at $32 billion, down 16 percent from last year. Volume is down 10 percent to 129 million tons.

Ample production around the world is a major factor in the decline in U.S. agricultural exports. Almost every country in the world has reported good crops in 1985. The fact that the U.S. dollar reached a 12-year high in March is the other major factor.

Agricultural imports into the United States are expected to reach $20 billion, up by one-fourth from five years ago. Other industries are seeing the same decline in exports over imports. U.S. high tech products such as business equipment, computers, aerospace equipment and medicines went from a $26 billion trade surplus in 1980 to $6 billion surplus in 1984 and the trend continues downward.

In addition to the high value of the dollar as a factor which is choking our exports, U.S. productivity has not kept pace with productivity growth around the world.

In 1984, our industrial productivity rate grew by 3.5 percent, which is comparable to the results from the past three years.

But in the same year, productivity in Japan rose *nine* percent; in France *five* percent; in Germany *4.7* percent and in Canada *four* percent. But despite the fact that these countries outdid the U.S. in increases in productivity, the gap between wages paid in the U.S. and other major industrial countries continues to widen. Productivity to me means producing more with less—but we are producing less with more.

In a recent speech to The Conference Board, the Chairman of RCA, talked about the impact on RCA of the loss of a competitive advantage in the U.S.

To meet competition from high-productivity, low-wage competitors in the Far East, RCA now employs 10,000 people in Taiwan, 10,000 people in Mexico and 3,000 people in Malaysia to produce goods destined for the U.S. market.

Although radios were developed in the U.S., largely by RCA, no radios are produced in the U.S. today.

No black and white television set is manufactured in the U.S., despite the fact it was developed here. The same is true for color television sets. Look inside the box which may have been made in the U.S., and you find that the works came from Mexico or Pacific Rim countries.

No video cassette recorders are produced in the U.S. although most of the basic patents are held here. The semiconductor was created in the Bell Laboratories in the United States, yet we are losing the manufacturing and development of new semiconductor techniques to the Pacific Rim countries.

The fertilizer industry is in another of its periodic life-or-death struggles. Imported ammonia now accounts for more than 15 percent of the market. Massive investments in domestic phosphate and potash mining and processing operations lay idle.

Where is the industry headed? Some industry spokesmen are clamoring for high duties in the interest of national defense.

Others say let the farmer have the benefit of the lowest-price source of plant food so he can compete in world markets and aid our balance of payments deficit.

Who is right?

Neither is right, and *both* are right.

High import duties carry significant domestic and international risks. On the domestic side, imposition of high duties will tend to promote a laissez faire attitude in the industry. As long as a high tariff wall exists, industry will not change its operations and inefficient operators will continue to be subsidized at farmers' expense.

On the international side, we are warned that high import duties on fertilizer will promote trade retalliation. For the most part, this is a scare tactic which has been shown by several recent studies to be a paper tiger. But who knows for sure?

Those who argue in favor of giving the farmer the best price overlook the fact that cheap imported goods are marked up to domestic prices, rarely benefiting the farmer and most often benefiting the importer. While it does offer the importer more pricing latitude than domestic manufacturers, any savings which might flow through to farmers are very small.

The fundamental question to be addressed, *in my opinion, is what will happen five* or *10 years down the road if we let our domestic industries fall victim to foreign production?*

That question applies to every industry you can name—steel, textiles, vehicles, small appliances, shoes, clothing, machine tools, telecommunications, computers, paper, pharamacauticals and basic chemicals. All are threatened by cheaper imports. Seventy percent of the goods produced in the U.S. face competition from imported goods.

There are about 300 protectionists bills in Congress right now.

Is that what we really want?

Once again, the answer is yes and no.

It is one thing to run a competitive race when everybody starts from the same line. It is quite another to run a race when one competitor is starting a mile behind the line. When we happen to be that competitor, it is discouraging, to say the least.

It would be nice if all the countries of the world had the same commitment to free enterprise and open trade that we say we do. But they don't. Some societies are closed, economically and every other way. Others are modestly open but are tightly regulated. Others pour forth a great deal of *free trade* and *open trade rhetoric*, which only serves to mask their real trade policy. And some of those who engage in such rhetoric *do not* have a trade policy at all. Their initials are U.S.

In the real world, there are unfair trade practices in the United States and everywhere else. Unfair in the eye of the competitor. There are protected markets. There are hidden trade barriers. There are subsidized industries. There are long range government plans. There are short term responses to imbalances. They are thoroughly and completely woven into the political and economic makeup of each country. They have been there a long time. They are neither self-correcting nor do they respond to quickly short-term solutions.

Take the value of the dollar. How long will it take to bring the U.S. deficit under control or bring *real* interest rates down and ultimately bring the U.S. dollar back to better parity with foreign currencies?

Can we ever expect to get average union wages in the U.S. *down* to the level paid in the Far East? Or, on the other hand, will they *raise* their wages to parity with U.S. union members?

It is said that the Japanese desire to save borders on the fanatic while the Americans are conspicuous consumers. Can that be turned around?

How long will it be before the Japanese buy American? They cannot find many American goods in their stores due to import restrictions, but the further problem is they often don't like what they do find. Can that be overcome?

The answer to all of these is a conditional yes, but it will take years and years of effort.

So what happens to the industries I mentioned a moment ago in the meantime? How long can the fertilizer industry wait for the end of the two-tiered energy pricing schemes of Mexico, the Soviet Union and other competitors?

Who is going to see that the farmers, the steel workers, textiles workers, shoemakers and others who are threatened by foreign competition survive the short run in order to take advantage of the long-term solutions?

It *is* certain that time will eventually provide solutions to these questions, *if* we permit economic forces to operate for long enough. But will we and will other countries permit those economic forces to operate long enough?

The record is not very promising. Can we resist the people pressures? I am talking about the pressure of people out of work and the pressure of people who are under employed because of the vast economic shifts which are not underway.

In the short run, I think the answer is no to all of these. *I think we must seek short term solutions to survive* and *to head off massive and unthinking protectionism.*

To dwell on long term solutions without considering short term ramifications is like a physician planning reconstructive surgery on an accident victim without giving any attention to stabilizing his immediate condition.

It is apparent that the mood in Washington favors protectionism. Some protectionist legislation will find its way to President Reagan's desk. I would hope that it will be adopted by Congress *only* after full examination of both sides of each specific application. I am further hopeful that this will at least point the way toward a trade policy which will put business and government on the same track, going the same direction, for the first time in our history.

In my opinion, any protectionist measures which may be adopted should be limited in duration, and should have a Sunset clause in them. I know that temporary legislation has a way of becoming permanent, so we must be very careful to seek short-term solutions which will help some of our basic industries survive, but head off massive and unrestrained protectionism which will create a false security for the protected industries.

Parallel to the short term solutions, it is absolutely vital to our industrial future that business and government hammer out a trade and economic policy which will lead us out of the mess we are in and keep us from ever getting back into it.

The U.S. cannot do this alone. But we are still the largest exporting nation in the world; we are the most efficient producer of food; we still are the leader in high tech development; we are the largest single market for consumer and industrial goods, and the richest in terms of land, willing labor and capital. With all these assets, there is no reason why we cannot overcome our domestic and international problems in trade with clear thinking and pragmatic and fair actions. We need a national trade policy. Japan has one, the European Community has one, Russia has one and their government and industry are on the same track.

Five years ago, economists around the world were blaming the United States for not controlling inflation. Look at it now. It is running between four and five percent per year.

We were blamed for letting interest rates get out of hand when they went above 20 percent. Look at it now. When was the last time you saw a headline about the prime rate? It's below 10 percent—out of the news.

Many around the world thought we could not control inflation or interest rates, yet we have.

We can get a handle on our trade problems, too, and solve them just like we have the interest and inflation problems.

I will close with a story which makes the point.

A poor farmer was struck by pestilence and drought. He was down to his last hand full of beans with which to feed his wife and child. All he had left in the world was an old grey mule. To survive, he must sell it.

So they set out for the village market. Walking along the road, he passed a neighbor who laughed at him for not riding his perfectly good mule. So, he got on. A short ways further, an early "women's libber" criticized him for making his wife walk while he rode the mule. So, he helped her aboard. Moments later he was criticized for making his child walk, so he helped the child aboard.

Just down the road he encountered a member of the Society for the Prevention of Cruelty to Animals who berated him for overloading his mule in the heat of the day. Exasperated, he got off his mule, cut down a long slim sapling, lashed the mule's legs together and strung it up on the sapling so he and his wife could carry it the rest of the way to town. (It was a very small mule.)

As they descended from the mountains, they came upon a swift mountain stream. The only crossing was a slippery log. Half way across, they lost their footing. The mule fell in the water and, since its feet were tied together, it drowned.

There is a moral to the story: If you try to please everyone you will surely lose your—jackass.

That's the message we in agriculture and every other American industry must deliver to policymakers every time they show signs of weakening their resolve to hold to our national priorities.

Thank you for letting me spend a few minutes with you this morning. I wish you well as you address your industries future.

Outlook for Nitrogen

Edwin A. Harre
National Fertilizer Development Center
Tennessee Valley Authority

You have already heard most of the reasons for the gloomy outlook in agriculture and in the fertilizer industry. And you will probably hear a few more things to worry about before this meeting ends. I can't tell you this morning that there's nothing to be concerned about, that you can look forward to business as usual, and that you should expect another increase in sales. That would be easy. But with the rapidly changing economic situation around the world, forecasting is best defined as intelligent guessing. Even then, there's a question of how much intelligence is involved.

My subject this morning is the nitrogen outlook. Normally, I'd begin by saying that demand has been increasing steadily, and that this trend will continue. I'd then talk about supply. But I can no longer do that because demand, not supply, is governing today's fertilizer supply-demand analysis. So I will look first at product trends and potential supply levels then follow those with some demand forecasts based on alternative farm programs.

CONSUMPTION OF NITROGEN MATERIALS

U.S. nitrogen consumption reached a peak in 1981 of 11.9 million tons N. Then it dropped in 1982 and 1983 and leveled off at about 11 million tons N. While the overall market has stabilized, significant changes have occurred in the market share of the major nitrogen materials entering the domestic market.

Use of ammonia for direct application has been consistent for the past 15 years and has accounted for 35 to 40 percent of total nitrogen use (figure 1). Ammonia remains the least expensive form of nitrogen. Farmers with suitable crop and soil conditions will continue to use it. We don't expect ammonia's market share to change except as weather and crop conditions dictate.

Nitrogen solutions are the second leading nitrogen source. They continue to increase in market share and already account for 21 percent of total nitrogen use. Urea ranks third with 11 percent of the market. The increased popularity of these products has been at the expense of other solid materials, particularly ammonium nitrate. These materials represent only 10 percent of the nitrogen market, limiting the potential for further substitution by UAN or urea.

Whether to use solid urea or nitrogen solutions is one of the choices that the market will be making. The choice will affect both our foreign trade and efforts by nitrogen producers to market their products.

NITROGEN PRODUCTION CAPACITY

Changes in production capacity tell us little about the future market share of UAN or urea. After 1986 no new UAN capacity additions are scheduled in North America, and only a small addition to urea capacity has been announced in Canada for 1988 (figure 2).

Although North American ammonia production capacity will increase 7 percent—from 22 million tons to 23.6 million tons during the next three years, total capacity will remain almost 1 million tons below the 1977 peak (figure 3). No plans have been announced for building downstream facilities to handle this extra ammonia. Producers could close plants, replace some of the ammonia being imported, or expand exports. The latter, however, could be limited by the lack of product conversion facilities.

U.S. NITROGEN SUPPLY

Let's now look at supply prospects for 1986. Three factors determine the U.S. short-term supply: inventory change, trade, and use of existing capacity. Each will significantly affect the market during the next few months.

Inventory

At the end of the 1983 season U.S. producers reported nitrogen inventory at almost 20 percent of annual production—the highest in 10 years (figure 4). With nitrogen's demand recovery in the aftermath of PIK-induced reductions, producers brought nitrogen stocks down to only 11 percent of annual production—the lowest level since 1977. There is little margin. So there should be some rebuilding of nitrogen stocks during the next few months. The net effect is that inventory will be a negative factor in the 1986 supply equation.

Foreign Trade

Nitrogen imports set a record in 1984, and the U.S. trade deficit reached a high of almost 2 million tons of nitrogen—18 percent of domestic demand. Last year, however, with increased production and a booming export market for diammonium phosphate which, incidentally, is our largest contributor to nitrogen exports, the U.S. lowered its nitrogen trade deficit to under 500,000 tons or only 4 percent of total nitrogen use (figure 5).

I won't try to analyze the phosphate market but in my opinion phosphate exports this year won't equal those of last year. Since this is critical to the Nation's nitrogen trade balance, a decline in nitrogen exports in 1986 is indicated. Reduced nitrogen export lowers total nitrogen requirements which, in turn, reduces import levels. As a result, the Nation's nitrogen trade deficit will remain at about 500,000 tons.

Capacity Utilization

Nowhere is the cyclical nature of the fertilizer market more pronounced than in the annual operating rates of nitrogen producers. Low points of 75 to 80 percent of capacity were recorded in 1977 and 1983 while rates of more than 90 percent were achieved in 1974, 1981, and this year (figure 6). Ammonia capacity in the U.S. is being fully used and little if any increase in production should be expected in 1986.

In summary, the nitrogen supply won't increase from further inventory reductions or increased production. Foreign trade won't be a factor because imports will be determined primarily by export levels. The contribution to nitrogen fertilizer supply from each of these factors and a forecast for 1986 is shown in table 1. In other years a forecast indicating limited nitrogen supply would have sent a shock wave through the marketplace. This year, however, adequate nitrogen supplies will be available. That assumes absence of a natural or manmade catastrophe such as an overreaction to current market conditions by producers.

NITROGEN DEMAND

As I said at the beginning, demand, not supply, will determine the nitrogen supply-demand situation. Total U.S. nitrogen demand consists of two parts: the nonfertilizer or industrial market and the larger and dominant fertilizer market.

Nonfertilizer Use

Nonfertilizer use of nitrogen is estimated to be 25 to 30 percent of total nitrogen demand. This market includes industrial ammonia, nitric acid, ammonium nitrate explosives, nonfertilizer urea, and industrial fibers. In 1980 those uses exceeded 4.1 million tons of ammonia equivalent. But since the U.S. economy began to weaken, there has been a steady decline in demand (figure 7). The economic recovery of the past year is reflected in an increase in nonfertilizer nitrogen use, but total demand remains well below the 1980 peak. Although some increase in demand is expected, the expansion will be small. High nitrogen prices have forced consumers to conserve or develop substitutes.

Fertilizer Demand

After reaching a peak in 1981 of 11.9 million tons, and diving to an 8-year low of 9.2 million tons in 1983, U.S. nitrogen consumption has been about 11 million tons for the past two seasons. In the meantime, the USDA crop production index has come very close to the records set in 1981 and 1982. This is an accomplishment to be proud of except that during this 5-year period farmers have seen a steady decline in total demand for their crop. And once again as this year's harvest season ends, crop inventories are almost up to the levels that forced USDA to adopt production controls in 1983. Overcapacity exists in U.S. agriculture. This must be accepted by those concerned with the farmer's welfare and by the industries that serve agriculture.

The surplus situation in agriculture can be illustrated by a comparison of inventory-utilization ratios during the past 10 years. Estimates for the 1985 corn crop indicate a stock to utilization ratio of 38 percent—almost twice the average of the past ten years and only 5 points below the record level before the PIK program announcement in 1983. Nearly half of the Nation's nitrogen fertilizer is used on this one crop.

Wheat accounts for 17 percent of the total nitrogen use, but the possibility of greater production is offset by a stock-utilization level that is 50 percent above the 10-year average. The same situation exists for cotton which will end the year with a ratio double its 10-year average. These three crops account for 7.6 million tons of the Nation's 11.1-million-ton nitrogen market. This clearly indicates that any attempt to control agricultural production will greatly affect nitrogen consumption.

We should also realize that the value of farm output determines the value of inputs used. This is a simple statement, but it must be considered if an attempt is made to raise input prices when prices of farm production are declining. An example is the decline in farmland values which reflects the more than 25 percent decline in corn prices since 1980. Weak corn prices are also being reflected in weak nitrogen fertilizer prices of the past year.

As I write this, farm legislation is before Congress. There is little to indicate that it will be a sweeping reform or a new solution to the farmer's problems. The solution is to expand markets, but this will take time. But farmers don't have time because they must continue to pay their bills.

Increased farm exports have been suggested as the key to solving the oversupply problems of American agriculture. Since 1980, the U.S. share of the world's commodity markets has steadily eroded. In some cases, countries which only a few years ago were large food importers with dismal prospects of ever achieving food self-sufficiency are competing with us. Our political actions and domestic farm programs have been partly responsible for production increases in other countries. However, a worldwide agricultural research and development effort started in the 1960's is also beginning to produce results. Since 1982, for example, wheat production in the major importing countries is up 8 percent and per capita protein production in areas other than the United States has increased 9 percent. No matter how much we would like to increase farm exports, the process will be long and slow.

DEMAND FORECASTING

In this uncertain time, meaningful forecasts are difficult. We can only suggest possible paths the market may take in the next few years. Table 2 indicates two nitrogen demand forecasts based on (1) a farm program adjusting crop production to bring stock-utilization ratios back to their 10-year average by 1988, or (2) a farm program that will not affect crop production in 1986, forcing the USDA to institute production controls in 1987 to bring stock-utilization ratios back into balance in one year.

Total crop utilization is forecast to increase at an annual rate of 2.8 percent for corn and 4.8 percent for wheat, reflecting a return by 1990 of export levels to their 1980 peaks. With these assumptions plus slight yield increases and no change in nitrogen application rates, the acreage needed and total nitrogen use were calculated. As indicated, by 1990, U.S. nitrogen consumption will have changed very little from the 11.1 million tons used in 1984.

The path to the 1990 level is the problem facing the fertilizer industry. Alternative 1 indicates that there will be decreases in nitrogen use in 1986 and 1987 before beginning to climb back to the 11-million-ton mark. In alternative 2, however, nitrogen use in 1986 remains very close to current levels but plummets by almost 2 million tons in 1987, equaling the market disaster of 1983 (figure 8).

This is not a bright forecast, but these are not the best of times. Perhaps the market downturn can be softened if we take a realistic view of the current situation and we don't gamble on a poor crop year, either here or in some other part of the world to solve the oversupply problem. Otherwise, these may turn out to be optimistic forecasts of what's ahead for the industry.

THE SUPPLY-DEMAND OUTLOOK

Regardless of the forecasts, the fertilizer market will be changing. Everyone will be forced to revise their expectations and reduce costs and increase efficiency. Based on the forecasts, several changes must occur in the North American market.

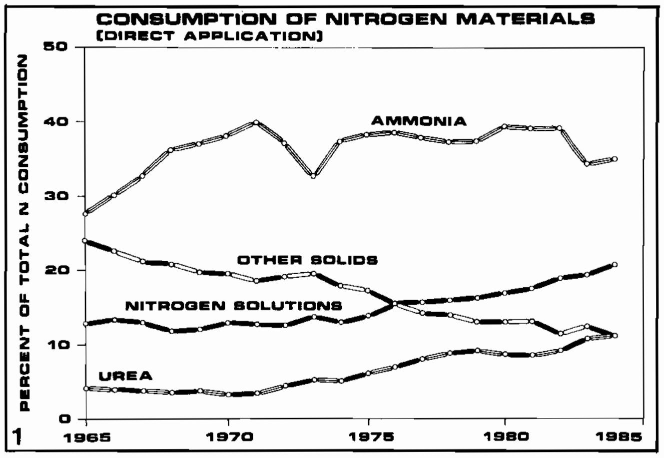
First, with reduced demand and continued capacity utilization of about 90 percent, the U.S. will return to self-sufficiency in nitrogen until 1988 (figure 9). This implies a continued reduction or elimination of our current trade deficit. If the trade deficit continues, capacity utilization reductions or plant closures will be forthcoming.

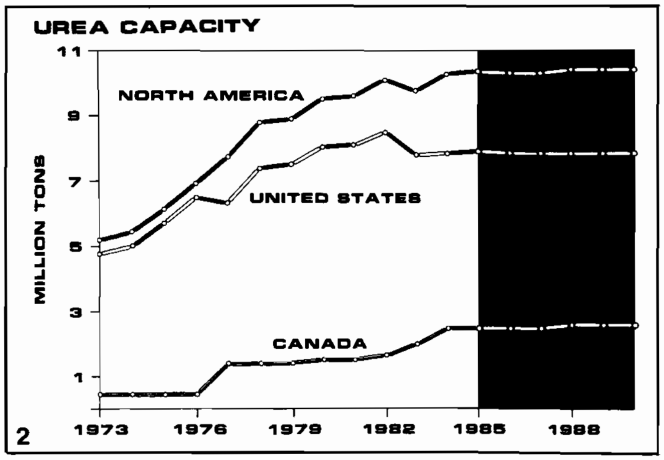
Second, the role of Canadian producers in the U.S. market will be increasing as capacity expansions are completed. In total, there will be about 10 percent overcapacity in North America, again reducing imports from other areas and raising the possibility of the region becoming a significant net exporter of nitrogen.

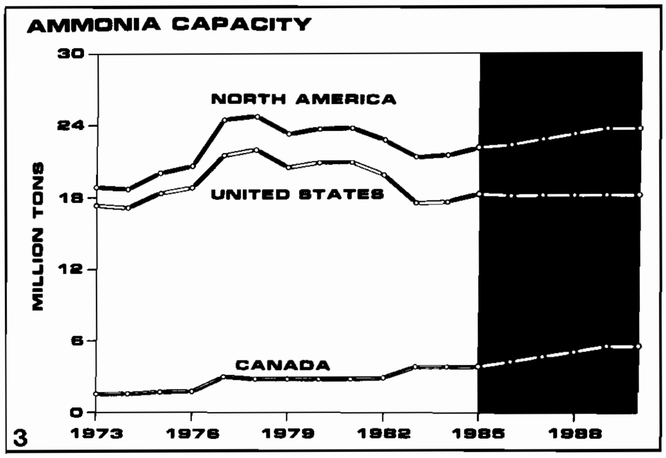
SUMMARY

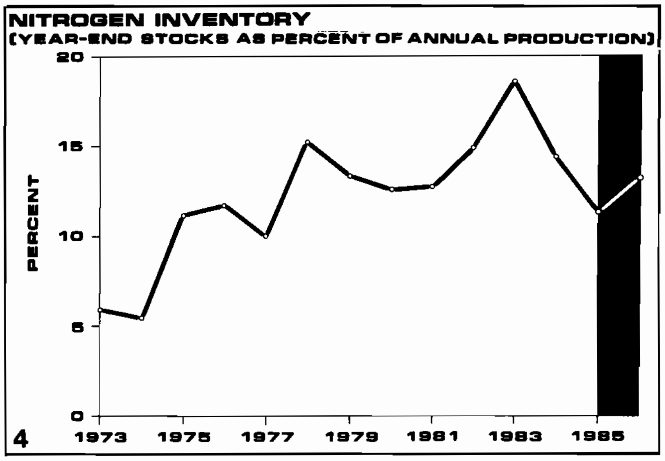
The nitrogen market in the U.S. and Canada is undergoing rapid change that will continue through the 1980's. Agriculture is facing a severe overcapacity crisis that will force nitrogen fertilizer demand downward until commodity markets begin to improve. The question facing the industry is whether there will be moderate change from year to year or a shock similar to the PIK market of 1983.

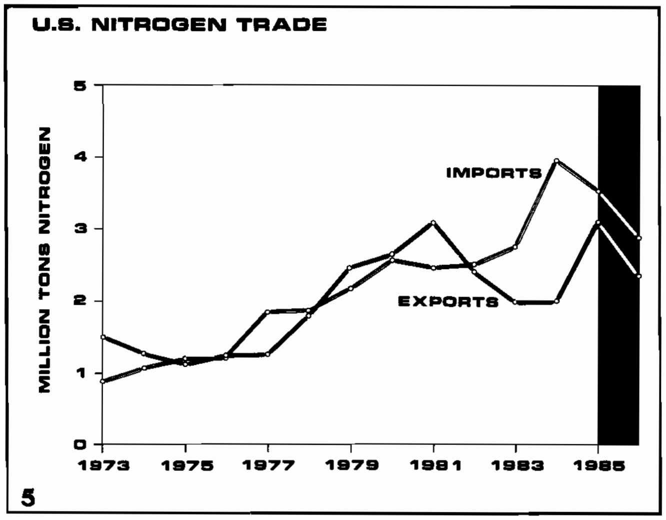
Without demand increases, nitrogen supply will be adequate to meet farmer needs. Rapid changes in trade levels, sources of supply, and domestic capacity utilization will be common in the industry as it reacts to the changing market situation. The market of the next few years will be a prime example of commodity marketing with supply, demand, and prices responding to international market developments both in agriculture and the fertilizer industry.










U.S. NITROGEN TRADE

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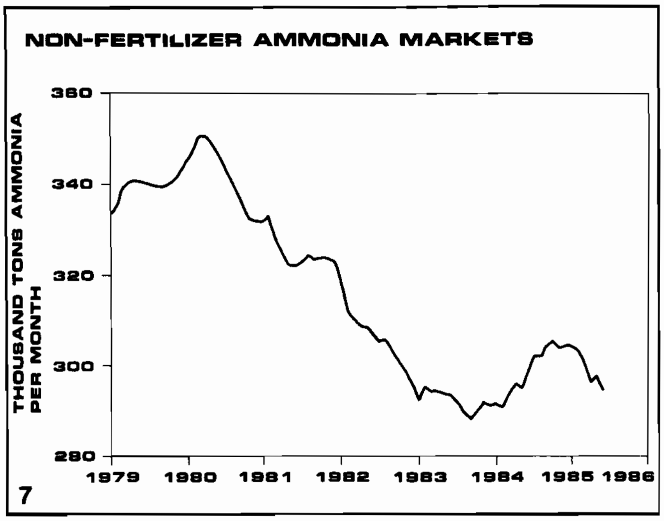
NON-FERTILIZER AMMONIA MARKETS

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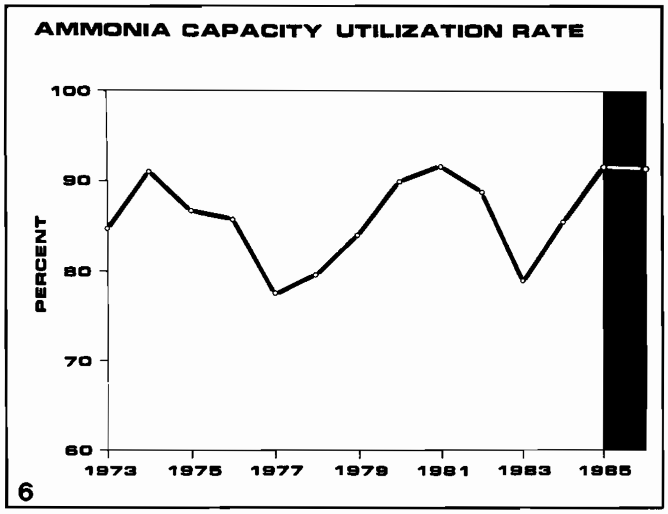
AMMONIA CAPACITY UTILIZATION RATE

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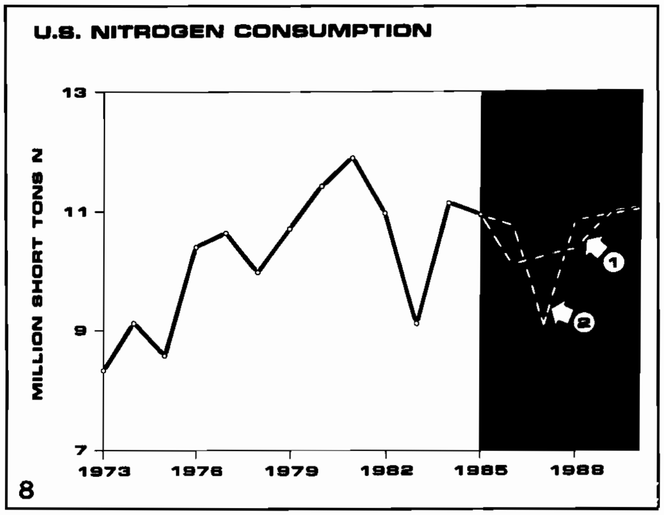

U.S. NITROGEN CONSUMPTION

8

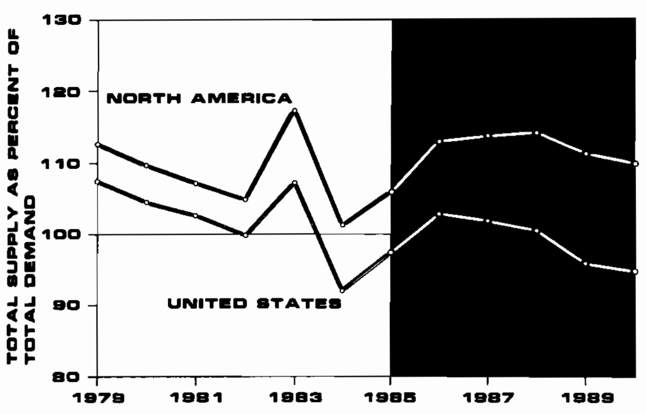
Table 1. U.S. NITROGEN FERTILIZER SUPPLY

Item	1979	1980	1981	1982	1983	1984	1985	1986
			(Thousand Short Tons of Ammonia)					
Beginning inventory	2,662	2,295	2,362	2,441	2,618	2,562	2,135	1,868
Ammonia	1,671	1,470	1,422	1,354	1,589	1,492	1,349	1,057
Nitrogen products	812	676	771	891	844	877	644	665
Ammonia production	17,220	18,839	19,235	17,667	13,811	15,052	16,689	16,500
Exports	3,019	3,036	3,619	2,923	2,409	2,420	3,788	2,840
Ammonia	554	776	816	758	426	390	998	400
Nitrogen products (N)	2,020	1,853	2,298	1,774	1,625	1,664	2,287	2,000
Imports	2,639	3,136	2,968	3,060	3,353	4,827	4,297	3,520
Ammonia	1,735	2,219	2,161	2,244	2,144	3,259	2,792	2,300
Nitrogen products (N)	741	752	661	669	991	1,285	1,234	1,000
Net trade balance	(380)	101	(652)	138	944	2,407	509	680
Ending inventory	2,295	2,362	2,441	2,618	2,562	2,135	1,871	2,176
Ammonia	1,470	1,422	1,354	1,589	1,492	1,349	921	1,200
Nitrogen products (N)	676	771	891	844	877	644	779	800
Total ammonia supply	17,206	18,872	18,504	17,627	14,811	17,886	17,462	16,872
Non-fertilizer use	4,081	4,127	3,872	3,663	3,499	3,625	3,502	3,500
Fertilizer supply	13,125	14,745	14,632	13,963	11,313	14,261	13,960	13,372
Fertilizer supply (N)	10,763	12,091	11,998	11,450	9,276	11,694	11,447	10,965
Fertilizer use (USDA)	10,742	11,407	11,924	11,709	9,195	11,146	10,950	10,400
Supply/use index	100	106	101	98	101	105	105	105

Table 2. U.S. CROP ACREAGE, UTILIZATION, AND NITROGEN CONSUMPTION FORECASTS

	Planted Acreage			Total Utilization			Nitrogen Consumption				
Year	Corn	Wheat	Cotton	Corn	Wheat	Cotton	Corn	Wheat	Cotton	All Other	Total
	(Thousand Acres)			*(Mil Bu)*	*(Mil Bu)*	*(Mil Bales)*	*(Thousand Tons N)*				
1973	72,300	59,300	12,400	5,896	1,971	13.5	3,832	919	335	3,209	8,295
1974	77,900	71,000	13,600	5,126	1,690	9.7	3,739	1,101	415	3,903	9,157
1975	78,700	74,900	9,400	5,804	1,894	10.4	3,896	1,086	235	3,384	8,601
1976	84,600	80,400	11,600	5,806	1,704	11.4	5,203	1,447	354	3,408	10,412
1977	84,300	75,400	13,600	6,283	1,983	11.9	5,184	1,282	408	3,773	10,647
1978	81,700	66,000	13,300	7,076	2,031	12.4	4,861	1,056	333	3,715	9,965
1979	81,400	71,400	13,900	7,616	2,158	15.6	5,291	1,285	348	3,791	10,715
1980	84,000	80,800	14,500	7,223	2,297	11.7	5,208	1,576	370	4,255	11,408
1981	84,100	88,300	14,300	6,980	2,618	11.8	5,551	1,766	379	4,228	11,924
1982	81,900	86,200	11,300	7,290	2,417	10.7	5,160	1,724	328	3,772	10,983
1983	60,200	76,400	7,900	6,574	2,540	12.7	3,973	1,643	209	3,302	9,127
1984	80,400	79,200	11,100	7,065	2,579	11.7	5,387	1,861	344	3,554	11,146
1985	83,200	75,800	10,700	7,070	2,260	9.4	5,574	1,706	332	3,338	10,950
					Alternative One						
1986	72,059	69,591	6,955	7,280	2,380	9.4	4,828	1,566	209	3,500	10,102
1987	73,574	71,784	6,790	7,485	2,500	9.4	4,929	1,615	204	3,500	10,248
1988	74,770	73,688	6,288	7,690	2,620	9.4	5,010	1,658	189	3,500	10,356
1989	80,765	80,328	7,735	7,895	2,740	9.4	5,411	1,807	232	3,500	10,951
1990	82,124	81,734	7,614	8,100	2,860	9.4	5,502	1,839	228	3,500	11,070
					Alternative Two						
1986	80,431	73,289	7,767	7,280	2,380	9.4	5,389	1,649	233	3,500	10,771
1987	60,625	62,887	4,394	7,485	2,500	9.4	4,062	1,415	132	3,500	9,109
1988	79,381	78,849	7,860	7,690	2,620	9.4	5,319	1,774	236	3,500	10,828
1989	80,765	80,328	7,735	7,895	2,740	9.4	5,411	1,807	232	3,500	10,951
1990	82,124	81,734	7,164	8,100	2,860	9.4	5,502	1,839	228	3,500	11,070

SUPPLY-DEMAND OUTLOOK



9

Phosphates Outlook

James A. Beck
Director, Administration and Planning
IMC Corporation

I would like to thank the organizers of the Fertilizer Roundtable for giving me the opportunity to present our view of the outlook for phosphates.

These are not good times for U.S. phosphate producers. Despite record phosphate chemical shipments last year, prices were depressed. At least two producers have declared bankruptcy. Other producers of chemicals and rock have decided to get out of the business and have placed their assets on the block.

With the depressed condition of the market, it is not easy to see a turnaround soon. Most forecasters are projecting a slow recovery of domestic demand and a decline in near-term exports following a record volume in 84/85.

This morning I'd like to review with you some recent developments in the phosphate market, cover 85/86, and the longer-term outlook to 1990. I also will discuss some reasons why our outlook could be wrong.

U.S. Industry Review

Let's look at P_2O_5 consumption in the United States.

We believe consumption fell by about 3% despite an increase in corn acreage (Exhibit 1). Given the economic condition of U.S. agriculture, this was not a bad performance. Consumption is well ahead of the depressed levels of 82/83, the year of PIK, but we are below the consumption levels of the early 1980s.

If we look at total shipments by U.S. producers of all phosphate chemical fertilizer products, we find that 84/85 was a record year and, the third consecutive year of increased volume (Exhibit 2). Total shipments increased by nearly 1 million tons over 83/84. This increase was based upon the 33% gain in exports.

For the first time, shipments to the export market exceeded shipments to the domestic market. Despite a 10% increase in volume, market conditions deteriorated throughout the year.

DAP has been of overwhelming importance to the phosphate business in the United States (Exhibit 3). Since 1981, essentially all of the increase in phosphate chemical shipments to domestic and export markets has been DAP. Tonnage of other products has fluctuated slightly, but over the period have remained essentially unchanged.

Who are the major buyers of our DAP?

Two countries dominated in 84/85—China and India (Exhibit 4). Roughly 43 percent of U.S. DAP exports last year went to these two countries. All tonnages indicated do include tran-shipments through other countries. This most commonly takes the form of bulk product shipped to a bagging location, reloaded and shipped to the country of final destination.

One of the bright spots in the world market for phosphate chemicals has been China. Over the last five years, U.S. exports of DAP to China have increased from a quarter million tons in 80/81 to 2.5 million tons in 84/85—a 10-fold increase.

Let's turn now to phosphate rock and examine the volumes to the domestic and export market over the past five years.

Exports of Florida, North Carolina phosphate rock have fluctuated around 11 to 12 million tons in recent years (Exhibit 5). Shipments of phosphate rock to domestic phosphate chemicals producers have been increasing since the low point of 1982. Most of this phosphate rock gain has been for processing into DAP and other phosphate chemical fertilizer materials for the export market.

In summary, the domestic market for phosphate fertilizers has been down to flat, but the export market has been strong and growing. Phosphate rock exports have been flat, but the market for domestic conversion into chemical fertilizers has been strong and increasing.

Economic Condition—U.S. Agriculture

I'd now like to turn our attention to some of the economic factors in the United States that have impacted and will continue to impact the farmer, his purchase of fertilizers, and the U.S. fertilizer industry in general. With all the attention that has been given to the plight of the American grain farmer, you may feel that you have heard enough. But let's look at some visuals that illustrate conditions that actually confront our agricultural businesses. There are a few facts that may surprise you.

Realized net farm income has fluctuated up and down . . . but mostly down in recent years.

The real condition of agriculture has been illustrated dramatically by the market for farmland (Exhibit 6). The average price of farmland in Iowa peaked in 1981 at around $2,000 per acre.

Since then, the market value of Iowa farmland has dropped nearly 50% to just over $1,000 per acre. This erosion of the asset base of farmers has been the primary cause of the much discussed credit crisis. Even though farm debt has stabilized in recent years, the key ratio of debt to assets has deteriorated for many farmers because of this drop in the value of their primary asset—their land.

We have attempted to estimate the total debt carrying capacity of U.S. farmers. We feel that the turn came in 1980. Since that time, the debt capacity of U.S. farmers has been declining. But it was only in 1982 that total debt started to exceed the farmers' capacity to service this debt.

Despite the resulting loss of borrowing power, in an industry that lives on short-term credit, the majority of grain farmers in the U.S. are not highly leveraged. The point to be made is that the so-called plight involves relatively few farmers.

Grain Prices, Stocks, Exports

This 10-year history of corn prices illustrates the tremendous fluctuations in price year-to-year and within each year (Exhibit 7).

This same point can be made for wheat and for soybeans.

I think it is logical to conclude that the fluctuation in commodity prices has had an unstabling effect on the fertilizer market.

With the harvest that's anticipated this fall, grain surpluses will have climbed to a level that's guaranteed to keep downward pressure on prices (Exhibit 8). U.S. corn stocks have not yet reached the level preceding the year of PIK, but they are far above the optimal range for market stability.

One indicator of the severity of the problem facing U.S. grain producers is the seven year decline in the U.S. share of world trade in feed grains (Exhibit 9). The same phenomenon applies to wheat and soybeans.

Many factors are responsible for this decline. Certainly the strength of the U.S. dollar has been a deterrent to U.S. exports. But production also has been increasing in overseas countries that were traditional importers of our grains. And production has increased in overseas countries which compete with us in the world market.

Ag Policy

Also contributing to the problem has been our government's agricultural policy.

Government subsidies assure participating farmers a level of compensation substantially higher than market prices. All this sounds like a spiral that generates its own momentum as it plunges downward and it is. Subsidies make farmers less competitive. Because they are less competitive, they lose markets. Loss of markets increases surpluses. Increased surpluses force prices down. Declining prices create greater dependence on subsidies. On and on it goes.

The sensible answer is a gradual phase-down of subsidies until the market communicates to our farmers how much it's prepared to take and how much it's prepared to pay.

The Senate and House now are considering legislation for the 1985 Agricultural Bill. We can only hope that the final bill will move us toward a policy that permits crop production in the United States to respond to market demand.

1985/86 Outlook

Let's look ahead now to the 1985/86 fertilizer year.

We have assumed that programs will be in place that will permit the Department of Agriculture to implement acreage reduction programs that will more or less balance supply with expected demand. We anticipate a 20% voluntary acreage reduction program for corn and a 30% acreage reduction for wheat. This more or less coincides with Ed Hare's soft landing scenario. We would expect a 10% reduction in wheat acreage. Over all, planted crop acreage in 1986 will be down 5%.

While this is a significant decline, it is a far less severe drop in crop acreage than experienced in 1983, the year of PIK. On the other hand, we will continue to be below the peak acreage planted in 1980.

So, the acreage situation in 1986 is definitely a negative for fertilizer consumption.

With target prices frozen above $3.00 per bushel for corn, participation in the program in 1986 should be very high. A positive cash flow is virtually guaranteed for those corn growers in the program. However, because of the combination of a weak agricultural economy and a reduction in acreage of principal crops, we have projected a decrease in phosphate consumption of 6% for 1985/86.

Last year, producer inventories of DAP and triple superphosphate were below average most of the year. Despite slow movement so far this year, producer inventories have remained near average as a number of phosphoric acid plants were shut down or running at reduced rates (Exhibit 10).

Let's examine the seasonality of producer shipments that can be expected in 85/86. After adjusting the forecast for expected changes in dealer inventory, we are forecasting a 2% decline in deliveries of P_2O_5 products to the domestic market. We expect the fall, or July/December period, to be down by 5%. However, the January/June period should see shipments to the domestic market up by 4% over last year.

In other words, we're looking for a weak fall and a relatively strong spring market.

Phosphate rock inventories of producers fell below average last year but increased to above average levels in the last quarter. Since June, rock inventories have remained virtually unchanged (Exhibit 11). Producers have reduced production to meet reduced shipping levels.

Phosphate Trends

Let's take a look at longer term expectations for phosphates.

I'd like to start by examining the longer-term trend lines in nutrient application rates per acre on corn (Exhibit 12). These are not actual data but rather trend lines fitted to actual data for the period 1964 to 1984. There can be no question that application rates of nitrogen and potash have grown much more rapidly than phosphate over the past 20 years. Twenty years ago, phosphate application rates were quite high, relative to nitrogen and potash.

Let's look at a different set of historical phosphate data.

The numbers charted were developed by John Douglas of TVA and updated with my estimates for 84/85 (Exhibit 13). During the 1960s and the early 1970s, application of phosphate to all crops in the United States exceeded removal of that basic nutrient. However, in recent years, the reverse has been true. Removal of P_2O_5 from the soil by growing crops has exceeded application rates in 7 of the last 8 years.

In 1985, record crop production removed more than one million tons of P_2O_5 in excess of the tonnage applied. Has phosphate become the forgotten fertilizer nutrient? How long can we continue to remove a million tons of P_2O_5 from our soils each year without negatively affecting yields or crop production economics?

Summary maps were published in the Spring 1985 issue of "Better Crops" by the Phosphate and Potash Institute showing the approximate percentage of soils analyzing medium or less in phosphorus.

"Medium" was selected as an arbitrary breakpoint realizing that interpretation varies among crops, soils and states.

A relatively high percentage of soils west of and along the Mississippi River as well as in the South tested medium or less in P.

It is generally recognized that, as we strive for high yields, soils should test in the high range for P *and* K. Crop production entails considerable risk because of such factors as economics, floods, droughts and pests. Soil fertility is easily controlled and having the soil test level high in P and K helps reduce the risk of fertility limiting yields and profits.

Outlook to 1990

Our analysis suggests that government programs to moderate planted acreage will be necessary for several years. Without programs to restrain acreage, we have the proven capacity to over-produce for the available market.

Our forecasts indicate that by around 1990, to meet projected demand, crop acreage will return close to historical highs. However, during this adjustment period, constraints on planted acreage will limit growth potential in phosphate consumption in the United States.

Following a decline in consumption in 85/86, we expect slow but steady growth throughout the balance of the decade in phosphate consumption (Exhibit 14). By 1990, consumption should exceed the five-million-ton level. However, this still will be below consumption levels of the early 1980s.

If we compare projected consumption of fertilizer nutrients in the United States with the rest of the world, there is no question where the growth potential lies. Of a forecast increase in world consumption of 26 million tons, less than 10% of the growth is expected in the United States. Over 90% of projected world growth in fertilizer nutrient consumption to 1990 will occur outside of the United States (Exhibit 15).

Based upon the analysis we have just seen, it becomes clear that the growth potential in phosphates for U.S. producers lies primarily in the export market. Deliveries to the domestic market will be increasing; however, shipments to the export market will be increasing more.

In the mid-1970s and again in the early 1980s we saw cyclical periods of tight supply in the phosphate chemical fertilizer business in the United States. Based on our analysis, it is unlikely that another tight supply demand period will occur during the next five years (Exhibit 16).

If the supply/demand situation does tighten more than we forecast, it most likely will be because production potential declines. This is, in fact, likely if present market conditions continue.

What can be expected in deliveries of phosphate rock by Florida and North Carolina producers?

If we examine the status of construction of foreign phosphoric acid capacity, we find that essentially all projects are being built near phosphate rock mines. This means that there is very limited potential for growth in phosphate rock trade. Nearly all growth in phosphate imports will be in the form of upgraded phosphate rock, that is, as phosphoric acid, ammonium phosphates, triple superphosphate or related products. This statement holds true for both developed and developing countries overseas.

Expected growth in demand for Florida, North Carolina rock will be in the domestic market for upgrading into concentrated phosphate fertilizer materials for the domestic and, primarily, the export market (Exhibit 17).

Around 1990, mine-out of a number of reserves in Florida can be expected. While operating rates of the industry are quite low today, during the next five years we will see increasing shipments and decreasing ability to produce. By the end of this period, a phosphate rock supply/demand situation will tighten significantly (Exhibit 18).

There is no question that market economics today do not justify new investment in grass roots/phosphate rock mining facilities. The postponement or cancellation of plans to construct new capacity in recent years supports this conclusion.

Summary

In conclusion, the phosphate market is depressed today..This is true for both phosphate chemicals and phosphate rock. We see nothing on the horizon that will quickly change this prospective.

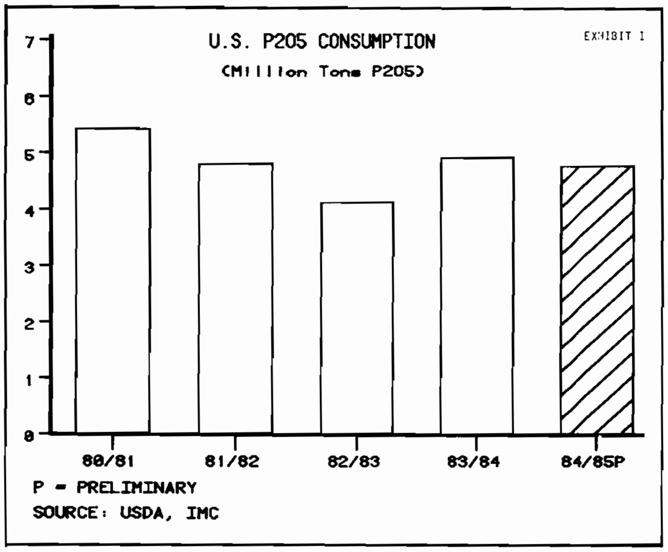
However, past experience tells us that when nearly everybody holds the same point of view, the contrary opinion generally prevails.

For example, with just two years of no growth in world grains production, we would be in a shortage situation.

If all U.S. phosphoric acid producers who are losing money were to close their plants, phosphate chemicals supply would become inadequate to meet projected demand.

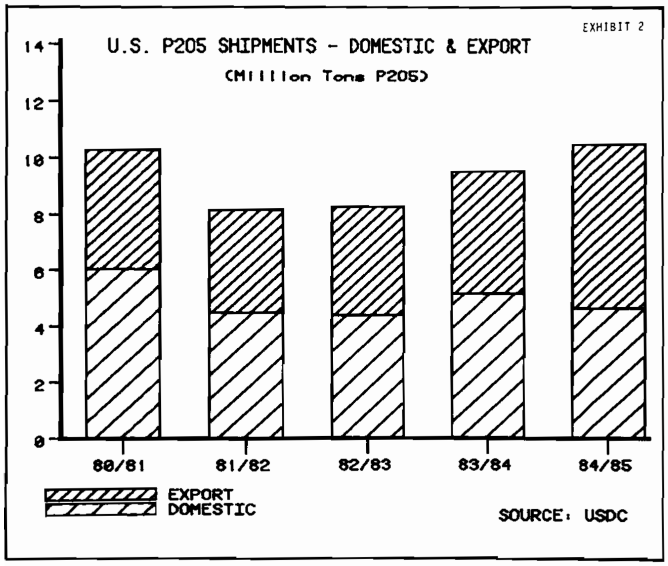
If supplies from North Africa were to be interrupted, there would be an immediate world phosphate shortage. If demand for U.S. P_2O_5 were to grow at a 5% per year rate, we would be sold out by 1988.

While any of these events are possible, they are not forecast. Therefore, our forecast parallels that of most industry observers. Phosphate rock and phosphate chemical supplies are expected to be more than adequate in the short-term and adequate for the next five years. But then, there is the principal of "the contrary opinion."

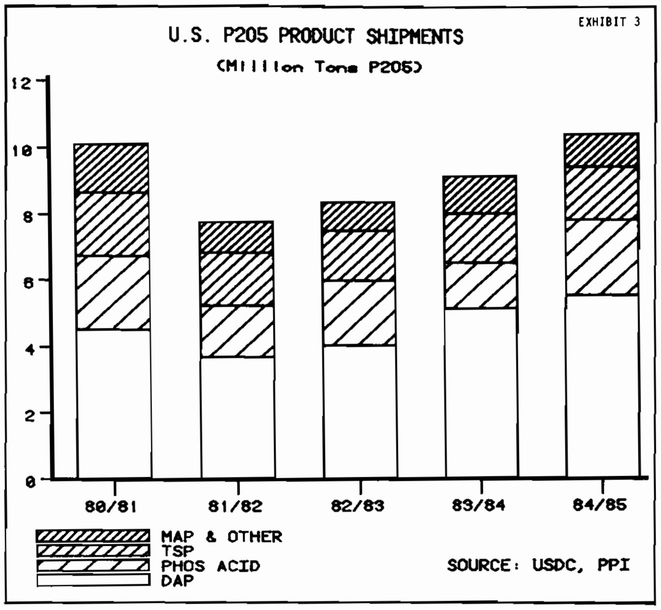


P - PRELIMINARY

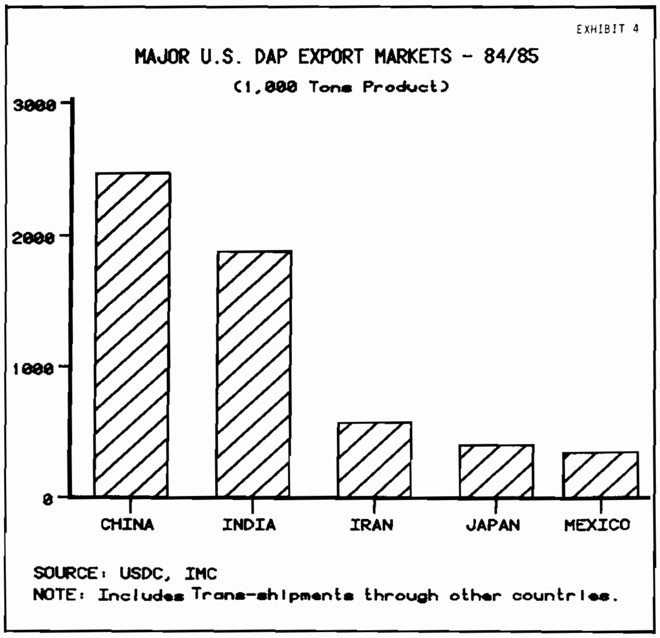
SOURCE: USDA, IMC



SOURCE: USDC

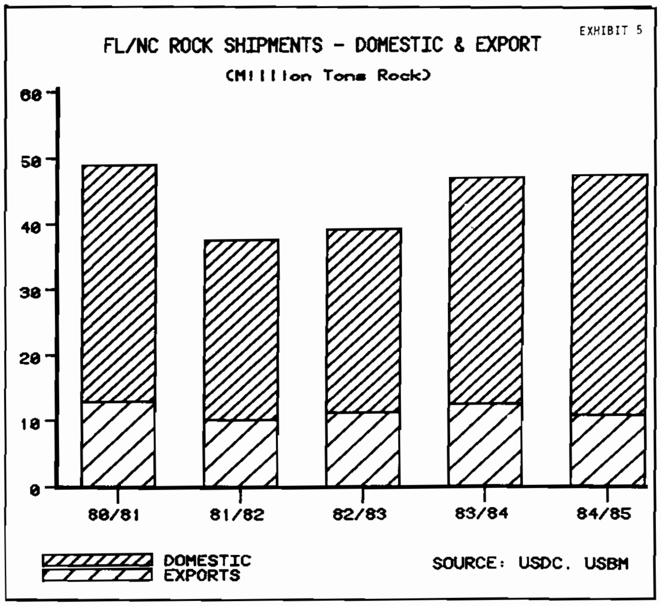


SOURCE: USDC, PPI



SOURCE: USDC, IMC

NOTE: Includes Trans-shipments through other countries.

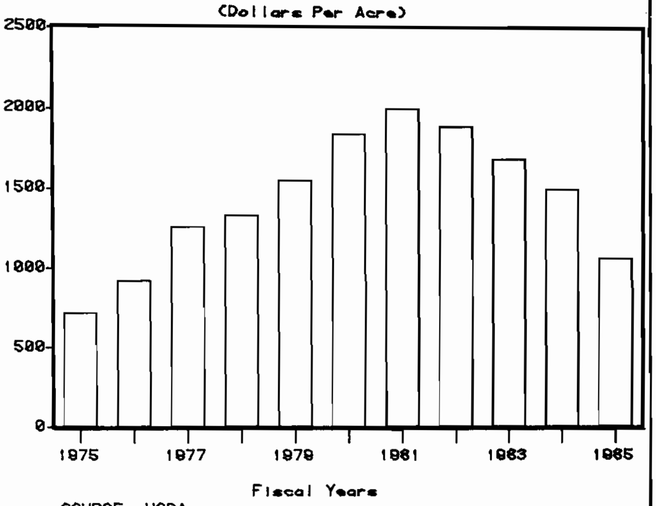


SOURCE: USDC. USBM

EXHIBIT 6

IOWA FARMLAND PRICES

(Dollars Per Acre)

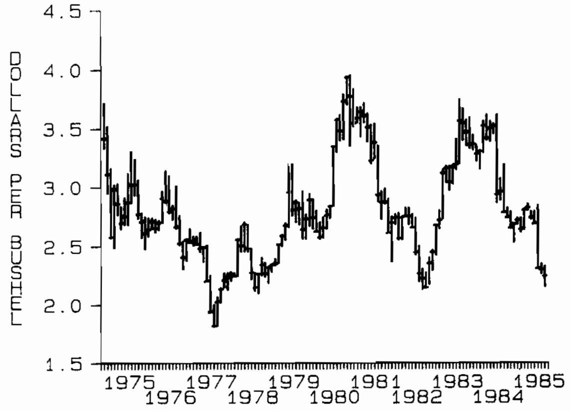


SOURCE: USDA

EXHIBIT 7

CORN PRICES

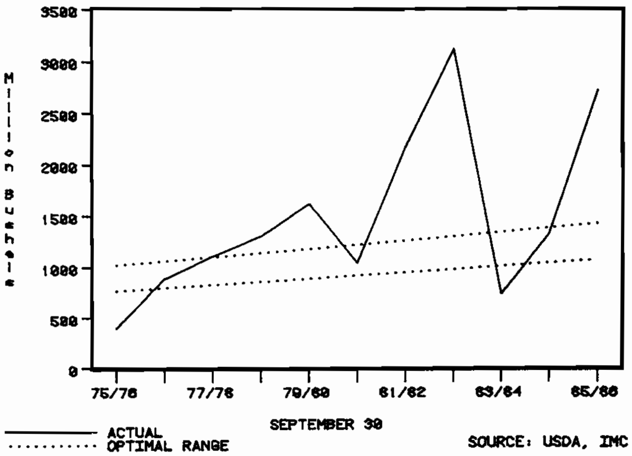
CHICAGO BOARD OF TRADE



NOTE: DATA FOR LAST TRADING DAY OF EACH MONTH

EXHIBIT 8

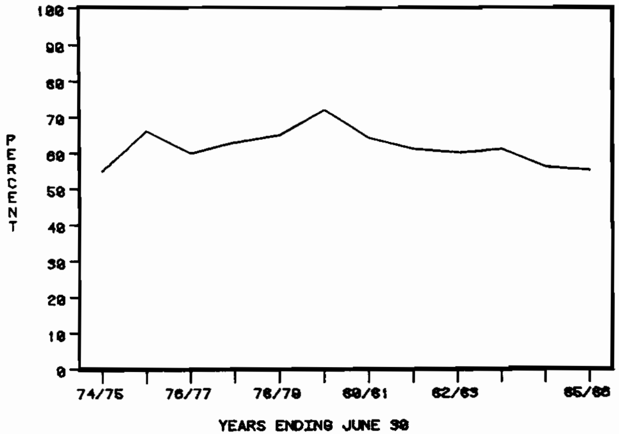
U.S. CORN STOCKS - YEAREND CARRYOUT



SOURCE: USDA, IMC

EXHIBIT 9

U.S. SHARE OF WORLD TRADE - FEEDGRAINS

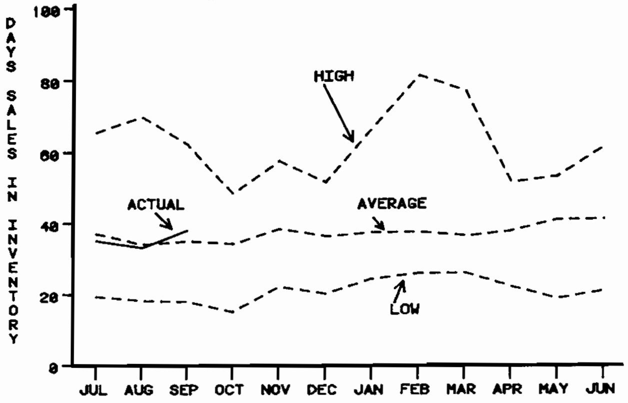


SOURCE: USDA

EXHIBIT 10

U.S. DAP/TSP PRODUCERS INVENTORY - 1985/86

(Plantsite and Offsite)

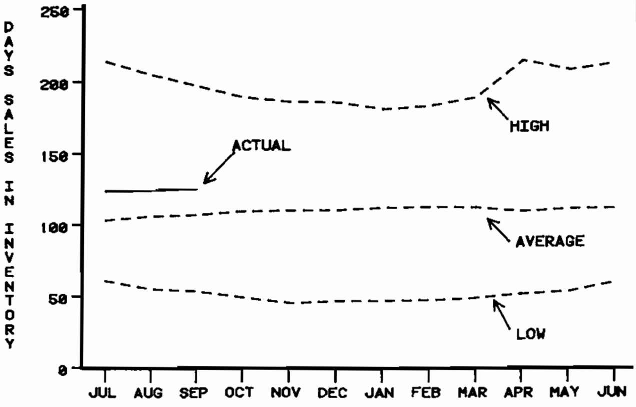


SOURCE: USDC & TFI

EXHIBIT 11

FLORIDA/N.C. PHOSPHATE ROCK PRODUCERS INVENTORY - 1985/86

(Plantsite and Offsite)



SOURCE: USDC & TFI

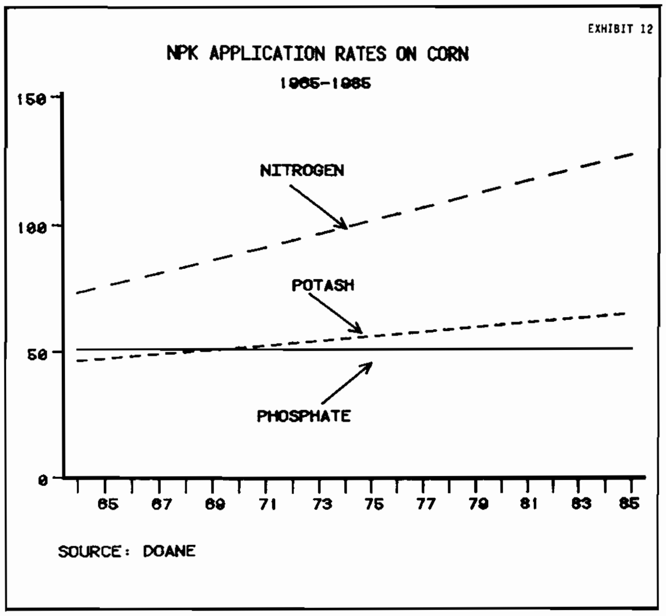


EXHIBIT 12

NPK APPLICATION RATES ON CORN

1965-1985

SOURCE: DOANE

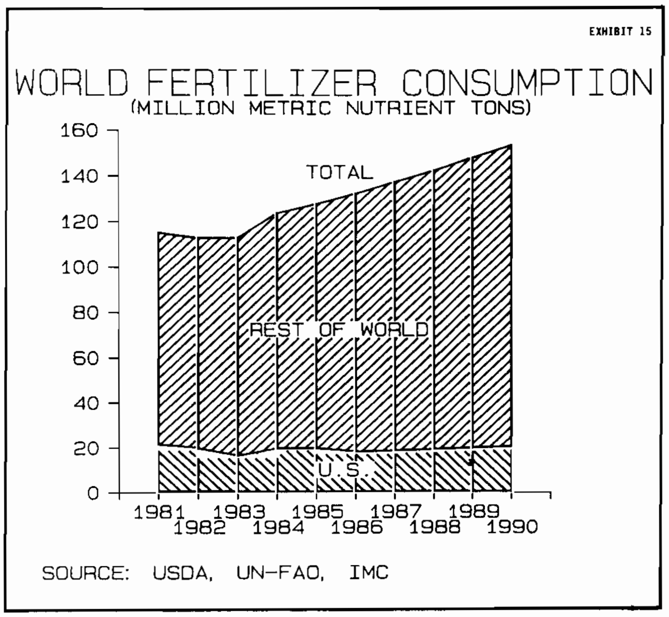


EXHIBIT 15

WORLD FERTILIZER CONSUMPTION

(MILLION METRIC NUTRIENT TONS)

SOURCE: USDA, UN-FAO, IMC

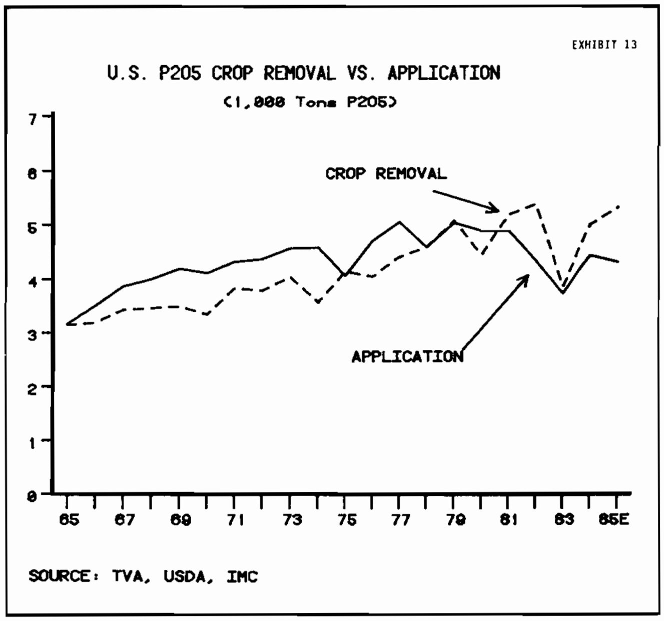


EXHIBIT 13

U.S. P205 CROP REMOVAL VS. APPLICATION

(1,000 Tons P205)

SOURCE: TVA, USDA, IMC

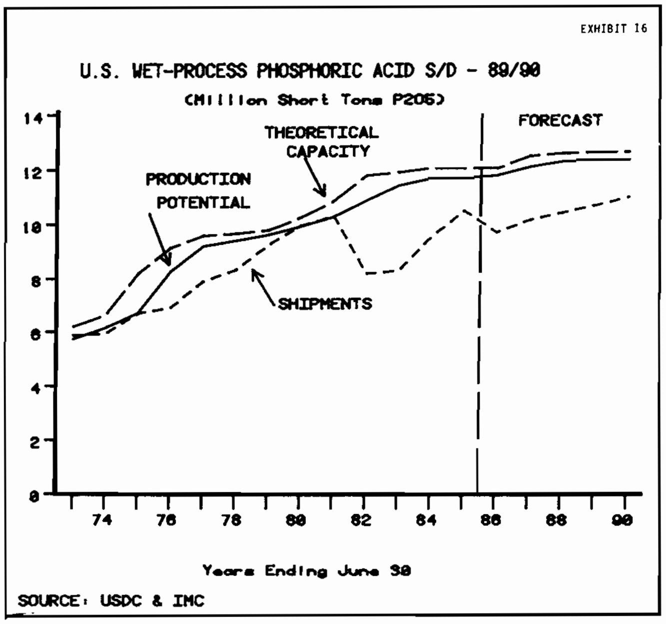


EXHIBIT 16

U.S. WET-PROCESS PHOSPHORIC ACID S/D - 89/90

(Million Short Tons P2O5)

SOURCE: USDC & IMC

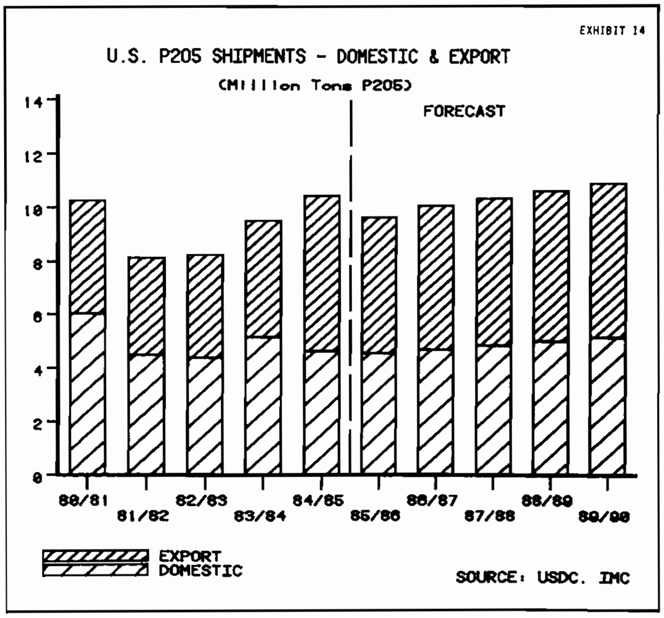


EXHIBIT 14

U.S. P205 SHIPMENTS - DOMESTIC & EXPORT

(Million Tons P205)

SOURCE: USDC. IMC

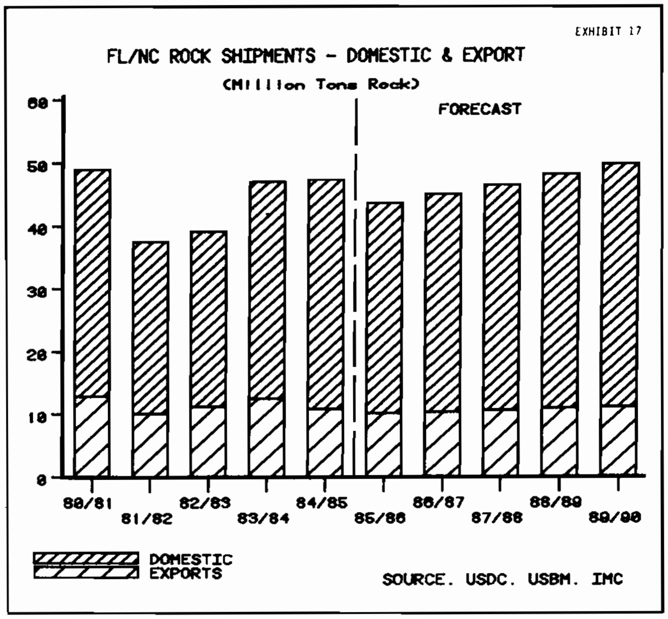
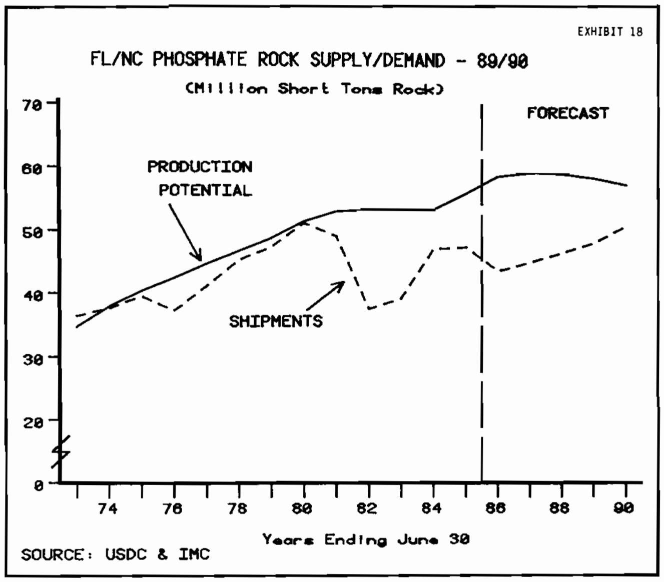


EXHIBIT 17

FL/NC ROCK SHIPMENTS - DOMESTIC & EXPORT

(Million Tons Rock)

SOURCE. USDC. USBM. IMC



Outlook for Potash

Gunter Rüping
Kali und Salz AG
West Germany

Introduction

Ladies and gentlemen,

It is indeed a great honour and pleasure to talk to you today and share with you my thinking on the present situation of the world potash market and its likely future development.

Several prominent experts have expressed their views on this subject in the course of 1985, mostly covering certain aspects in detail. It is to be hoped that these various papers and articles will serve a dual purpose: to spread the knowledge of the beneficial effects of this important nutrient and to obtain an internationally accepted level of identical information with all the people and institutions involved in the potash business.

With this purpose in mind, I intend to present a global and regional overview of the rôle of potash in agriculture, world potash deposits, the present market situation, a brief retrospective of developments, and finally a long-term perspective up to the year 2000.

1. The Rôle of Potash in Agriculture

1a) Potash,—Indispensable for the Nutrient Balance

According to the World Bank there is "no substitute for potassium in the life of plants and animals. Potassium aids in the synthesis of starch and sugars, stiffens the straw of cereal grains, promotes root growth and enables the plant to better withstand adverse conditions of climate and disease." These beneficial effects of potash had already been recognized by the ancient Greeks and Romans—and the American Indians—who used it in the form of wood ashes to increase the fertility of their fields and gardens.

In view of such a long history it may seem surprising that today potash only ranks third on the worldwide scale of nutrients after nitrogen and phosphates. (Figure 1)

The explanation is not too difficult:

First, the developed countries had used potash—and later phosphates—for so long that its extensive use resulted in grave deficiencies of N. The new emphasis placed on this nutrient gave it an impetus which made it overtake K_2O. Second, in the developing countries, nitrogen is invariably the preferred nutrient when they start to systematically apply mineral fertilization. The dramatic optical proof of nitrogen efficiency has encouraged this process which is still in full swing.

Thirdly, the occurrence of potash deposits is restricted to a few locations, not many of which are to be found in the developing countries.

Still, as the World Bank pointed out in a report, "a rising potash deficit in the soil could eventually limit the efficiency of nitrogen." Imbalances in the relation between nutrients may cause losses of efficiency of 20%–50%.

Unfortunately such imbalances are still very widespread in the developing countries, so potash must catch up if serious consequences are to be avoided.

Let me demonstrate this by quoting some examples.

Relations	N	:	P	:	K
Belgium	1	:	0,5	:	0,7
Germany	1	:	0,5	:	0,7
Norway	1	:	0,6	:	0,8
France	1	:	0,7	:	0,8
USA	1	:	0,5	:	0,5
Japan	1	:	1,04	:	0,8
India	1	:	0,3	:	0,2
Mexico	1	:	0,3	:	0,07
Morocco	1	:	0,9	:	0,4
China	1	:	0,3	:	0,04

Certain developing countries have made remarkable progress, however:

Brazil	1	:	1,6	:	1,3
Colombia	1	:	0,5	:	0,5

China certainly presents the most striking example of an enormous potash potential.

According to the Chinese Soil and Fertilizer Institute, a ratio of N : K_20 at 1 : 0,3 or 1 : 0,4 is needed in South China,—in other words, ten times the present application. Due to K deficiency, in some areas as much as 60% of the N is wasted.

1b) The Different Grades; Organic Potash

So far we have been talking of K_2O generally. Of course there is a wide range of grades, each in different physical qualities, in response to the different requirements of various crops and also the technical conditions stipulated by complex fertilizer plants, blenders and manufacturers of solutions. I shall revert to the subject a little later. At this stage I only should like to point out that the complexity of the structure of potash supply is easily underestimated. Kali und Salz, my own company, offers 12 grades of muriate, 5 grades of sulphate, 9 grades for the chemical industry and several grades of special magnesium-containing fertilizers. (Figures 2a, 2b)

Looking at potash containing fertilizer mixtures and complexes, their number is beyond the wildest statistical imagination!

Just in Sri Lanka, there are 28 officially approved fertilizer mixtures all containing potash in different concentrations.

Now let me touch very briefly upon the subject of potash contained in organic matter.

For various reasons this is mostly neglected in national nutrient balances. If it were added, so agricultural engineers explain, an incorrect impression would be created of the K saturation levels within the soil. The fact remains that in countries with intensive stock breeding such as the Netherlands, Switzerland and Austria, mineral potash consumption has been stagnating, as there is a certain amount of potash recycling by manure.

In the developing countries, China is also a case in point. In the form of manure, straw, night-soil etc. Chinese soils receive many times more K_2O than the 0,5 mill. t K_2O in the form of mineral fertilizer!

On the other hand, environmentalists are completely off the mark when they pretend that mineral fertilizer can be replaced completely by organics.

At the IFA meeting in Munich the German minister for Development Aid said:

"There is no doubt that the possibilities of biologically determined agriculture are far from effecting the required increase of agricultural production. In order to mobilize the world's agricultural potential, a massive use of mineral fertilizer is indispensable. Even if full use were made of both methods, the food needs of the world's population could not be met in the short-term!"

2. World Potash Deposits

2a) Location and Size

Growing quantities of potash are consumed every year and this has been going on for more than a century. We are also aware of the fact that potash is a non-renewable resource. Inevitably, some urgent questions arise: where are the potash deposits? How large are they? Have all of them been discovered yet? How long will they last?

Many of these questions have already been answered by Bill Sheldricks paper for the Atlanta potash symposium in July, so I can be brief.

Nature can be very discriminating when distributing the riches of the earth. She certainly was in the case of potash. Of all the known world potash resources, more than 90% are located in the industrialized countries of the West and the Socialist Bloc. (Figures 3a, 3b)

Their availability in close proximity to the most important and productive agricultural regions of the world has worked in two ways: it has assured large and fairly stable markets to the potash producers and in turn has enabled the respective agricultures to produce the high yields for which they are famous.

In the East European countries the deposits presently exploited are rather isolated from the markets and transport leaves much to be desired.

With regard to the proximity of export outlets, not much less important, similar distinctions can be made.

Such strategic considerations may add to or detract from the basic value of a deposit which is determined by its K_2O content, its accessibility and the potash minerals it consists of.

Just a brief word of explanation of terms: resources are the complete deposits including parts or layers that are not yet accessible by actual mining techniques and under present cost/price relations. Reserves can be economically mined under contemporary conditions. Reserves are usually only a fraction of resources, 13% in fact worldwide. Typically, the percentage of reserves is much higher in the developed countries with 19% on the average than in the developing regions where it is hardly 2%. In the Socialist countries, the figure of 7% is in between.

The total size of world potash reserves is 17–18 billion t K_2O. Grouped according to size, individual countries have:

	Bill. t K_2O	
Canada	10.0	
USSR	5.0	
USA	0.3	
GDR	0.8	
FRG	.5	
Group	16.6	= 97.0%
Rest of West Europe	0.3	= 1.5%
All developing countries	0.3	= 1.5%

2b) Brine Operations

Another distinction may be of interest: that between deposits conventionally mined (including solution mining) and brine deposits. In the latter case, potash is extracted either by "mining" the salt crust of a dried-up lake or the still liquid brine underneath a dry surface.

In a few cases when there is a large stretch of highly concentrated salt-water and the climate permits, the water is led into evaporation pans and the thick salt sediment is harvested by huge dredging machines.

Operations of this kind can be found in Utah (Great Salt Lake, the Bonneville salt flats), Searles Lake in California, the Dead Sea which is exploited by both Israel and Jordan, in Tunisia where exploratory work is in progress, and China where small quantities are recovered from the salt flats of Lake Cha-Erh-Han.

All of them taken together represent only a fraction of presently known reserves but they have their own merits as some of them contain minerals from which sulphate of potash can be manufactured and furthermore represent indigenous resources which may be used by the respective national agricultures and/or may serve as a means to earn foreign currencies from exports.

This explains the importance which several developing countries attach to their national deposits in general.

2c) Deposits in the Developing Countries

A quick comparison shows however, that on the whole the capacities that are envisaged will not always cover the expected demand of the respective countries, and their rôle in a world context will not be decisive:

a. World potash reserves 1985: 17–18 Bill t K_2O
   Developing countries 0.3 Bill. t K_2O
b. Envisaged capacities, possible production and total demand of developing countries:

1 000 t K_2O	1984	1990
Capacity	1.020	max. 3.220
at 80% operating rate	816	2.576
Demand	3.330	4.550
Balance	−2.514	−1.974

Even at the end of this decade, and under the most favourable circumstances, the import requirements of the developing countries are still almost 80% of those of 1984.

Typical examples for different motivations in exploring indigenous potash sources are Brazil and Jordan.

In Brazil, potash consumption is at present approximately 0,9 mill. t K_2O. The Brazilian potash operation at Sergipe has a capacity of 0,3 mill. t K_2O. So the import dependance of the country may be diminished by one third but there is not going to be an exportable surplus. Furthermore difficult logistics may handicap supplies to some domestic market regions.

In Jordan on the other hand, consumption is almost nil but the nominal capacity of Arab Potash Company is 0.7 mill. t K_2O. Evidently the project serves the sole purpose of contributing to the national currency reserve.

In the industrialized and Socialist countries, things were different. From the start, both considerations had applied. Usually there always was a comfortable exportable surplus but national agricultures had first priority. This is still the case today.

As to the lifetime of world potash deposits, the global view, as always, is the most reassuring. According to the US Bureau of Mines, 96% of world potash reserves will still be intact in the year 2000! And don't forget: these reserves are only 13% of the world resources.

Of course the lifetimes of individual resources vary widely and some will be depleted when the year 2000 arrives. This holds true for some mines in Alsace as well as for most of the New Mexico operations in the USA.

3. The Present World Potash Situation

3a) Regional Production and Sales 1984/85

We are satisfied now that

a. potash is an indispensable agricultural input
b. the raw material base guarantees ample supplies far beyond the year 2000.

A philosopher would say that this is the metaphysical level. What we really want to know is of course the actual situation as reflected by supply, demand and prices in the market-place. We begin by examining the present, continue by finding out which developments have led to the situation of today and close by making a "fearless forecast."

In fertilizer year 1984/85, world capacity was 36.8 mill. t K_2O world production 28,9 mill. t K_2O, the operating rate 79%, world sales were 28,1 mill. t K_2O, the annual surplus consequently 0,8 mill. t K_2O and the accumulateld year end stocks were almost 3 mill. t K_2O.

In other words: in spite of a very moderate operating rate, production still surpassed the sales possibilities and accumulated stocks remained high. The international price level faithfully reflects this situation.

However, these very general statements do not do justice to regional developments which were quite diversified.

Production of the Western World as a whole reached 15,7 mill. t K_2O vis-à-vis capacities of 20,0 mill. t K_2O, the operating rate was 78,5%. Sales amounted to 15,2 mill. t K_2O so the annual surplus was 0,5 mill. t K_2O. Of course percentages varied significantly at individual producing regions.

GDR and USSR, the only potash producers in Eastern Europe, turned out 13,3 mill. t K_2O, corresponding to 79% of their capacities. Their sales were 12,8 mill. t K_2O, the annual surplus reached 0,5 mill. t K_2O.

On the whole, and prices apart, this is not an unsatisfactory situation but it was still influenced by the strong growth tendencies in 1984 after a prolonged slump. Psychologically, the high stocks were mainly responsible for the low price level.

World supply grew by 3,6%, world sales only by 2,3%. In other words, some adjustment of supply still appears to be necessary. The world and regional supply: demand relation was not yet balanced.

You may find it worthwhile to form an idea of the relative importance of individual potash producing countries and to examine the different emphasis placed by these producers on home markets and exports. (Figure 5)

3b) Regional Market Shares

WORLD POTASH PRODUCTION IN 1984/85

(1.000 m.t K_2O)

Producer	Production	Shares % a) World	Shares % b) Region
1. USSR	9.800	33,8	73,9
2. Canada	7.284	25,2	83,7
3. GDR	3.463	11,9	26,1
4. FRG	2.634	9,1	39,8
5. France	1.729	6,0	26,0
6. USA	1.414	4,9	16,3
7. Israel	1.124	3,9	17,0
8. Spain	665	2,3	9,9
9. Jordan	340	1,2	—
10. UK	337	1,7	5,1
11. Italy	128		2,1
12. China	40		—
World Total	28.958	100,0	

The USSR, Canada, GDR, FRG and France seen together represented no less than 86% of world potash production. The USSR, Canada and the FRG are the prominent producers within their region and have a share of 68% in world potash production.

The Canadian producers sold roughly 32% overseas, 68% in North America. With the US producers, the relation was 38%:62%.

It may surprise you to hear that the West European producers exported 47%, but taking into consideration that these exports largely remained within the region, we find that actually 16% of production was sold overseas.

Within Western Europe, the extremes are Israel whose home market share is only 14%, and the UK which sells 82% in its home market. However, the figure for Israel includes potassium nitrate which is mostly re-exported.

The fertilizer season of 1984/85 was an inconspicuous one, a period of consolidation after the dramatic recovery in 1983/84 which ended the slump of the preceding couple of years. It is well to remember that in 1983/84 world demand had grown by almost 12% after having dropped by 1% in 1982/83 and even by 7,5% in 1981/82. So now apparently we are getting back to normal, as the long-term growth rate is thought to be 3,6%, vis-à-vis about 2,3% in the past season.

In examining the market regions more closely, we see that the largest markets are those closest to the production sites, but they are not growing! The smaller ones, farther apart, are the growth markets. This is clearly demonstrated by the following figures which represent the situation in 1984: (Figure 6)

Market	Volume	World Share %	Long-term annual growth %
North America	6.060	21	2,6
Western Europe	6.660	24	1,7
Eastern Europe	9.674	34	3,6
Other Developed	1.387	5	—
Total Developed	23.781	84	2,6

Middle East	51	1	2,5
Africa	173		
Far East	2.565	9	7,3
Latin America	1.703	6	12,5
Total Developing	4.492	16	8,7

The developing countries more or less completely depended on imports. These were covered by producers as follows (1984): (Figure 7)

Destination/ Origin	N. Amer.	W. Eur.	E. Eur.	Others	Total %
Middle East	2	88	—	10	100
Africa	8	76	13	3	100
Far East	60	15	19	6	100
Latin America	40	15	45	0	100

The North American producers were predominant in Latin America and the Far East, the West European producers in the Middle East and Africa.

Freight has apparently much to do with this distribution of regional market shares. The surprise is Eastern Europe which had a stronger position in Latin America than the USA or Canada,—in spite of the enormous freight distance. The explanation is simply that the GDR has a bilateral Government to Government agreement with Brazil which contains very favourable financial clauses and gives the GDR a unique competitive advantage.

Now for a parting glance at the producers' national domestic markets where imports are still fairly small. (Figure 8)

	1984		
	N. America	**West. Europe**	**East. Europe**
Total home market	6.060	5.662	6.815
From national producers	5.621	5.073	6.815
From imports	438	589	—
Degree of autonomy	93%	90%	100%

Eastern Europe is a "closed shop", North America not quite so strictly and Western Europe—in this context—the least restricted area.

3c) The Situation First Half 1985

We are now deep into calendar year 1985 and it is legitimate to ask how the year has developed so far. I should like to base my answer on the figures for the first half which are fairly reliable. As usual, there are no intermediate data for East Bloc countries so we will concentrate on the Western World, but excluding Jordan for the same reason of a lack of data.

	1st half		
	1984	**1985**	**Change, %**
North America			
Production	4.935,6	4.331,6	−12,2
Home market	2.733,1	2.799,8	+ 2,4
Exports	1.524,8	1.315,7	−13,7
Total sales	4.257,9	4.115,5	− 3,3
Balance	+677,7	+216,1	
Western Europe*			
Production	3.464,1	3.451,9	− 0,3
Home market	2.058,2	2.049,1	− 0,4
Exports	1.794,9	1.722,3	− 4,0
Total sales	3.853,1	3.771,4	− 2,1
Balance	−389,0	−319,5	
Total West			
Production	8.399,7	7.783,5	− 7,3
Home market	4.791,3	4.848,9	+ 1,2
Exports	3.319,7	3.038,0	− 8,5
Total Sales	8.111,0	7.886,9	− 2,7
Balance	+288,7	−103,4	
Stocks	2.468,1	2.843,9	+15,2

*excl. Italy. incl. Israel

How did the two big groups of producers fare, compared to the great year 1984? (Figure 9)

Financial results were also a mixed bag of losses and profits but the remark of a Canadian fertilizer man at the recent IFA meeting in Munich seems to be slightly exaggerated. Asked what he thought of the mood of the industry, he answered: "Well, if you have to be on the Titanic you might as well go first class!"

3d) What About the Second Half?

In reviewing 1985, we find that the general economic situation and certain agricultural policies, but also the predicament of the potash industry itself have shaped the market situation and will continue to do so.

IFDC has summed up market expectations for the second half as follows, based on a worldwide survey of fertilizer people:

On the average, respondents expected a price increase for MOP of 0,2% and expressed a feeling that fertilizer prices were at or near their bottom.

Regionally, the following changes were expected for MOP:

in North America	+0.3%
in Western Europe	+0.8%
in Africa	+1.3%
in Oceania	−0.4%
in Asia	−0.4%
in Latin America	−1.0%

Factors which are thought to affect potash prices in the next six months were (in brackets: origin of statement) the following:

—World's surplus of MOP is evident (North America)

—Weak market demand with plenty availability; producers may not resist downward price pressure (Western Europe)

—High stock levels of producers mainly in Canada and consumers (Asia)

—High inventories pressure potash producers, especially in North America, and will bring prices down (Asia)

—Potash capacity and inventories will cause further price fall (Oceania)

I should like to add the following elaborations:

—The phasing-in of additional capacity (PCA and DPPC New Brunswick, the Lanigan expansion, Jordan, Sergipe)

—Several US potash mines being put up for sale (Duval, Amax, PCA), having been sold (Kerr-McGee) or idled for several years (GSL)

—High fertilizer import prices due to the relation of national currencies to the US$

—Continuing high degree of indebtedness of many developing countries

—The threat of drastic changes in US agricultural policies

—Efforts of EEC authorities to stem the tide of agricultural surpluses by reduced agricultural prices and production quotas

—Fierce competition in grain export markets based on surpluses with resulting weak grain export prices (US agricultural exports in 1984/85 dropped to 23,7 billion US$ against 27,3 billion US$ in 1983/84 or by 13%!)

—Depressed farm incomes both in the US and Western Europe

—Low prices for developing countries' agricultural exports

Potash producers in Western Europe and North America tried to reduce oversupply and create a better position for themselves in the second half of 1985. They did this by temporarily idling several mines:

Producer/Mine	Scheduled Overhaul Period	Additional Period of Closures
PCS (all mines)	28 days	35 days
IMC (Esterhazy)	37 days	24 days
PCA (Saskatchewan)	21 days	21 days
PCA (New Brunswick)	21 days	21 days
Central Canada Potash	Indefinite—may re-open in October	
Kalium (Belle Plaine)	44 days	None planned—but production reduced

In Western Europe, Kali und Salz AG had also contributed to a stabilization of markets by closing down several mines for the summer months and Dead Sea Works have done the same.

Nevertheless, in the second half of 1985, dollar prices in many export markets were under considerable pressure, reflecting the earlier strength of the US currency as well as the notion that the North American industry with its inventories is in a relatively weak position.

However, if the big markets stay on a normal consumption level (Europe, USA, India), slightly improve their demand (Japan, Brazil) or give up their hesitation to buy (China, Indonesia), calendar year 1985 may yet turn out to be a moderate success or at least not to be much worse than 1984 which after all was a banner year! This is confirmed by IFDC.

The survey which I mentioned before arrives at the following results for regional K_2O consumption changes, 1984 to 1985:

in North America	−1.1%
in Western Europe	+0.9%
in Oceania	+1.3%
in Latin America	+3.0%
in Asia	+3.3%
in Africa	+9.6%
World	+0.5%

4. A Retrospective Survey of Developments

4a) Market Shares From 1970 to 1985

What makes the situation in 1985 different from that of 1980 or 1970? Or are there no important differences at all? Vice versa: Are there similarities, maybe a set of fixed unchangeable conditions, trends that have worked in a certain direction and may continue to do so?

A satisfactory answer to these questions would possibly help considerably in supporting forecasts of the fate of potash markets.

The shares of the producing regions in world capacity show important changes: (Figure 10)

The relation North America : Western Europe : Eastern Europe : Others was as follows:

	mill. t K_2O –		
	1970	1980	1985
N A M	10,8 = 39%	10,6 = 39%	11,6 = 32%
W E	7,2 = 27%	7,8 = 24%	7,3 = 20%
E E	9,4 = 34%	13,7 = 43%	16,7 = 46%
Others	—	—	1,1 = 2%

Of the total capacity growth considered here, amounting to 9,3 mill. t K_2O, 78% can be attributed to the USSR!

Let us see now if the relation between home market and export sales has changed appreciably: In 1970/71 the share of home markets in total West European sales was 55%, in North America the rate was 77% and in the Socialist Bloc the percentage amounted to 53%. The heavy emphasis placed by all producers on their home markets is apparently a characteristic sign of the potash market at all times.

With regard to market shares, there have definitely been changes. In 1970/71, considerations of freights and distances obviously were not as decisive as in 1985, as the following figures show:

MARKET SHARES, %

Destination/Origin	North America	West Europe	East Europe
North America	96	4	—
West Europe	11	54	35
East Europe	—	3	97
Middle East	—	71	29
Africa	2	92	6
Latin America	33	47	20
Far East/Oceania	65	23	12

Market shares were spread much more evenly then, although in the potash producing regions the local producers absolutely dominated. It is interesting to see how strong a position the West Europeans had at that time in the distant region of Latin America.

4b) Technical Progress

As regards the structure of supply, the number of grades has certainly grown and their physical qualities have been improved. Even in this field, however, progress was slow and regular rather than spectacular and dramatic.

There were three distinct developments:

- —the increasing share of compound fertilizers in total potash sales, especially in Western Europe
- —the growing importance of coarse and granular grades
- —the advent of the bulk blending technology.

In West German agriculture, for example, all the potash used in 1938/39 was in the form of straights. In 1950/51, the share of compounds—practically all as complexes—was just 6% but in 1970/71, it had jumped to 61%. Since then, compounds have not grown any more.

In judging the importance of coarse and granular grades, let us concentrate on the last 6 or 7 years. During that period, the dominant rôle of these grades became very apparent but simultaneously, a contradictory trend could be observed in North America and Western Europe:

In the first case, the share of coarse grades in total production stagnated, with exports it dropped from 33% to 22%, in domestic sales however it went up from 71% to 74%.

In Western Europe, there were strong increases across the board: in production from 14% to 19%, in domestic sales from 12% to 16%, in exports from 16% to 22%. Nevertheless, the emphasis in North America remains overwhelmingly on coarse grades, in Western Europe on standard grades.

Sulphate of potash has an almost solid share of about 8% in total Western potash production, of 4%–6% in domestic consumption and of 13% in exports.

East European producers also made progress in modernizing their supply structure. In the USSR, the share of SOP, sulphate of potash magnesia and muriate of potash for complex fertilizers rose from 6% in 1970 to 8% in 1980 while the low MOP grades decreased from 28% to 6%.

4c) Growth and stagnation

When looking back at the growth of supply and demand it appears to the observer that the above changes in the structure of the worldwide supply have not had much influence on the pace of growth of total potash demand and on its regional distribution; on the contrary: in spite of these improvements, the pace has slowed.

First let me show you how the average growth rates p.a. have changed over the years for potash fertilizer consumption:

Region	68/69–73/74	76/77–83/84
North America	5,4%	0,4%
Western Europe	5,2%	1,4%
Eastern Europe	9,0%	0,6%
Africa	10,5%	4,4%
Latin America	10,4%	1,0%
Far East	15,5%	8,0%
World	7,0%	1,5%

The share of the individual regions in total world consumption has developed as follows (mill. t K_2O and %): (Figure 11)

	1970/71		1980/81		1983/84	
	t	%	t	%	t	%
North America	4.01		6.09		5.66	
West Europe	4.95		5.32		5.53	
Other developed	0.92		0.90		1.13	
Total developed	9.88	60	12.31	51	12.32	48
Africa	0.13		0.25		0.27	
Latin America	0.64		1.87		1.21	
Near East	0.03		0.06		0.10	
Far East	0.46		1.27		1.38	
Total developing	1.26	8	3.45	14	2.96	12
Social. Europe	5.10		7.90		9.31	
Social. Asia	0.15		0.57		0.91	
Total Socialist	5.24	32	8.47	35	10.22	40
World	16.38	100	24.23	100	25.50	100

Clearly, the developing countries are on an upward move, the Socialist countries' share is also growing and the developed countries' importance is gradually waning.

Within all three country groups, a few markets have always stood out by their large volumes. That, too, is very typical of the world potash market and coincides with the preponderance of a very few producing countries:

In 1983/84, the US market represented 93% of the total North American market.

In Western Europe, the 4 countries, FRG, France, Italy, UK together account for almost 70% of total consumption. In East Europe, 67% of total demand stems from the USSR.

75% of African demand originates from the 6 countries, South Africa, Zimbabwe, Algeria, Morocco, Nigeria and Ivory Coast. But Africa encompasses about 40 sovereign states!

In Latin America, 87% of regional consumption is in just 4 countries, Brazil, Cuba, Mexico, Colombia.

In the Far East, Japan, India, Indonesia and Malaysia represent almost 80% of regional consumption.

Another quick exercise should give us a better grasp of market potentials as they have developed in the past: If we group the regions into markets of growth, stagnation and recession, we obtain the following breakdown:

	1973/1974	1983/1984
Growth markets	19.63	11.97
Stagnation markets	0.78	13.43
Receding markets	—	—

Of the growth markets in 1983/84, 9,3 mill. t K_2O or 78% are out of reach for Western producers as they represent the self-sufficient COMECON bloc.

4d) Factors Influencing Demand

A multitude of factors have influenced demand in the period under study.

It is hardly possible to quantify their impact which is undeniable but if we want to increase our insight into the workings of the fertilizer and potash market we are well advised to familiarize ourselves with the more important ones:

First there are the factors influencing requirements as distinct from actual demand. (Figures 12, 13, 14)

The requirements are determined by:

—Limitation of arable land

—Population growth

—Food minima per capita

—Food quantities needed to meet these minima

—Objective nutrient needs of the different crops and soils

—Potash quantities necessary to obtain the desired yields in conjunction with other inputs.

Provided the data base is there, the calculation of theoretical potash requirements is not too difficult; they are typified by two aspects:

a. they are usually enormous

b. they are worlds apart from actual demand.

FAO's publication "Agriculture toward 2000" on page 135 develops different scenarios resulting in fertilizer targets only for the developing countries of between 76 and 94 mill. t of NPK in the year 2000. That is just 15 years away, and today, the developing countries use not quite 24 mill. t NPK as nutrients. Assuming, pessimistically, an unchanged NPK ratio, these targets would include between 9.12 and 11.30 mill. t K_2O vis-à-vis 2,9 mill. t K_2O today. My forecast of actual demand in 1995 is 5,7 mill. t K_2O, possibly, at a growth rate of 7% p.a., 8 mill. t K_2O in 2000.

The study makes fascinating reading and certainly fulfils the commendable purpose of drawing the world's attention to the imperative need to improve food supplies—but I should rather concentrate, for the time being, on those factors that shape actual demand. These have found to be:

—the general economic situation

—agricultural policies

—internal and external purchasing power

—priorities in external trade

—freight distances, infrastructure, logistics

—intensification of agricultural production

—farm credit

—fertilizer:crop price relationship

—fertilizer development aid

—potash level already attained.

For decades in the past, the general economic situation has had but a limited influence on fertilizer consumption; however, there have always been specific aspects of it which were of greater importance than others, and regionally, economic conditions influence demand in varying degrees. In Western Europe and North America the general economic situation has always been more or less stable. An important exception was the jump in oil import prices in 1974/75 and the second rise of oil prices some years later. This increased the cost of energy of fertilizer producers as well as of farmers and complex manufacturers so much that there was a distinct drop in fertilizer consumption due to the steep ensuing rise in fertilizer prices. Potash suffered from this development although prices stayed on a much lower level. Fortunately energy costs for potash are not as all-important as in the case of nitrogen where natural gas represents up to 85% of ammonia production costs. Still, to cite the example of my own company, the share of the cost of energy in total costs rose from 9% in 1972 to 22% in 1984!

In the developing countries, the general economic situation often has a direct impact on potash markets in so far as the emphasis may be much more on industrial projects than on the development of agriculture and a scarcity of financial means may cause economic priorities to be set in favour of industry. This behaviour fortunately is becoming much less frequent than during the fifties and sixties.

In Socialist Europe, the impact of general economic factors is direct and decisive as both supply and demand of potash are systematically fitted into the framework of general economic planning by the supreme authority of GOSPLAN in Russia, for instance.

Usually, however, a country's agricultural policies influence potash demand more strongly than general economic factors. The most drastic example in recent times was undoubtedly the PIK programme of the USA. It resulted in potash consumption dropping from 1981/82 to 1982/83 by 0.6 mill. t K_2O or 12%, followed by a demand explosion in 1983/84 when consumption shot up by almost 1 mill. t K_2O or 20%!

In the European Economic Community, the aim of agricultural policies was much the same as in the USA. Farmers were systematically encouraged to step up production and their incomes were stabilized by artificially lifting the prices of imported competing agricultural products to the EEC level. In view of the rather high level of food autonomy within the Community, exports were the obvious way to dispose of surpluses but this was increasingly barred by foreign competition and receding demand in the developing countries. Lately measures have been taken to cope with this situation which ultimately may lead to a change in the pattern of agricultural production. The imposition of quotas for milk production and the reduction of the price for wheat point in this direction.

Agricultural policies in East Europe still aim at increasing production of most crops to improve the level and the quality of national diets.

In the developing countries, state influence in agriculture is often overriding. The state's activities range from recommending fertilizer applications over credit facilities and subsidies to actual price fixing and the buying of crops.

Let me give you a few examples of how such measures could influence potash consumption:

—In China, officially recommended rates of potash application are so high that if they were adhered to, the country would use 3 mill. t K_2O p.a. instead of the 700.000 or 800.000 t K_2O it is actually consuming.

—In Japan, potash consumption is more or less stagnant because of the government's policy to switch acreage away from rice which no longer plays such a big rôle in the Japanese diet.

—In Africa, the growth rate of fertilizer consumption is 15,3% where direct subsidies are paid. In countries without subsidies, the rate is only 8,8%.

For a long time, the policy in many developing countries was to keep agricultural producer prices as low as possible in order to feed the mushrooming urban proletariat. Farmers reacted by producing only for their own private requirements. This policy is becoming outmoded. As Zimbabwe's minister of agriculture said: "A low food price policy is a no food policy!"

The fall in value of agricultural exports of the developing countries resulted in a steady erosion of their purchasing power for import commodities,—except for the oil producing countries. (Figure 15)

In many instances the developing countries have been forced to heavily shift the priorities of their import programmes in favour of energy. The Sudan for example has to sacrifice 80% of its export earnings for the purchase of crude oil. This is aggravated by balance of payment deficits and a staggering debt burden. The external debt of Latin America has reached 360 billion US$, that of Africa 170 billion US$.

Peru which was paying 45% of her export earnings to service her debt, has now decided to limit this share to 10%. All this has not been without influence on those countries' ability to import the necessary amounts of potash. The financing of such imports within the framework of donor countries' foreign aid programmes does help but is no long-term solution.

An assessment of fertilizer imports by African countries south of the Sahara, in 1983/84, revealed that of 33 countries which imported fertilizers only three relied totally on direct purchases. Fifteen relied totally on aid. The rest supplemented direct purchases with fertilizer aid.

On the other hand, US aid in this special field has been reduced steadily from 3,4 mill. t in 1968 to a mere 0,2 mill. t in 1982.

Canada is still practicing fertilizer aid through its CIDA agency. FAO, via its industry-supported Fertilizer Supply Scheme, is also trying to help, while the EEC is not too much interested in this policy.

Let us turn to problems of transport now:

Infrastructure and logistics seem to be so perfected in the Western industrialized nations that they do not seem to present handicaps to potash distribution and consequently consumption. This is basically correct but much depends on the distances to be covered. Freight costs can be forbidding and may easily prevent a potash producer from reaching an otherwise desirable market.

On the other hand, mere distance may not be decisive. A long overseas distance may be less costly than a shorter distance on firm ground. The following tables should be seen with this in mind.

In nautical miles distances from Vancouver and Antwerp, representing North American and West European potash ports, are:

To	Antwerp	Vancouver
Ravenna	2.980	10.006
Santos	5.435	8.498
Singapore	8.293	7.078
Visakhapatnam	7.580	8.651
Voyage times, in days, are:		
Ravenna	8.6	29.7
Santos	15.6	25.4
Singapore	24.8	20.3
Visakhapatnam	22.8	24.9

In the USSR transport is still a genuine bottleneck.

In many developing countries the share of transport and storage in total marketing costs is very high. Lumping the two together, we arrive at the following percentage share in: Congo 85%, Kenya 40%, Upper Volta 59%, India 43%, Indonesia 36%, Pakistan 38%.

It goes without saying that the basic condition for potash use all over the world is the farmer's awareness of the commercial and agricultural advantages connected with it. Many international institutions and the potash industry itself have done a lot to create this awareness, naturally in the first place in the developing countries again. One convincing argument should be the potash price which is generally lower than that of the other fertilizers and consequently makes for a better fertilizer:crop price relationship. This is true in developed as well as in developing countries.

I have chosen West Germany as a representative country for the first category: average prices in Dm/t nutrient were:

	N	P_2O_5	K_2O
1950/51	925	380	230
1960/61	1.159	649	308
1970/71	1.047	739	349
1980/81	1.681	1.552	593

In the second category, to simplify things, I have put the price of N = 100. The following relations result:

	N	P_2O_5	K_2O
Nigeria	100	118	63
India	100	114	42
Brazil	100	86	57

To conclude this overview, let me show you how world potash prices have developed. This proves quite impressively how moderate price increases have been and how stable potash prices were over such a long period. The industry would be well advised to continue aiming at such a stability,—which does not in the least imply that the present price level as such is satisfactory. (Figure 16)

How have all the many variables influencing the potash market worked out?

Reconsidering very briefly its characteristics up to 1985, we may state that:

—the growth of capacities accelerated from about 1980 onwards

—the share of North America and Western Europe became smaller, that of the Socialist and developing countries larger

—all producers place heavy emphasis on their home markets

—otherwise market shares are normally determined by cost of freight

—the structure of supply has changed in favour of coarse grades and bulk blending

—the growth rates of potash consumption have drastically decreased in the second half of the period considered.

—the regional shares in demand have developed parallel to the regional shares in supply

—a few countries represent the bulk of consumption in each region

—the market potential with a growth tendency is smaller than the stagnating potential

—part of the growth potential is out of reach for Western producers

—potash prices showed a moderate and rather even trend

5. A Forecast of World Potash Supply and Demand

5a) Environmental Considerations

In forecasting the future, it is safe to assume that many of the former characteristics will continue to be typical for potash supply and demand.

Increasing attention, however, is focused on environmental issues connected with the fertilizer industry and with agriculture. It seems that in Western Europe the emphasis is greater in view of the small and densely populated area. I am not too familiar with the US situation but TFI recently published an article about the last decade of environmental protection legislation and said that "six laws resulting from major revisions or additions to three older statutes, and creation of 3 entirely new ones cover nearly every facet of possible pollution from industrial facilities." Potash mining is affected by the Clean Water Act, the Resource Conservation Act, the Safe Drinking Water Act and the Comprehensive Environmental Response, Compensation and Liability Act!

In Western Europe, each country still has its own environmental legislation which is already very strict and getting more so.

In Germany, the potash industry is today least affected as it has found ways and means to dispose of its residues without harming the environment. This process was enforced by the introduction of governmental control at a very early time. K+S has spent 19% of its total investments in 1984 to further perfect these technologies!

The German government has tabled a so-called "concept for protecting the soil" which in many ways would impact mineral fertilization as well as the crop structure and the agricultural area as such. This concept is to be copied in Austria and conceivably by other European countries. Fortunately, potash is not one of the nutrients accused to cause cancer or be responsible for the eutrophication of rivers and lakes.

5b) Agricultural Policies

Agricultural policies that are meant to cut agricultural production and prevent surpluses will stay with us for the next five or six years. Again, I need not tell you about the dangers connected with a possible reoccurrence of PIK. In Western Europe, the EEC authorities have introduced quotas restricting the production of milk and intend to freeze or reduce farm prices, first of all for grain. The Commission is also thinking of introducing bonuses to farmers who take their fields out of production. It is to be anticipated that this kind of measures will increasingly be taken.

On the other hand, the exaggerated propagation of organic fertilizer is apparently doomed to fail,—even in the developing countries.

The agriculture and food minister of the Philippines stated for instance that a total shift to organic fertilizers would sacrifice 40%–50% of potential yields.

5c) Changes of Industry Structure; Countertrade; Development Aid

Let me be brief in summing up a few other things likely to influence potash markets in the medium and long-term: Doubtlessly, the industry itself has entered a period of transition. In North America, the big grain companies are entering the fertilizer field in the wake of the oil companies. International affiliations are growing,—the giant moves of Norway's Norsk Hydro are not the only example.

Already potash companies are dropping out, or are offered for sale, others are coming in.

Competition on the world's grain export markets is getting fiercer and repercussions on agricultural incomes will be inevitable. In the developing countries, growing preference will be given to countertrade as long as the debt situation does not improve considerably.

Even India has started to practice this kind of trade (naphta to the USA, DAP and Urea to India).

In those countries where agriculture has been most neglected or suffered the most from natural catastrophes, the emphasis on its promotion will be strongest.

International developing aid may not be stepped up appreciably in view of the mixed results but also increasing efforts by the affected countries themselves.

The subsidy systems in many countries may be reduced or abolished altogether as their burden on national budgets is getting insupportable. This is true even for China. Around 30% of the Chinese budget so far has been channelled into agricultural subsidies in one way or another. The government has proposed a gradual phasing-out whilst keeping a fixed grain price. If this policy is carried through, then fertilizer prices for the farmer will definitely rise.

Fertilizer demand, so far calculated by the central authorities, will in future be determined at the local level where potash is not yet very well known. Still China can and will not ignore the enormous potash deficit it has and in the long-term, potash consumption is bound to increase strongly.

On the whole it would appear that most agricultural markets will be exposed to conflicting tendencies: on the one hand, external influences and pressures may grow stronger, on the other hand there is definitely a tendency to return to the free play of supply and demand and a certain degree of recognition that agriculture may fare best if it accepts the consequences and results of market forces. A new system of checks and balances may develop. As I said before, such things cannot be quantified but should implicitly be taken into consideration when forecasting potash developments which is what we are trying to do now.

5d) Future Supplies and Balances

The most authoritative forecasts are generally considered to be those of the FAO/UNIDO/WB Fertilizer Working Group. I shall be using the group forecasts of consumption and only slightly modified forecasts of supply.

By being brief on world developments I shall be able to dwell a little longer on Western and Eastern Europe which may be of special interest.

Worldwide, we expect capacity to rise from the present level of 39.2 mill t K_2O to about 40.1 mill. t K_2O in 1990. This may appear to be minimal but the big additions to capacity were made during the past couple of years.

There are new projects in the planning or even more advanced stages some of which will certainly materialize until 1995. Consumption will probably rise from 25.7 mill. t K_2O (1984/85) to 31.4 mill. t K_2O in 1990.

The balance represents a more than comfortable theoretical surplus but available supply in the target year, downgraded by the amount of technical grades and losses, may just be 31.8 mill. t K_2O, resulting in a very minimal surplus. Of course if operating rates are higher and losses smaller than we assumed, the surplus may turn out to be somewhat larger. (Figure 17)

The reserve potential in the form of more or less likely projects is considerable:

North America	3.9 mill. t K_2O
Western Europe	0.2 mill. t K_2O
Latin America	1.6 mill. t K_2O
Africa	1.0 mill. t K_2O
Near East	0.5 mill. t K_2O
Far East	1.2 mill. t K_2O
USSR	2.9 mill. t K_2O
World	11.3 mill. t K_2O

This number corresponds to no less than 29% of present capacity and represents the potential of 11 new mines with an average capacity of about 1 mill. t K_2O. Assuming an operating rate of 80%, losses of 5% and technical grade production of say 5%, the level of available supply would still be 8.1 mill. t K_2O, bringing world available supply up to 39.9 mill. t K_2O. Naturally this additional capacity will be phased-in gradually but this could easily happen until the second half of the nineties, and consumption in 1995 is expected to be 36.2 and in the year 2000 could be around 40.0 mill. t K_2O. Thus a balance would be ensured up to that year.

Regionally, the relation of supply to demand will be quite different. (Figure 18)

5e) Future Consumption

Turning to consumption, the working group believes that average annual growth rates will be 2% for the industrialized countries, 4% for the Socialist countries and 7,5% for the developing countries.

The shares of the regions in world consumption may change as follows (1983/84–1994/95):

Industrialized countries	48,0% to 42,0%
Socialist countries	40,0% to 42,0%
Developing countries	12,0% to 16,0%

The absolute quantities (mill. t K_2O):

Industrialized countries	12,2 to 15, 1
Socialist countries	10,2 to 15,4
Developing countries	3,0 to 5,7

If this forecast is roughly correct, the developing countries together will use the same amount as North America in 1995!

The degree of import dependence of the developing countries will increase in spite of expected local production and represents a level of 3.8 mill. t K_2O in 1990.

This is the market volume for which all world potash producers compete!

5f) The Situation of Western Europe

Now let me be somewhat more specific on the situation in Western and Eastern Europe with which you may be less familiar. The two regions have little in common, except that each has a German potash industry!

Otherwise, the differences are marked:

The East European or COMECON market is practically the captive market of the 2 local producers. Small imports are possible of grades in short supply or when there are general supply bottle-necks. Vice versa: Western Europe receives imports from the COMECON producers. In 1984, they had a share of about 40% in West European imports.

West European agriculture markets are highly developed and based on a rather sophisticated agricultural structure. Their demand is complemented by important NPK plans in many locations, some with important export sales. There are no trade barriers to prevent potash imports from entering Western Europe.

All European governments have set high priorities on the maintenance and development of their agricultures as important members of the Community still depend to a large degree on the contribution of their agricultures to their general economy. These are France, Spain, Portugal, Italy, Greece and Turkey.

The level of potash consumption is fairly elevated but there is still room for improvement. Application rates range from 89 kg K_2O/ha in Belgium to only 4 kg in Greece or 7 kg in Spain.

In Eastern Europe, agricultures are also on a high level of development and there is no lack of attention from governments but apparently the politico-economic system is not able to generate a consistently satisfactory level of production. Potash application rates are generally lower (USSR 8 kg, Romania 12 kg,—exceptions GDR 96 kg, Hungary 79 kg). The future uptake capacity of East Europe is thought to be greater than that of West Europe.

Just as there is still a modest growth tendency in Western Europe, so there is also some possibility of increasing supplies. Italkali, located in Sicily, will go up from 0.2 to 0.25 mill. t K_2O, Dead Sea Works of Israel has medium-term plans to increase capacity from 1.26 to 1.8 mill. t K_2O and it is possible that Cleveland Potash of the UK will manage to get closer to its original nameplate capacity of 0.6 mill. t K_2O vis-à-vis the present plateau of about 0.36 mill. t K_2O. K+S, my own company, will at least maintain its present capacity of 3 mill. t K_2O, while Spain is expected to also stay at a level of 0.85 mill. t K_2O The phasing-out of Potasas de Navarra will be compensated by a new operation not far from the old mine.

The MDPA of France is the only company which is faced with a situation of decreasing supplies.

Some years ago, nameplate capacity of the 3 mines was 2 mill. t K_2O. The mine Théodore has ceased production, leaving a capacity now of 1.8 mill. t K_2O, concentrated at the mines Marie Louise and Amélie. As MDPA is part of the state enterprise EMC, and considering that France is certainly unlikely to rely completely on foreign potash imports in view of the difficult labour situation in Alsace, it is safe to assume that the national potash industry will be kept alive at a capacity level not much lower than the present one for at least another 15 or 20 years. The French potash market will continue to be supported by deliveries from other European producers.

Moreover SCPA sells part of the Jordanian production and, together with K+S, holds a share of 40% in the New Brunswick potash company DPPC. This has just become operational with a nameplate capacity of 0.8 mill. t K_2O. About 40% of the total will be sold offshore, 60% in North America, thus relieving the drain on West European potash supply possibilities.

Further engagements abroad may not be wholly ruled out.

K+S, MDPA, Spain and Italy are all SOP producers with a production, in 1983/84, of almost 0.9 mill. t K_2O of that grade, vis-à-vis 0.3 mill. t K_2O in North America. Reverting to exportable surpluses, the figure for Western Europe was 365.000 t K_2O, that for the USA was 40.000 t K_2O.

K+S is steadily increasing its SOP capacity.

Overall, West European potash capacity in 1995 will probably be almost 9 mill. t K_2O, as compared to the 7,5 mill. t K_2O in 1985. This includes the planned expansion in Israel.

Balances of available supply versus consumption up to 1990 may develop as follows:

	1984/85	**1989/90**
Available Supply	6.409	6.596
Agricult. Consumption	5.600	6.050
Balance	809	546

I cannot help emphasizing that these exportable surpluses are in a way theoretical.

In 1984/85, West European overseas exports actually were 1,5 mill. t K_2O instead of the 0.8 mill. t K_2O appearing as exportable surplus. There is no denying, however, that this is only a share of about 40% in total West European exports of 3,6 mill. t K_2O and a share of just 20% in total West European sales. In other words: 80% of deliveries are made to destinations within the region,—and these deliveries are tailormade to fit the sophisticated requirements of that market by making available a wide range of products, from granulated kieserite to 40% K_2O "Kornkali" to sulphate of potash magnesia to granulated sulphate of potash.

K+S of West Germany is the biggest West European potash producer. It may also be considered as typical for the region as regards the distribution of grades and destinations. (Figures 19, 20)

5g) The Situation of Eastern Europe

Let us finally move to Eastern Europe now. The GDR potash industry has almost reached its capacity level of 3.5 mill. t K_2O. It is not intended to build any additional potash mines. In view of the high rate of potash application attained in the domestic market, it is likely that the present level of 600.000–700.000 t K_2O will not be surpassed. Therefore the export potential squeezed in between stagnating capacity and stagnating home market demand, cannot expand and will stay at a theoretical level of 2.8 mill. t K_2O.

It is anybody's guess how much of this will be actually produced and distributed in the COMECON area and how much will go to the West in future. So far, the emphasis has always been on Western destinations.

I have saved a description of the USSR situation until the last as it eludes any effort at precision and yet is so important.

There are three production associations in the USSR, each with a large capacity:

Uralkali	8.3 mill. t K_2O
Bjeloruskali	5.2 mill. t K_2O
Ukraine	0.5 mill. t K_2O
Others	0.05 mill. t K_2O
Total	14.05 mill. t K_2O

Uralkali consists of 7 mines, 2 of which are recent ones. No one knows, however, if these have already become operational and if so, in what steps they are being phased-in. Russian mining journals are enigmatic about this.

Further problems: it is generally assumed that losses in storage and handling amount to at least 10%. The operating rate averages at around 78%. According to this calculation, available supply would reach not more than 9.9 mill. t K_2O in 1990.

USSR consumption may reach 7,6 mill. t K_2O in that year which leaves just 2.3 mill. t K_2O as exportable surplus. In 1984, the USSR exported already 3.2 mill. t K_2O, of which 1.8 mill. t K_2O to the COMECON. If they want to maintain that level, only 0.5 mill. t K_2O could be exported to the West, as compared to 1.3 mill. t K_2O in 1984,—assuming all the time that those 2 new mines are producing all-out.

In reality, COMECON demand will of course be higher in 1990 than in 1984. What are the alternatives?

a. if the demand projections are correct, then the Russians must achieve a much higher operating rate and drastically reduce losses,—or they must phase-in completely new capacities.
b. if demand in the USSR and the COMECON proves to be lower than anticipated, then the surplus exportable to the West will be higher,—but not as high as it is today.

Personally I do feel that the USSR will in future pay much more attention to supplying her domestic market, that her potash supply availability will not grow fast enough to maintain present priorities and that as a result exports to the West will be affected.

5h) Conclusions

If you wanted me to draw some very broad conclusions from weighing all the pro's and con's of the world potash market, they might be like this:

1. Potash resources and reserves will last for several hundred years.
2. Potash demand will continue to grow along a fairly regular trend but with increasingly frequent fluctuations.
3. The demand curve is flattening in North America, Western Europe and some additional developed countries, it will get steeper in the developing countries and rise somewhat in the Socialist countries. Worldwide this balances out to cause an almost straight line trend within the period under review.
4. Existing capacities and projected mines will be sufficient to satisfy demand until at least the year 2000.
5. Theoretical surpluses, at least in the West, could be prevented from materializing to any dangerous degree if all world potash producers continued to practice voluntarily a policy of wise self-restriction in a market structure which is by the nature of things oligopolistic.

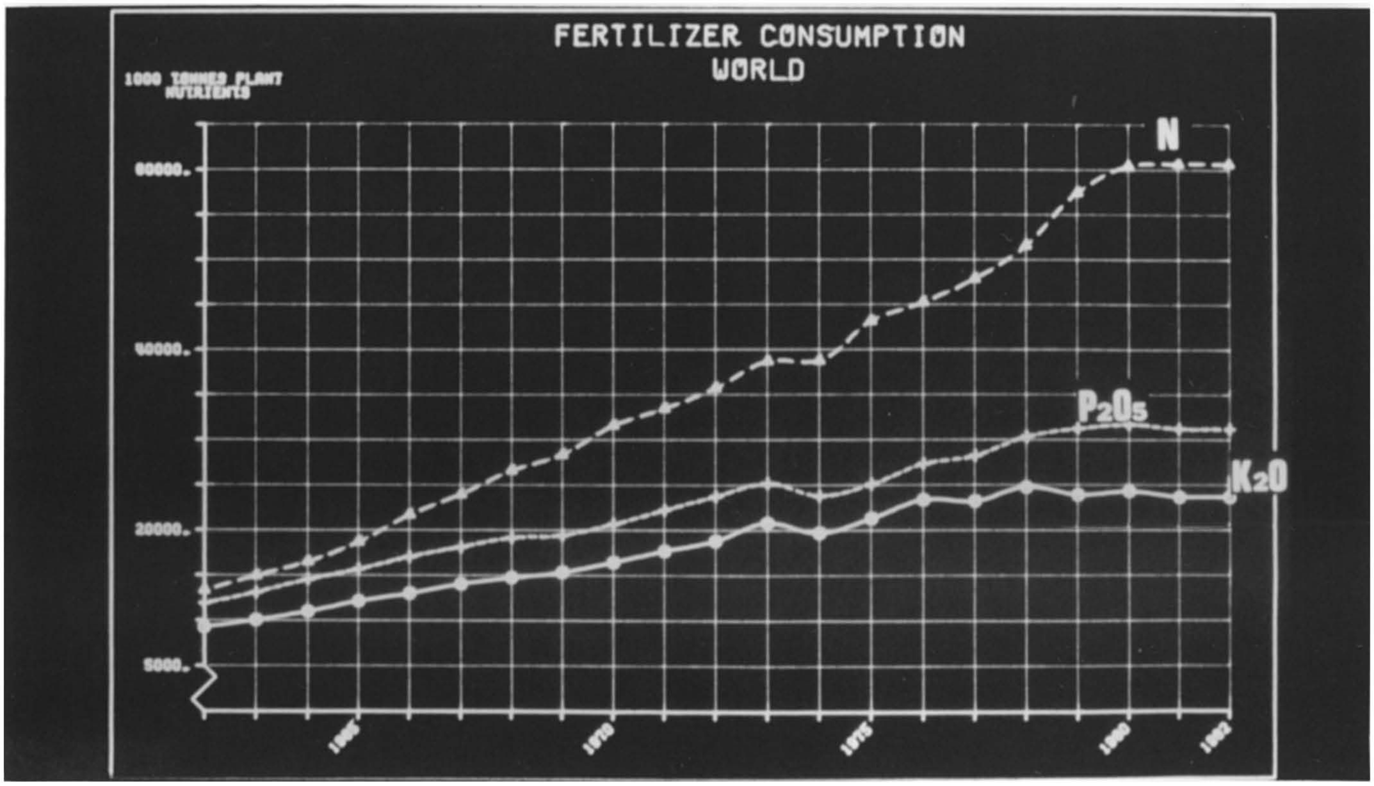


Figure 1

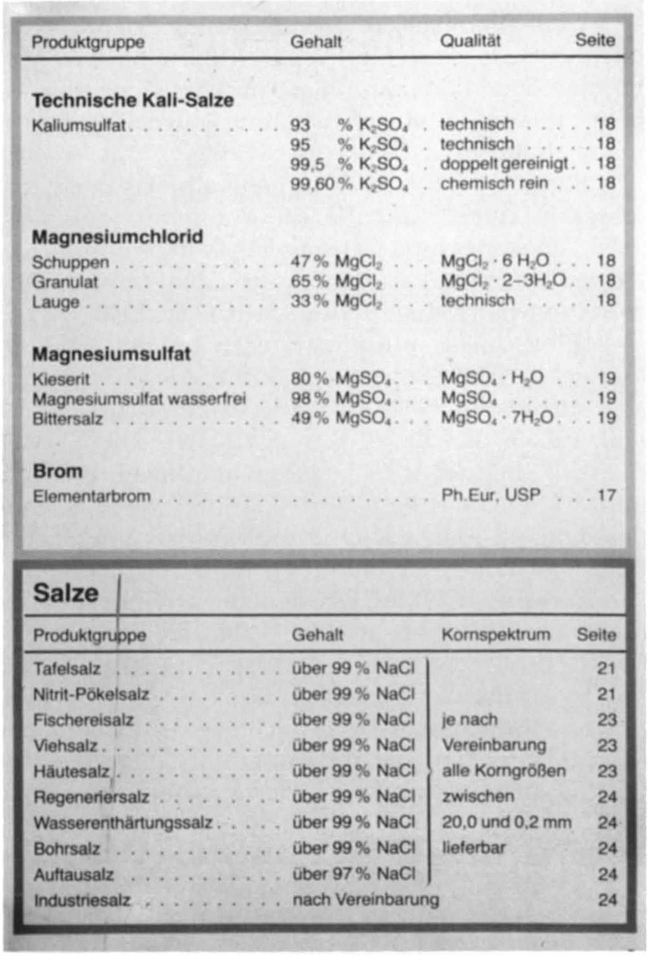
Düngemittel

Produktgruppe	Gehalt	Kornspektrum	Seite
Chloridische Kalidünger			
Kaliumchlorid 60 fein	60 % K_2O	0,8–0,01 mm	11
Kaliumchlorid 60 staubfrei	60 % K_2O	1,0–0,2 mm	11
Kaliumchlorid 60 crist. coarse	60 % K_2O	2,0–0,6 mm	11
Kaliumchlorid 60 coarse	60 % K_2O	2,4–0,8 mm	11
Kaliumchlorid 60 gran.	60 % K_2O	3,6–1,6 mm	11
Kaliumchlorid 60 grob	60 % K_2O	3,6–0,8 mm	11
Kaliumchlorid mit Magnesium 40/5 grob	40 % K_2O 5 % MgO	4,0–0,8 mm	13
Kaliumchlorid 50 fein	50 % K_2O	1,0–0,01 mm	13
Kaliumchlorid 50 grob	50 % K_2O	4,0–0,8 mm	13
Angereichertes Kalirohsalz 20	20 % K_2O	4,0–0,1 mm	13
Kalirohsalz 12/6 grob	12 % K_2O/6 % MgO 24 % Na_2O	4,0–0,8 mm	13
Sulfatische Kalidünger			
Kaliumsulfat 50 fein	50 % K_2O	0,5–0,01 mm	14
Kaliumsulfat 50 grob	50 % K_2O	3,6–0,8 mm	14
Kaliumsulfat mit Magnesium 30/10 grob	30 % K_2O/10 % MgO 18 % Schwefel	4,0–0,8 mm	14
Sulfatische Magnesiumdünger			
Magnesiumsulfat 27	27 % MgO 21-22 % Schwefel	1,0–0,1 mm	14
Magnesiumsulfat 16	16 % MgO 13 % Schwefel	1,0–0,2 mm	14

Chemikalien

Produktgruppe	Gehalt	Qualität	Seite
Technische Kali-Salze			
Kaliumchlorid	80 % KCl	technisch	18
	97 % KCl	technisch	18
	98,5 % KCl	technisch	18
	99,3 % KCl	doppelt gereinigt	18
	99,80 % KCl	chemisch rein	18

Figure 2a



Produktgruppe	Gehalt	Qualität	Seite
Technische Kali-Salze			
Kaliumsulfat	93 % K_2SO_4	technisch	18
	95 % K_2SO_4	technisch	18
	99,5 % K_2SO_4	doppelt gereinigt	18
	99,60 % K_2SO_4	chemisch rein	18
Magnesiumchlorid			
Schuppen	47 % $MgCl_2$	$MgCl_2 \cdot 6\,H_2O$	18
Granulat	65 % $MgCl_2$	$MgCl_2 \cdot 2–3H_2O$	18
Lauge	33 % $MgCl_2$	technisch	18
Magnesiumsulfat			
Kieserit	80 % $MgSO_4$	$MgSO_4 \cdot H_2O$	19
Magnesiumsulfat wasserfrei	98 % $MgSO_4$	$MgSO_4$	19
Bittersalz	49 % $MgSO_4$	$MgSO_4 \cdot 7H_2O$	19
Brom			
Elementarbrom		Ph.Eur, USP	17

Salze

Produktgruppe	Gehalt	Kornspektrum	Seite
Tafelsalz	über 99 % NaCl	je nach Vereinbarung alle Korngrößen zwischen 20,0 und 0,2 mm lieferbar	21
Nitrit-Pökelsalz	über 99 % NaCl		21
Fischereisalz	über 99 % NaCl		23
Viehsalz	über 99 % NaCl		23
Häutesalz	über 99 % NaCl		23
Regeneriersalz	über 99 % NaCl		24
Wasserenthärtungssalz	über 99 % NaCl		24
Bohrsalz	über 99 % NaCl		24
Auftausalz	über 97 % NaCl		24
Industriesalz	nach Vereinbarung		24

Figure 2b

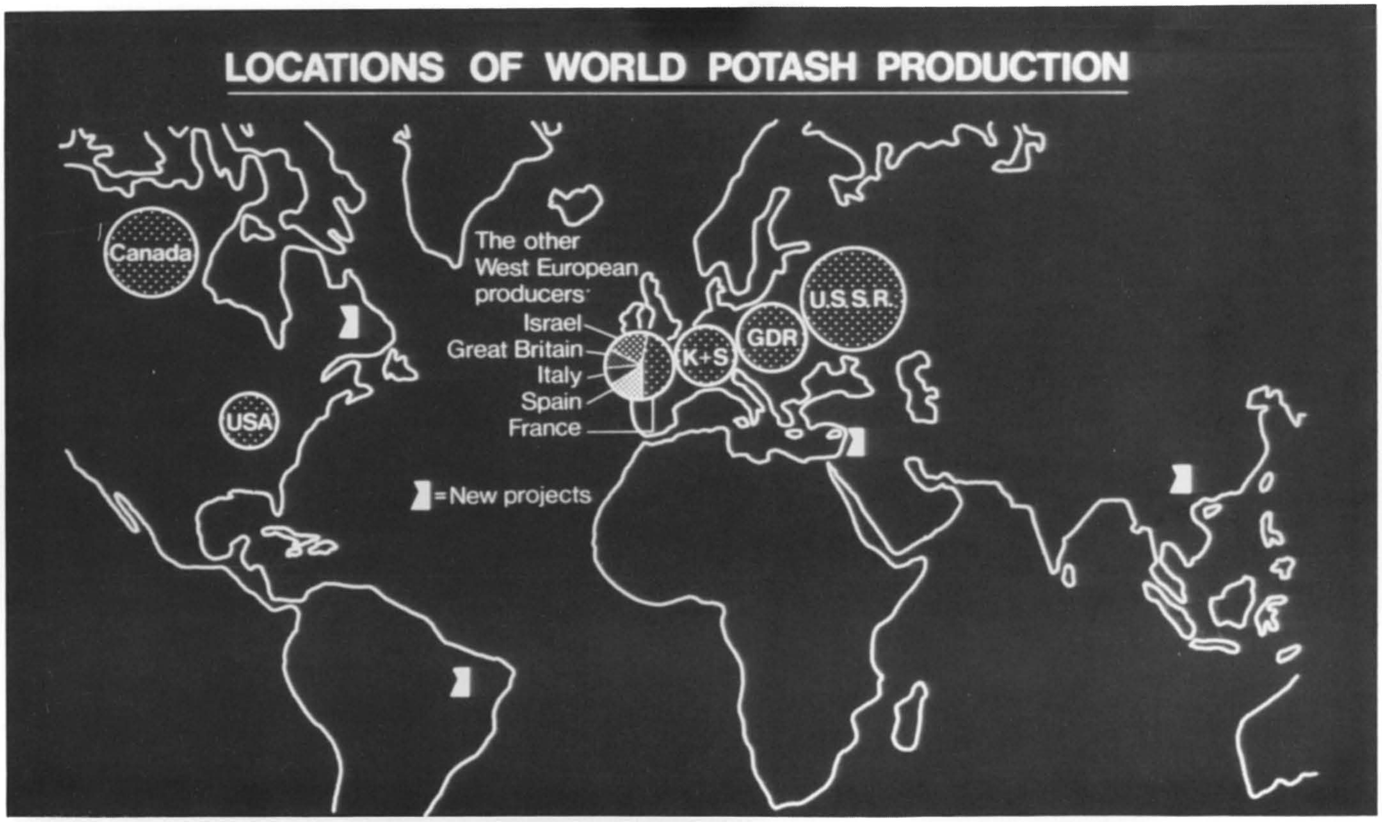


Figure 3a

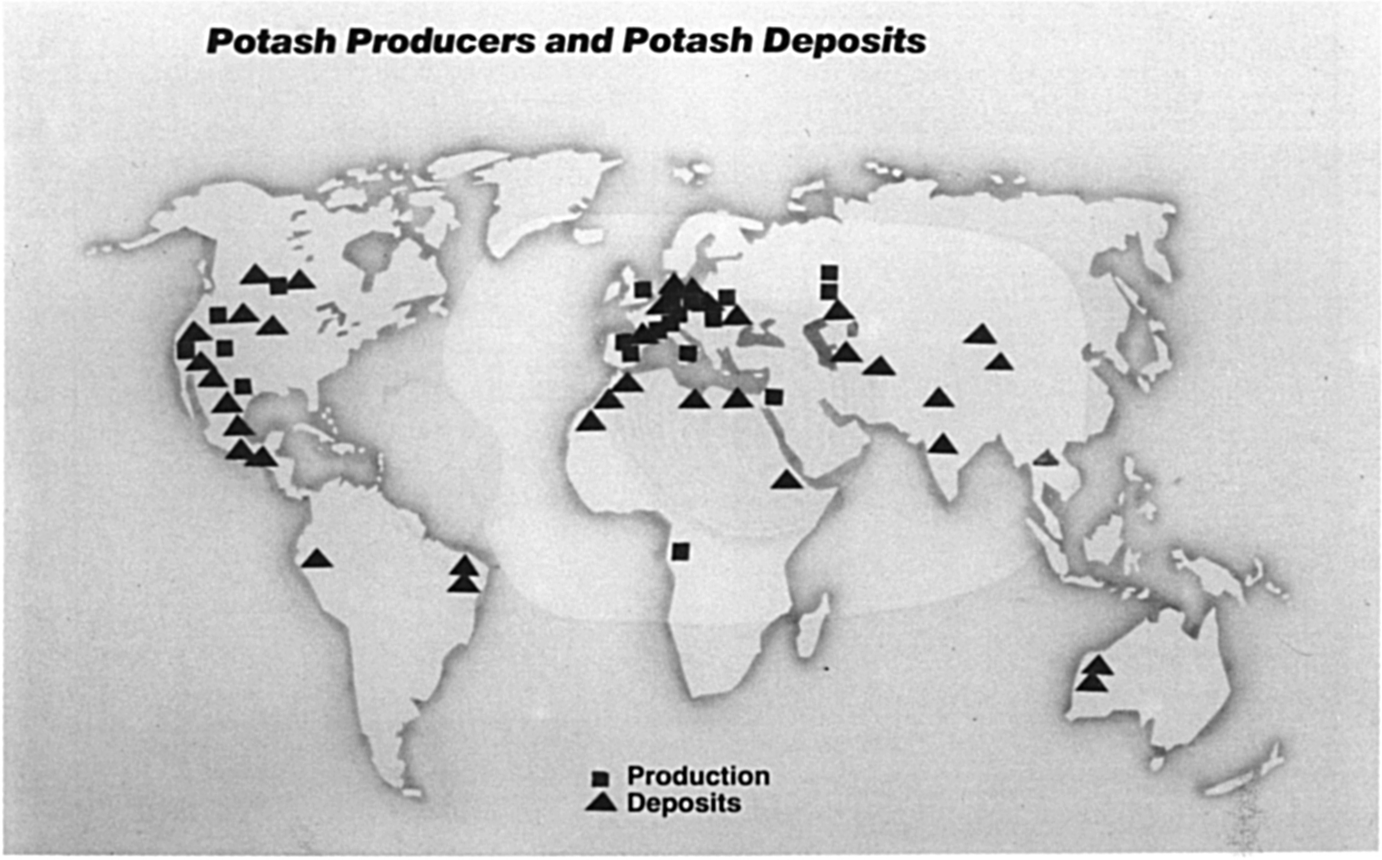
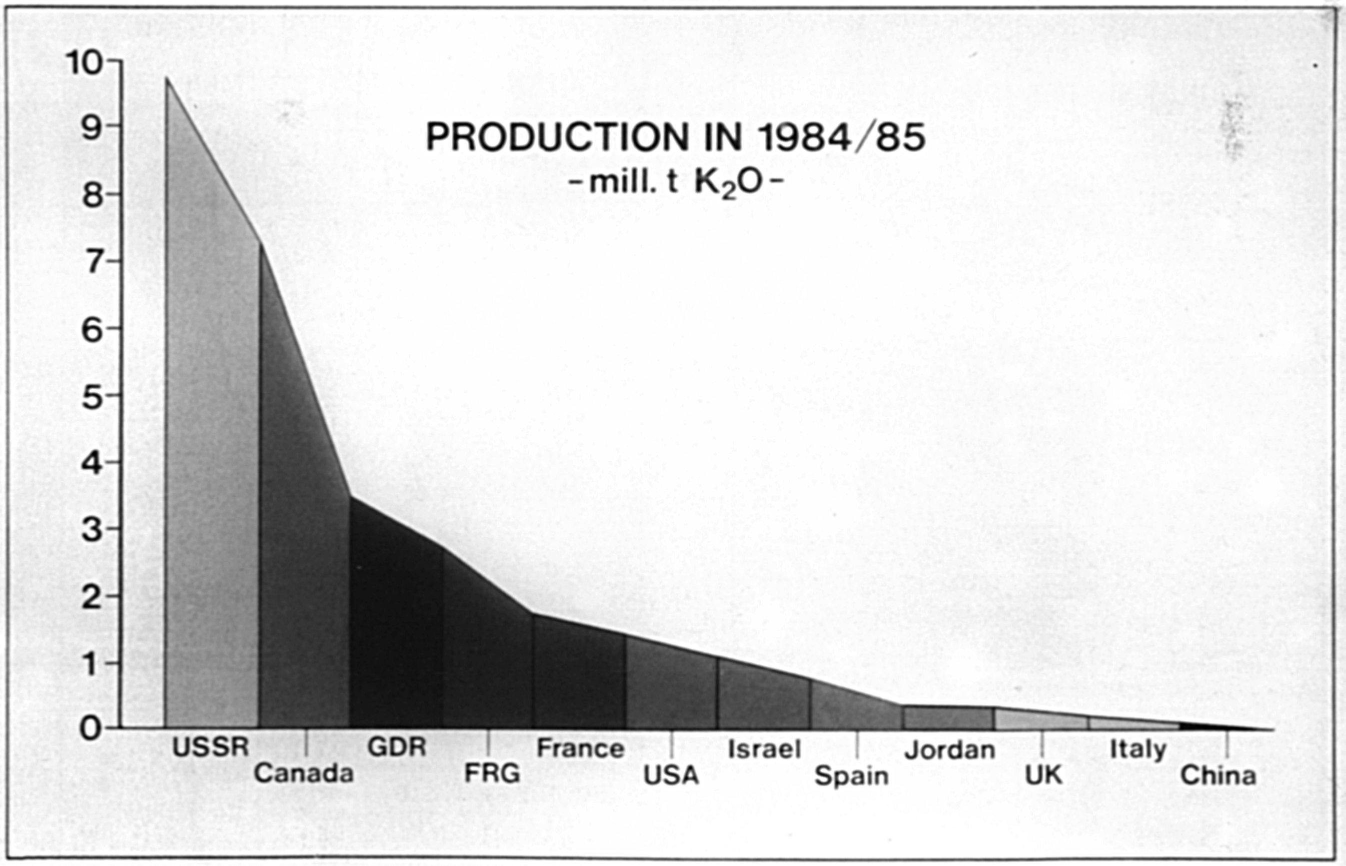


Figure 3b



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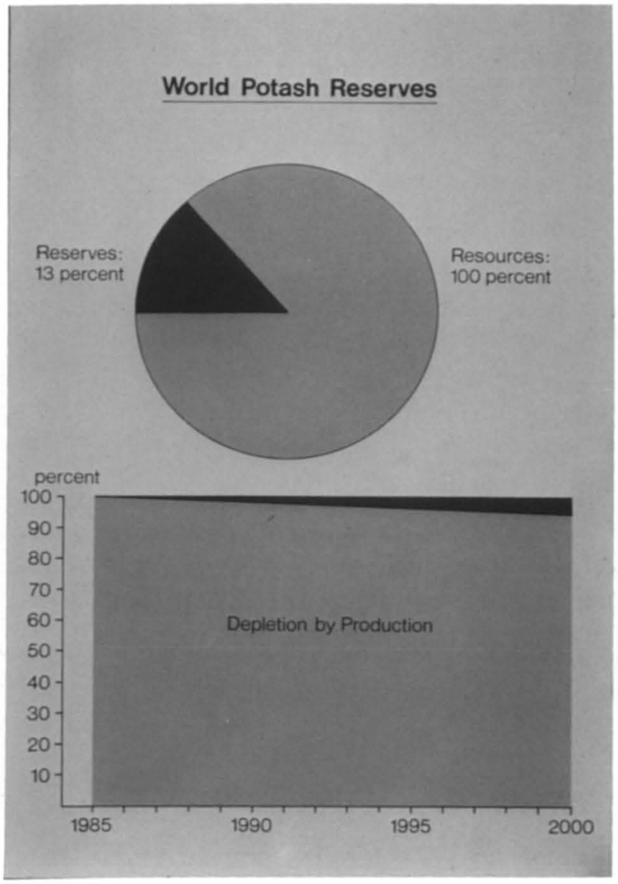

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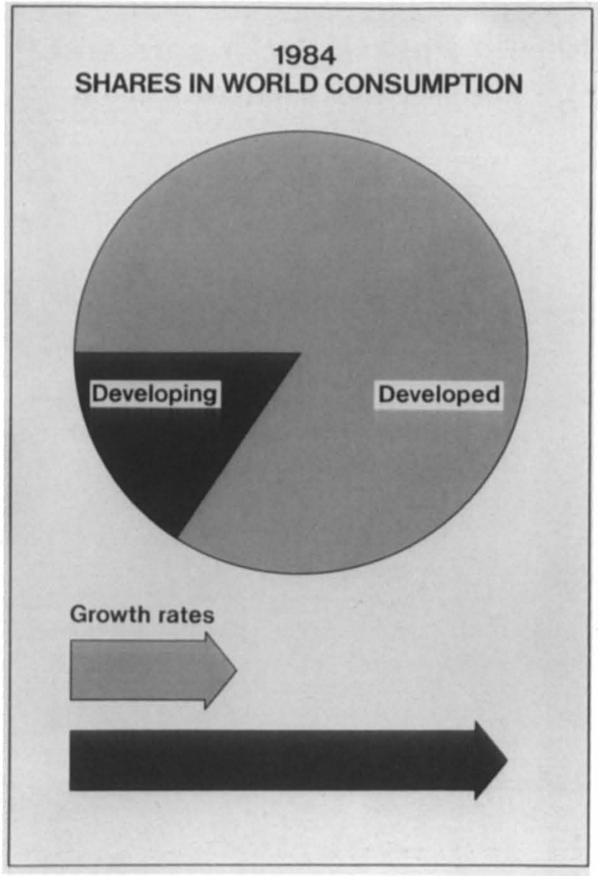

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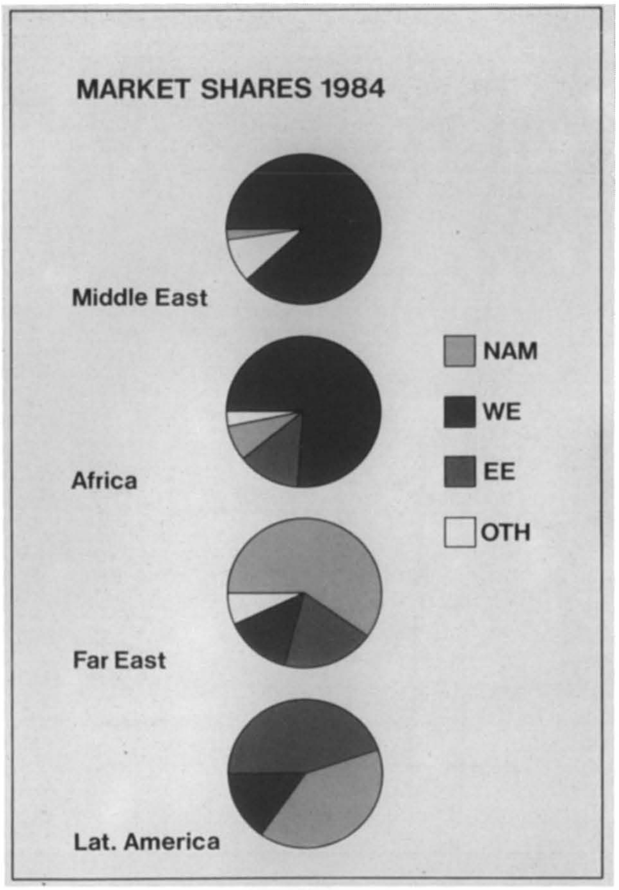

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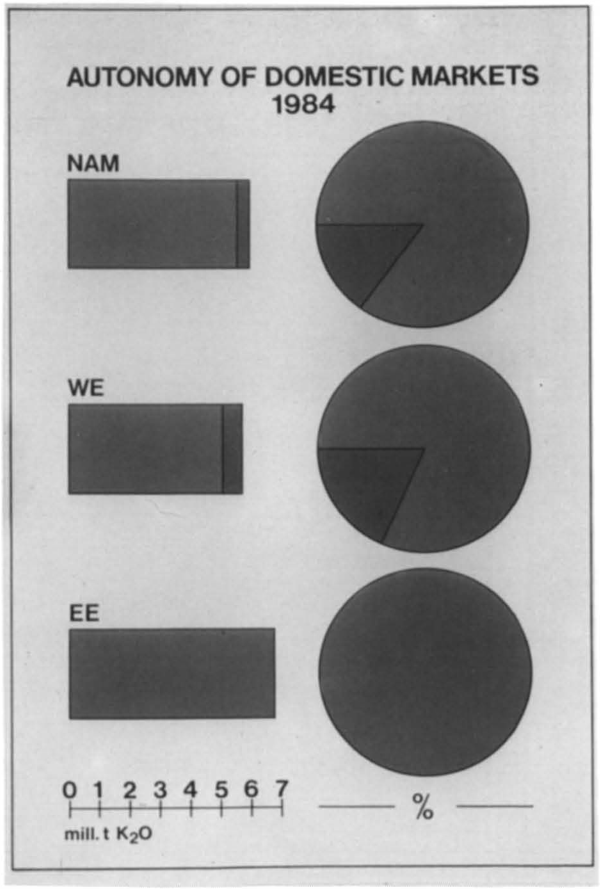

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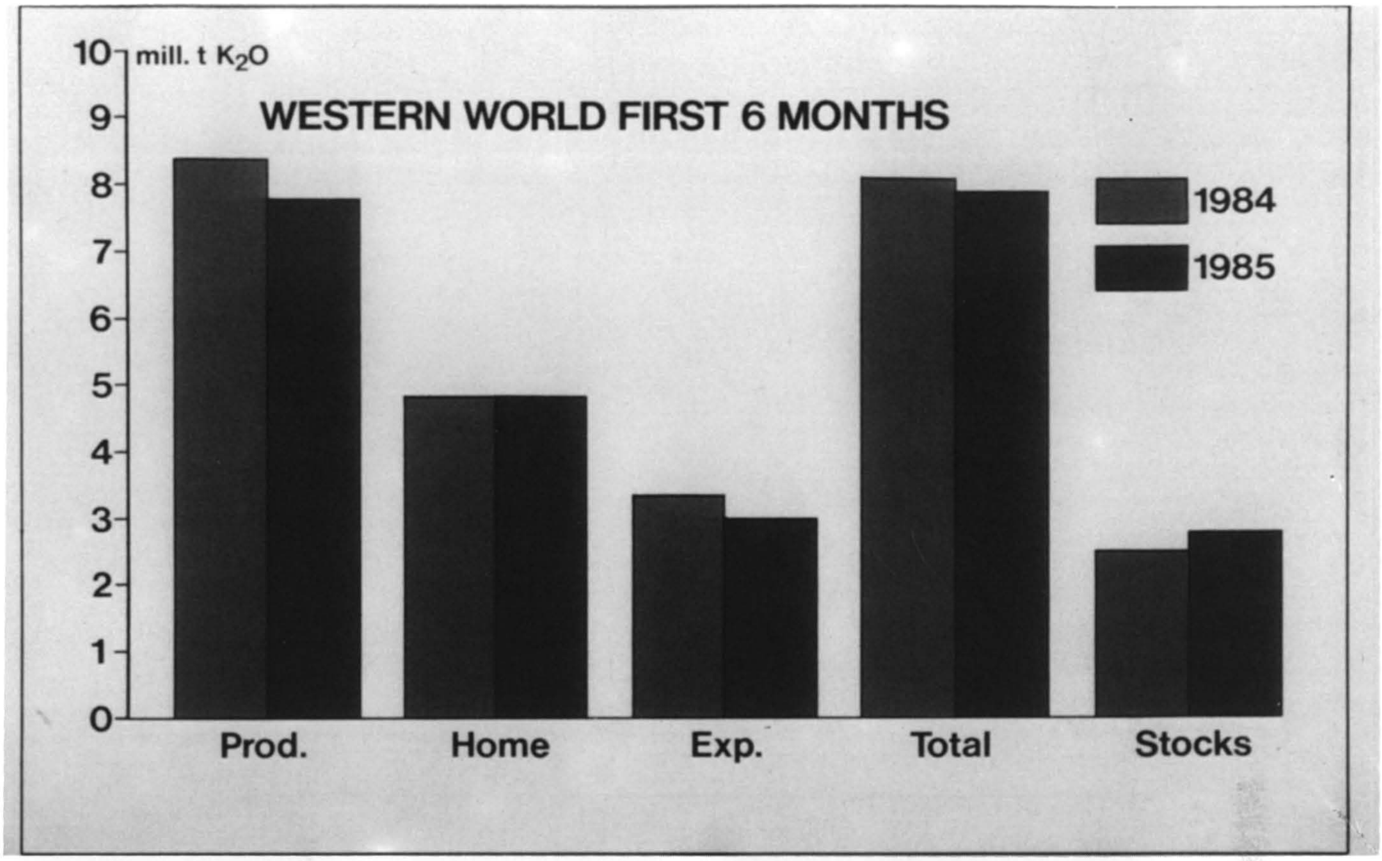

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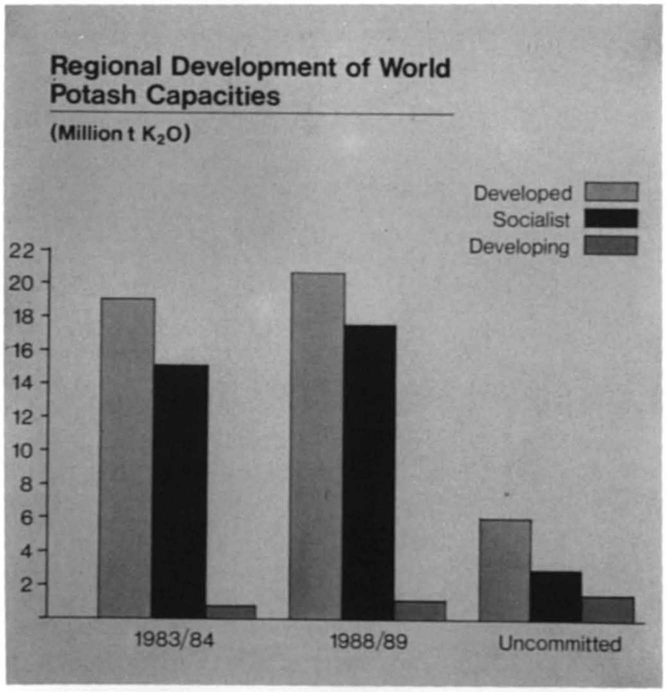

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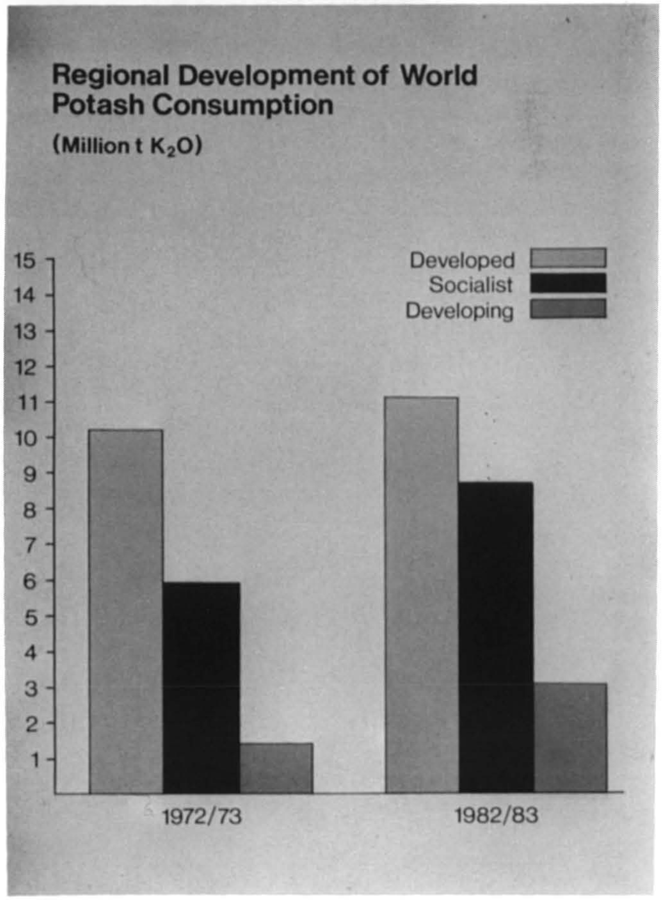

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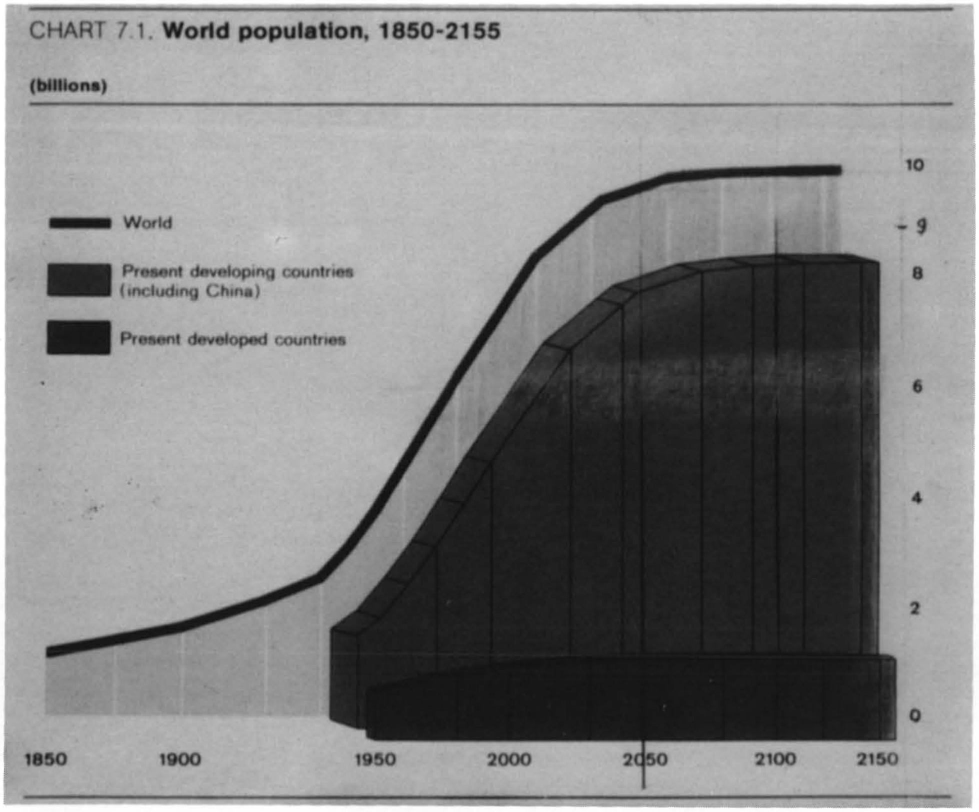

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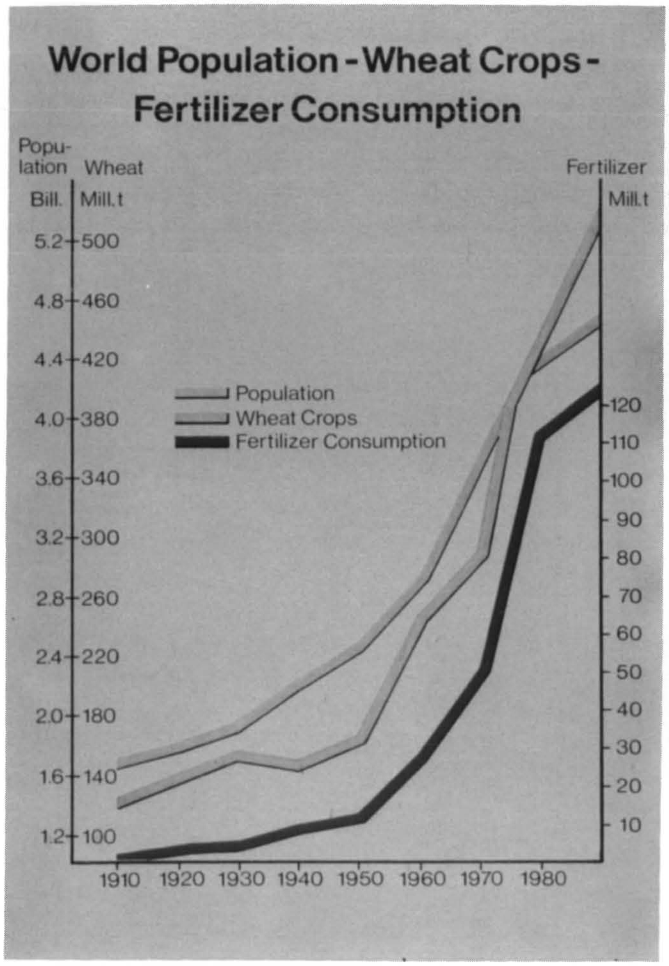

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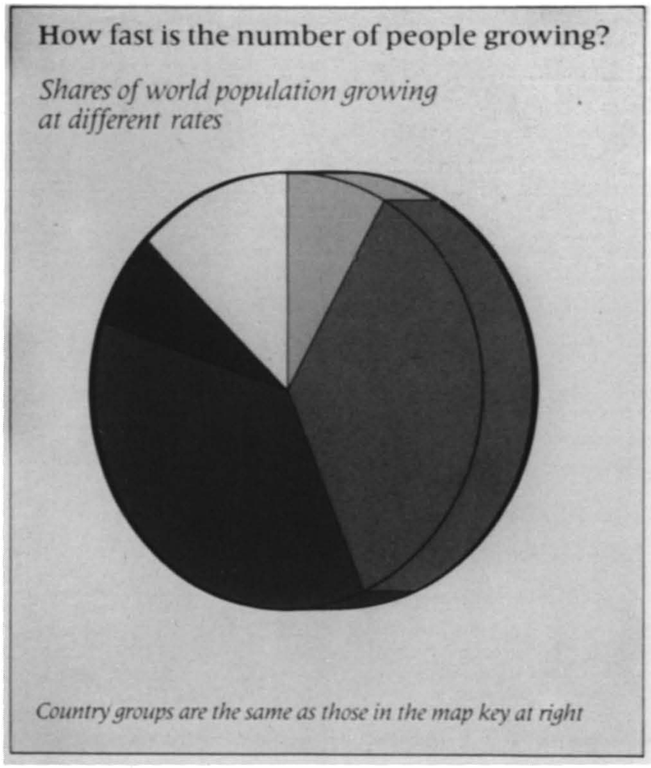

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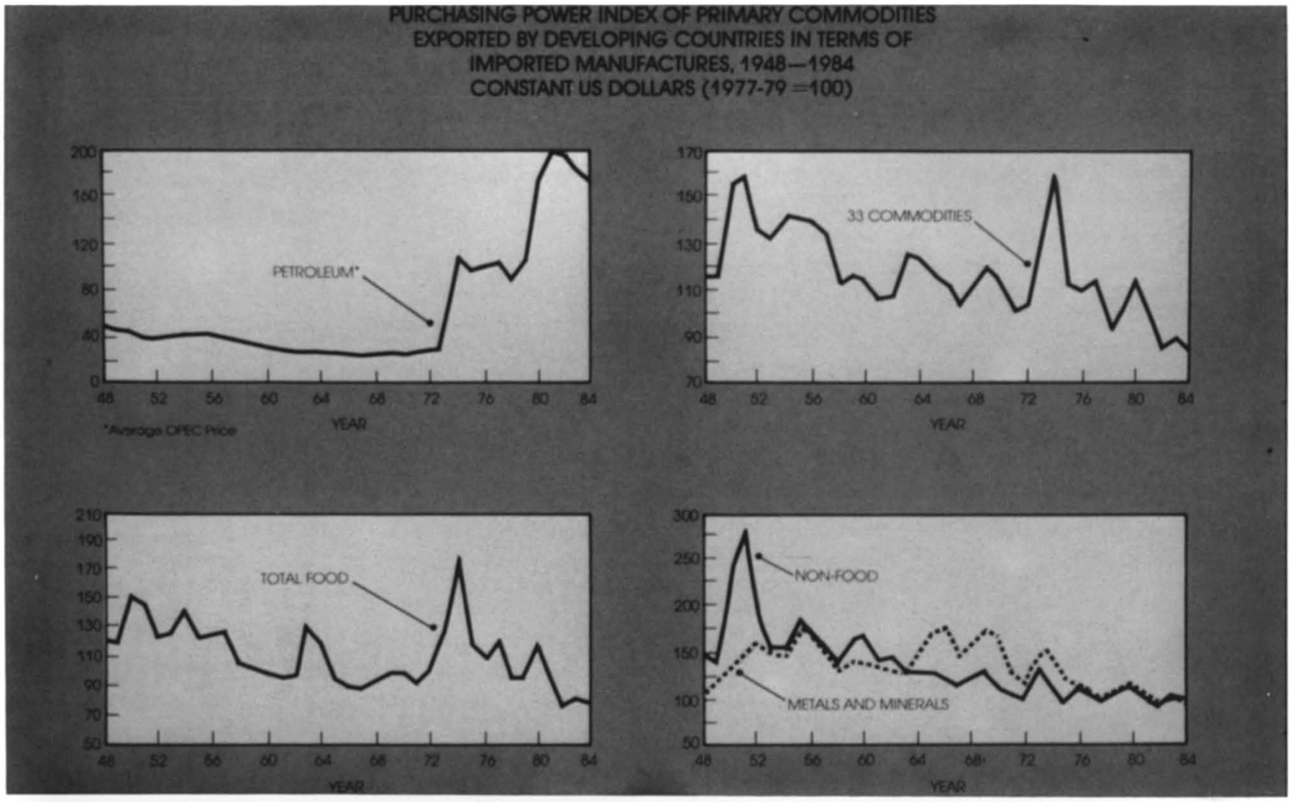

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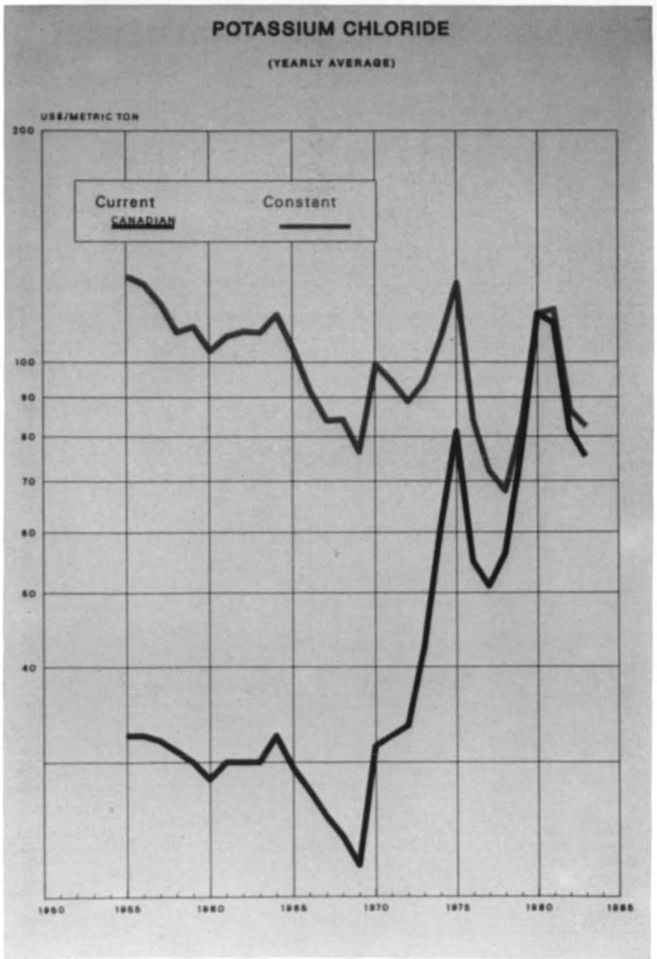

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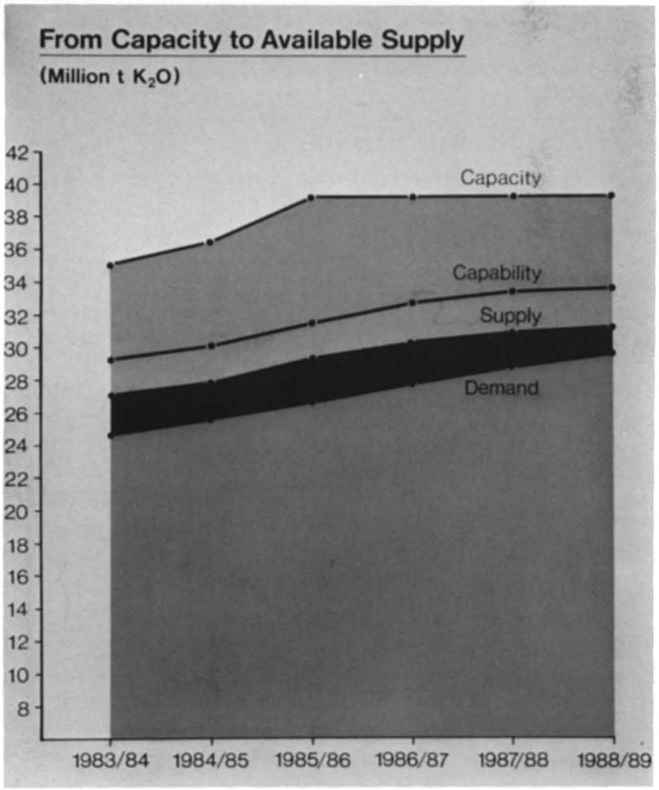

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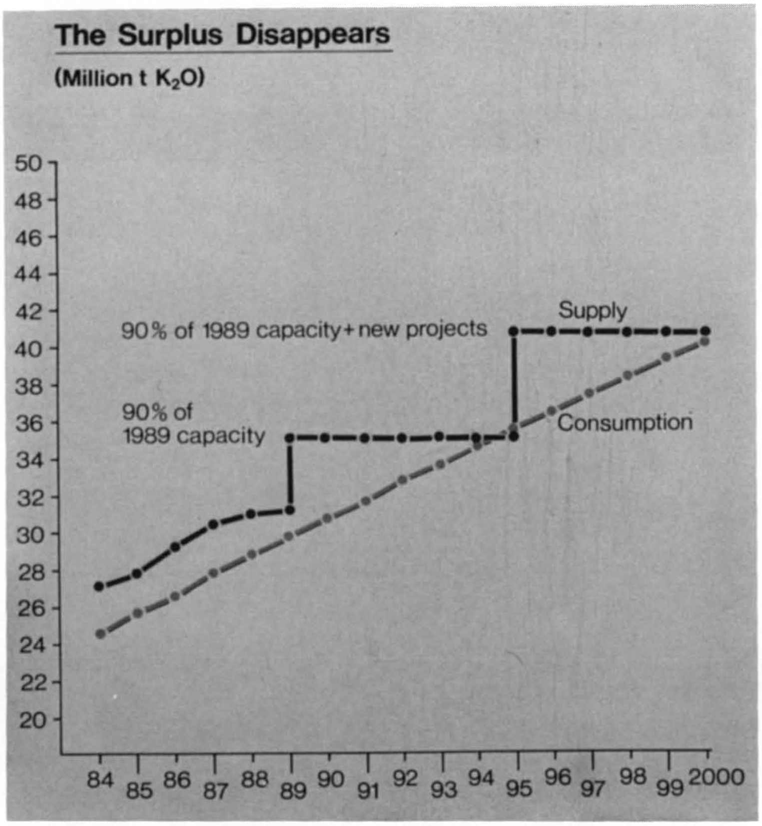

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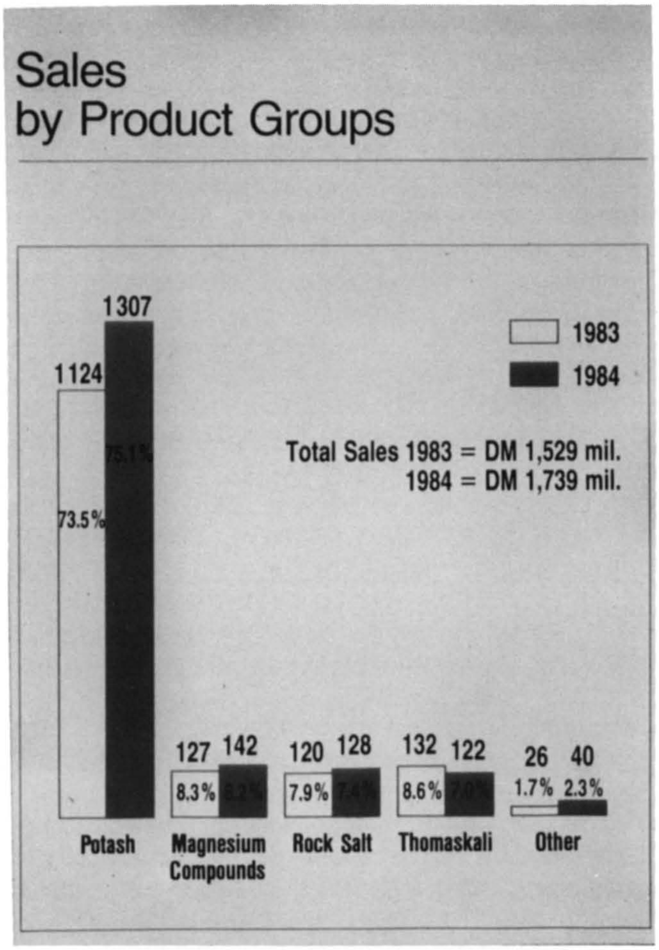


Figure 19

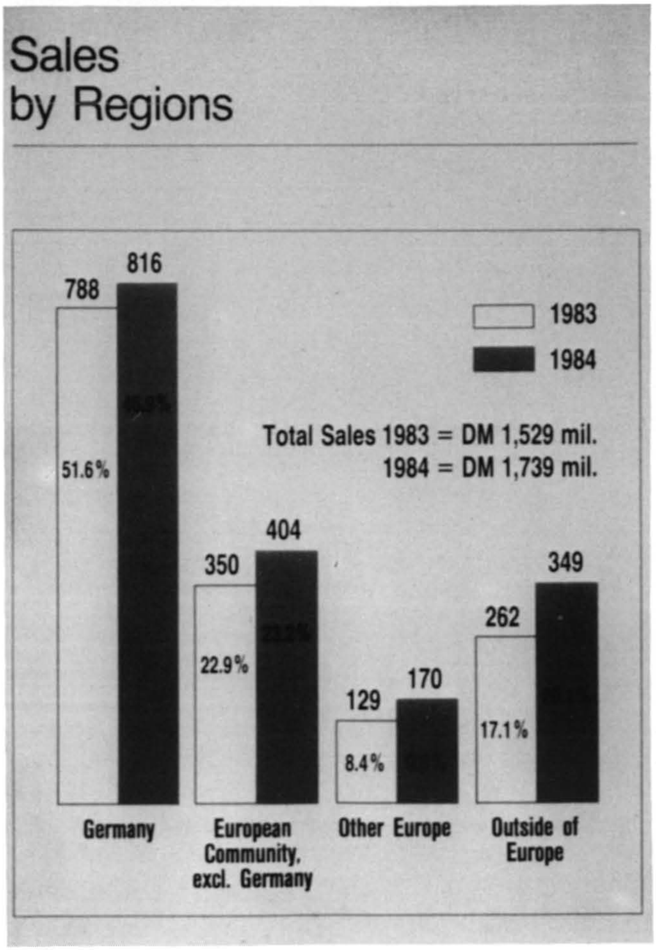


Figure 20

Sulfur Supply/Demand from the Perspective of a U.S. Recovered Producer

T. D. Callaway, Jr.
Sales Manager-Sulfur
Shell Oil Company

The title of my presentation implies an ability to foresee the future, but surely all that have been bold enough to try, realize that precision in such an endeavor is truly lacking. The future of sulfur supply and demand depends on many factors, all of which hold a great degree of uncertainty. Today, I must admit to being in the position of a blind man trying to see the future in a cloudy crystal ball.

Let us first set the scene for world recovered sulfur supply and demand:

Figure 1: Sources of Gas Recovered Sulfur

Sulfur recovered from natural gas production accounts for 25% of all-forms sulfur and is dominated by only a few countries. At present Canada has the largest sulfur production capability from natural gas and by judicious use of the sulfur block that accumulated during the late 70's, early 80's, Canada has been a reliable supplier to the world. Russia is expected to emerge in the future as the dominant supplier once the Astrakhan projects come onstream and I call your attention to the significant natural gas reserves underlying the U.S.S.R. These reserves will, depending on the national strategy of the U.S.S.R., allow continued natural gas production and sulfur domination by the U.S.S.R. well into the 21st century.

Natural Gas Reserves are expected to be available in the U.S. to allow potential production increases, but as I will show you later, these potential increases will be delayed because of the current gas oversupply and falling price conditions existing in the U.S. market today. Additional development plans to some extent will be delayed waiting for the natural gas market to approach a more balanced state.

There is the potential for supply increases in the Middle East. Europe is expected to have a reduced supply from domestic production.

Figure 2: Sources of Oil-Recovered Sulfur Production

Again only a handfull of countries dominate the sulfur supply recovered from crude oil production. The U.S. and Japan are expected to maintain their dominance in sulfur supply from crude oil refineries. Growth potential exists in the major oil producing areas of the world as more countries try to capture additional value from their crude oil production by investing in downstream refineries to process the crude and then market sulfur and other finished or semi finished products.

Figure 3: World's Sulfur Supply/Demand

Whereas I showed that sulfur supply is concentrated in relatively few countries, demand is widely spread.

Figure 4: Sulfur Demand

The major key demand area for sulfur production in the world is fertilizer manufacturing. Phosphate fertilizer manufacture is moving from the U.S. to North Africa where the demand for sulfur is expected to grow.

It is important to remember in any forecast of sulfur supply and demand that everything is interdependent. Agricultural policies, import/export policies, currency strengths/weaknesses, political goals, and hydrocarbon economics are just some of the host of factors that must be considered in developing a sulfur forecast. Since it is impossible to consider the impact of everything on everything else, and since the future will certainly contain unpredicted events, my perception of sulfur supply/demand must be tempered by the individual assumptions held by each of you about the future of the world economy.

When I was first requested to present my thoughts to you here today, it seemed that we had a world economy that was rebounding from a recession and was starting to grow. It seemed to many that there was higher sulfur demand than could be met from existing supplies. Today, the picture is not that clear.

In the U.S., the domestic phosphatic fertilizer industry is operating at reportedly near or below cash cost recovery levels. Some producers have sought the protection of the Federal Bankruptcy Code. A number of others have reported plant cutbacks and curtailments, and several members of the industry are for sale.

The U.S. farm economy is beleagured. The credit situation is, at best, bleak. Many farmers are being forced to sell their land. The U.S. dollar remains high, decreasing the competitiveness of U.S. farm commodity exports. Historically major food/feed grain importers are at or near internal self-sufficiency; and the high yields of the 1985 harvest will exacerbate the farm products surplus already existing.

The world hydrocarbon market is oversupplied and prices are in turmoil. Saudi Arabia has recently announced production increases and pricing incentives, which will move increased crude oil onto the world market at a time when the market has surplus supply. Crude oil prices have declined from the high $30's, to a level today nearer to the mid $20's.

The U.S. natural gas market remains in a position of excess deliverability as reflected by the continuing downward price spiral producers realize for production at the well head. The decline in revenues received by a hydrocarbon producer in the U.S. for its natural gas or crude oil production has a direct impact on that producer's ability to explore and drill areas for additional reserves. During 1984, U.S. natural gas consumption was approximately 17.5 Trillion cubic feet (TCF), but reserve replacements only approached 11 Trillion cubic feet.

A valid question is what impact does this have on Sulfur?

Figure 5: U.S. Elemental Sulfur Production

As you probably know, sulfur recovered from oil and natural gas now accounts for nearly 50% of total U.S. sulfur production and a reduction of supply in this sector will have an obvious effect on U.S. production totals.

Figure 6: Crude Oil Price

Crude oil prices to a U.S. refiner both from domestic and imported sources have fallen from the mid $30/barrel range to a current upper to mid $20's price.

As margins have declined on refined petroleum products, refineries in the U.S. have gone increasingly toward purchase of finished petroleum products. As these products are refined elsewhere, less recovered sulfur is available for the U.S. market. New refineries such as the one at Yanbu, Saudi Arabia, will continue to exert pressure on refining margins worldwide.

On the other hand, if the crude oil supply imbalance reaches equilibrium, U.S. refineries, for the most part, have existing capability to handle heavier crude oil runs and thus have the potential for recovery of sulfur. However, at best, this potential would only offset sour natural gas production declines.

Figure 7: Quarterly Domestic Drilling Rig Count

With the turmoil in domestic oil and gas markets, is it any wonder that producers are unwilling to invest in new drilling ventures? As you can see, active drilling rig utilization is declining with most rigs being used to develop previously exploited fields and reservoirs.

Current natural gas production is declining. The continuing reduction in the available reserve base of sour and deep natural gas is further tightening U.S. sulfur supply. In my opinion, the near term forecast for natural gas prices offers little or no incentive for development of new sour gas reserves.

Figure 8: Spot Natural Gas Price

The spot price for natural gas has fallen from over $3.00/MCF late last year to a current level in Texas near $2.00/MCF.

Figure 9: Investment Comparison Deep/Shallow Field

A decision to invest in major sour gas fields to develop new sulfur supplies cannot be easily justified with the conditions currently prevailing in the oil patch.

Let me explain. A major new U.S. sour natural gas field:

—would typically entail production from deep and/or hostile geologic environments;

—would have "drilling" costs of between 4–6 million dollars per well;

—would require an additional 7–10 million dollar investment just to complete each commercially productive well;

—would require an additional prorated per well investment of approximately 12 million dollars for an amine treating/claus sulfur recovery facility,

—would entail a total field development investment of between ¼ to ½ billion dollars before the first cubic foot of gas or ton of sulfur was sold.

Compared to deep well develops, the typical sweet natural gas well drilled in the U.S. is about 5,600 feet deep and requires a total investment of about one million dollars.

In view of the foreseeable future for oil and gas prices, sour gas developments requiring multi-million dollar investments does not appear to be economically prudent.

Apart from Exxon's sour gas and CO_2 project in Wyoming which has been reported due on stream in phases during 1986 and 1987, I'm not aware of any large new single source of increased recovered sulfur production anywhere in the free world. There is a great deal of offshore exploration in the U.S. Gulf, particularly the Mobile Bay Area, where Mobil has made a discovery, but the commercial quantities to be available from these areas have not been announced to the public at the present, and absent a better economic climate in the oil patch, the U.S. petroleum industry is unlikely, long term, to offset declining sulfur production from the existing major fields.

The only other known major new supplies are the Astrakhan project in the U.S.S.R. with its first phase due on stream late 1986 or early 1987. Additional production there will come on stream in phases and is estimated to ultimately reach near the 3 million long ton level in the early 1990's.

How much of this will be available in the world market to replace reduced exports from Canada and from the U.S. is currently unknown. How much will be used to generate hard currency for the Russian economy and how much will be used to meet domestic P_2O_5 requirements and how much will replace Polish imports merely adds to the difficulty of forecasting a supply/demand balance for sulfur.

Is my blind forecaster pessimistic enough to suggest that, near term, sulfur will be short worldwide? I don't believe that the crystal ball is that cloudy. There is some potential spare capacity short-term in North America.

In 1984, Free World sufur demand totaled 38.6 million metric tons and current production reached 36.6 million metric tons, with producers balancing the supply/demand equation by re-melting 3.1 million metric tons of inventory. U.S. Frasch, Canadian, and French remelt, will likely be enough to balance the supply/demand position through late '88, early '89.

Canada currently has inventories of approximately 10 million tons, U.S. inventories are approximately 2 million tons and French inventory is about 1 million tons. Inventories in the rest of the Free World are negligible. It appears to me that, unless we have another recession, world-wide supply and demand will stay in very tenuous balance until Astrakhan allows exports from the U.S.S.R.

Notice that I said worldwide supply and demand will remain in tenuous balance. The picture for the U.S. is a little more bleak. The phosphate industry is in an oversupply position. Its posture as supplier to the export market has been eroded by the development of domestic phosphate industries in Mexico, Brazil, India and China; as well as by the continued expansion of the North African phosphate industry. This trend is likely to continue since a strong U.S. dollar encourages the development of offshore fertilizer capacity utilizing non dollar denominated investments or counter trade contracts.

The capability of the American farmer to export his grain into the world market has been reduced by the increased self-sufficiency of major consuming nations and by political actions on the part of the U.S. government since the mid-'70's, the most notable being the grain embargo to the U.S.S.R. in 1980. The strong dollar has encouraged exports from other farming nations who have the capability and who have added acreage to their productive areas to take advantage of the export window left open by the U.S.

Currently, we cannot suggest that the U.S. growth rate for sulfur in all forms will be as robust as once thought. Neither will the supply of smelter acid nor sulfur from power plant stacks, coal liquefication and gasification projects yield the quantities of sulfur that were once projected. Stack gas SO_2 is likely to increase due to environmental constraints, but there continues to appear to be insufficient economic incentive to recover the sulfur values versus the limestone scrubbing/gypsum throw-away process.

Considering today's oil and natural gas oversupply and low price, synthetic fuels, once touted during the late '70's and early '80's, appear to be uneconomic, and are unlikely to make any significant contribution into the middle 1990's.

There is always the possibility that known very high H_2S deposits in Canada and the U.S., that is deposits that approximate 90% H_2S, could be developed and exploited at a cost. However, these projects are burdened by extremely difficult technological and environmental concerns, require long lead times, and are extremely expensive. Given the volatile nature of sulfur prices, it is not possible at this time to make a projection as to the minimum sustainable sulfur value that would be required to justify this type of investment. Therefore, it appears unlikely that companies will be willing to take the economic risks necessary to exploit these reserves.

In conclusion, I suggest that worldwide sulfur supply/demand will be in tight balance through the early 1990's. It appears that U.S. supply/demand will remain in tight balance, but only if there is a significant and permanent reduction in U.S. phosphatic fertilizer capacity. Such a reduction will allow domestic sulfur production to meet the remaining U.S. demand for sulfur. Should this pessimistic sulfur consumption picture of the U.S. be unduly pessimistic, then absent significant increases in natural gas and crude oil prices, the U.S. will be supply short. And, in all probability by 1990, would have to supplement domestic North American production for non-traditional sources or utilize alternative technology to manufacture commodities currently using the wet phosphoric acid process.

Ladies and gentlemen, trying to foresee the future, as I indicated earlier, is fraught with risk. Any projection can be overturned by factors unforeseen at the moment. However, absent major political, economic, or catastrophic events, in the near-term I do not see anything but a pessimistic position for the U.S. hydrocarbon industry and sulfur supplied phosphate industry, and therefore, for the development of additional recovered sulfur supplies in the U.S.

Tuesday, October 29, 1985

Afternoon Session
Moderator:

Douglas Caine

General Status of Agriculture or "What's Good About American Agriculture"

Dr. W. P. Flatt
Dean of Agriculture
University of Georgia

Agriculture has been and still is the most successful industry in the United States. And despite current problems, the need for inexpensive food will continue to grow, as will demand for high-quality raw material from the farm. If a stable economy is the backbone of our way of life, agriculture is its heart.

Many people have lately been dwelling on the problems of agriculture, and those problems must be addressed. But it's about time we stood up and said—no, shouted—what is good with agriculture in America. Sure, it is a business, but it is also a way of life and one that will continue to serve us, well into the next century.

With that in mind, let's take a brief look at just what agriculture means to us and how it remains vital in all aspects of our lives.

A man once said this: "I know of no pursuit in which more real and important services can be rendered to any country than by improving its agriculture." That man was George Washington, and he spoke those words in an address to Congress. And it's as true now as it was two centuries ago. Farms today are more specialized, more capital-intensive, more reliant on world markets and more influenced by economic policies than ever before.

Agriculture is very important economically to this country. While only about 3 million people earn their living from farming, some 22 million are employed in related fields. The food-farm-fiber system accounts for 20 percent of our Gross National Product and 18½% of all exports.

As a whole, agribusiness is the single biggest economic sector in this country. One national publication called it "a giant economic engine driving employment, foreign trade and production." But agriculture is, of course, really more than one industry: it is dozens of industries, and their interests aren't always the same. In fact, they are often at ideological opposites. And since they carry different interests, it is difficult to see a farm policy as a whole.

Still, Americans spend less and eat better than any other nation on earth, paying only about 16 percent of their disposable income for food, at home or in restaurants. In the Soviet Union, that figure is 34 percent and in many countries citizens spend well over 50 percent of their disposable income on food. Agriculture in the U.S. is an incredibly productive machine.

We are all familiar with current problems in agriculture, but let's take an upbeat look at the near future and point out a few bright spots—and there are many if we only look.

Organizations such as the Fertilizer Industry Round Table have provided vital leadership toward our goal of a more productive and profitable future in agriculture. As you know, it was founded by an agronomist, the late Dr. Vincent Sauchelli, and many of the improvements in fertilizer products, manufacturing and distribution have made life directly better for all of us. I salute this organization and the extremely important industry that it represents.

Agricultural economists tell us that prospets for export trade should improve by the spring of 1986. There is a good chance for lower interest rates and a consequent falling of the dollar on world currency markets. Farmers are now selling off livestock herds, indicating we are at the bottom of the price cycle in livestock.

Increased prices of meat could occur as early as next spring, with a consequent increase in demand for feed grain. Thus, the spring of 1986 could begin to have a decidedly upbeat look. Further, since agriculture is the largest industry in the United States, it should have a multiplier effect of increased profits throughout the country. Since agriculture is often many different businesses, it is sometimes difficult for state and local leaders to fully appreciate its effects. We hope by next spring those good effects will once again become obvious.

As I said earlier, the demand for inexpensive, high-quality food will grow. And as that production increases, it will be the future basis for a world comparative advantage for agriculture in the U.S.

And there is reason to hope that improved agricultural practices will fuel the trends toward production of high-quality food and fiber. As we know, the trend lately has been toward fewer and larger farms, but some might not know that more people who own farms are actually living on those farms than did in the boom years of the early '70s—nearly 10 percent more.

Part-time farmers are increasingly more important. This new breed of farmers tends to farm fewer acres, and they are more likely to farm their own land. And, of course, our traditional production farmers, the real heart of our country, will meet the challenges of the '80s as they always have in the past, with adaption, innovation and change.

During the early '70s, there were low real interest rates, a weak dollar and rapid growth in agricultural exports, so we did exactly what we should have done: We increased production to meet the heightened demand. In the '80s, on the other hand, real interest rates have been high, the dollar is strong and there have been declining agricultural exports, leading to an excessive supply of agricultural products.

As the old joke says, if you don't like things the way they are now, just wait a few minutes. Agriculture is almost synonymous with change. The '70s were, in part, boom years for agriculture. Many people made a profit and net farm income in our great state of Georgia, for example, actually doubled between 1970 and 1984. But drought and economic factors often beyond the control of farmers changed all that. Still, we have reason to hope that, as it always does, things may change. And even if things do not change as fast as we would like, our responses to those problems are already changing. This response is one of the most hopeful aspects of agriculture in the '80s.

I would like to talk about agriculture in the state of Georgia briefly, but the lessons learned here are being learned at the same time all over the country and the world. Our crops are among the leaders in the nation in many areas. An outstanding example is the peanut industry, where the United States controls 50 percent of the world market with less than 10 percent of the world's population. This dominance rests entirely on quality, since U.S. prices are typically at a premium on the world market. Georgia is the top national producer of peanuts.

Georgia is also the national leader in the poultry industry and ranks high in soybeans, pecans, hogs and sweet potatoes. In all, Georgia ranks amount the top 11 states in the production of 10 different commodities. But it hasn't come easy, and Georgia's farmers have faced the same problems others have throughout the country.

Farmers in this state are very productive, using the latest methods. There has been, for example, a nearly nine-fold increase in irrigated acres between 1964 and 1982. In 1964, less than 2 percent of our land in Georgia was irrigated. Now that figure is 12 percent. Georgia agriculture is a highly diversified industry in continual change. Fewer farmers use less land, but they use it more intensively now than ever before, and cash receipts are about equally divided between crops and livestock sources.

And while the traditional sources of agriculture in Georgia are the main source of our strength, new, exciting things are happening. Specialty crops are becoming more and more important. In south Georgia, we are developing a strong blueberry industry, for example. And the raising of catfish is a growing segment of the fast-food industry. One chain is already marketing catfish and the promise of aquaculture is strong.

The business of ornamental horticulture is very good and the development of that industry in Georgia is going strong. Chicken nuggets are providing a bright new market for poultry, too.

And farmers of all kinds in Georgia are working hard to make the best use of their land. One example is the Soil, Plant and Tissue Analysis lab. It was originally set up to run an average of about 50,000 samples per year. Last year, it processed 168,893 samples. People are interested in doing things right!

Do we need more and better methods in agriculture? You bet we do! Agriculture feeds the world. By 1996 we will have some 6 billion people on this earth and that means we must have a 40 percent increase in food production in the next 12 years if we are to feed them. The need is obvious for even better varietites and more research.

Since 1974, oil and fuel prices have risen 123 percent, machinery and equipment are up 108 percent and interest costs are up 168 percent. Farm prices? They're up ony 29 percent. And even with all that, even with all the bad news we hear, there is reason to hope.

The people of the world care about farming and what it has meant to us. Listen to what one man said about agriculture: "The troubles by which the farmer is surrounded are not of his making. In large part they are due to world-wide conditions over which he has no control . . . When finally we emerge from this . . . period, we shall find ourselves at the beginning of a new agricultural era." That was written by the United States Secretary of Agriculture. His name was Henry C. Wallace and his remarks came in 1921.

Without our steady progress in agriculture, America's industrial might could never have come about. And so I say to you, with confidence in our people and a strong belief in our abiities to solve the problems facing us, that there is hope for that new agricultural era that Secretary Wallace foresaw 64 years ago. We believe it has already begun.

Hemihydrate Performance of Florida Rock in a Converted Phosphoric Acid Plant

N. W. Kolmeijer
Windmill Fertilizer
Presented by:
C. Vinke
Windmill Fertilizer

1. *INTRODUCTION*

Windmill Holland's hemihydrate experience dates from 1970 when next to the existing dihydrate plant a new phosphoric acid unit was commissioned, with the capacity to produce 210 mt/day P_2O_5 in the form of 50% P_2O_5 acid using Togo rock as raw material.

It was the first commercial plant based on the single-stage hemihydrate process which had been developed, after lengthy laboratory and pilot plant research by Fisons Fertilizers Ltd. (now Norsk Hydro Fertilizers).

In the 15 years of its existence this plant has been continually optimized. At present the capacity based on Togo rock is 600 mt/day (as 43% acid) with the same reactor battery as in 1970, but with a 70 m^2 UCB table filter (originally the plant was built with a 63 m^2 EIMCO tiltingpan filter). This plant is very reliable and has an on-stream factor and an efficiency which are at least the same as with dihydrate processing.

This plant has been the subject of many articles (Ref. 1–6), all except the first of which have been written by the inventors of the process and by one of the major contractors.

In this report we as Windmill will describe our experience with this advanced process which has been accumulated from many years of commercial operation. It should be stressed that our company has experience solely with single-stage processing and this paper limits itself to this system.

Not many companies will have such a strong incentive to use the hemihydrate process as we at Windmill. This is because our company has always had a relatively small own sulphuric acid production resulting in little availability of (cheap) by-product steam for evaporation of dilute filter-strength acid.

This motive has become stronger over the years as the energy price has increased and in 1982 we were faced with a costprice for P_2O_5 produced in the dihydrate plant which was so high when compared with the hemiplant, that the company decided to convert the dihydrate plant to hemi-processing as well. We ventured to do this because we had such an extensive and favourable experience with this process.

In the sixties a hemihydrate plant in Northern France had been converted to a dihydrate unit and in 1978 in Orlando a paper was given (Ref. 7) on the successful conversion of a Finnish hemiplant to dihydrate processing. This paper describes the opposite case.

At today's energy cost a company with byproduct steam available could find savings which would make conversion to hemihydrate worthwhile (Ref. 4, 5, 6). Our successful retrofit project proves that it is not necessary to build a new plant, but that it suffices to convert an existing dihydrate plant and so limit the investment.

2. *THE OPTIMIZED SINGLE-STAGE HEMIPROCESS*

For as long as phosacid has been manufactured research has been done into ways of manufacturing the product directly with the highest possible strength. It appeared, however, that to get concentrations that lie substantially above the customary 30% P_2O_5, it was necessary to operate at high temperatures and to precipitate the calcium sulphate as hemihydrate or anhydrite. These efforts have failed in the past, partly because of the fact that at the time there were no suitable (resistant) construction materials available, but at the same time there have been major process problems concerning how to obtain an efficient filtering crystal at the high acid viscosity and how to prevent scaling in the filtration system. For these reasons hardly any attention has been paid to this sort of process for decades; research has been focused almost completely on perfecting the dihydrate route. In the introduction it was already mentioned that a relatively short time ago even hemihydrate plants were converted to dihydrate plants.

From this background we may conclude that in order to operate successfully at this moment in 1985 on hemihydrate technology in such a way that the advantages which are apparent in theory can actually be obtained in practice, a great deal of specialized know-how is required.

The basis for this know-how has been developed over many years of laboratory and semi-technical research work carried out by Fisons Fertilizers Ltd. (now Norsk Hydro Fertilizers).

Subsequently this knowledge has been increased and the practical aspects optimized in particular as a result of 15 years of commercial experience in the Windmill plants.

It is remarkable that while you might expect that with such a history the plant would be technically complicated and difficult to operate, the reality is otherwise. No phosacid plant is as simple and easy to operate as a single-stage hemiplant, provided you know how to do it. After all, the operators are working with an enormous quantity of "plaster of Paris" and if this is not treated with the necessary expertise, the stuff will surely behave itself accordingly.

According to the most modern design a single-stage hemihydrate plant for the manufacture of 43% acid with relatively fine rock as feedstock (e.g. Togo, Morocco or Florida flotation concentrate) has the following main process steps:

—rock screening to 10 mm

—rock and 96–98% sulphuric acid metering systems

—an air- or vacuum-cooled reactor battery with lower slurry recycle and less cooling when compared with a dihydrate plant

—a belt-, table- or tiltingpan filter

—fluorine scrubbing of reactor and filter off-gases

—an antifoam system for ores with foaming tendency

—a metering system for conversion retarder in the filtration section and additionally for some phosphates to stabilize the filter cake discharge slurry.

Of the process steps which are normally found in a dihydrate plant the following items will be avoided:

—rock grinding unit

—sulphuric acid dilution/cooling

—filter-acid settling and buffering tanks

—evaporators

—clarification system

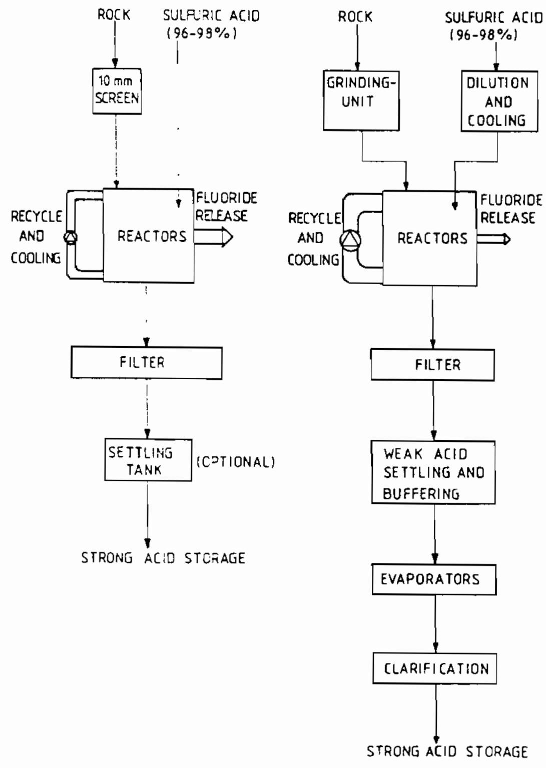


FIG 1 UNIT OPERATIONS FOR HH AND DH PLANTS

The avoidance of all these operations must of course lead to lower investment, less maintenance, fewer operators, lower product losses, and is beneficial for the on-stream time.

If coarser rock has to be used in such a plant, it is not necessary to grind all the rock. A scalping-screening operation to 1.6 mm and grinding the oversize will be sufficient.

Since start-up in 1970 optimization of hemitechnology has been performed in a large number of areas. We will now review the most important of these:

—Initially we operated the plant at an acid strength of 48–50% P_2O_5. Later this was reduced to 43%; at this concentration capacity and efficiency are substantially higher. Under the conditions which prevail at Windmill, if we want an end concentration of 50% P_2O_5, it is even more economical to run the plant at 43% P_2O_5 and to evaporate the acid afterwards. At this 43%-concentration level the overall efficiency is at least equal to that of a dihydrate operation.

—Due to the present much higher capacity compared with the original design, the reactor volume and filter-area figures are much more favourable:

	Design 1970 50% P_2O_5 (Togo)	**Actual 1985 43% P_2O_5 (Togo)**
Effective reactor volume m³/mt P_2O_5 produced per day (excl. filterfeed tank)	2.4	0.85
Filter-load mt P_2O_5 produced/m² day	3.3 (tiltingpan)	8.6* (table)

*Not fully loaded.

—Scaling in the filter-section resulting from the conversion of hemi- to dihydrate is absolutely non-existent due to the use of a cheap but very effective conversion retarder (with counter-current washing on the filter, it is inevitable that the phase will be reached where dihydrate is the stable crystal form).

—It appears to be possible to reduce the recycling of slurry over the flash-cooler to the relatively small flow which is required to adjust the correct process conditions in reactor 1. In spite of the large temperature drop (8°C) in the cooler, no scaling takes place. Scaling in the reactors is also much less than in dihydrate processing.

—Conversion of waste hemihydrate to dihydrate before disposal is no longer necessary.

—Drastic extension of the lifetime of agitators and pump impellers due to better design and more effective materials of construction.

—Re-use of hot waste-water-streams reduces the consumption of energy even further.

In addition, the quality advantages of hemi acid are retained:

—Lower sulphate content.

—Lower aluminum content.

—Practically no post-precipitation during storage of 43% acid.

—Very little precipitation during concentration of 43 to 52%.

—Practically no post-precipitation during storage of 52% acid.

Item	**Florida DH Acid %**	**Florida HH Acid %**
P_2O_5	43	43
Total SO_4 (Soluble)	4.0	1.6
Al_2O_3	1.05	0.53
Solids	4.0	0.7

3. *THE CONVERSION PROJECT*

The dihydrate plant which had to be retrofitted was designed and built by Windmill itself, and was commissioned in 1963. The reactor battery consisted of 4 reactors of equal size in series. Most of the time Togo rock was used as feed.

Prediluted and cooled sulfuric acid (65%) was added in reactor 3 together with filter return acid and there was a 10:1 slurry recycle from reactor 3 to reactor 1. Cooling took place partly by air injection and partly by ventilation of the reactors with fresh air.

The reactor temperature was 85°C, the solids content of the slurry 36–38%, the total soluble SO_4 content 36 g/$_2$l and the filter acid strength 28% P_2O_5. The slurry was filtered on a 40 m^2 Prayon tiltingpan filter with two wash sections. The 28% acid subsequently passed through a settling tank and was stored in buffertanks from which the acid was concentrated in forced-circulation steam-heated vacuum evaporators to useable strength (most of the time 52% P_2O_5).

Before the acid went to the storage tanks it was cooled and centrifuged to remove the sludge. The gypsum slurry was pumped directly into the river.

Just prior to conversion, the capacity of this plant was about 350 mt/day P_2O_5 using Togo rock, while on Central Florida rock (72–73 BPL) the capacity was approx. 320 mt/day. The efficiency figures were as follows:

based on cake samples : 95%
based on gypsum slurry samples : 94%
based on conc. acid out/rock in (year balance) : 92%

In the old (dihydrate) situation, the product acid was used mostly for fertilizer manufacture and was consequently evaporated from 28 to 52%. After conversion to a hemi unit, we intended to use the acid in downstream units which could accept acid of 43%. The process scheme then looks very simple (fig. 2).

An important question which came up during the conversion design was whether efficiently-filtering hemihydrate crystals would be formed if we

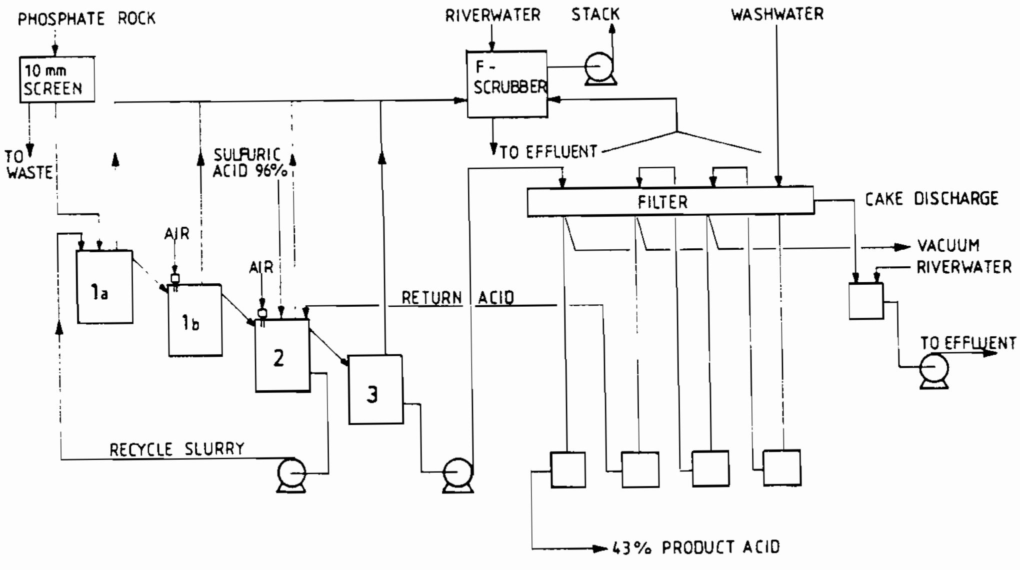


FIG. 2 SIMPLIFIED FLOWSHEET OF CONVERTED PLANT

deviated from the standard (2:1:1) reactor volume configuration as developed by Fisons (fig. 3).

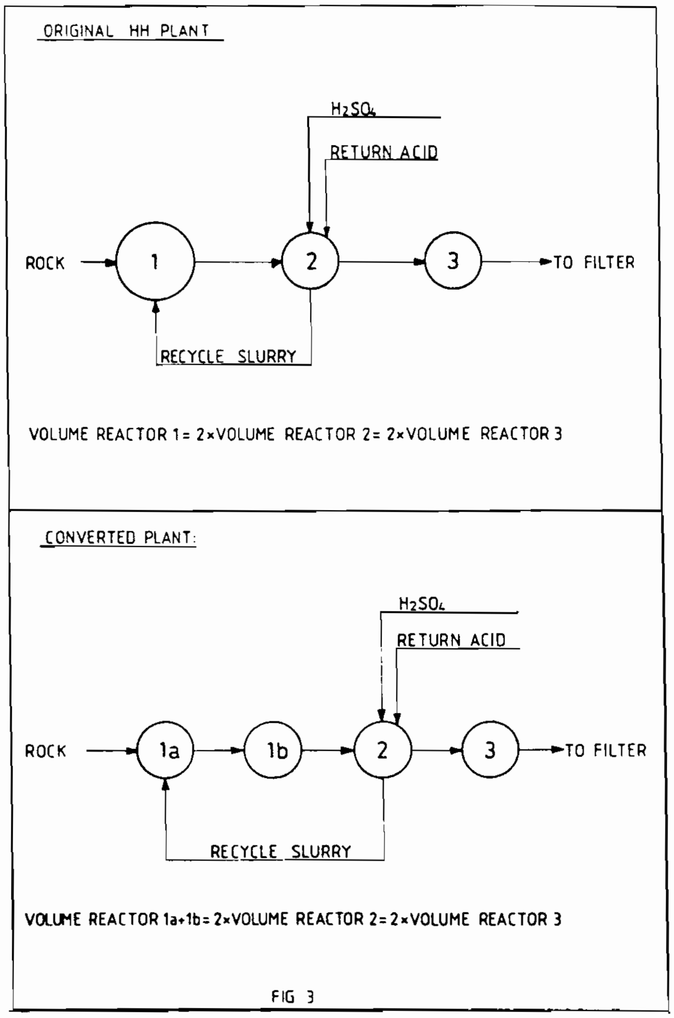


FIG 3

If we maintained the original Fisons design, rock and return slurry would be fed 50/50 in parallel to reactor 1a and 1b. We decided to take the risk and go for 1a and 1b in sequence.

Although the designer of the dihydrate plant had a far sighted view in 1962, and selected reactor-linings which in the future would be resistant to temperatures as occurring under hemihydrate conditions (100°C), we decided after inspection to reline one of the 4 reactors.

The characteristics of the existing agitators proved to be suitable for hemiprocessing conditions, but calculation showed that the mechanical strength of the polypropylene impellers was borderline. The same was valid for the cooling air nozzles.

We decided to maintain the original equipment for the time being. As slurry recirculation in the hemiprocess is much smaller than under dihydate conditions, it was not difficult to adapt the recycle pump system. However, the ventilation system of the reactors required fundamental change. The heat balance showed that in spite of the much smaller heat development during hemiprocessing, it would be necessary to maintain full cooling-air injection and tank ventilation if non-diluted 96% sulfuric acid was used.

During hemiprocessing, however, more fluorine is released from the reactors than under dihydrate conditions; moreover it is a fluorine-containing gas with a relatively high silicon content which presents problems of SiO_2 scaling when condensation takes place.

In this connection, we found it necessary to build an exhaust system, consisting of a sprayed duct followed by a fluorine scrubber with in total 7 transfer units in order to remain below the limit set by the authorities (max. 5 mg F/m^3 offgas). Fan and stack could be retained.

As the 40 m^2 Prayon filter would be on the small side for the task, we decided to connect the 63 m^2 Eimco tiltingpan filter of the existing hemiplant with the converted reactor battery and to install a new UCB table filter with 70 m^2 effective filter area in the original hemiplant.

As far as instrumentation was concerned, the project allowed us to switch from recorder registration to data storage on a minicomputer. The advantages are: a lot of data on a small display, more effective process control, prevention of data deterioration, the possibility to print out 24 hrs reviews and the automatic computation of performance data which are also printed out once a day.

The conversion project was engineered by Windmill's own process and engineering group in close collaboration with Norsk Hydro Fertilizer's licensing department. The construction work was also carried out by Windmill. The whole conversion project was completed in two months during summer 1983. The converted plant was started up in July 1983.

4. *PERFORMANCE OF THE CONVERTED PLANT*

Although the converted plant was started up on Togo rock (this was done because we had by far the most experience with that rock), in the two years or more in which the plant has been operating it has been run most of the time on 72% BPL Central Florida flotation concentrate with the following typical analysis:

Particle size analysis

+ 0.50 mm	21.6%
0.50–0.22 mm	50.0%
0.22–0.15 mm	14.7%
0.15–0.10 mm	10.8%
0.10–0.05 mm	2.0%
– 0.05 mm	0.9%

Component	w/w %
P_2O_5	32.8
CaO	48.1
SO_4	1.1
Fe_2O_3	1.1
Al_2O_3	1.26
MgO	0.29
Na_2O	0.62
K_2O	0.10
F	3.6
SiO_2	4.7

In spite of the modified reactor configuration the same hemi crystals were formed as in the existing plant, from Florida rock these have a spec. surface of 1900 cm^2/g and a permeability of 25×10^{-9} cm^2.

Fig. 4 shows these hemi-crystals from Florida rock obtained in the converted plant, fig. 5 crystals from Togo rock in the original hemiplant.

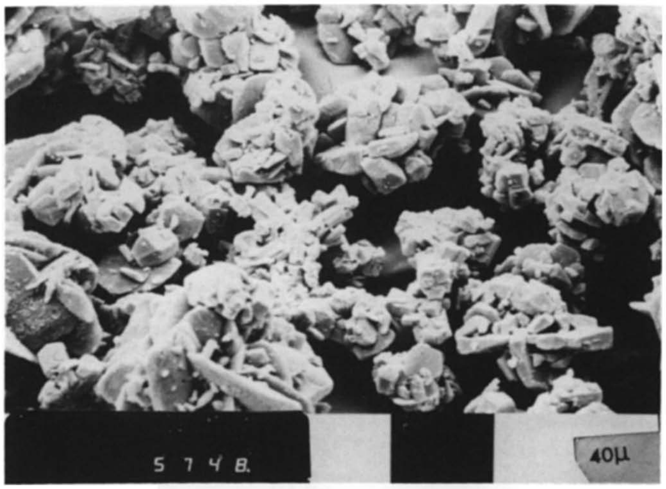


Figure 4.
Hemi Crystals from FLORIDA Rock

Figure 5.
Hemi Crystals from TOGO Rock

Right from the beginning the performance of the converted plant was excellent, both with regard to capacity and yield. However, during the first year the production had to be interrupted a number of times for major repairs. There were mechanical problems with the agitators and they were replaced by a heavier type. The broken agitators in turn damaged the reactor lining and we decided to reline two more reactors in the summer of 1984. Since these teething troubles have been resolved we may say that the on-stream time of the converted plant is about the same as in the dihydrate period.

We will now discuss some of the relevant data that have been obtained in the two operating years.

Capacity

To begin with we should mention that it is not necessary for us to run this plant continuously at the highest possible capacity rate. This is because the total quantity of calcium sulfate which we are allowed to discharge into the river is limited by the authorities. Production is also influenced by the capacity of our downstream units, sales policy, rock prices, etc.

The bottleneck in this plant is in the cooling, especially in the summer period.

The capacity with Florida rock is approximately 320 mt/day and at this rate the reactor volume (excl. filterfeed tank) is 1.3 m^3/mt P_2O_5 produced per day while the filter loading is 5.1 mt P_2O_5 produced/m^2 day.

However, as mentioned before, neither filter nor reactors are bottlenecks in this plant and therefore not too much significance should be given to these data.

Efficiency

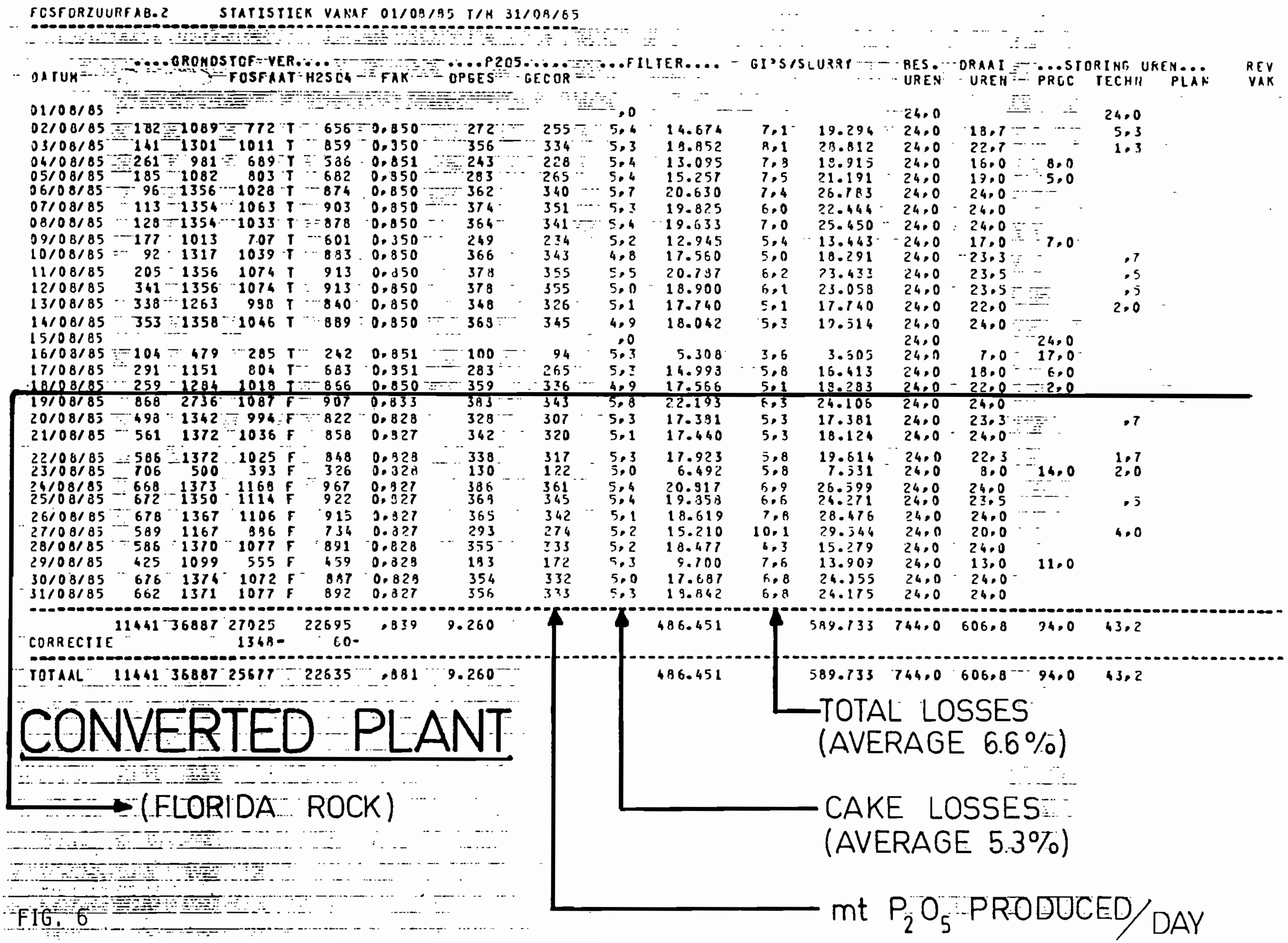
The presentation of realistic efficiency figures is always a tricky business. The best-definable figures are always the losses which are measured in filter cake samples, taken from a filter which is not quite overloaded but in good mechanical condition. On Florida rock, losses are as follows:

unreacted rock P_2O_5	0.5%
lattice P_2O_5	4.0%
water soluble P_2O_5	1.0%
total	5.5%

At Windmill we also sample the hemihydrate slurry which is pumped into the river. Therein we find following figures:

unreacted rock P_2O_5	0.5%
lattice P_2O_5	3.5%
water soluble P_2O_5	3.0%
total	7.0%

(see fig. 6 for production print-out of converted plant)



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FOSFORZUURFAB.2      STATISTIEK VANAF 01/08/85 T/M 31/08/85
-----------------------------------------------------------

        ....GRONDSTOF VER....         ....P205.......  ...FILTER....   GIPS/SLURRY   BES.  DRAAI  ...STORING UREN...  REV
DATUM          FOSFAAT H2SO4   FAK     OPGES   GECOR                                UREN  UREN   PROC  TECHN  PLAN  VAK

01/08/85                                            ,0                              24,0                24,0
02/08/85   182  1089   772 T  656 0,850    272     255   5,4  14.674   7,1  19.294  24,0  18,7          5,3
03/08/85   141  1301  1011 T  859 0,350    356     334   5,3  18.852   8,1  28.812  24,0  22,7          1,3
04/08/85   261   981   689 T  586 0,851    243     228   5,4  13.095   7,8  18.915  24,0  16,0   8,0
05/08/85   185  1082   803 T  682 0,850    283     265   5,4  15.257   7,5  21.191  24,0  19,0   5,0
06/08/85    96  1356  1028 T  874 0,850    362     340   5,7  20.630   7,4  26.783  24,0  24,0
07/08/85   113  1354  1063 T  903 0,850    374     351   5,3  19.825   6,0  22.444  24,0  24,0
08/08/85   128  1354  1033 T  878 0,850    364     341   5,4  19.633   7,0  25.450  24,0  24,0
09/08/85   177  1013   707 T  601 0,350    249     234   5,2  12.945   5,4  13.443  24,0  17,0   7,0
10/08/85    92  1317  1039 T  883 0,850    366     343   4,8  17.560   5,0  18.291  24,0  23,3           ,7
11/08/85   205  1356  1074 T  913 0,d50    378     355   5,5  20.787   6,2  23.433  24,0  23,5           ,5
12/08/85   341  1356  1074 T  913 0,850    378     355   5,0  18.900   6,1  23.058  24,0  23,5           ,5
13/08/85   338  1263   988 T  840 0,850    348     326   5,1  17.740   5,1  17.740  24,0  22,0          2,0
14/08/85   353  1358  1046 T  889 0,850    368     345   4,9  18.042   5,3  19.514  24,0  24,0
15/08/85                                            ,0                              24,0         24,0
16/08/85   104   479   285 T  242 0,851    100      94   5,3   5.308   3,6   3.605  24,0   7,0  17,0
17/08/85   291  1151   804 T  683 0,351    283     265   5,3  14.993   5,8  16.413  24,0  18,0   6,0
18/08/85   259  1284  1018 T  866 0,850    359     336   4,9  17.566   5,1  18.283  24,0  22,0   2,0
19/08/85   868  2736  1087 F  907 0,833    383     343   5,8  22.193   6,3  24.106  24,0  24,0
20/08/85   498  1342   994 F  822 0,828    328     307   5,3  17.381   5,3  17.381  24,0  23,3           ,7
21/08/85   561  1372  1036 F  858 0,827    342     320   5,1  17.440   5,3  18.124  24,0  24,0
22/08/85   586  1372  1025 F  848 0,828    338     317   5,3  17.923   5,8  19.614  24,0  22,3          1,7
23/08/85   706   500   393 F  326 0,328    130     122   5,0   6.492   5,8   7.531  24,0   8,0  14,0   2,0
24/08/85   668  1373  1168 F  967 0,827    386     361   5,4  20.817   6,9  26.599  24,0  24,0
25/08/85   672  1350  1114 F  922 0,827    369     345   5,4  19.358   6,6  24.271  24,0  23,5           ,5
26/08/85   678  1367  1106 F  915 0,827    365     342   5,1  18.619   7,8  28.476  24,0  24,0
27/08/85   589  1167   886 F  734 0,827    293     274   5,2  15.210  10,1  29.344  24,0  20,0          4,0
28/08/85   586  1370  1077 F  891 0,828    355     333   5,2  18.477   6,3  15.279  24,0  24,0
29/08/85   425  1099   555 F  459 0,828    183     172   5,3   9.700   7,6  13.909  24,0  13,0  11,0
30/08/85   676  1374  1072 F  887 0,828    354     332   5,0  17.687   6,8  24.355  24,0  24,0
31/08/85   662  1371  1077 F  892 0,827    356     333   5,3  18.842   6,8  24.175  24,0  24,0
----------------------------------------------------------------------------------------------------------------------
         11441 36887 27025  22695  ,839  9.260               486.451        589.733 744,0 606,8  94,0  43,2
CORRECTIE              1348-    60-
----------------------------------------------------------------------------------------------------------------------
TOTAAL   11441 36887 25677  22635  ,881  9.260               486.451        589.733 744,0 606,8  94,0  43,2
```

FIG. 6

The higher w.s. loss percentage is due partly to the fact that cake sampling gives a too favourable picture and partly to poor drainage of the flat (!) bottom pans of the filter. Moreover it looks as if during the repulping of the cake with water some lattice P_2O_5 is liberated. This might in future be an added reason to apply hemihydrate refiltration on this plant.

If the filter is in bad mechanical shape, the water-soluble P_2O_5 losses may increase significantly.

If we take these and other incidents into account, in spite of the imperfect filter we arrive at an average overall loss of 8% and this is the same figure as we had in the dihydrate period (after 15 years experience and optimization).

We are sure that if this filter were replaced by a filter with a lower "mechanical loss", the overall efficiency based on "acid out/rock in" would be significantly higher (93%). This is shown in the original hemiplant with the table filter where the average difference between the cake and slurry loss figures is usually below 0.5% (see fig. 7 for production printout of original hemiplant).

Summarizing we get following efficiency data for Florida rock:

	DH	HH	
	pan	pan	table
Cake %	95	94.5	94.5
Gypsum slurry %	94	93	94
Overall %	92	92	93

Scaling

When Florida rock is used silicofluoride scaling occurs in the first wash section and it is necessary to flush the filter once every 7–10 days with hot water for approx. 8 hours. This compares favourably with our dihydrate experience.

In order to prevent conversion of hemi to dihydrate in the filter section which would lead to gypsum scaling, a conversion inhibitor (retarder) is applied. This stabilizes the hemihydrate for several hours so that it can also be pumped without problems through the 1.5 km long pipeline into the river.

Hemihydrate filtration does not involve chukhrovite scaling in the apertures of the filter-cloth, so that no time is lost in cleaning the cloth with a high-pressure water-jet. This also lengthens the cloth life.

Start-up of the plant

Since Windmill has two hemiplants, start-up from an empty system can occur easily by pumping reactor slurry from the running plant into the battery which must be started up, after which the rock and acid feeds are started and normal running conditions are quickly obtained.

If such favourable conditions do not prevail, start-up from an empty system is somewhat more difficult than in a dihydrate plant. It is, however, straightforward to start-up from acid.

In the course of the years at Windmill we have developed a method which is very efficient and whereby a good quality crystal is immediately formed, so that start-up does not lead to extra losses.

Plant standstill

During standstill of the plant, we of course have to make sure that the hemihydrate will not convert to dihydrate, because the consequences would be extremely troublesome.

It is vital that the concentration does not fall below a certain critical level which lies in the neighbourhood of 40% P_2O_5, and which differs with the rock. The temperature is in this connection much less important.

During a shutdown the concentration rises a bit due to evaporation and this compensates for the condensation of live steam should this be necessary later for reheating purposes.

If it were required, there is no reason whatever why the slurry in the reactor battery could not be kept stable for a period of 2 weeks or more.

In 15 years operation we have never experienced a serious problem with hemihydrate conversion to gypsum or anhydrite.

Analytical control

At Windmill, samples for direct plant control are taken by our laboratory which operates around the clock 7 days a week for the various plants on our site.

The analyses are done in the lab and the most important figures are telexed to the control-room within 30 minutes and there put into the computer. Before long the lab itself will be connected to this computer so that the data can be put in on the spot.

The following analyses are done:

Hourly

—Sulfuric acid content of the slurry in reactor 2

Two Hourly

—P_2O_5 content of the slurry in reactor 2

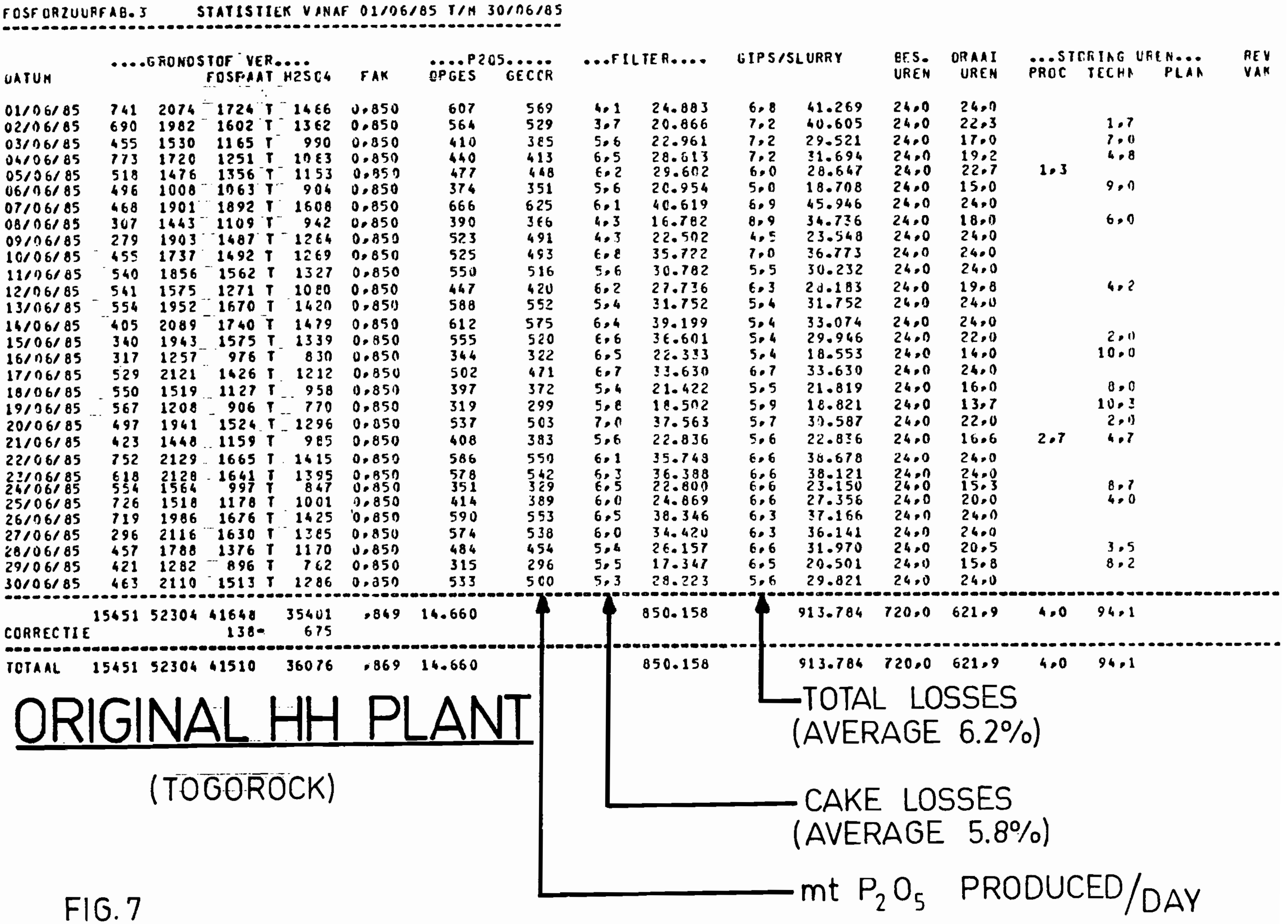
Once per Shift

—Solids content of the slurry in reactor 2

—CaO content of the slurry in reactor 2

—w.s. P_2O_5 in filtercake

—P_2O_5 conc. in production acid



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FOSFORZUURFAB.3     STATISTIEK VANAF 01/06/85 T/M 30/06/85
--------------------------------------------------------------

          ....GRONDSTOF VER....             ....P2O5.....     ...FILTER....    GIPS/SLURRY       BES.   DRAAI   ...STORING UREN...     REV
DATUM                FOSFAAT H2SO4    FAK   OPGES   GECOR                                        UREN   UREN   PROC  TECHN   PLAN   VAK

01/06/85   741  2074  1724 T  1466  0,850    607     569      4,1    24.883     6,8   41.269    24,0   24,0
02/06/85   690  1982  1602 T  1362  0,850    564     529      3,7    20.866     7,2   40.605    24,0   22,3          1,7
03/06/85   455  1530  1165 T   990  0,850    410     385      5,6    22.961     7,2   29.521    24,0   17,0          7,0
04/06/85   773  1720  1251 T  1063  0,850    440     413      6,5    28.613     7,2   31.694    24,0   19,2          4,8
05/06/85   518  1476  1356 T  1153  0,850    477     448      6,2    29.602     6,0   28.647    24,0   22,7   1,3
06/06/85   496  1008  1063 T   904  0,850    374     351      5,6    20.954     5,0   18.708    24,0   15,0          9,0
07/06/85   468  1901  1892 T  1608  0,850    666     625      6,1    40.619     6,9   45.946    24,0   24,0
08/06/85   307  1443  1109 T   942  0,850    390     366      4,3    16.782     8,9   34.736    24,0   18,0          6,0
09/06/85   279  1903  1487 T  1264  0,850    523     491      4,3    22.502     4,5   23.548    24,0   24,0
10/06/85   455  1737  1492 T  1269  0,850    525     493      6,8    35.722     7,0   36.773    24,0   24,0
11/06/85   540  1856  1562 T  1327  0,850    550     516      5,6    30.782     5,5   30.232    24,0   24,0
12/06/85   541  1575  1271 T  1080  0,850    447     420      6,2    27.736     6,3   28.183    24,0   19,8          4,2
13/06/85   554  1952  1670 T  1420  0,850    588     552      5,4    31.752     5,4   31.752    24,0   24,0
14/06/85   405  2089  1740 T  1479  0,850    612     575      6,4    39.199     5,4   33.074    24,0   24,0
15/06/85   340  1943  1575 T  1339  0,850    555     520      6,6    36.601     5,4   29.946    24,0   22,0          2,0
16/06/85   317  1257   976 T   830  0,850    344     322      6,5    22.333     5,4   18.553    24,0   14,0         10,0
17/06/85   529  2121  1426 T  1212  0,850    502     471      6,7    33.630     6,7   33.630    24,0   24,0
18/06/85   550  1519  1127 T   958  0,850    397     372      5,4    21.422     5,5   21.819    24,0   16,0          8,0
19/06/85   567  1208   906 T   770  0,850    319     299      5,8    18.502     5,9   18.821    24,0   13,7         10,3
20/06/85   497  1941  1524 T  1296  0,850    537     503      7,0    37.563     5,7   30.587    24,0   22,0          2,0
21/06/85   423  1448  1159 T   985  0,850    408     383      5,6    22.836     5,6   22.836    24,0   16,6   2,7    4,7
22/06/85   752  2129  1665 T  1415  0,850    586     550      6,1    35.748     6,6   38.678    24,0   24,0
23/06/85   618  2128  1641 T  1395  0,850    578     542      6,3    36.388     6,6   38.121    24,0   24,0
24/06/85   554  1564   997 T   847  0,850    351     329      6,5    22.800     6,6   23.150    24,0   15,3          8,7
25/06/85   726  1518  1178 T  1001  0,850    414     389      6,0    24.869     6,6   27.356    24,0   20,0          4,0
26/06/85   719  1986  1676 T  1425  0,850    590     553      6,5    38.346     6,3   37.166    24,0   24,0
27/06/85   296  2116  1630 T  1385  0,850    574     538      6,0    34.420     6,3   36.141    24,0   24,0
28/06/85   457  1788  1376 T  1170  0,850    484     454      5,4    26.157     6,6   31.970    24,0   20,5          3,5
29/06/85   421  1282   896 T   762  0,850    315     296      5,5    17.347     6,5   20.501    24,0   15,8          8,2
30/06/85   463  2110  1513 T  1286  0,850    533     500      5,3    28.223     5,6   29.821    24,0   24,0
-----------------------------------------------------------------------------------------------------------------------------------------
          15451 52304 41648   35401   ,849  14.660                   850.158               913.784   720,0  621,9   4,0   94,1
CORRECTIE              138-     675
-----------------------------------------------------------------------------------------------------------------------------------------
TOTAAL    15451 52304 41510   36076   ,869  14.660                   850.158               913.784   720,0  621,9   4,0   94,1
```

ORIGINAL HH PLANT

(TOGOROCK)

TOTAL LOSSES (AVERAGE 6.2%)

CAKE LOSSES (AVERAGE 5.8%)

mt P_2O_5 PRODUCED/DAY

FIG. 7

There is a continuous automatic sampling/P_2O_5 analysis system on the hemi-slurry which is pumped into the river and the same sort of monitoring takes place in the sewer with the other effluents.

Acid quality

We already mentioned the low sulfate and aluminum content and the favourable sludge characteristics when compared with dihydrate acid.

In the following table, more complete analyses are shown for di- and hemihydrate acid manufactured from 72% BPL Florida flotation concentrate:

Component %	dihydrate acid		hemihydrate acid
P_2O_5	28.3	43	43
Total SO_4 (soluble)%	2.7	4.0	1.6
Fe_2O_3%	0.92	1.37	1.45
Al_2O_3%	0.73	1.05	0.53
MgO%	0.27	0.39	0.58
Na_2O%	0.07	0.08	0.09
K_2O%	0.02	0.07	0.05
F%	1.8	1.5	1.3
SiO_2%	0.86	0.6	0.5
Solids%	0.15 (settled)	4.0	0.7

It should be pointed out that the low sludge figure for hemi acid cannot of course be attained if there are many holes in the filter-cloths. Therefore it is advisable to lead the acid via a settling tank before it goes to store. However, this tank can be of modest size since the entrained hemicrystals are very large compared with the well-known dihydrate sludge particles which precipitate during and after evaporation. After passing through such tank sludge content is below 0.2%.

Consumption figures

Finally here is a comparison of the raw materials and utility consumption figures as these were in the original dihydrate situation and in the converted plant (adjusted for use of a table filter).

Raw material: unground Florida rock (32.8% P_2O_5, 48.1% CaO)

Acid strength: 43% P_2O_5.

		Consumption per MT P_2O_5 produced	
	unit	hemihydrate	dihydrate
Phosphate rock	MT	3.28	3.31
H_2SO_4 (100%)	MT	2.69	2.80
Steam	MT	0.05	1.80
Electricity	kWh	110	140
Process water	m^3	3.5	6.7
River water	m^3	55	50
Chemicals	US$	0.9	—
Antifoam	kg	2.5	—

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Effects of Waste Gypsum Disposal on Some Aspects of Teleost Fish Physiology

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The major role played by the ocean, in our life, is so obvious that nobody talks about it. Nevertheless the ocean sustains life, it does so, not only by providing water, but also by providing minerals and food. Furthermore for a lot of people the sea is a source of pleasure and of health, so we must contribute to its protection.

To study the effects of waste gypsum disposal on sea life we have selected fish because they are at the end of the food chain that includes mineral, vegetal and animal elements.

Sites selected for this study

Different sites were considered:

—*Kavala*, in Greece (PFI factory) where waste gypsum is disposed of on the land; most of the chemical elements are withheld by calcareous soil, this is also the true for phosphoric acid. Fish were caught by diving from this place.

—*Le Havre*, France (COFAZ factory) where waste gypsum is disposed directly into the sea via a pipeline. Fish species living at the surface of the gypsum are caught by sucking up the gypsum with a dredging pump, and they are collected in a net.

—Apart from these first two studied locations "Kavala" and "Le Havre" we work on fish caught one mile from "Le Havre" waste gypsum disposal. This site is contaminated by pollution coming from the "Baie de Seine" but may be supposedly free of gypsum.

—For all cases, we compared our results with those obtained on fish caught in open sea and considered as controls.

Selection and treatment of experimental samples

We have selected *gills, glands of Stannius (corpuscles of Stannius)* and *bone* for the following reasons:

—*Gills* are at the "interface" between external and internal medium; they have not an exclusively respiratory function, they play a major role in ionic exchanges leading to maintain blood ionic composition.

—*Corpuscles of Stannius* (CS) are endocrine glands situated on fish kidney. They secrete a hormone, regulating gill Ca^{++} transfer (1). The important role played by Ca^{++} ion in many physiological functions such as: muscular contraction, nervous influx, reproduction, has led us to consider CS as the sensitive indicators of variations in the composition of the environmental medium (2). Modifications of environmental medium provoke a hyperstimulation of these glands which can result in total destruction (3).

—Gypsum contains fluoride (1,1%) and the effects of fluoride on *bone* are well know. The most part of fluoride picked up by animals is deposited in the skeleton; this fluoride impregnation leading to more or less pronounced bone structure alterations: modifications of the quality of the mineral substance (hydroxylapatite) and severe disturbances in the bone turn over (4, 5, 6).

Experimental samples were picked up by dissection and put in a fixative liquid, immmediately after fishing. They were principally taken on: sole, plaice and flounders.

Gills and corpuscles of Stannius were embedded in paraffine and then cut in serial sections (5 μ) stained for microscopic observation.

Bone was embedded in methyl methacrylate. Microscopic observation was done on undecalcified serial sections and on the corresponding microradiographies.

RESULTS AND DISCUSSION

Gills

Gills are complex organs, they are composed of primary filaments and secondary filaments called respiratory platelets (Fig. 1). In gills two types of cells are particularly important, these are ionocytes (also called chloride cells) and mucocytes. Ionocytes work exclusively in ionic exchanges; mucocytes secrete mucus which principally play a role of protection during aggression coming from external medium.

In fish caught in "Kavala" (Greece), we did not observe severe modifications of gills apart an important proliferation of mucocytes. In some parts, mucus completely lined respiratory platelets and this may greatly disturb respiratory function. We have also detected a proliferation of ionocytes indicating an unusual ionic regulation (7).

In fish caught in "Le Havre" (France), *which are living in close contact to waste gypsum*, gills contained undetermined mineral matters and we observed a pathological cellular proliferation which completely disturbs the branchial structure (Fig. 3). Respiratory filaments appear broken (Fig. 2); we have detected a cellular lysis (compare with control gills, Fig. 1). Furthermore, as in the case of "Kavala", we show an extremely important proliferation of ionocytes and an important production of mucus. (Fig. 4).

In gills of fish caught one mile from the waste gypsum disposal, we did not observe major structural modifications; their histological aspect is approximatively similar to that observed in controls (8). Similar gills modifications have also been observed in fish contaminated with hydrocarbons (9, 10).

Corpuscles of Stannius

Corpuscles of Stannius, which secrete the hormone regulating gill ca^{++} exchanges, are composed of glandular cells grouped in spherical follicles (Fig. 5).

In corpuscles of Stannius of fish, caught in the site of "Kavala", we did not observe changes in the histological structure (7). *But, on the other hand, Stannius corpuscles of fish caught in "Le Havre" disposal* presented important modifications (8). Some of them were very activated as it is shown by the disappearance of the follicular structure. This hyperactivity of corpuscles of Stannius observed in many fish, lead to a cellular destruction of the major part of the glandular tissue.

We did not observe similar aspects in CS caught *one mile from waste gypsum disposal.*

This hyperactivity of corpuscles of Stannius may be related to the modifications observed in gills which probably induce disturbances in ionic exchanges.

Bone

Bone is a rather complex tissue. In this special connective tissue we can observe three types of cells, osteoblasts which are forming bone, osteocytes which are enclosed in mineralized bone substance and big plurinucleated cells, the osteoclasts, which destruct bone. In healthy bone, formation of mineralized substance by osteoblasts and destruction of this one by osteoclasts are two processes which are always well balanced. It has been shown by many authors (5, 6) that exposure to fluoride resulted in a drastic disturbance of the bone turn over. This bone disease is called fluorosis.

No drastic modifications was observed in *skeleton of fish caught in "Kavala" and at one mile from waste gypsum disposal, in "France".*

But in *skelton of fish caught in close contact to waste gypsum on "Le Havre",* we detected important signs of fluorosis, for example:

- —an important stimulation of the number and activity of osteoblasts: these cells synthetize a great deal of osseous substance which is not properly mineralized.
- —osteoclasts multiply excessively and their destructive function appear to be greatly enhanced (9). An important decrease in bone

SITE AND DISPOSAL DATA

Kavala

Gypsum Disposal	~900 t/day	
Disposal	Impounding on land close to beach	
Transportation	Mixing with sea-water and pumping	
Stack Piling	By settling from the slurry. Acidic sluice water (pond water) is evacuated by percolation through porous soil consisting mainly of calcarous clays and silica material (5.9% Ca0, A1203 5.7, Mg0 0.4, Si02 85.5%).	
Composition of sluice water	P205	3.37 gr./l
before percolation	F	6.3 gr./l
(measured 1983)	Cd	0.46 mg/l
Percolating liquors move	P205	200 mg/l
through the sand to the sea.	F	10 mg/l
Aquifer at 10 m from the	Cd	≤0.005 mg/l
shore was measured:	pH	7.0

Le Havre

Gypsum Disposal (1984)	~3,000 t/day	
Disposal	Sea (mouth of Seine River)	
Transportation	Mixing with brackish water and pumping	
Pipe End Dispersion	A multi-outlet dispersion device is supposed to operate through mixing with tide moving sea-water. As depth is only about 18 feet, some of the material settles and periodic dredging is required.	
Composition of Gypsum (solids only, not including sluice water components)		
Rock origin N. Carolina	SO_3	44.0%
	CaO	31.5%
	H_2O (cristal water)	19–20%
	P_2O_5	0.59
	F	1.1
	SiO_2	2.1
	Na_2O	0.13
	Fe_2O_3	0.031
	Al_2O_3	0.060
	MgO	0.013
Composition of settled material on sea bottom where flounders and similar species lived in direct contact	SO_4	36
	F	0.4–0.5%

mass results from these bone modifications; skeleton became fragile (Figs. 7, 8).

CONCLUSIONS

These pathological modifications induced by waste gypsum disposal in some organs and glands of teleost fish may not lead to the accelerated death of these animals. However they can result in important disturbances in their behaviour, for example during migrations, reproduction and in their ability to weather a storm or fight against other aggressions occurring in ambient environment.

This research work did not concern edible parts, presently we cannot give an opinion on the dietetic quality of such animals. Industry and research will join their effort to preserve the integrity of our sea world.

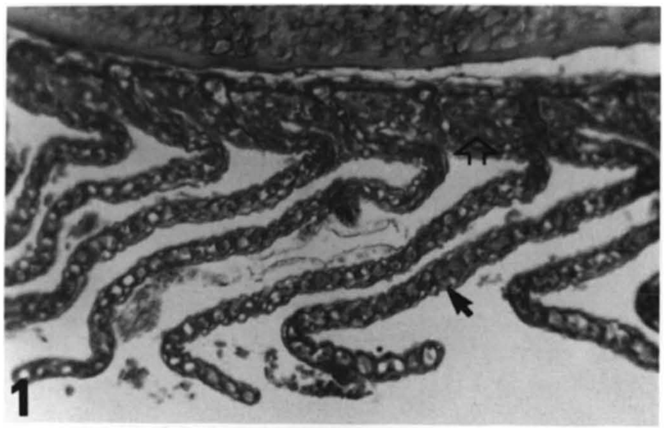

Figure 1

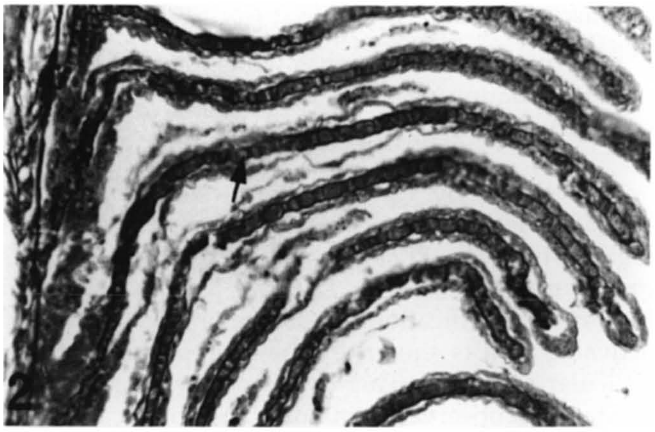

Figure 2

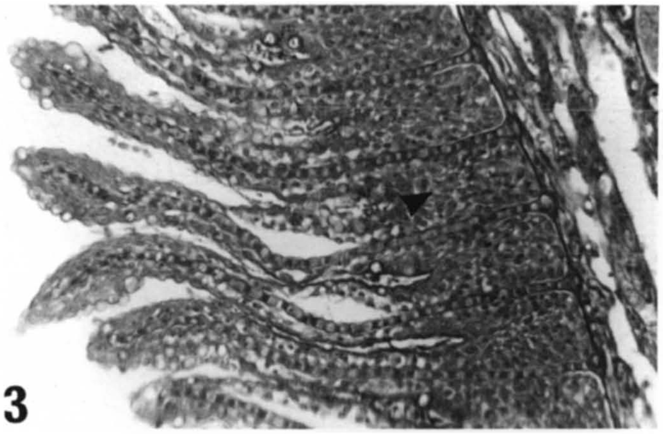

Figure 3

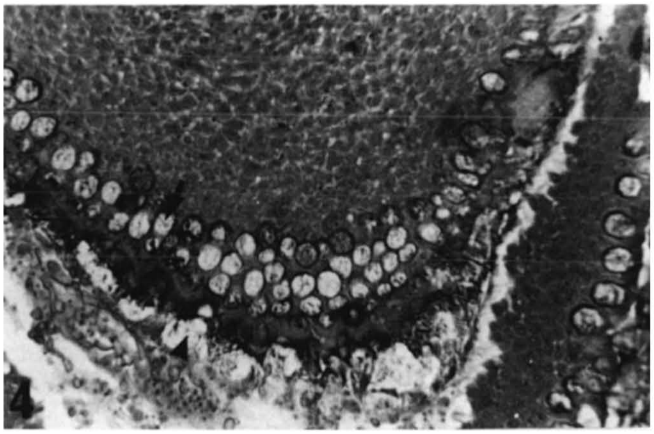

Figure 4

Fig. 1 : Longitudinal section of parts of fish control gills. Primary filament (⇨). Secondary filaments also called respiratory platelets (➜). x 100.

Figs 2-3-4 : Longitudinal sections of parts of fish gills living in close contact to gypsum "Le Havre", France. x 100.

2 : Respiratory filaments are broken. Cellular lysis (➜)

3 : Drastic proliferation of cells (▶) ; compare with fig. 1.

4 : Proliferation of mucocytes (➜) at the end of a primary filament. Mucus (▶).

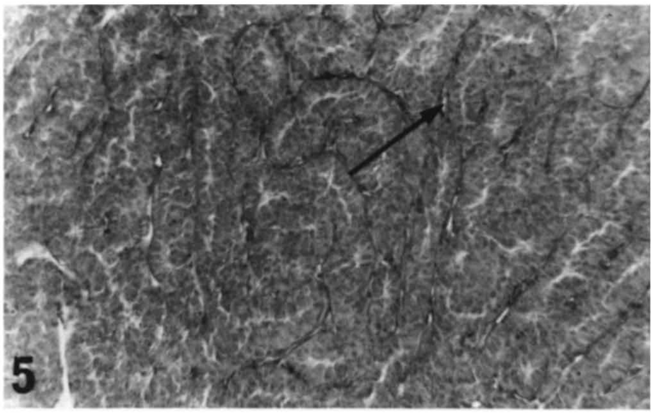

Figure 5

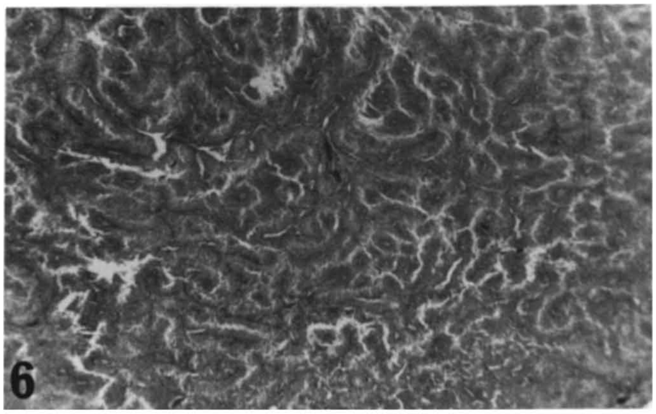

Figure 6

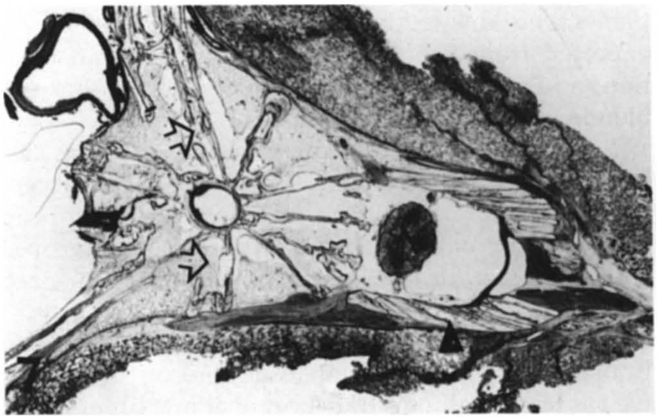

Figure 7

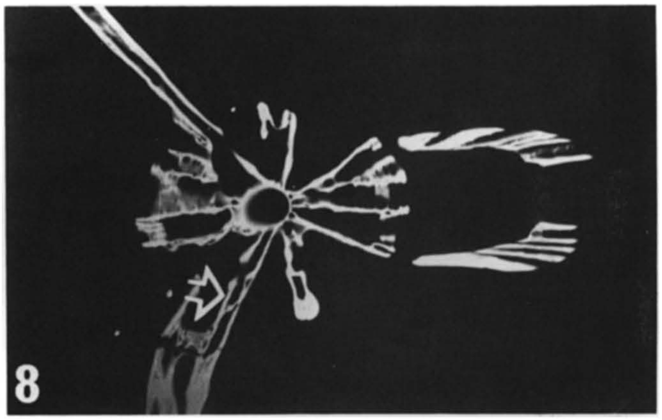

Figure 8

Figs 5-6 : Transversal sections of corpuscles of Stannius

5 : Control fish corpuscles of Stannius. Cells are grouped in follicles (➞).

6 : Corpuscles of Stannius in fish living in close contact to gypsum "Le Havre" ,France. Disappearance of the follicular structure and cellular lysis

Figs 7-8 : Transversal sections of axial skeleton of fish living in close contact to gypsum "Le Havre ", France.

7 : Histological view showing the decrease in bone mass. bone substance (⇨).

8 : Microradiography of the section 7 showing the destruction of bone substance (⇨).

Marketing Fertilizer in The Caribbean Area

Gustavo Berges
Ferquido
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History

Strange as it may sound, Charleston, South Carolina, played a determining role in the present marketing of fertilizers in the Caribbean area. This was the location of the old Pringer operation that was dismantled and set up in San Pedro de Macoris, Dominican Republic, 28 years ago. A small pilot plant had been in operation in Santo Domingo since 1954, 5 years after farmers had first seen the results of the initial 200 tons of fertilizers imported to that country. With the establishment of the first large-scale bulk-blending plant outside of the United States of America, the foundations were laid for the interesting situation that has developed.

It was from this new base of operations that bulk blends were introduced to the Caribbean islands and much of Central America. Because of its particular status, Cuba is not included in this report.

The original bulk blends exported were a poor match for the American and European chemical mixes that dominated the area's consumption. Caking and settling out of the different raw materials were very common. This, in turn, led to limited shelf life, uneven field results, unfavorable application conditions, and other disadvantages that created a strong initial resistance. The price advantage, however, was considerable, and it was the strongest selling point at that time.

Another advantage of the blends was that, as soil analyses gained greater popularity and specific requirements were dictated for different crops, it became apparent that the three or four "magic chemical compound formulas" that had been traditionally imported would no longer satisfy all the requirements. This led to an offering of technical services to the farmers, usually at little or no cost, a a means of increasing sales and acceptance.

With a few exceptions, such as ammonia in Trinidad, there are no indigenous fertilizer raw materials in the Caribbean nations. This makes imports a necessity.

The Domonican Republic pioneered bulk blending in the area and was aided by the establishment of a second large-scale plant in the late 1960s.

When the original Ferquido plant was destroyed in a fire, a larger, more modern one was set up on the original foundations in 1969.

The even lower prices that resulted from the domestic competition that ensued forced these companies to seek export markets. Considerable success was obtained, and the markets were extended into Central America and the northern countries of South America. Four yours after starting exports in 1969, the Ferquido operation exported almost 25,000 tons in 1973.

New markets were being created for a heretofore unknown product. Partially as a result of this, a plant was also established by French investors in Guadeloupe. Esso Standard Oil also set up bulk-blend plants in Jamaica, St. Lucia, and St. Vincent, of which only the Jamaican installation remains.

Improved regional ocean transport with smaller sized vessels allowed greater offerings from the Dominican Republic which, because of the economies of scale, technology, and experience that existed, dominated the area's trade. As a result, two of Esso's plants were dismantled, bagged raw materials were exported from San Pedro to Guadeloupe's installation, and thousands of tons of bagged straights and blends were exported to Jamaica.

Other countries, territories, and possessions also began importing bulk blends, which competed very favorably in price with the American and European chemical compounds. The quality was also improved considerably with the availability of uniformly sized raw materials and newly discovered blending technologies. The previously mentioned change in ocean transport led to decreased lead time on orders, as well as lesser volumes transported at one time, which in turn lowered storage time requirements and improved shelf life and appearances.

As captive markets continued to increase, other bulk-blend plants were set up in Martinique and, more recently, in Haiti. Guatemala had a respectable plant installed in Esquintla, whose capacity today is at the level of the Dominican plants, and subsequently established facilities at Santo Tomas de Castilla. Panama also set up several bulk-blend plants. Both Nicaragua and El Salvador had installations. In addition, Costa Rica, after having a chemical compound plant for many years, recently established a bulk-blend operation.

Instrumental in all these relatively recent installations was the availability of compact, integrated equipment that produced a product of very acceptable quality. We should note, however, that minimum fertilizer demand quantities are needed or the experience of St. Lucia and St. Vincent, in the past, and, more recently, that of the Bahamas will surely repeat itself. The small plant outside of Port-au-Prince, Haiti, has some of the inherent problems associated with small size, notably in the procurement and timely delivery of diverse raw materials. Overhead and operational cost distribution over a more limited volume also affects cost per ton.

Comparison

We must remember that bulk blending outside of the United States is considerably different, in terms of logistics and other factors, from the normal operations we are familiar with here. First of all, the geographic area covered is considerably larger than the relatively more limited radius covered by the American counterparts. Some installations serve whole countries, and some, as in the Dominican Republic and Martinique, also serve foreign markets.

There is no significant custom application or sales in bulk fertilizer; all of the plants' production is bagged. Because no local sources exist for any raw materials other than the inert fillers used, such as calcium carbonate or sand, and no small-volume transport infrastructure is available, inventories have to be considerably larger and lead times proportionally longer. Capital requirements are of a much greater magnitude for these and many other reasons.

Inventories of spare parts, machinery, and bags also have to be much greater. In certain countries, local bag manufacture is also available, but inventories still have to be large to compensate for any unforeseen circumstances in the traditional delivery process.

Land tenure necessitates small lots of fertilizers to a large base of customers, many of whom also want grades customized for their particular crop, area, or other criteria. It is not uncommon to find about 250 different grades being offered by the Dominican suppliers because of agronomic and marketing requirements. Although the other bulk-blend plants in the area usually supply a more limited offering, they still provide considerably more grades than is the case in the United States.

Product Characteristics

With increasingly smaller volumes of chemical compounds entering the area and the nonexistence of any considerable applications of liquid fertilizers or ammonia, the basic raw materials used are the same ones we are familiar with here, namely, urea, ammonium sulfate, diammonium phosphate, triple superphosphate, muriate and sulfate of potash, and sulfate of potash magnesia. Lesser amounts of potassium and ammonium nitrate are used, as well as some dolomite.

The smaller batch sizes allow for relatively easier incorporation of micronutrients such as boron, zinc, manganese, and magnesium. Sulfur and calcium, derived as subproducts of other raw materials, are usually present in most of the blends. By using ammoniacal N and urea N bases, the bulk blends offer an advantage in yields over that obtained with some chemical compounds that are manufactured from lower cost nitric phosphates, because the tropical weather tends to liberate this particular source with greater facility. In addition, there are red-tag restrictions on shipping some of the nitric-base raw materials.

As there is greater flexibility in choosing raw material sources inherent to blends (keeping in mind the effects of mixing different raw materials on the critical relative humidity of the ensuing finished product), blends are readily customized for requirements that dictate nitric sources or have limitations on chlorine or other criteria.

Foliar blends have experienced a very large growth, although total volume is still somewhat limited. Custom garden-variety blends, offered in 1- to 5-pound bags, are also meeting increased success as the beneficial results of their application are being recognized.

For normal products, the packaging offered consists of a woven polypropylene outer bag with a polyethylene liner that may be loose or glued to the outer bag. Ultraviolet stabilizing compounds are frequently incorporated into the polypropylene to delay degradation of the fibers caused by exposure to sunlight. Thicknesses and weave vary according to size. Domestic capacity for some countries is 100 lbs, whereas in others it is 50 kg. Some clients prefer the 50-lb size, but such packaging is limited because of the higher cost involved. The specifications for bags used for export are usually equivalent to those of the United States Agency for International Development in their international tendors.

Because of the different densities of the raw materials used and the requirements of acceptable packaging, bags have to be of different sizes to accommodate the same weight of different products.

Capacities and Consumption

I would like to repeat the opening phrase of a section on this subject in a paper I presented many years ago, because some things never change. It read, "Statistical data are most difficult to obtain and, when found, they are not timely or one finds wide divergence from the limited sources available." This notwithstanding, let us consider the individual situations of the many small, heterogenous islands that make up the Caribbean.

Belize

A small riverside plant satisfies the consumption, estimated at less than 7,500 mt annually, of this Central American country, associated with the Caribbean because it is the easternmost of the Caricom nations. Under this particular regional agreement, it is classified as a lesser developed country and given protectionary status which allows the existence of the operation, in addition to the small volumes consumed.

Bahamas

Five years ago the Bahamas Fertilizer Manufacturing Company, a small fertilizer plant, was established in Nassau to try to serve that country's consumption of about 4,000 mt of special grades for vegetables and turfs, which had been largely served by east coast U.S. producers. The market proved to be too small to sustain the operation, and the needs are again being satisfied by the traditional suppliers from the United States.

Jamaica

The Antilles Chemical bulk-blend plant, originally built by Esso, has been processing close to 25,000 tpy of raw materials received from Canada under loans from the Canadian International Development Agency for the past 2 years. In the past it processed up to 50,000 tons in only 1 year, with additional imports completing their market demand. Blends dominate that market and, at one time, the Dominican Republic shipped upwards of 15,000 tons to private and public buyers in direct sales and tendors.

Haiti

A small bulk-blend plant, set up outside of Port-au-Prince, shares the dock facilities of the country's cement plant. Plans are underway at present to move to a larger installation at a port location at the mouth of the centrally located Gonaives Valley. The plant provides less than 50% of the 15,000 tons presently consumed yearly. The balance is imported by ship or 40-ton trucks from the Dominican Republic. An "organic waste fertilizer plant" had been set up, but it has had very little success as has largely been the case with similar installations worldwide.

Dominican Republic

The previously mentioned pioneer of bulk blending outside of the United States, the Dominican Republic has three plants with enough combined capacity to completely satisfy the country's demand, which is now down around 40% to about 160,000 mt annually, and that of all the other Caribbean and Central American countries. Fertilizantes Quimicos Dominicanos (Ferquido) is located at the port of San Pedro de Macoris, some 70 km east of the capital city of Santo Domingo. Fertilizantes Santo Domingo (Fersan) is at the port of Haina, 13 km to the west of the capital, and Kettle & Almanzar is inland at Haina. Ferquido and Fersan have been competitive enough to have exported over 80,000 mt in 1 year to places as far away as Africa. The Dominican Republic has become the established base of operations for many successful deliveries to other countries, in lots of up to 15,000 mt, under the throughput (tolling) mechanism, devised by Ferquido some years ago. Throughputs could represent at least 75,000 mt this year, in addition to the traditional exports to the region.

Puerto Rico

Actual consumption has been decreasing over the years to the present level of about 90,000 tons for 1985. Its first bulk-blend plant was set up by the owners of Ferquido in 1956. San Miguel Fertilizers was later sold to Esso. Esso, in turn, sold its investments in the region—valued at more than $20 million, with installations in Puerto Rico, Jamaica, St. Vincent, St. Lucia, and Aruba—to Grace, for just $1. Grace also bought out another local blender and dismantled its plant, completely controlling the market with its own operation and selling raw materials to two other small blenders. An enormous facility exists in Aguadilla, on the eastern end of the island, that could be converted to a bulk-blend plant and could possibly offer Grace competition and end its domination of that market, if the plans are approved.

St. Kitts-Nevis-Anguilla

One Government agency does the purchasing of about 3,000 mt consumed annually. The National Agricultural Corporation (NACO) holds an annual tender which has been won by one of the area's blenders for many years. At one time Colombia exported some product to these islands but has not been in the export market recently. World sugar prices have provoked measures to reduce the 12,000 acres planted in sugarcane and to diversify these into other crops. This measure will significantly affect the quantities and grades consumed.

Antigua

A consumer of limited quantities of straight and bulk-blended materials in the past (less than 100 mt this year), this country is practically abandoning its agriculture because of increasing difficulties with the quality and availability of its irrigation water supplies. It is concentrating, instead, on tourism, as are many much smaller islands, notably Cayman, Turks, Caikos, the Virgins, and smaller outlying areas.

Guadeloupe and Marie Galante

This is the site of the second bulk-blend facility outside the Dominican Republic (Societe de Production de la Caraibe-S.P.E.C.). The plant was a combined investment of French public and private interests and serves both Guadeloupe and the neighboring Marie Galante. Both are considered as oveseas territories of France, along with Martinique and French Guyana. In the past, a considerable segment was served from the Dominican Republic, but this changed when Martinique set up its privately owned, medium-scale installation that enjoys economic size, as well as procurement and production advantages that outweigh the cost of the ocean freight.

Dominica

This is the northernmost and largest of the four islands that made up the Winward Islands Banana Grower's Association (WINBAN), a large organization that held annual tenders for up to 20,000 tons of fertilizers in the past. WINBAN has lost much of its original influence, and the norm is for each country to procure its needs. Because of the great losses suffered during the 1979 David and Frederick hurricanes, Dominica became eligible to receive aid, which at the present time will amount to over US $2.5 million from the United Kingdom for fertilizers. Because of this and the situation with bananas, the main income crop, commercial purchases have been somewhat limited in comparison with the average of about 4,500 mtpy in the past.

Martinique

A domestic market of about 25,000 mt prompted the importing agents for the Dominican products to set up their own port-side plant. Although using nonconventional weighing apparatus, the Societe Caraibe D'Industrie Chimique (S.C.I.C.) plant is not only satisfying that island's requirements but also complementing those of the other French Oveseas Departments and exporting to other regional consumers.

St. Lucia

The home for one of Esso's original bulk-blend plants, this is also the base of WINBAN's offices, which are undergoing a complete reorganization. Their main source of present supply is Martinique which, because of export credits and insurance from France (of which it is a part), was offering sight draft payment terms at 270 days under the Lome Agreement to which St. Lucia is signatory. It was very difficult for the other suppliers of the region to compete against this, especially when we understand that several payments were delayed. The closeness of Martinque also contributed to shorter lead times at competitive freight rates. There have been serious quality control problems, however, that could radically change the situation in the immediate future. A centralized buying agency, the St. Lucia Banana Grower's Association, purchases close to 11,000 mt of fertilizers for its members and an additional 500 mt for others. An additional 500 mt is imported by other private parties.

St. Vincent

The second location for one of Esso's unsuccessful bulk-blending facilities and also a member of WINBAN, St. Vincent decided to tender for its own fertilizer requirements this year. Consumption has been up to 8,000 mt. The arrowroot industry, long a staple in this country's economy, has had one of its worse moments in history. This, coupled with the poor banana situation and the price obtained for its new sugarcane crop, initiated in the early 1980s, has severely limited consumption. The West Indies Tobacco Company and the St. Vincent Banana Grower's Association have plans to dedicate more land area to their respective crops, which should have a favorable impact on future consumption.

Grenada

The southernmost of the WINBAN countries and the world's largest producer of nutmeg, the "Spice Island," as it was known until recently, has consumed over 3,400 mt of fertilizers per year. Because of a misconstrued report from the new authorities at WINBAN, wherein bulk blends are highly criticized in favor of chemical compounds, after more than 15 years of importing and using bulk blends, the local authorities have resorted to accepting only the chemical compounds, at a hefty premium in price. Needless to say, steps are being taken to correct this abnormality.

Barbados

This is the Caribbean area's last bastion for chemical compounds. A strongly traditionalistic feeling and considerable ties with England have allowed the European suppliers to satisfy the 12,000 mt market almost exclusively. In the late 1970s, Dominican bulk blends accounted for almost 25% of this volume, but because of various circumstances, this market share has steadily declined.

Trinidad and Tobago

With the Agrico Overseas marketing effort for the locally produced formaldehyde-treated granular urea and ammonia, this country is a net exporter of fertilizers. National Agro, a small bulk-blend plant with limited operations, has imported bagged raw materials for local bagging. A large consumer, Caroni Sugar Estates, has been holding annual tenders for the approximately 8,000 mt it consumes yearly. These two have been served by the Dominicans. The National Petroleum Corporation has traditionally imported about 4,000 mt of chemical blends, mainly for vegetable farmers. Tobago is dedicated primarily to tourism.

Monserrat

This small island received its requirements of about 500 mt of ammonium sulfate from Trinidad production, before that operation was converted; in addition, it obtained several hundred tons from those imported by a neighboring island. Total annual consumption is less than 1,000 mt.

CONCLUSION

Fertilizer marketing in the Caribbean region has continued to be dominated by bulk blends with a clear tendency toward establishing plants in those countries that have developed a captive market. There are still a few exceptions that continue to offer resistance to the world standard and continue to insist on importing the higher priced chemical compounds. Because of the geographical nature of the market, transportation is by small tramp vessels, although there is a marked increase in transportation in containers, namely by the West Indies Shipping Company (WISCO). We can expect to see more use of this mode of transport as the landing and other costs for breakbulk and palletized shipping continue to go up.

Large-scale bulk-blending and/or bagging facilities are rumored to be planned for Venezuela, who has imported considerable quantities of throughput materials bagged en route in the Dominican Republic. Similar plans are being discussed for the Colombian Atlantic port of Turbo, which has also received large quantities of Dominican bagged product. As installations require less investment and the plants satisfy their local demand, it is only a question of time before they try to enter the highly competitive regional export market.

To conclude, all indications are that for the midterm prices will be more attractive to the farmers, all other conditions remaining equal. For a longer time frame, either the plants will become subsidized by their local governments or they will cease to exist. It is highly improbable that the excessive installed capacity will be absorbed without a significant increase in demand, for which there are no indications. Because volume will be paramount to survival, we can expect to see unprecedented efforts in obtaining larger market shares by those involved.

Additionally, we can expect to see more protectionist measures, such as the tax applied to fertilizers imported into the French territories to compensate for the higher prices the local producers charge; licensing or other requirements imposed to limit imports, as in Haiti and Jamaica; or similar actions. This, coupled with regional preferential agreements will offset the savings that could be realized by the farmers in trying to obtain the lowest costs of production.

It is interesting to note that the country that introduced bulk blends in the Caribbean and still offers the most competitive, highest quality product, under free trade conditions, has no protectionist measures, duties, or other artificial crutches to make its fertilizer industry efficient. There must be a message here.

Please accept the sincerest appreciation from Gustavo Berges for the privilege of sharing some of these facts and impressions with the delegates to the Fertilizer Roundtable in Atlanta, Georgia.

Thank you very much.

The Role of Dry Fertilizer Blending Plants in Latin America

Enrique J. Tomeu, Jr.
Siboney International Corp.

Chemical fertilizers have been imported to Latin America for many years, primarily from Germany, Holland, Norway, Italy and United States. More recently, some Latin American countries have contributed to the supply of the area such as Mexico, Venezuela, Costa Rica, etc.

With a very few exceptions, these supplies were limited to a very short variety of formulas at best. In some areas, one or two formulas were the only choices available to most local farmers.

As we all know, the results were:

A. Reduction of production due to improper ratios of nutrients.
B. Increased fertilization costs due to use of unnecessary nutrients.
C. Increase in freight, storage, and bags as the necessary filler in formulas was imported and handled.

Attempts have been made, like in Peru, encouraging the use of straight nutrients by the farmers, but the gap of communication between agronomists and farmers harbored the improper use of these materials, creating perhaps a worst condition of unbalanced plant nutrition.

We must keep in mind that facilities and services that are common to us in the developed countries and we take as a matter of fact, can be an unsurmountable barrier in most developing countries, unless we handle them with substantial local expertise and flexibility.

More recently, within the last 30 years, a few regional chemical granulation or semi-granulation plants have been built, alleviating somewhat the availability and distribution, but at a very high cost of construction and operation and, in most cases, a lengthy and costly redistribution once the products are manufactured.

The new alternative subject of this paper is not so new, as it is the metamorphosis of the old powdery and dusty fertilizer blending plants of the forties and fifties where names like Atlanta Utilities Works, Sturtevant, and A. J. Sackett and Sons were the most common suppliers of rotary batch mixers, bucket elevators, etc. of these primitive plants driven by pulleys and flat belts out of a single power source and fed by hand shovels and "Georgia Buggies."

The dusty material gave way to the dustless granular materials, the "Georgia Buggies" were traded for diesel front end loaders, the flat belt pulleys became shaft mounted reducers and individual electric motors, the lever scales transformed to digital computerized scales.

All of us over thirty years in this industry have seen this evolution take place.

The newer medium size, well equipped, ample storage dry blending plants are the absolute answer to the production and distribution of fertilizers in Latin America and other developing countries. Compared to the more sophisticated granulation plants, their cost of construction, financing, and operation is less than 30% with more flexibility in formulation changes as required and capability of utilization of some local materials.

Since the oil crisis of a few years ago, the world lost its more or less balanced pace, primarily by its explosive increase in costs of production, followed by the lightly planned aid of developed countries' governments to the developing countries governments and followed by private international banks pushing petrodollar loans in what has been recently proven to be disastrous sovereign loans.

All the above has created the present scenario in most developing countries, including Latin America.

A. Unbearable loans with little or no possibility of repayment.

B. Industrial complexes run by governments with little incentive for profitability or efficiency.

C. Protective duties harboring inefficiencies of operations.

Fertilizer was no exception. In Latin America, this industry, today, is emerging from its worst crisis ever.

The construction of well designed and strategically located physical blending fertilizer mixing plants is undoubtedly the most economical means of improving agricultural production in developing countries.

The costs of these plants versus their immediate local benefits, justify them in most circumstances. Together with these plants, an aggressive and educational agricultural extension service, soil analysis, and other agronomical recommendations help the determination of near perfect utilization of plant-food and pesticide, leading to the most efficient crop production. This in itself promotes a permanent transfer of technology in efficient food production thus solving the most immediate local needs.

Being these plants of a fairly simple design and construction, the period between funding and start-up of fertilizer production is normally less than one year. It is very common that feasibility studies, financing, legal and local matters take more time than the actual construction.

Plants capable of mixing 50,000 to 100,000 tons per year should cost approximately 3 to 5 million dollars, depending on the necessary supporting equipment and buildings. It is also a feature of these plants that if at any time production increases above the planned capacity, a new location for an additional plant is generally the best cost effective solution, which also helps simplify distribution to the users.

My experience in Latin America to this date has been with Panama and Peru. At present, I am evaluating two other countries.

In Panama, our plant has been in production for five years utilizing local management and labor with excellent results.

In Peru, the plant was built in 1984 and it is too early to evaluate.

Wednesday, October 30, 1985

Morning Session
Moderator:

Dr. Ole Lie

Production of Granular Ammonium Phosphates from Sludge Acids and Evaluation of the Products for Suspension Fertilizers

Byron R. Parker, Melvin M. Norton, and James R. Burnell
Tennessee Valley Authority
National Fertilizer Development Center

A heightened interest in the usage of high-impurity sludge phosphoric acids has been obvious in recent years within the fertilizer industry. This sludge acid is made during the normal process of wet-process phosphoric acid production when the wet-process phosphoric acid is concentrated. The acid is concentrated either to produce a low-impurity merchant-grade acid that can be readily shipped without excessive settling of solids or to produce an acid of suitable quality to allow production of ongrade (18-46-0) granular diammonium phosphate (DAP). During the concentration step or steps, some impurities in the acid precipitate, and these precipitated solids must be removed in a clarification step. During clarification, most of the impurities exit the process as a high-impurity side stream commonly referred to as sludge acid.

As rock quality has decreased, the impurity level in wet-process phosphoric acid and the amount of sludge acid produced have increased. In many cases the quality of the sludge acid also has decreased as evidenced by a higher proportion of precipitated solids in the acid. The situation has been further aggravated by the higher rate of production of clarified acids needed for production of higher grade, better quality suspension fertilizers.

In the past, much of this sludge acid has been used onsite in production of granular triple superphosphate (TSP), a use for which it was well suited. Now, however, some of these relatively older TSP plants have been shut down because of newer, more rigid pollution control standards and decreased demand for TSP. There has therefore been a search for other methods for use of sludge acids. The most promising options now appear to be use in production of solid monoammonium phosphate (MAP) or ammonium polyphosphate (APP). Both of these options have been studied extensively by TVA with merchant-grade and sludge phosphoric acids as process feeds. The granular MAP and APP products made from various sludge acids have exhibited excellent physical and storage properties, and they are well suited for direct application or bulk-blend uses. The APP product, however, is superior for use as an intermediate for production of suspension fertilizers because the presence of a small amount of polyphosphate (abut 10% of total P_2O_5) in the final suspension fertilizer sequesters impurities and allows a higher grade of suspension fertilizer to be made than can be made from a MAP product that contains no polyphosphate.

Production of Granular Ammonium Phosphates from Sludge Acid

TVA has conducted both bench-scale and pilot-plant tests to develop processes or process modifications to make granular MAP or APP fertilizers from sludge acid. This work has been carried out not only to find uses for large quantities of sludge acid, but also to determine whether lower cost and/or improved fertilizer material can be made from such acids.

Bench-Scale Testing

Initial testing was done using a bench-scale preneutralizer and drum granulator. Sludge acids containing up to 40% by volume of solids were used. The acid was partially neutralized in the preneutralizer, and the resulting slurry was fed to the drum granulator where it was further neutralized and granulated. In this work, sludge acids were satisfactory for use in production of granular MAP. Good quality products with nominal grades of 9-50-0 to 10-50-0 were produced. No pilot-plant tests were made using a preneutralizer and drum granulator; however, based on previous experience with scale-up of a similar process using merchant-grade wet-process phosphoric acid, no difficulties would be expected in scaling up the process to produce granular MAP from sludge acids in pilot-plant facilities.

Pilot-Plant Testing

In cooperation with four major producers of wet-process phosphoric acid in Florida, TVA, over the past 3 years, has conducted pilot-plant granulation tests using sludge acid from each of the four producers. The acids were shipped to the National Fertilizer Development Center in Muscle Shoals, Alabama, in trailer-truckload quantities of 20 to 25 tons each. Because of poor handling properties of the acids and the tendency for the solids in the acid to settle quickly, special measures were taken to minimize settling of solids. The acid was loaded directly into the trailer from production and immediately transported to Muscle Shoals to minimize transit time. In most cases, the acid was still warm (90-100°F) upon arrival in Muscle Shoals. Immediately upon arrival, the acid in the trailer was air sparged through the trailer discharge line and with air lances from the top inspection ports of the trailer. The acid then was pumped into storage tanks where it was continuously agitated either with mechanical mixers or by air sparging until it was fed to the granulation process. When essentially all the acid was unloaded from the trailer, some of the acid was recirculated back to the trailer in an effort to redissolve and wash more solids from the trailer. Even with this special handling, some solids were left in the trailers used for transport. The remaining solids were not uniformly deposited, but from 1 to 5 inches of solids usually remained. With continuous agitation during storage, there was essentially no settling of solids in the storage tanks.

The degree of difficulty of shipping and handling sludge acids must be carefully evaluated, especially if a large scale operation is considered. Shipping, especially of large quantities, is not recommended. At this time, only onsite processing of sludge acid is recommended.

Composition of Sludge Acid Tested

Typical compositions, as received, of the four sludge acids that were tested are given Table I. As shown, the compositions of the sludge acids varied widely. The P_2O_5 contents varied from 45.6 to 50.0%, but more significant was the variation of some of the other components of the acids, namely, the Fe_2O_3 content which ranged from 1.9% in acid A to 4.2% in acid D and was greater than 3.0% for the remaining two acids. The Fe_2O_3 content appears to be a significant factor when solids made from the acids are used to make suspension fertilizers, as will be discussed in a later section of this paper. The methanol-insoluble solids contents of the acids ranged from 15 to 25% by weight. Although there is not a direct correlation, the water contents tended to decrease and handling and processing problems tended to increase with increasing solids content. Microscopic characterizations showed that the solids were predominantly (50 to 60% in acid A and more than 80% for the remaining acids) composed of $(Fe,Al)_3 KH_{14} (PO_4)_8 \cdot 4H_2O$; the remainder was chukhrovite, $(Na,K)_2SiF_6$, and calcium sulfate compounds, either alone or in combination.

Process Modifications

All pilot-plant testing was done using the TVA pipe-reactor and drum-granulator process. Production rates were 800 to 1,100 lb/h. Figure 1 is a simplified flowsheet of this process showing the equipment used and some equipment sizes. In some tests designed to produce APP products, an inverted-L-shaped pipe-reactor configuration was used because previous studies had shown that this configuration results in slightly higher product polyphosphate contents that those normally attained under similar conditions with the horizontal pipe-reactor configuration shown in Figure 1. The inverted-L-shaped pipe-reactor is composed of a vertical section joined by an elbow to a horizontal section which dicharges melt into the drum granulator. The existing pilot plant that was used in the tests had a rotary cooler and a rotary dryer; both were used as coolers in these tests. A new plant using this process would require only one suitably sized cooler. To simulate this in the existing pilot plant, low airflows were used in each cooler. In processing acids A, C, and D, a water solution was used as the scrubbing medium to remove free ammonia and particulates from the granulator exhaust gas stream. In processing acid B, the feed sludge acid was used as the scrubbing medium, and some buildup of solids in the scrubber occurred during tests with acid B. The scrubber was a packed-bed type which is not recommended for use with sludge acid as the scrubbing medium. A scrubber with a minimum of internals, such as a venturicyclonic type, should be used, and in some cases, water or a weak solution sulfuric or phosphoric acid may be the preferred scrubbing medium. The latter might be especially viable during production of MAP where the evolution of ammonia from the granulator is low.

Test Results

Granular products made from the sludge acids were either MAP or APP of the nominal grades shown in Table I. The phosphate was 100% available in all the products. The water-soluble phosphate averaged 91% for products made with acid A and 82 to 86% for products made with acids B, C, and D. When APP products were made, the process was modified to operate under conditions of high temperature and low water so as to convert a portion of the phosphate to the polyphosphate form. Polyphosphate is particularly desirable in granular products that are used to produce suspension fertilizers because polyphosphate in the final suspension product sequesters impurities and reduces precipitation of solids.

Results with Acid A: MAP products of a nominal 9.5-49-0 grade were made with acid A. Three different process modifications were tested in which the ratios of the ammonia and acid fed to the pipe reactor and drum granulator were varied. In all tests, a final product NH_3:H_3PO_4 mole ratio of 1.0 was maintained. Granulation was satisfactory, and good quality products containing 1.1 to 1.2% water were produced with no drying. Storage and handling properties of these products were good and comparable to those of MAP produced from typical merchant-grade wet-process phosphoric acid. There was no effort to make a product containing polyphosphate; therefore, the feed acid was not preheated and the products contained less than 5% of the P_2O_5 as polyphosphate.

The maximum satisfactory suspension grade that could be made from the 9.5-49-0 grade MAP product was 8-24-0. This is significantly lower than the 10-30-0 grade that usually can be made from a good quality 10-53-0 grade commercial MAP made from merchant-grade acid.

Results with Acid B: Acid B contained significantly more Fe_2O_3 than acid A (3.1 vs 1.9%). In addition, this acid contained more P_2O_5 and less water than acid A; both favored formation of polyphosphate during processing to make APP products of nominal 11-52-0 grade. Product polyphosphate contents of 7% of the total P_2O_5 were obtained with no external heat added to the process. By further preheating the already warm sludge acid from the scrubber in a heat exchanger with steam before the acid was fed to the pipe reactor and use of the inverted-L-shaped pipe-reactor configuration, product polyphosphate contents of up to 13% of the total P_2O_5 were obtained. Products of intermediate polyphosphate contents also were made to give a range for suspension testing; the relationship of increasing product polyphosphate content with increasing acid feed temperature is shown in Figure 2.

The maximum satisfactory suspension grade that could be made from the granular 11-52-0 grade APP containing 13% of the total P_2O_5 as polyphosphate was 10-30-0. This is the same as is obtainable from a good quality commercial MAP of 10-53-0 grade, but is lower than the 12-36-0 grade that can be made from TVA 11-55-0 APP made from merchant-grade acid. In contrast, the maximum satisfactory suspension grade that could be made from the 11-52-0 grade APP containing 7% of the total P_2O_5 as polyphosphate was 9-27-0.

Results with Acid C: Acid C differed significantly from the other acids in that it had a much higher solids content (23–25% vs 15–19%) and a lower water content of less than 14%. As a result, more problems were encountered in processing this acid. In producing 10-48-0 grade MAP products under the optimum conditions required to maintain both good pipe-reactor operation (235–250°F) and good granulation, high product moistures of 8 to 10% were obtained. Although the product looked dry and was free flowing during production, storage tests showed that products with moisture contents above 4% have the potential for caking. To produce an acceptable product under these optimum conditions would require drying. To produce MAP without drying or to produce APP (7% of P_2O_5 as polyphosphate as was done in one test), requires operating the pipe reactor at higher temperatures (above 300°F) with subsequent more rapid buildup of solids in the reactor. These buildups were composed of 80 to 90% solidified MAP and 10 to 20% of an optically amorphous material. These solids can be removed by passing steam through the reactor, but the rate of buildup is relatively high, so operation of the pipe reactor at the higher temperatures with this acid is not recommended.

The maximum satisfactory suspension grade made with the 10-48-0 grade product containing essentially no polyphosphate was only 8-24-0.

Results with Acid D: Acid D had a solids content of 17 to 18%, but was unique because of its high Fe_2O_3 content (4.2%). The main purpose of tests with this acid was to produce APP products of different polyphosphate contents and to determine the effect of the polyphosphate level on suspensions made with this granular product. For this reason, an inverted-L-shaped pipe-reactor configuration was used to facilitate production of polyphosphate. Overall, pilot-plant operation was very good. Granulation was excellent, especially when small quantities of ammonia and water were metered to the bed of the granulator to improve granulation. Product polyphosphate levels from 5 to 13% were obtained by varying the amounts of preheat on the feed acid (Fig 2). Satisfactory product hardness and moistures were obtained in all tests, and storage properties of the product were good. Buildup in the pipe reactor was significant in one test where a relatively low melt temperature (400°F) was maintained to produce a product containing 5% of the total P_2O_5 as polyphosphate. However, in other tests where higher melt temperatures were maintained, the pipe reactor operated longer than 11 hours without any evidence of significant buildup. Buildup generally occurred in the transition area between the vertical and horizontal sections of the pipe reactor. A horizontal pipe reactor should decrease the chance of buildup, but might result in a slight decrease in polyphosphate content of the product for otherwise identical conditions. If a horizontal reactor is used, it is recommended that it be installed in an inclined position and sloping upward toward the granulator.

The products made with acid D were not particularly well suited for use in preparation of base suspensions, probably because of the high iron content. With the 10-51-0 APP product of lowest polyphosphate content (5% of P_2O_5), the maximum satisfactory suspension grade was only 8-24-0. With the APP product of highest polyphosphate content (13% of P_2O_5), the maximum satisfactory suspension grade still was only 9-27-0, as compared with a 12-36-0 grade possible with a high-grade granular APP made from merchant-grade acid.

Conclusions

Overall results of this work with granulation of sludge acids show that production of MAP or APP by the pipe-reactor and drum-granulator process is a viable use for these acids. Granulation could be controlled to produce acceptable products using all four sludge acids which varied widely in composition. Problems encountered, the degree of which generally increased with increasing solids content of the acid, centered around areas other than granulation. A brief description of these areas is given in the following listing.

1. *Acid handling:* Some setting of solids occurred in the truck trailers during transport, and only a portion of these solids could be redissolved or washed from the trailer by recirculating the acid from the storage tanks to the trailer. Continuous agitation of the acids during storage before processing eliminated settling of solids in the storage tanks. Onsite use of sludge acid as produced is recommended.
2. *Scrubber operation:* Significant buildup occurred in the scrubber and exhaust duct during one series of tests where the sludge acid was used as the scrubbing medium. A scrubber with a minimum of internals, such as a venturi-cyclonic type, should be used. Even then, especially with sludge acids of higher solids content, a scrubbing medium of water or a weak solution of phosphoric or sulfuric acid may be necessary.
3. *Pipe-reactor operation:* Buildup in the pipe reactor can be a significant problem, especially with sludge acids of higher solids content. This buildup is typically 60 to 90% solidified MAP, 10 to 30% amorphous material (typically a metal ammonium phosphate or fluorophosphate), and in some cases, up to 20% of unreacted $(Fe,Al)_3KH_{14}(PO_4)_8 \cdot 4H_2O$ from the feed acid. In general, this buildup increases with increasing solids content of the acid. The melt temperature should be maintained at about 300°F or below when making MAP products and above 400°F when making APP products. Melt temperatures between 300 and 400°F should be avoided when possible.

Because of the variability in the composition of sludge acids, potential problems in each of these three areas should be carefully evaluated, and production requirements and product properties should be determined for each sludge acid to be used.

Evaluation of Suspension Fertilizers Made from Granular Ammonium Phosphates Produced from Sludge Acid

The granular MAP and APP products made in the granulation pilot plan using sludge acids A to D (Table I) were evaluated for suspension fertilizer production. The evaluation consisted of the batch production of various grade suspension products from each of the granular products and evaluation of the suspensions both initially and after storage for 30, 60, and 90 days at 80 and 32°F to determine the highest satisfactory grade that could be produced from each of the granular products. TVA criteria for satisfactory base suspensions are as follows:

1. Viscosity must not exceed 1,000 cP at 80°F or 1,500 cP at 32°F.
2. Pourability from a container tilted at a 45-degree angle must be at least 98% by volume after slight agitation is supplied by running a stirring rod twice around the inside of the container.
3. Crystals present must not exceed 20 mesh (850 μm).
4. No settling and packing of crystals during static storage.
5. For suspensions intended to be shipped long distances, loose, settled crystals after the TVA vibrational settling test must not exceed 2% by volume.
6. For suspensions that are to be stored during winter in the colder regions of the United States, the solidification temperature must be -5°F or lower and the viscosity at 0°F must not exceed 2,000 cP.

Syneresis, as evidenced by the formation of a clear layer in the suspension, is undesirable because it promotes growth of crystals to large size at the interface of the clear layer and suspension. However, if there are no large crystals present and the clear layer and suspension can be easily remixed, syneresis does not cause a suspension to be rated as unsatisfactory.

Batch Production of Suspension Products

The batch equipment for production of the suspension fertilizers (Fig 3) consisted essentially of a reactor and a combination cooler/clay mixer. The procedure used in batch production of the suspensions were those found previously to result in high-grade, good-quality suspensions. All of the solid material and water of formulation were charged to the reactor and quickly ammoniated to a pH of about 6.5. The temperature after the ammoniation step was about 150°F. After the ammoniation step was completed, the hot slurry was transferred to the cooler/clay mixer where it was cooled to 135°F and attapulgite clay (1.5% by wt) was added and gelled by mixing with a turbine-type agitator. The suspension then was cooled to 120°F before it was pumped to storage. The use of a cold heel from a previous batch in the cooler/clay mixer causes rapid cooling of the hot material from the reactor to well below the salting-out temperature of ammonium phosphate, thus producing an abundance of small ammonium phosphate crystals that do not grow to large size during storage. Batch sizes of 50 and 500 pounds were produced. Total batch time was about 20 minutes regardless of the batch size.

Test Results

The highest satisfactory suspension grade that could be produced from the granular MAP and APP products made from each of the four sludge acids was discussed previously. A comparison of the highest satisfactory suspension grades made from each of the solid ammonium phosphates made from the sludge acids and physical properties of the suspension products are given in Table III along with similar information for suspension products made from commercial MAP and TVA 11-55-0 grade APP. All of the products shown in this table remained satisfactory after storage for 90 days at 80 and 32°F. Compositions of the sludge acids and the granular products are given in Tables I and II, respectively.

The overall results of these tests of the production of suspension fertilizers from granular ammonium phosphates made from sludge acids (Table III) indicate that the lowest suspension grade (8-24-0) was produced from the MAP grades containing little or no polyphosphate (sludge acids A, B, and C). The highest suspension grade was made from the 11-52-0 grade APP product made from sludge acid B. The suspension product made from this granular material contained 10% of the P_2O_5 as polyphosphate. This grade product is comparable to that attainable from commercial MAP of 10-53-0 grade made from merchant-grade acid, but is somewhat lower than the 12-36-0 grade attainable from TVA 11-55-0 APP containing about 10% of the total P_2O_5 as polyphosphate.

These results show further that if the sludge acid used to produce the granular APP contains significantly more impurities (Fe, A1, Mg, F, and Ca) or a different proportion of these impurities such as sludge APP D (Table I), the maximum satisfactory suspension grade made from the granular product will be lower even though the polyphosphate content of the suspensions may be the same. For example, the maximum satisfactory suspension grade produced from the granular APP of 10.5-51-0 grade (made from sludge acid D) was only 9-27-0 because gels formed by the impurity compounds in a higher grade suspension could not be broken with agitation.

The major cause of gelling or solidification of the suspension fertilizers produced from these sludge products evidently was the large quantity of iron present. The iron was present in the original sludge acid as $Fe_3KH_{14}(PO_4)_8{\cdot}4H_2O$. Upon ammoniation in the pipe reactor to make the granular products, the bulk of the crystalline $Fe_3KH_{14}(PO_4)_8{\cdot}4H_{20}$ was converted to amorphous $FeNH_4(HPO_4)_2{\cdot}nH_2O$. During processing to a suspension fertilizer, the amorphous $FeNH_4(HPO_4)_2{\cdot}nH_2O$ dissolved incongruently to form $FePO_4{\cdot}nH_2O$ gel. This gel entrapped and retained a large amount of water, causing high viscosity or solidification.

In the APP products, the pyrophosphate combined with iron to make $(Mg,Al,Fe)NH_4\,HP_2O_7F \cdot nH_2O$. At higher polyphosphate levels (10% or higher) more $(Mg,A1,Fe)NH_4HP_2O_7F{\cdot}nH_2O$ was formed resulting in less Fe being precipitated as amorphous $FeNH_4(HPO_4)_2{\cdot}nH_2O$. It appears that the higher polyphosphate materials (made from sludge acids B & D) produced more $(Mg,Al,Fe)\,NH_4\,HP_2O_7F \cdot nH_2O$ and; therefore, higher quality suspensions (lower viscosity).

The results (Table III) also show that even with a small amount of polyphosphate present in the APP suspensions, the APP suspensions had lower solidification temperatures than those of ammonium phosphate base suspensions that contained no polyphosphate (−2 to −5°F vs 13 to 16°F). Thus, these APP base suspensions have satisfactory low-temperature storage and handling properties that would allow them to be stored during the winter in most of the colder regions of the United States.

Additional tests were made to determine the optimum $N:P_2O_5$ weight ratio for suspension fertilizers made from a granular APP product made from sludge acid. The suspensions tested contained about 10% of the total P_2O_5 as polyphosphate. The optimum $N:P_2O_5$ weight ratio for this suspension was in the range of about 0.300 to 0.310. In this $N:P_2O_5$ weight ratio range, the suspensions had the lowest solidification temperature (−6°F) and the lowest initial viscosity at 80°F, 150 cP (Fig 4 and 5, respectively). The low viscosity was expected because the maximum solubility of saturated ammonium phosphate solutions occur at about 0.30.

Also tests were made to determine the optimum amount of attapulgite clay required to keep the solids suspended in a suspension produced from a granular MAP made from sludge acid. The suspension tested was of 10-30-0 grade and contained 10% of the total P_2O_5 as polyphosphate. Levels of clay studied were 0.25, 0.50, 0.75, 1.0, 1.25, and 1.5% by weight. Results indicate that the suspension products made from sludge acid should contain at least 1.5% by weight of clay to prevent solids from settling during storage and to have satisfactory gel strength for prevention of settling of crystals during shipment. This is the amount of clay that is usually required for orthophosphate base suspensions produced from merchant-grade acid.

CONCLUSIONS

As the quality of the wet-process phosphoric acid used to produce the granular APP products decreases, so does the highest satisfactory grade base suspensions that can be produced from the granular material. However, by producing sludge granular APP that contains sufficient polyphosphate to give 10% of the total P_2O_5 as polyphosphate in the final suspension product, satisfactory grade suspensions of 9-27-0 to 10–30–0 can be produced, depending on the impurities in the sludge acid used to to make the granular material. In general, for a particular sludge acid, a higher polyphosphate content in the granular APP product made from the sludge acid will allow a higher satisfactory suspension grade. The presence of polyphosphate in solid intermediates will continue to grow in importance with the increased need for high-analysis nitrogen-phosphorus suspension fertilizers. Whether the APP suspension fertilizer is used as produced for direct application or cold blended to produce APP mixed-grade suspensions, the use of solid APP products in the production of suspension fertilizers has a promising future.

Advantages of the use of solid APP, as compared with solid MAP with no polyphosphate, to make suspension fertilizers include the following:

1. Higher satisfactory suspension grades can be produced.
2. Ease of disintegration of APP granules during production of the suspension fertilizer with resultant shorter batch times and reduced needs for high-intensity mixing equipment.
3. Suspension products that contain at least 10% of the P_2O_5 as polyphosphate usually have solidification temperatures of −5°F or lower which makes them satisfactory for winter storage in most regions of the United States.
4. Fewer storage problems are encountered with the APP base suspension products, whereas suspensions made from solid MAP products tend to form strong gels and to solidify during storage.

Table 1. TYPICAL COMPOSITION OF SLUDGE ACIDS AND GRANULAR PRODUCTS MADE FROM SLUDGE ACIDS

	Composition of indicated acid, wt %			
	A	B	C	D
Sludge acid analysis				
P_2O_5	45.6	50.0	48.3	48.7
Al_2O_3	1.5	2.0	1.9	1.4
Fe_2O_3	1.9	3.1	3.6	4.2
F	2.3	1.3	2.8	1.6
MgO	0.8	0.6	1.0	0.8
SO_3	7.0	4.6	5.3	5.0
CaO	3.0	1.2	2.6	1.6
H_2O	18.2	16.4	13.7	17.5
Solids				
Water—insoluble	13.4	10.6	18.2	11.7
Methanol—insoluble	18–19	15–18	23–25	17–18
Granular products				
Type[a]	MAP	APP	MAP, APP	APP
Nominal grade	9.5-49-0	11-52-0	10-48-0	10.5-51-0

[a] MAP = monoammonium phosphate; APP = ammonium polyphosphate.

Table 2. TYPICAL COMPOSITION OF GRANULAR PRODUCTS MADE FROM SLUDGE ACIDS

Sludge Acid	Granular product							
	Nominal grade	Polyphosphate, % of total P_2O_5	Composition, wt %					
			Al_2O_3	MgO	Fe_2O_3	F	CaO	SO_4
A	9.5-49-0	0-4	1.6	0.9	2.0	2.4	3.2	9.0
B	11-52-0	7-13	2.1	0.6	3.2	1.4	1.2	5.7
C	10-48-0	0-7	1.9	1.0	3.6	2.8	2.6	6.4
D	10.5-51-0	5-13	1.5	0.8	4.4	1.7	1.7	6.3

Table 3. COMPARISON OF SUSPENSIONS PRODUCED FROM MAP AND APP MADE FROM SLUDGE ACID, COMMERCIAL MAP, AND TVA-PRODUCED[a] MAP AND APP

	Products from merchant-grade acid			Products from indicated sludge acid					
	Commercial MAP	TVA APP		Acid A	Acid B		Acid C	Acid D	
	10-53-0	11-55-0		9.5-49-0	11-52-0		10-48-0	10.5-51-0	
Highest satisfactory grade	10-30-0	12-36-0	11-39-0	8-24-0	9-27-0	10-30-0	8-24-0	8-24-0	9-27-0
$N:P_2O_5$ wt ratio	0.33	0.33	0.28	0.33	0.33	0.33	0.33	0.33	0.33
Polyphosphate, % of P_2O_5	0	10	10	3	7	10	0	0[b]	10
Solidification temperature, °F	13	−5	−5	2	−4	−2	16	14	−2
Viscosity, cP									
at 80°F	400	600	700	350	250	500	300	200	350
at 32°F	~1,500	1,250	1,400	350	350	650	750	450	400

[a] Produced in TVA pipe reactor-drum granulator pilot plant.
[b] Granular product used to make this suspension was obtained from acid supplier.

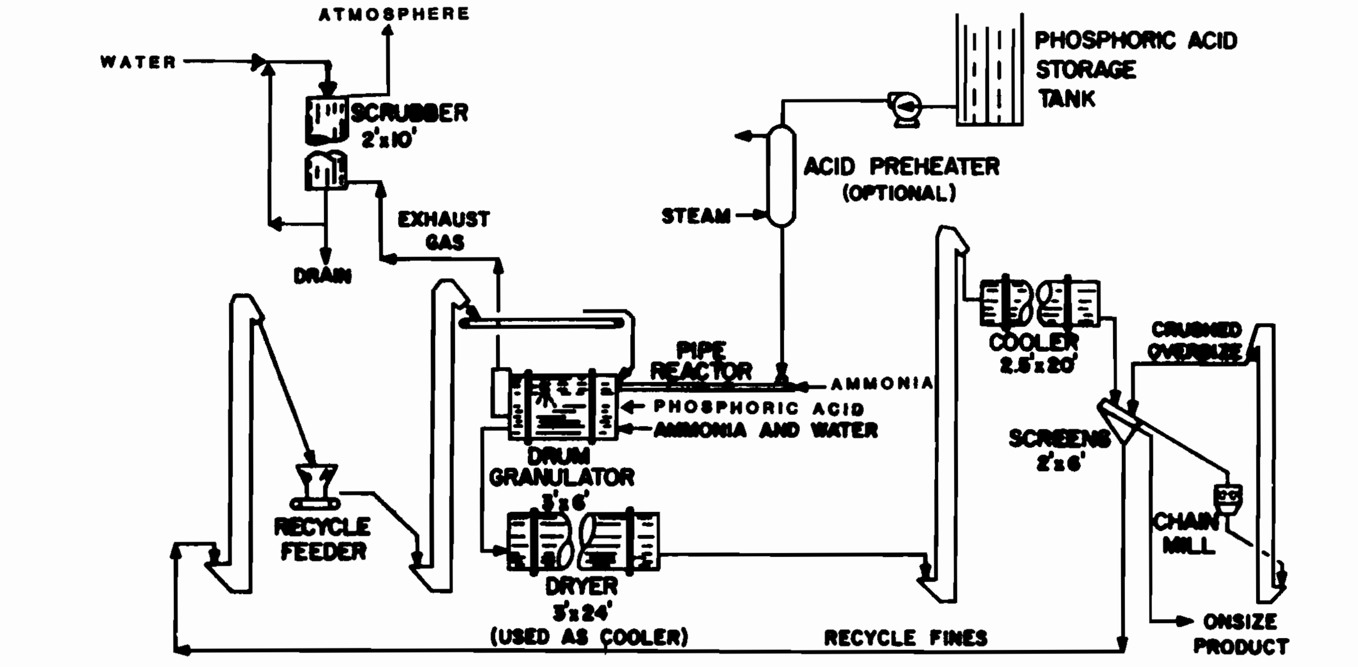

FIGURE 1

Flow Diagram of the Granulation Pilot Plant for the Production of Ammonium Phosphate Using the TVA Pipe Reactor

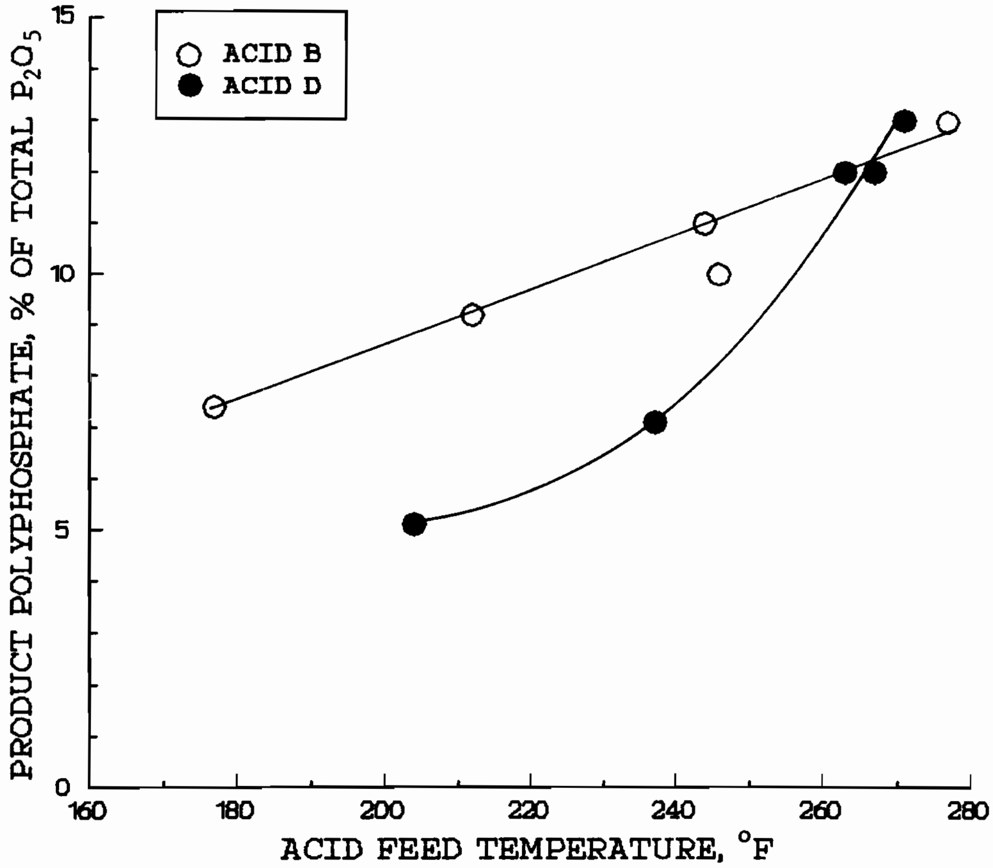

FIGURE 2

Production of Granular Ammonium Polyphosphate

from Sludge Acid

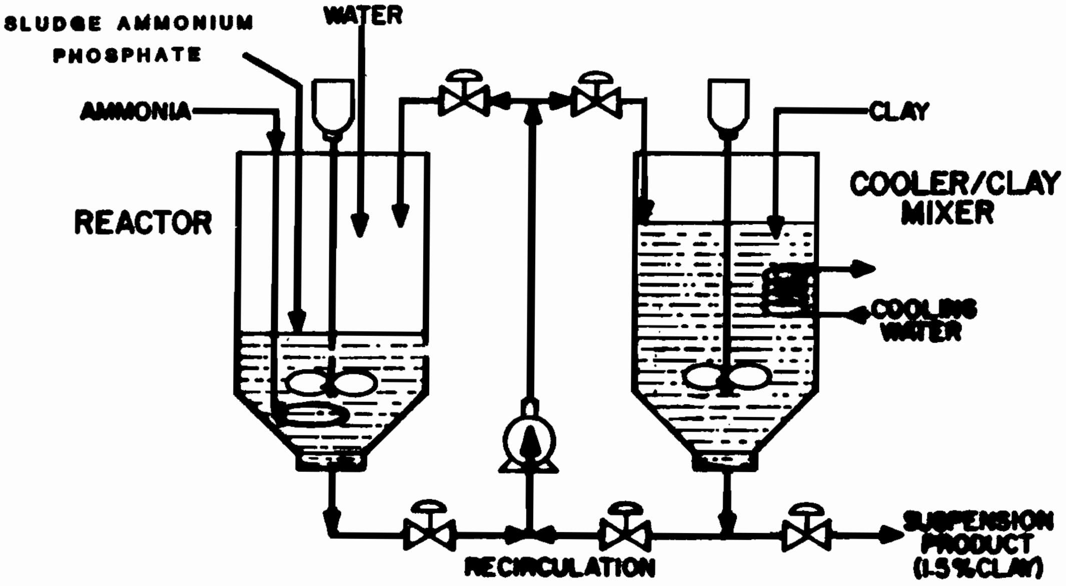

FIGURE 3

Batch Production of Suspension Fertilizer from Granular Ammonium Phosphate Made from Sludge Acid

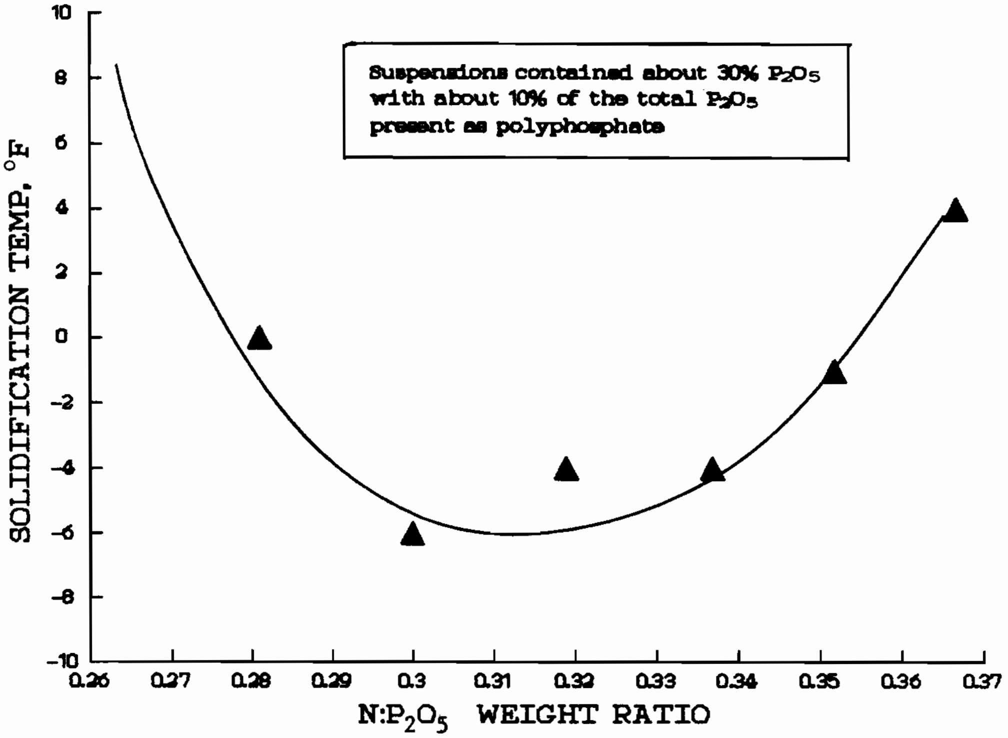

FIGURE 4

Effect of $N:P_2O_5$ Weight Ratio on Solidification Temperature of Suspension Fertilizers Made from Sludge APP

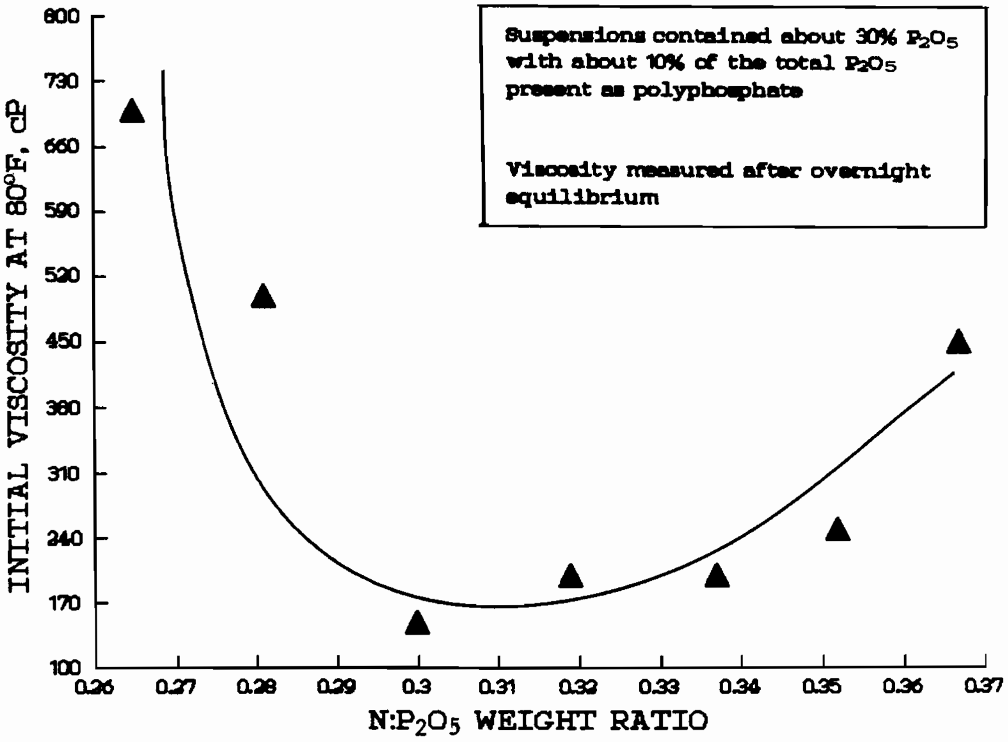

FIGURE 5

Effect of $N:P_2O_5$ Weight Ratio on Viscosity of Suspension Fertilizers Made from Sludge APP

Granulation of Urea Based NPK

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Urea, today the most abundant and at the same time most concentrated source of nitrogen, is often the most economical source of that nutrient. It is logical, therefore, to try to produce granular NPK using urea as one of the nitrogen-bearing ingredients, particularly as this material is easily handled and requires no reaction during the production of NPK.

Unfortunately, when urea is used in the production of granular NPK formulas, certain problems arise that are related to such physical and chemical properties of urea as its reactivity with superphosphates, its high solubility and its high hygroscopicity.

Urea reacts with monohydrated monocalcium phosphate, the main component of superphosphates, by releasing water that causes deterioration of the product. To all practical purposes, nothing can be done to prevent this reaction, and therefore the two compounds are simply not used together in the same formulation.

The other two characteristics of urea just mentioned, its high solubility and its hygroscopicity, combine in such a way that urea-based NPK products require special treatment during their processing and later handling. The high hygroscopicity makes the elimination of water durng the drying process difficult, while its high solubility, particularly in the presence of other soluble salts such as ammonium phosphate and potassium salts, prevents the use of high temperatures during drying. This combination of characteristics makes it necessary to provide special conditions in the dryer, with which those who aim to produce this type of fertilizers successfully must be acquainted.

The high hygroscopicity of the material means that it must be bagged almost immediately or stored in premises offering a relatively low (less than 50%) atmospheric humidity.

FERTIMEX is interested in producing urea-based granular NPK fertilizers in its DAP/NPK plant of the Pajaritos Unit located in Coatzacoalcos in the State of Veracruz, Mexico. It is also interested in including in the formulas, as a source of sulfur and instead of a filler, the greatest possible amount of ammonium sulfate, since its installations in the area produce this salt, as well as surplus amounts of sulfuric acid. It therefore decided to use pilot plant tests as a basis for determining the conditions required for optimum production using urea & ammonium sulfate as raw materials.

The tests were run in the facilities of the International Fertilizer Development Center (IFDC) in Muscle Shoals, Alabama, and required certan adaptations to be made in the pilot plant in order to simulate the operating conditions of the Pajaritos plant, originally designed for the production of triple superphosphate and later modified to permit the production of NPK.

The process includes the production of monoammonium phosphate and ammonium sulfate in a preneutralizar and the subsequent addition of urea, potassium chloride and more ammonium sulfate, if necessary, to a pug mill granulator, in order to obtain a 17-17-17 end product.

Eighteen test runs were made for different purposes, among them establishing the values of parameters, for optimum operation of the preneutralizer, granulator and dryer, such as the maximum operable temperature of the dryer and the behavior of the preneutralizer slurry, particularly as regards its viscosity.

Other runs were aimed at determining the best method of adding ammonium sulfate. In some cases, 50% of the ammonium sulfate was prepared in the preneutralizer by reacting sulfuric acid with ammonia and the remaining 50% was added as crystalline ammonium sulfate to the granulator, through the recycle. In others, the proportions were changed to 75/25 and in the final runs, all the ammonium sulfate was produced in the preneutralizer.

Additional runs were made to determine differences in the behavior of the product according to whether it is hot screened and crushed, directly upon discharge from the dryer or screened and crushed after cooling.

RAW MATERIALS

The following raw materials were used:

Ammonia: In gas form, added in the preneutralizer and in the granulator.

Phosphoric acid: Average concentration 54%, added in its entirety to the granulator scrubber tank and recycled through the scrubber itself prior to sending it on the preneutralizer.

Sulfuric acid: Concentration levels of from 91 to 93%, added to the preneutralizer.

Urea: In all test runs the urea used was prilled and incorporated into the recycle for addition to the granulator.

Ammonium sulfate: When added as crystals, these entered the granulator after being incorporated into the recycle.

Potassium chloride: Also added to the granulator via the recycle.

Defoamer: The defoamer used to improve the operation of the preneutralizer was CCJ 550 Westvaco.

PROCESS & PLANT DESCRIPTION

In making the tests, 14 of the 18 runs were based on the configuration of the pilot plant shown in Figure 1, in which the product was screened and crushed after cooling. The 4 other runs were made with hot screening and crushing as shown in Figure 2.

Figure 1

If we consider the preneutralizer as the starting point, the first step in the process is to feed into it all the phosphoric acid, all the sulfuric acid and part of the ammonia.

All the P_2O_5 needed to obtain the 17-17-17 was added, as mentioned before, in the form of phosphoric acid of 54% P_2O_5 to the granulator scrubber recirculation tank, built of reinforced polyester, and pumped from this tank to the preneutralizer.

The amount of sulfuric acid fed in depended on the percentage of ammonium sulfate desired as a direct reaction product of the NPK manufacturing process.

Sufficient ammonia was added to maintain a 0.55 to 0.6 NH_3/H_3PO_4 mole ratio in the preneutralizer slurry.

The preneutralizer gases were scrubbed with water and exhausted into the atmosphere.

In the granulator, the preneutralizer slurry was mixed with the recycle, to which the urea (prilled), the solid ammonium sulfate (when required) and the potassium chloride had been added: also, sufficient ammonia was fed in to obtain an NH_3/H_3PO_4 mole ratio between 1.0 and 1.1.

On discharge from the granulator, the product had a water content of 3%; this was reduced to an average of 1% in the dryer by using as a heat source a cocurrent flow of combustion gases issuing from a propane-fired combustion chamber.

The product was then cooled in a rotary cooler and transferred to the screens and crushing mill installed next in line. The undersize material was used as recycle and the oversize material was returned to the screens after crushing.

Figure 2

As mentioned previously, other test runs were made in which the material was hot screened and crushed under the conditions shown in Figure 2, which as may be seen are the same as the configuration of Figure 1, except for the fact that neither the cooler nor its dust-collection system were included in the equipment used on those occasions.

DISCUSSION OF OPERATION & RESULTS

Four basic test groups designed in each case to obtain a specific type of information, were run. In three of these, varying amounts of sulfuric acid/ammonium sulfate were added, with the material screened and crushed after cooling, while in the fourth a 75/25% ratio of hot screened and crushed material was employed. As a general rule, these tests consisted of three separate runs, with a final extended run preceded by two short runs.

All the test groups resulted in obtaining basically the same composition of the 17-17-17 formula:

	% of product weight
Urea (46.6% N)	20.6
Ammonium sulfate (21.0% N)	20.0
Monoammonium phosphate (10.8% N, 54.8% P_2O_5)	31.0
Potassium chloride (60% K_2O)	28.4
TOTAL	100.0

The runs employing a 50 to 50% mixture of reaction-obtained ammonium sulfate and crystalline ammonium sulfate resulted in a stable operation of the preneutralizer, with the temperature maintained at 127°C, the density of the slurry at 1.62 and the NH_3/H_3PO_4 mole ratio between 0.55 and 0.60.

The slurry, composed of ammonium sulfate and ammonium phosphate, was fluid when it contained sufficient water (9% ± 2%), which facilitated agitation and pumping.

When 75% of the ammonium sulfate was obtained by reaction, viscosity remained below 40 cps and the slurry was pumped without difficulty, but it was found that ammonium sulfate crystals were formed when the continuous flow of stream that had been fed in was suspended.

In runs employing 100% reaction-obtained sulfate, crystals were formed rapidly when viscosity increased to more than 100 cps, while the slurry remained easy to handle and retained a good appearance when viscosity was controlled to between 40 and 75 cps.

During the final runs, at start up and mainly when pH was approximately between 1.0 and 1.2, a dark green tint was observed that indicated excessive corrosion of the preneutralizer (Type 316 L stainless steel) and of the pumping and transporting equipment. Although this coloration disappeared once normal operating conditions were reached, this point should be studied before opting for formation of all the ammonium sulfate in the preneutralizer, in industrial plants.

All granulation tests were carried out in a "pugmill" in which the two shafts (lengthwise-installed) rotated in opposite directions so as to lift the material along the center line of the granulator. Each shaft was equipped with 24 paddles set at a 45° pitch that could be adjusted either to advance the material along its path or hold it back.

After several test runs it was found that the best setting in this case was to give a reverse pitch to the final 8 paddles on each shaft so as to allow the material a sufficient retention time.

The ammonia gas was fed to the granulator through a drilled pipe distributor with ⅛″ diameter holes set 4″ apart. The feed rate was manually controlled so as to obtain the desired NH_3/H_3PO_4 mole ratio of 1.0 to 1.1.

To obtain optimum granulation, saturated steam was fed to the granulator through this sparger in the amounts required by the process.

The slurry was distributed through a full-cone pattern.

The recycle was maintained at a recycle-to-product ratio between 4 and 6 by feeding steam to the granulator at a rate of about 65 kg/tonne of product and maintaining an average temperature of 71°C in the material discharged from the granulator.

Drying is perhaps the most critical step in the granulation of urea-based NPK formulas, since, as mentioned previously, the high solubility and hygroscopicity of the urea can lead unless this step is carefully controlled to serious problems that can quickly result in a complete shutdown of the plant, owing to post-granulation material buildup within the dryer and incrustation of the remaining equipment.

Behavior of the product within the dryer was satisfactory up to a temperature of 85°C, after which a buildup of the material began to be noted.

The material remaining within the equipment on shutdown of the plant tends to harden rapidly, requiring an entire shift to clean it manually or to wash it off with water if the plant design permits.

The screens and crushing mill worked satisfactorily, both when the material discharged from the dryer was previously cooled and when it was not.

It must be remembered, however, that experience elsewhere has frequently shown the need for prior cooling of the urea in order to prevent blocking of the screens. Furthermore, the atmospheric temperature and relative humidity conditions prevailing at the site where the tests were held were at the time far lower than those often encountered in industrial plants located in tropical coastal regions. In addition, it should be noted that the results obtained in the manufacture of this 17-17-17 formula are not necessarily applicable to other grades.

As a result of the tests held, it was concluded that the Pajaritos plant of Fertilizantes Mexicanos, S.A. can, without serious problems and using the raw materials available and installations already existing at the site, produce a urea-based 17-17-17 formula using ammonium sulfate derived from sulphur and thereby eliminating the need of a filler.

Operation with 75% of the ammonium sulfate produced in the preneutralizer by reacting sulfuric acid with ammonia and the remaining 25% added as crystals to the recycle appears to be the most acceptable method, since although good operation results were obtained when 100% of the ammonium sulfate was produced in the preneutralizer this also led to seemingly excessive corrosion of the stainless steel, a problem which must be studied in depth before attempting to employ the latter method on an industrial scale.

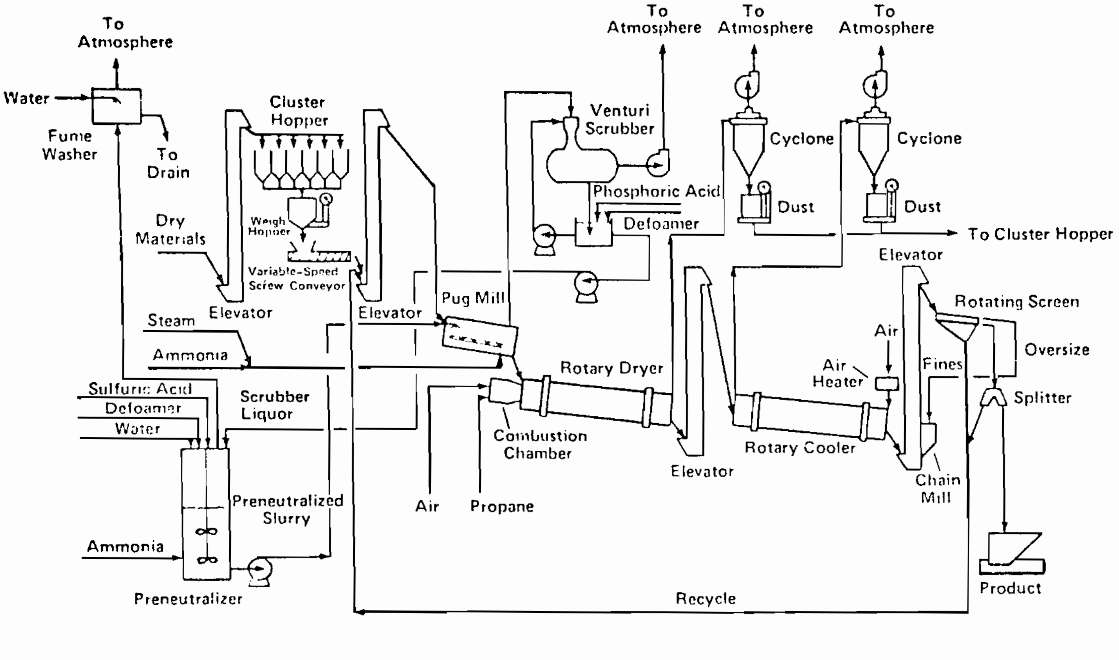

Figure 1. Pilot–Plant Configuration Used for FERTIMEX Studies--Cold Screening and Crushing.

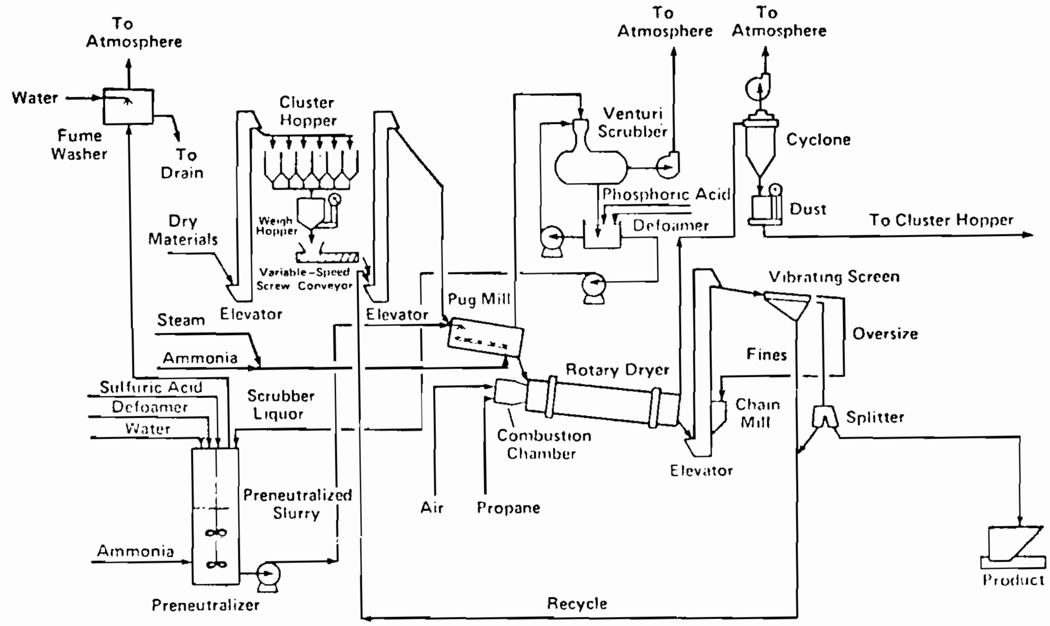

Figure 2. Pilot–Plant Configuration Used for FERTIMEX Studies--Hot Screening and Crushing.

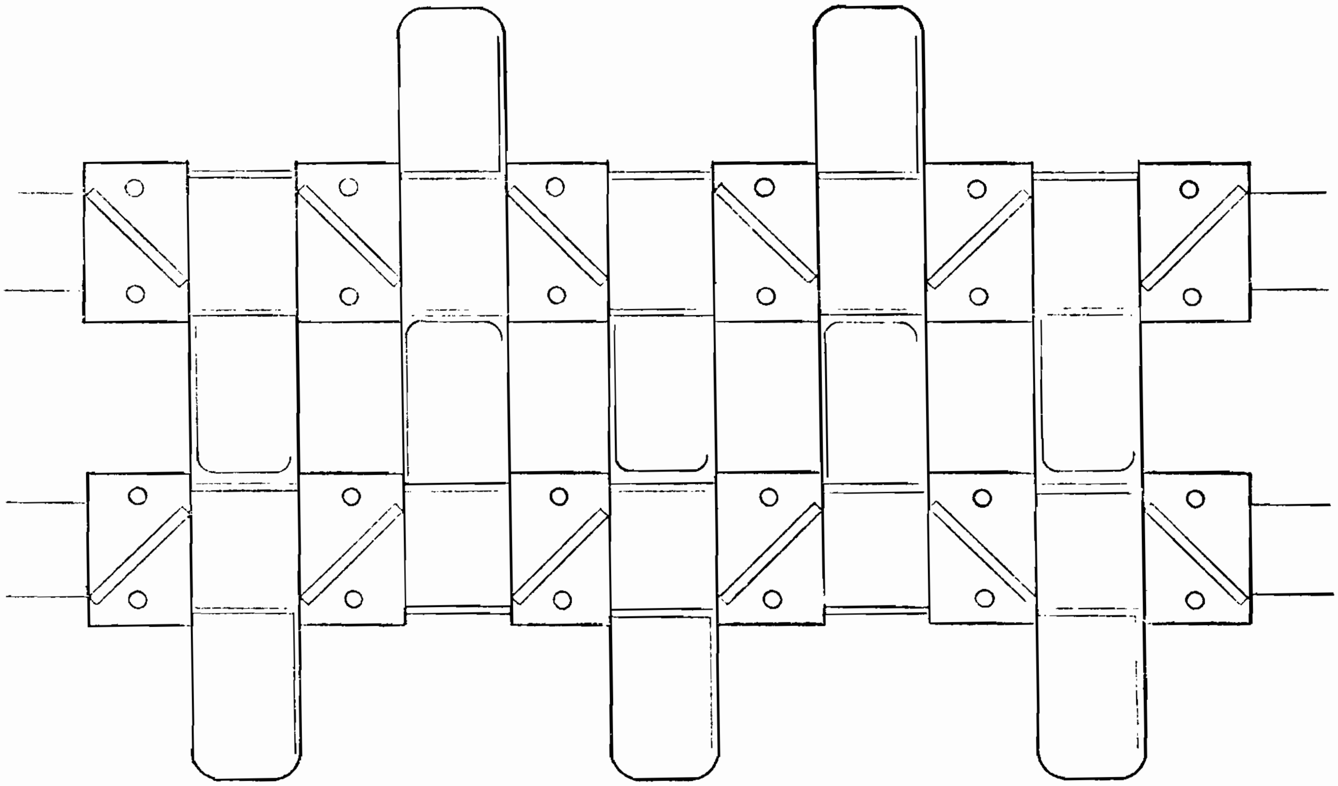

Fig. 3. Paddle Configuration used for FEPTIMEX studies.

Table 2. PRODUCTION FORMULA FOR UREA BASED 17-17-17

50% of the Ammonium Sulfate Produced in the Preneutralizer

Amount Required	Material	Nutrient Content			
		N	P_2O_5	K_2O	S
(kg/tonne product, feed basis)		*(kg/tonne product)*			
315.2	Phosphoric acid (54% P_2O_5)		170.2		
78.6	Sulfuric acid (93% H_2SO_4)				23.9
49.9	Ammonia to preneutralizer	41.0			
110.0	Water to preneutralizer				
16.4	Ammonia to granulator	13.5			
65.0	Steam to granulator				
206.3	Urea	94.9			
100.0	Ammonium sulfate (solid)	20.8			23.8
283.4	Potassium chloride			170.0	
(–)224.8	Water evaporation (overall)				
1,000		170.2	170.2	170.0	47.7

75% of the Ammonium Sulfate Produced in the Preneutralizer

Amount Required	Material	Nutrient Content			
		N	P_2O_5	K_2O	S
(kg/tonne product, feed basis)		*(kg/tonne product)*			
315.2	Phosphoric acid (54% P_2O_5)		170.2		
118.0	Sulfuric acid (93% H_2SO_4)				35.9
62.5	Ammonia to preneutralizer	51.4			
140.0	Water to preneutralizer				
16.4	Ammonia to granulator	13.5			
65.0	Steam to granulator				
206.3	Urea	94.9			
50.0	Ammonium sulfate (solid)	10.4			11.9
283.4	Potassium chloride			170.0	
(–)256.8	Water evaporation (overall)				
1,000		170.2	170.2	170.0	47.8

100% of the Ammonium Sulfate Produced in the Preneutralizer

Amount Required	Material	Nutrient Content			
		N	P_2O_5	K_2O	S
(kg/tonne product, feed basis)		*(kg/tonne product)*			
315.2	Phosphoric acid (54% P_2O_5)		170.2		
157.3	Sulfuric acid (93% H_2SO_4)				47.8
75.2	Ammonia to preneutralizer	61.8			
160.0	Water to preneutralizer				
16.4	Ammonia to granulator	13.5			
65.0	Steam to granulator				
206.3	Urea	94.9			
—	Ammonium sulfate (solid)	—		—	—
283.4	Potassium chloride			170.0	
(–)278.8	Water evaporation (overall)				
1,000		170.2	170.2	170.0	47.8

Table 3. UREA/AMMONIUM SULFATE BASED 17-17-17

Summary of Data. Pilot-Plant Tests

	Test				
	50% Cold	75% Cold	100% Cold	75% Hot	Max. Capacity Hot
Venturi scrubber:					
Phosphoric acid concentration, % P_2O_5	53.9	54.0	52.9	53.7	53.9
Mole ratio, NH_3/H_3PO_4	0.01	0.06	0.03	0.02	0.01
Preneutralizer:					
Venturi liquor feed rate, kg/h	147.6	147.0	146.3	147.9	233.3
Sulfuric acid feed rate, kg/h	31.6	55.7	72.1	55.7	92.7
H_2SO_4 in sulfuric acid, %	91.4	92.4	92.8	92.6	92.4
Ammonia feed rate, kg/h	18.7	29.0	35.0	27.6	51.9
Slurry conditions:					
Temperature, °C	128	127	127	127	127
Mole ratio, NH_3/H_3PO_4	0.58	0.59	0.59	0.59	0.57
pH	2.2	2.2	2.4	2.2	2.1
Viscosity at operating temperature, cP	33	35	39	38	33
Cluster hopper:					
Urea feed rate, kg/h	92.7	88.3	90.1	92.5	154.2
Ammonium sulfate feed rate, kg/h	45.0	20.9	0.0	21.9	37.1
Potash feed rate, kg/h	127.2	121.1	127.6	126.9	212.3
Internal recycle:					
Temperature, °C	64	63	60	62	64
Pug Mill:					
Ammonia feed rate, kg/h	9.2	7.5	7.0	5.6	11.5
Temperature, °C	74	74	74	72	81
Mole ratio, NH_3/H_3PO_4	1.00	1.07	1.06	1.01	1.02
Dryer:					
Air temperature at outlet, °C	82	81	79	80	80
Temperature of fertilizer discharge, °C	82	80	80	81	80
Air through shell, outlet conditions, m^3/h	4,332	4,586	4,628	4,727	4,712
Moisture in discharge material, %	0.3	0.5	0.7	0.4	0.5
Drum speed, rpm	7.0	7.0	7.0	7.0	7.0
Cooler:					
Air temperature at outlet, °C	66	66	66	—	—
Fertilizer discharge temperature, °C	73	73	71	—	—
Airflow, m^3/h	1,478	1,478	1,478	—	—
Air speed in cooler, m/second	0.6	0.6	0.6	—	—
Screens:					
Cold or hot configuration	cold	cold	cold	hot	hot
Top screen, mesh (Tyler)	4	4	4	4	4
Opening, mm	4.75	4.75	4.75	4.75	4.75
Bottom screen, mesh (Tyler)	10	10	10	10	10
Opening, mm	1.70	1.70	1.70	1.70	1.70
Product analyses:					
Composition					
Total N, %	18.4	16.8	16.2	16.6	16.8
Total P_2O_5, %	17.3	15.9	16.2	16.6	15.2
K_2O, %	15.8	17.1	16.9	18.4	18.4
H_2O, %	0.4	0.5	0.5	0.4	0.5
Crushing strength, kg/granule	2.79	2.35	1.46	2.90	1.96

Production of Granular Urea Ammonium Phosphate Sulfate

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Introduction

Most granulation of fertilizer has been done in the past by producing a water slurry and wetting fine dry materials in a rotating drum or mixer until granules formed from the adhesion of the fine materials to each other. One disadvantage of this process is that water is used for granulation and the water must be evaporated with the use of auxiliary dryer heat. With continued increases in energy costs, there has been increased interest in eliminating as much of this drying as possible. One approach to eliminating this energy usage is to replace the water required to hold the particles together during granulation with melted product (melt granulation).

Although fertilizer melts have been used extensively in prilling towers to produce ammonium nitrate and urea grades of fertilizer, only a small amount of fertilizer has been produced using a true fertilizer melt in a pug mill or granulation drum. Kirk-Othmer (1) describes the various processes developed by the Tennessee Valley Authority and Norsk Hydro, where the melting characteristic of urea has been used to granulate and prill urea ammonium phosphate combinations. The Tennessee Valley Authority (TVA) published reports of development work on granulation of ammonium polyphosphate melts as early as 1962 (2). Product was granulated in both a granulation drum and a pug mill, with best success in the pug mill. They continued work and publishing reports on granulation using melts for a number of years and commenced operation of a 400 ton/day demonstration plant in 1973.

Most of the reported early work involving melt granulation was done with the production of polyphosphate melts from the ammoniation of heated superphosphoric acid with anhydrous ammonia. Later, urea was added to the melt and urea ammonium phosphate sulfates were produced and marketed by TVA for demonstration purposes.

In September of 1983, J. R. Simplot Company made experimental runs using melt granulation to produce two grades of urea ammonium phosphate sulfate (UAPS) fertilizers in its fertilizer plant located in Lathrop, California. Melt was produced in a cross pipe reactor and granulation was done in an ammoniator drum.

Before the run, information was collected from TVA, and some lab work was done with laboratory scale granulation equipment at Lathrop to determine operation parameters. The trial plant runs were successful and good material was produced. The two grades of fertilizer added to the Lathrop plant production capability were 32-16-0 and 16-16-16. The Lathrop experimental production resulted in the development of some operating techniques which appear to produce a very good product and keep energy usage to a minimum.

These urea ammonium phosphate sulfate products are more hygroscopic than products which do not contain urea, but the storage problems are not serious in the California climate. Some crusting of the surface of storage piles is caused by moisture absorbed from the air during winter months, but the crust breaks up easily and the center of the storage piles remain free flowing.

To date, acceptance of the products has been less than expected. This is probably because of general market conditions and use of blends to replace homogenous granular fertilizer. Only development and publication of yield data comparing the individual homogenous products and blends will clarify the value of these products and perhaps justify the additional cost of processing necessary for the homogenous product.

Laboratory Process Development

Before attempting the production of a urea phosphate sulfate fertilizer in the plant, laboratory work was done to provide plant technical personnel with understanding of the process and to assess the probability of success. The work was done with small laboratory granulating equipment consisting of a small cement mixer with lifters removed, a small kerosene burner, a simulated rotating drum made from a coffee can, and some small gas burners. Materials were fed to the drums manually and screening was done using laboratory screens.

When urea is mixed with ammonium sulfate and ammonium phosphate and heated to approximately 240°F, the mixture melts and forms a eutectic with a melting point lower than the 240°F temperature required to establish the melt. The melting point of the product is dependent on both composition and pH. A reduction of pH reduces the melting point. Laboratory results developed for a number of possible products are shown on Table 1.

A number of laboratory experiments were performed to detemine granulating characteristics when products were heated to the melting point during granulation. These experiments showed that, when water was used in the granulation of materials containing urea, the products were very soft and appeared to be very hygroscopic. When only heat was used to melt the fines in the granulator, and the liquid phase from the melted fines was used for granulation, a better looking pellet was formed. This product was slower to absorb water from air and had a smoother surface. However, the reduced sensitivity to moisture in the air appears to be due to the reduced surface area rather than from an actual difference in critical humidity. Based on these early findings, laboratory work concentrated on development of a water free melt process.

More comprehensive laboratory work showed that, if a formulation using a minimum of 500 pounds of urea per ton of product was used, enough liquid phase could be developed with reaction heat from the ammoniation of phosphoric and sulfuric acid to cause melting and melt granulation of product. A number of grades were produced and a summary of the data taken during the laboratory batch runs is shown in Table 2. Plant formulas for these grades were developed assuming recycle at 150°F, and 3 tons recycle per ton of product. These formulas are shown in Table 3.

As a result of this laboratory work, a decision was made to attempt a plant run using existing plant equipment with the intention of using melt granulation as much as possible. The trial runs were successful and the process techniques developed are now a part of the Simplot operating technology.

Plant Design

The basic flow sheet of the granulation plant used for the production of the urea phosphate sulfate fertilizers is shown on Figure 1. The cross pipe reactors are made with a 6 inch diameter 316 stainless steel pipe. The ammoniator drum is 20 feet long and 10 feet in diameter, and the natural gas heated dryer drum is 90 feet long and 9 feet in diameter. The screening system consists of conventional Tyler hummer screens with two Cedarapids hammer mills used for ovesize grinding. Because the warm product is soft and can be sticky, a chain mill would be a more proper piece of equipment for the ovesize grinding. However, when grates are removed from the hammer mills to avoid plugging, the grinding is still sufficient to provide proper sized recycle. The recycle system uses a drag chain and elevator to return the fines to the ammoniator drum. A virbrating fluid bed cooler with the associated baghouse dust removal is used for additional cooling of the product before conveying it to storage. The cooler is bypassed for the production of 32-16-0 because the dryer acts as a cooler. The cooler is used for 16-16-16 production to provide some additional drying.

One major design item which contributes to the success of the process and appears to be critical is the damper system on the vent from the granulator drum. This damper controls the amount of air which is allowed to pass through the ammoniator drum to the scrubber. When this damper is closed, the cooling effect of the air is reduced and the granulator temperature increases. Without this control, the melt process would not be possible.

Process Operation

Processing of the materials is started by charging the plant with a dry blend of urea ammonium sulfate and ammonium phosphate. The recycle process is started and dryer heat is used to heat the recycle to approximately 150°F. Then ammonia, phosphoric acid, and sulfuric acid are sprayed in the ammoniator drum through one of the cross pipe reactors, and make up urea is added to the recycle system through the dry additive system.

The pH of the material leaving the ammoniator drum is measured by dissolving approximately 10 grams of material in 100 ml. of water, and reading the pH with test paper. The pH is allowed to drop until the material melts and then additional ammonia is added to the bed of the ammoniator drum until proper granulation commences.

Use of pH to control granulation is satisfatory for start up or immediate recovery from a wet or dry granulator situation. However, the desired pH of the granulator discharge is 4.5 for 32-16-0 production and 6 for 16-16-16 production. Therefore, temperature control adjustments must be made until proper granulation takes place at the desired pH. Control of the liquid melt phase is finally accomplished by controlling the pipe reactor temperature, ammoniator drum vent system, and the dryer air damper. The pipe reactor temperature is controlled by addition of a very small amount of cooling water. Reaction heat is used to melt the material in the ammoniator drum and auxiliary gas dryer heat is totally removed for production of both the 32-16-0 and 16-16-16. The basic idea is to regulate the temperature of the recycle until it is just below the melting point of the product. The reaction heat then melts the smaller particles which agglomerate to the larger particles resulting in granulation.

During production of 16-16-16 in the plant, the amount of urea present is marginal, and at times it is not sufficient to provide adequate liquid phase for granulation. However, addition of a small amount of water in excess of the amount required for cross pipe reaction cooling promotes successful granulation.

Table 4 is a listing of the formulation and processing parameters used during production of 32-16-0 and 16-16-16.

Summary

The J. R. Simplot Company has produced good quality urea ammonium phosphate sulfate products using basic ideas developed by TVA combined with techniques developed by J. R. Simplot Company. The unique characteristic of the Simplot process is the use of temperature and pH controls to allow a true melt liquid phase for granulation and reduce use of water to an absolute minimum. True melt granulation is dependent upon a minimum of 500 pounds of urea per ton of product and, when the minimum urea requirement is used, a liquid phase melt can be made sufficient to provide good granulation of the product. Using this operation procedure, water usage is held to the amount necessary for reaction equipment cooling. However, even if the minimum urea content is not possible, a combination of melt and moisture provides a liquid phase that will cause granulation and production of a good product.

Table 1. MELTING POINT DETERMINATIONS OF TYPICAL MELT GRANULATION GRADES

Grade	Variation	pH	Melting Point °F
40-0-0-3S		6.4	240
	Add 5% KCl	6.7	233
	Add 5% K_2SO_4	6.6	235
32-16-0-3S	Low pH	5.9	238
	Mid pH	6.4	241
	High pH	6.8	245
	Add 5% KCl	5.9	233
	Add 5% K_2SO_4	5.9	237
32-0-0-12S		6.4	242
	Add 5% KCl	6.6	238
	Add 5% K_2SO_4	6.5	242
22-8-16M-6S	Low pH	6.0	248
	Mid pH	6.4	252
	High pH	6.9	248
16-16-16M-6S	Low pH	5.9	254
	Mid pH	6.4	258
	High pH	6.8	260
	Add 5% K_2SO_4	5.8	252
16-16-16S-8S		6.0	248
17-17-17S-8S		6.0	250
25-5-10S-12S		6.1	245

Procedure: Mixed salts were placed in test tubes in a hot oil bath, and temperature was raised to past the melting point to fuse the salts. The melts were then cooled to below the fusion point, then raised back to the melting point. The temperature was then measured by a thermometer at the point at which the mixture liquefied.

Laboratory work indicates that a large number of UAPS products can be made using this process, if the additional processing cost necessary to produce a homogenous product can be economically justified. To date, product acceptance has been less than anticipated due to general poor market conditions, and lack of data to show justification for use of the homogenous products over blends.

REFERENCES

1. Kirk-Othmer: *Encyclopedia of Chemical Technology*, Third Addition, Vol. 10, Interscience Publishers, 1980, pp 88–90.
2. Tennessee Valley Authority: "Developments in Technology of Fertilizer Production." 4th Demonstration, Wilson Dam, Alabama, 1962, pp 9–15.

Table 2. LABORATORY BATCH DATA

Data is shown for as many as 3 experiments per grade

Grade	Maximum °F Batch Temp.	pH of Product	6 to 10 Mesh Weight %
40-0-0	230, 235, 255	7.0, 7.2, 7.2	34, 42, 71
32-16-0	245, 240	7.2, 6.3	43, 48
32-0-0	234, 238	7.6, 7.1, 7.1	34, 47, 46
25-5-10S	240, 235	5.9, 7.1	28, 38
25-5-10S-1Fe	236	6.2	44
22-8-16M	235, 240	6.6, 6.9	49, 27
18-18-18M	220, 230	7.0, 6.4	45, 56
17-17-17S	225, 220	6.8, 5.9	39, 42
16-16-16M	262	7.0	33
16-16-16S	230, 235	7.2, 6.2	40, 39

Table 3. PLANT FORMULAS FOR 3:1 RECYCLE WITH RECYCLE AT 150°F

	Pounds Material Per Ton Product							
Grade	Urea 46% N	A.S. 21.1% N	KCl 60.5% K_20	K_2SO_4 52% K_2O	H_2SO_4 98.8%	Phos Acid 50% P_2O_5	Iron Pyrite	NH_3 Gas
40-0-0-5S	1535	103			257			88
32-16-0-3S	1135	0			163	640		140
32-0-0-12S	900	736			257			88
25-5-10S-12S	741	346		385	237	200		104
25-5-10S-1Fe	817	180		385	237	200	90	104
22-8-16M-6S	670	187	530		210	320		114
18-18-18M-2S	500	0	595		151	720		146
17-17-17S-8S	500	0		655	157	680		143
16-16-16M-6S	500	105	530		163	640		140
16-16-16S-8S	500	15		620	163	640		140

Table 4. FORMULATION AND AVERAGE OPERATING CONDITIONS FOR PRODUCTION OF UREA PHOSPHATE FERTILIZER PRODUCED BY J. R. SIMPLOT COMPANY

Nominal Grade	32-16-0	16-16-16
Formulation, lbs./ton of product		
Ammonia Vapor		
To Cross Reactor	131	117
To Granulator Bed	9	23
Sulfuric Acid		
To Cross Reactor	162	162
To Dryer Scrubber	0.03	0.03
To Granulator Scrubber	0.01	0.05
52% Phosphoric Acid		
To Cross Reactor	640	640
Urea		
To Recycle System	1135	500
Potassium Chloride	0	530
Cross Pipe Reactor Temperature	300°F	300°F
Cooler (dryer)		
Inlet Air Temperature	60°F	60°F
Discharge Air Temperature	150°F	155°F
Gas Usage—Therm/Ton Product	0	0
Drum Granulator		
Recycle Temperature	150°F	155°F
Discharge Temperature	210°F	190°F
Moisture Content	1.4%	1.5%
Recycle Ratio	3:1	3:1
Product		
Screen Analysis		
+6 Mesh	5%	6%
−6 +12 Mesh	82%	85%
−12 Mesh	7%	9%
Moisture	1.0-1.2	1.5-1.7
Temperature Delivered to Storage	80°F	80°F

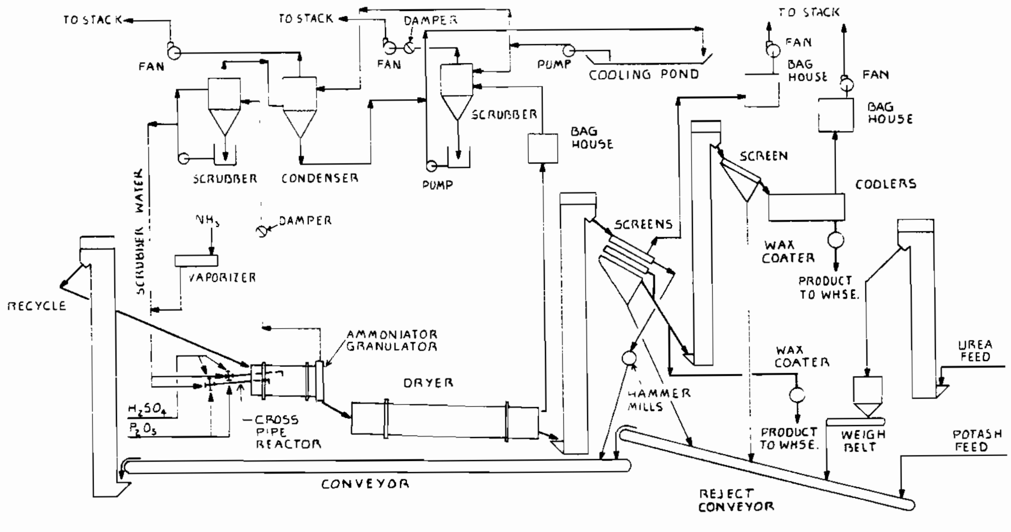

FIGURE 1 GRANULATION PLANT FLOW DIAGRAM

Implementation of Urea-Based NPK Granulation Plant in Malaysia

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Summary

The design and construction of NPK granulation plants in developing countries are often difficult to obtain. The traditional multinational engineering and construction firms engaged in fertilizer projects usually prefer to handle the large, integrated complex-type projects for basic producers of nitrogen and phosphate fertilizers. These firms are often less responsive to the relatively modest requirements of the local or regional NPK granulation projects. Likewise, local engineering and construction firms may lack experience in chemical process design and construction, including the specialized requirements of NPK production facilities.

FPM Sendirian Berhad (FPM), a newly formed fertilizer production organization in Malaysia, faced these problems when it elected to build a relatively large urea-based NPK granulation plant in the State of Johor. This paper describes how FPM managed the project over a 4-year period (1979–82) from the early stages of process development through engineering, procurement, construction, and plant commissioning. The procedures used by FPM are expected to serve as a useful model for others.

Background

About 50% of the arable land in Malaysia is planted in oil palm or rubber trees. The individual holdings (estates) are relatively large—averaging about 1,200 ha. To thrive, both crops require rather large quantities of fertilizer. Each mature tree is usually treated with about three applications of compound fertilizer per year, totaling about 14 kg. The size of the estates and the undulated terrain make the task of fertilizer application very labor intensive and costly. The use of compound NPK fertilizers in powdered or granular form has decreased the labor required for application since all of the nutrients can be applied at the same time.

Achieving uniform application of fertilizer over the entire estate is still another problem. Again, the large size of the estates and the hilly terrain prohibit easy acccess to much of the crop. Consequently, a disproportionate amount of fertilizer is usually applied to the trees near the access roads and trails, and the trees in the interior may be inadequately fertilized.

The use of aircraft offers a possible alternative for solving most of the traditional fertilizer application problems. The decision to change from manual application methods to aerial application using fixed-wing aircraft or helicopters depends upon two main factors: First, there must be a ready supply of homogenous, nonsegregating, free-flowing fertilizer materials that will facilitate quick, reliable loading and discharge and uniform distribution from the aircraft; second, the improved benefit/cost ratio obtained by using such fertilizing practices must justify the investment in the necessary fertilizer production and application equipment and facilities.

In the late 1970s the Federal Land Development Authority (FELDA) of Malaysia together with the Agricultural Development Bank of Malaysia and Behn, Meyer & Company (Pte.), Ltd., of Singapore began to investigate the feasibility of producing homogeneous, granular compound fertilizers especially designed to fit the needs of the growers and the aerial distributors. The technical aspects of producing the required compound fertilizers using the available and most cost-effective raw materials—namely, prilled urea, unacidulated phosphate rock, potassium chloride, and kieserite–posed problems. To find solutions to the technical problems of production, Behn, Meyer & Company (Pte.), Ltd., engaged the International Fertilizer Development Center (IFDC) in 1979 to perform pilot plant-scale trials designed to identify an appropriate production process. Following the successful completion of pilot-plant granulation trials, the company joined FELDA and the Agricultural Development Bank in forming the new company, FPM, to implement the project.

PILOT-PLANT GRANULATION TRIALS

The typical compound fertilizers used for rubber and oil palm contain relatively large amounts of nitrogen, potassium, and magnesium. Phosphorus, while important, is usually present in lesser quantities than are nitrogen and potassium. Urea is now, and is expected to continue to be, the most abundant and the cheapest source of nitrogen in Malaysia. The use of urea also fits nicely into Malaysia's overall national strategy designed to become self-sufficient in the production of nitrogen. Therefore, urea was used as the major source of nitrogen for the formulations proposed by FPM. The perennial growing season, together with abundant rainfall and acidic soils, minimizes the need for using traditional water-soluble phosphate fertilizer sources. Instead, ground phosphate rock is the preferred and most cost-effective phosphate source. Potassium and magnesium, required by both crops, are provided from water-soluble sources—usually potassium chloride and kieserite.

Compound granular fertilizers containing large percentages of urea are more difficult to produce than those based on other sources of nitrogen such as ammonium nitrate, ammonium phosphates, or ammonium sulfate. The difficulty in producing urea-based NPK and NPK-Mg products is partially due to the relatively high solubility of the urea/potash/kieserite mixtures used in the granulation process. The difficulties are further increased when some forms of soluble phosphate, especially superphosphates, are present.

Consequently, most NPK producers avoid using urea in large quantities, and reliable commercial production data are limited. For this reason, exploratory pilot-plant granulation trials were performed to determine the feasibility of producing the desired urea-based NPK and NPK-Mg grades. The objectives of the pilot-plant trials were to (1) determine if the proposed granular products could be produced using the specified raw materials and (2) develop a process design and operating parameters suitable for use in a commercial-scale granulation unit.

During a 3-month period in early 1979, approximately 100 mt of granular products was produced in the IFDC pilot plant at a rate of about 1 mtph, and the objectives of the trials were largely achieved. A photograph of the pilot plant and a flow diagram of the process are shown in Figures 1 and 2, respectively. A discussion of the significant process variables, operating techniques, and equipment design features required for the production of the desired fertilizers follows.

Granulation

A drum-type granulator was used for the FPM studies. However, recent work by IFDC indicates that a twin-shaft pug mill-type granulator offers significant advantages over a drum-type unit with respect to more thorough mixing and improved granule consolidation, sphericity, and integrity. The drum granulator was lined with neoprene panels. The panels were designed to flex away from the wall of the granulator as the drum rotates and thus to prevent the accumulation of sticky material. In recent years, most rotary drum-type granulation plants have replaced their traditional stationary- or reciprocating-type scraper units with the rubber panel system.

A relatively long retention time and a shallow bed of material in the granulator are preferred for urea-based granulation. Therefore, a length-to-diameter ratio of about 3 is preferred instead of the more traditional ratio of 2 used for most ammonia-based NPK granulation units.

Drying

Drying is the most troublesome process step in the production of products containing large amounts of urea. The critical relative humidity of urea and other salts, such as ammonium phosphate, ammonium sulfate, potassium chloride, and kieserite, decreases and their solubility increases when they are mixed together and heated. Therefore, if proper operating precautions are not observed during drying, the consequences may be (1) excessive granulation in the dryer, (2) sticking of material to the dryer interior walls and lifting flights, and (3) insufficient heat transfer and inadequate evaporation of water from the product. These conditions, if allowed to occur for more than a few minutes, cause excessive buildup of material in the dryer, plugging of the material chutes and ovesize crushers, and coating (blinding) of the sizing screens with moist, semi-plastic material. Such conditions will quickly necessitate a plant shutdown for cleaning and result in excessive losses of material and production. Most of these problems with drying can be minimized or eliminated by proper selection of raw materials, formulation techniques, and design and operation of the dryer.

Because of the potential problem of buildup of material on the inside surfaces of the dryer, the dryer discharge should be designed so that the dryer can be easily cleaned by washing with water. The layout of the dryer with respect to other equipment should allow sufficient space for a sump at the discharge end of the dryer to collect the wash water. Experience has shown that the dryer can be washed and returned to service in about 8 hours. The alternative to water washing is to manually remove the buildup of material from the dryer walls and lifting flights. This method of cleaning is very time consuming and potentially dangerous to the workmen who would have to enter the equipment.

Cooling

The material discharged from the dryer is relatively hot and plastic. Before it can be sized, it must be cooled to sufficiently harden the granules to minimize plugging of the screens and oversize crushers. In tropical regions additional cooling after screening may also be needed to improve the storage properties of the product. Primary cooling to facilitate screening is best accomplished in a rotary drum-type cooler, whereas secondary cooling of the closely sized screened product may be most effectively accomplished with a fluidized bed-type cooler. Because of the hygroscopic nature of the fertilizer, the cooler inlet air must usually be dehumidified and/or reheated to ensure that the relative humidity is below about 50%.

Screening and Crushing

Single-deck, gyratory-type screening machines are preferred for urea-based NPK fertilizers because they (1) can be easily cleaned during operation and

(2) are very efficient for producing a closely sized, dust-free product. Stainless steel square mesh screen wire is used. The square mesh screen wire is preferred over slotted wire screens because it is more effective in producing a product that will be more closely sized and uniformly spherical. The uniformly sized, spherical product results in a minimum surface area per unit of weight; this decreases the contact surface between granules and thus the tendency to cake. The relatively large, spherical granules are also preferred for aerial application.

Oversize material from the screens is crushed and returned to the screens. Chain mill-type crushers are preferred because they are less likely to encounter buildups and become plugged than are other types of crushers in the event of an upset that may result in moist or sticky oversize material. The material discharged from the crushers is rescreened to ensure that only material smaller than product is returned to the granulator. This is important because the major granulation mechanism is agglomeration. If the recycle material is too large (because of normal crushing inefficiency), it will not agglomerate with the other materials and unstable operation will occur.

Material Handling and Pollution Control

The generation of an excessive amount of dust during the manufacturing and bagging operations results in the loss of product, dirtiness of plant and equipment, excessive maintenance, and worker discomfort. These conditions can largely be avoided by the selection of appropriate equipment for material handling and pollution control.

Bucket Elevators—Double-chain, continuous discharge-type bucket elevators are preferred for all applications where the material is dry or dusty. These elevators are slow speed and do not "blow" as severely as the higher speed, centrifugal discharge-type units used in many fertilizer plants.

Conveyors—Belt conveyors are preferred for most horizontal material transport applications. Belt conveyors are preferred over drag- or screw-type conveyors for most applications because they (1) permit visual observation of the material, (2) are easy to maintain, (3) require less power to operate, and (4) are less likely to plug and overload if wet material should inadvertently be fed during upsets in operation.

Dust Collectors and Scrubbers—The dust from urea-based NPK granulation processes is very hygroscopic. Therefore, to avoid plugging with "mud-like" solids, it is essential to maintain a relative humidity of less than about 40% in all dry-type dust collection equipment, including the ductwork. Dry cyclone-type dust collectors have proven to be most effective. If they become plugged because of a process upset or entrance of moist air, they can be easily washed and quickly returned to service. Bag-type dust collectors are less satisfactory. The inadvertent entrance of humid air into these units causes the fabric filter bags to quickly plug. Cleaning and restoring these units to service is difficult.

Low-energy, spray-type wet scrubbers are well suited for final cleaning of the air from the cyclones before it is exhausted to the atmosphere. Water scrubbing is effective in removing fine particulates, ammonia, and fluorine that may escape from the process.

AERIAL APPLICATION TRIALS IN MALAYSIA

Although the pilot-plant trials indicated the technical feasibility of producing urea-based NPK and NPK-Mg products, the ability of the products to withstand long-term storage and still remain suitable for aerial application remained uncertain. To obtain additional information, a trial shipment of approximately 10 mt of material produced in the pilot plant was sent to Malaysia. The products (four different grades) were packaged in the standard 50-kg export-type bag consisting of a polyethylene liner in a woven polypropylene outer jacket. The liner was closed with a wire tie, and the jacket was stitched. The bags were placed in a standard sea-going container and transported to Malaysia by ocean freight. The shipment arrived at the FELDA test site approximately 2 months after being shipped from IFDC.

In general, most of the products adequately withstood the postproduction storage and handling and were sataisfactory for aerial application. A tractor-mounted dump hopper was used to load a fixed-wing aircraft with 0.75 mt (15 bags) of product. During this loading operation, it was observed that the NP and NPK products that did not contain magnesium were more free flowing and exhibited better physical properties than did the NPK products containing magnesium. These handling and application trials generally confirmed the expectations that were based on previously performed laboratory-scale physical properties tests. The trials were sufficiently successful to justify further development of the project.

FPM PLANT DESIGN AND CONSTRUCTION

The success of the pilot-plant production trials and the favorable handling and application characteristics exhibited by most of the products led to the formation of the joint venture company (FPM) in early 1980 for the purpose of constructing and operating the proposed granulation plant. A discussion of the engineering and construction phases of the project follows.

Plant Site

Pasir Gudang, an industrial development area adjacent to the newly developed port on the Johor Strait (south shore of the Malay Peninsula), was selected for the plant site. In addition to the availability of a 4-ha site, other favorable factors that led to the selection of the Johor site included easy access to deep-water shipping facilities, good roads, a railroad and related infrastructure, and an abundant work force. A disadvantage of the Johor site is that the fertilizer market area stretches as much as 1,000 km north to the border of Thailand. A veiw of the plant site is shown in Figure 3.

Project Management

The execution of the FPM project was unique in that traditional expatriate engineering and construction management was not used. Instead, FPM assumed the role of project manager and managed all engineering, procurement, and construction activities. However, because FPM did not have broad engineering and related technical expertise specific to fertilizer, engineering consultants were employed on a short-term basis to perform most of the basic engineering. Essentially all equipment fabrication and plant construction were performed by Malaysian firms.

This engineering and construction management approach proved to be very cost effective, but coordination of the engineering consultants' activities was somewhat difficult. The local engineering consultants, although expert in their respective fields, had little or no experience in fertilizer plant engineering. As a result some of the facilities were not designed to withstand the dirty, corrosive, and otherwise hostile environment common to fertilizer production units. These facilities were subsequently modified according to a systematic program designed to minimize interruption of production.

An alternative to FPM's project management approach would have been to obtain an engineering/construction/project management contract from a single firm complete with performance guarantees. Experience has shown that such contracts, even if they can be obtained, command relatively large fees. Furthermore, the assigning of financial responsibility is still usually ambiguous. This is especially true when dealing with NPK processes that must be designed to produce a large number of products using a number of raw materials and process conditions.

Many of the plant design and construction decisions that faced the FPM project management team were influenced by the size of the larger-than-normal rotary dryer. FPM did not possess the skills required for the design, fabrication, and assembly of such a large unit, and only a few engineering and construction firms in the world were capable of supplying them. Some major components for the dryer, such as the riding rings and girth gear, were available from only a few sources in Europe and the United States. Furthermore, because of the large size of the dryer, specialized field fabrication, foundation, and plant layout features were required.

Despite these obstacles, FPM was effective in developing a strategy to design, fabricate, and install the dryer and effectively integrate it into the total design and construction of the process plant. The project management and engineering and construction methods used by FPM were practical and cost effective. The experience obtained during this project should ensure that the execution of another fertilizer plant project of this type would proceed smoothly and with even greater cost effectiveness.

PRESTARTUP ACTIVITIES

From the beginning of the project FPM recognized the need for implementing a sequence of activities designed to prepare for the commercial operation of the factory. These prestartup activities focused upon (1) training of personnel, (2) equipment testing and adjustment, and (3) incorporation of additions and modifications during the final stages of construction. A discussion of the implementation of these activities follows.

Training

FPM was a new fertilizer production organization with essentially no experience in the technical and operational aspects of fertilizer production. Recognizing this, FPM and organizations that preceded it started to develop and orient key personnel nearly 3 years before the scheduled startup of the plant. IFDC assisted FPM in coordinating two individual training and orientation programs for two FPM-affiliated technical staff. The programs were conducted primarily at IFDC Headquarters but included orientation in several NPK granulation plants in the United States. The first program also included participation in most of the pilot-plant trials that ultimately led to the process design used by FPM.

During the course of the engineering and construction phases of the project (about 2 years), IFDC engineers, representatives from a U.S.-based fertilizer engineering firm, and other engineering consultants employed by FPM met on several occasions to evaluate engineering and design alternatives proposed for the plant. Throughout this period IFDC served as FPM's technical consultant. Most of the IFDC consultation with FPM and the other consulting engineers selected by FPM focused on describing the unique and specialized design and construction features required for the fertilizer production unit. This consultation and orientation were essential because many of the Malaysian firms had only a minimum of design and construction experience in the fertilizer industry.

Approximately 3 months before the scheduled startup of the granulation plant, an IFDCC production engineer began a formal operator training program at the plant site. The program was designed to broaden the understanding of plant management and operations personnel in the details of fertilizer plant management, operations, and maintenance. Classroom-type training sessions combined with on-the-job orientation provided the foundation for the formal training that occurred over a period of about 6 weeks.

Equipment Testing and Adjustment

Concurrent with the formal training program activities, an equipment testing program was begun. As equipment installations were completed, a testing and adjustment program was initiated. This approach gave the operations personnel an opportunity to become familiar with each equipment item and provided a valuable opportunity for prestartup testing and adjustment of each item. Many minor problems and a few major mechanical and electrical problems were identified and corrected during this period.

Additions and Modifications

The third major prestartup activity involved the incorporation of many small but essential additions and modifications to the process plant during the final stages of construction. Walkways, staircases, ladders, inspection doors, piping, and electrical cable and conduit routing were completed or modified. During this period, the FPM operations staff made many practical suggestions that were incorporated to help make the plant work areas safer and to facilitate access for inspection, cleaning, and repair.

PLANT STARTUP

In mid-November 1982, approximately 4 years after initiating the basic pilot plant-scale trials, the first commercial product was manufactured by FPM. A discussion of the performance of the granulation process and equipment follows.

Performance of Process

During the first 6 months of operation, the plant was operated at a rate of 12–25 mtph, depending upon the grade being produced. The nominal design rate of 30 mtph could not be achieved initially because construction of the raw material feed system was not completed and an improvised feeding system with limited capacity was used. At the decreased production rate, granulation efficiency was purposely retarded by minimizing the liquid phase and plasticity in the granulator to achieve a higher-than-normal recycle ratio. The high recycle ratio was desired to achieve a throughput rate (material load) close to what would be expected at the design production rate of 30 mtph and a normal recycle-to-product ratio of about 3.

A typical formula such as 15-12-17 contained approximately 33% urea. Of this amount one-half was fed as dry prills through the solid material feed system along with the phosphate rock and potash. The remainder of the prilled urea was dissolved in the urea melt/solution system and fed to the granulator as a hot, concentrated solution containing from 75% to 90% urea. The distribution between solid urea and urea solution used for the various formulations is dependent upon a number of factors, including required liquid phase, drying and cooling capacity, and equipment throughput capacity. The urea solution was sprayed onto the rolling bed of material in the drum granulator. A small amount of steam was used to control the granulation efficiency. The steam was added through a drilled pipe distributor located below the rolling bed of material in the granulator. The moist granular material discharged from the granulator was dried, cooled, and screened. The product, after curing for a few days, was bagged in 50-kg woven polypropylene bags fitted with waterproof polyethylene liners.

The operating data obtained during the initial production of three grades (15-12-17, 12-19-9, and 14-6-22-3.5 MgO) agreed closely with expectations based upon the pilot-plant trials.

Performance of Equipment

Most choices in equipment and operating parameters used in NPK granulation plants are usually a compromise because of the variety of process conditions and materials required for the large number of grades that must be produced. For this reason a succcessful NPK production unit must have built-in flexibility to accommodate wide variations in processing. The pilot-plant trials provided the basis for sizing the major equipment items and for selecting the optimum operating parameters, but much of the design was based upon experience and related empirical data. A discussion of the performance of major equipment systems follows.

Drum Granulator—A conventional drum granulator is used in the FPM process (Figure 4). This type of granulator was selected because it can accommodate a wide variety of raw materials and because the distributors for urea melt or solution and for steam can be arranged with relative ease as needed above and below the rolling bed of material. Furthermore, in the future FPM may choose to use acids and ammonia to produce some grades, and the drum granulator is very well suited for this purpose.

The interior of the granulator is fitted with flexible reinforced rubber panels to minimize the accumulation of buildup. The panels effectively control the accumulation of deposits without the adverse effects of excess power consumption and maintenance usually associated with mechanical cleaning devices.

Rotary Dryer—As previously mentioned, the most critical equipment component in the FPM granulation plant is the rotary dryer. The primary function of the dryer is to decrease the mositure content of the partially granulated material from a level of about 3.0% to about 0.5%. During the drying process, granule formation and compaction also continue; this is necessary and important but sometimes troublesome if the temperature and plasticity of the material are not carefully controlled.

The temperature sensitivity and soluble nature of urea-based products make it necessary to operate the dryer with an abnormally low air temperature and a relatively high airflow. These conditions are required to achieve the low relative humidity conditions within the dryer needed to obtain adequate drying without overheating the product. Overheating usually leads to melting, overgranulation, and unmanageable downstream (cooling, screening, and crushing) processing.

Rotary Cooler—Although smaller in size than the dryer, the rotary cooler also required specialized design features.

The FPM urea-based fertilizers are usually bagged within a day or two after being produced. Immediate bagging is preferred because the products are very hygroscopic and the moistureproof bags offer excellent protection against the local high humidity ambient conditions. Futhermore, dehumidified bulk-storage space is limited. Good long-term bagged storage properties can be obtained if the product is reasonably cool (about 38°C) before it is bagged. Therefore, the performance of the rotary cooler is critical in achieving good product storage characteristics. To avoid the possibility that the product will absorb moisture from the moist ambient air fed to the cooler, the air is usually heated to decrease its relative humidity to about 50%. The warm air significantly decreases the cooling capacity of the unit and makes it necessary to again use a larger-than-normal rotary cooler for this service. Cooling of the entire throughput is also necessary to achieve high quality screening and minimize the problems associated with plugging of the oversize crushers.

Urea Melt/Solution Preparation System—Urea melt or solution provides a portion of the liquid phase needed to promote granulation and granule strength. The quantity of urea fed to the process as a melt or solution depends upon the grade being produced.

The FPM plant is equipped with a system that can be used to prepare a melt or a solution of urea. For preparing either a melt or a solution, unconditioned prilled urea is fed to the unit continuously. When a solution is desired, the prescribed amount of water is also added on a continuous basis.

Material Handling and Sizing—Three double-chain, continuous discharge-type bucket elevators are used in the FPM granulation plant. Each unit has a capacity of approximately 150 mtph. One unit is used to feed raw materials (urea, phosphate rock, potash, and kieserite) to the raw material feed system, the second is used to feed the blended mixture of raw materials and recycle to the drum granulator, and the third unit is used to transfer material discharged from the rotary cooler to the sizing screens.

Sizing of the cooled product is performed with single-deck, gyratory-type screens. Two screening machines arranged in parallel are used to remove the oversize fraction. The product fraction (usually 3 to 5 mm) is separated from the undersize material on a second pair of screens. The single-deck, parallel arrangement of the screens makes it possible to easily observe and clean the screen surfaces without interrupting operation of the plant.

The screening machines are fitted with square mesh stainless steel screen cloth to yield a product that is uniform and spherical. The stainless steel construction also eliminates corrosion and decreases buildup and blinding of the screen surfaces.

The oversize fraction (usually 5%–15% of the total feed to the screens) is processed by three single-shaft, chain mill-type crushers arranged in parallel. The crushed oversize is returned to the screens. The undersize fraction (minus 3 mm) is returned to the drum granulator along with dryer and cooler dust from the dry cyclone-type dust collectors.

The relatively large product size (3–5 mm) is desired for aerial application. Also, the large granules are preferred for urea-based NPK products because they contain less surface area per unit weight than the smaller-sized granular products; thus, intergranular bonding and caking are decreased significantly.

Dust Collection and Pollution Control—The FPM plant utilizes dry cyclone-type dust collectors and wet scrubbers to remove dust and fumes from the process air before it is exhausted to the atmosphere. A venturi-type scrubber is used to treat the air exhausted from the drum granulator and the ammonia-laden air discharged from the urea melt/solution preparation system. The air from the dryer and cooler passes through dry cyclones where most of the dust is removed before it is wet scrubbed to remove fine particulates and traces of ammonia and fluorine. A miscellaneous dust pickup system is used to minimize the escape of dust at most material transfer points within the process. The large quantity of air required for the dryer and cooler is drawn through air supply ducts from outside the process plant building to minimize the loss of dehumidified air within the plant.

Process Plant Dehumidification—The pilot-plant trials clearly identified the need for humidity control in the process plant and in the bulk product storage building. Most of the FPM products quickly absorb moisture from the atmosphere if the relative humidity is above about 50%. Absorption of moisture from the atmosphere is further accelerated by finely divided dust normally associated with the process. When exposed to the moist ambient conditions typical of Malaysia, the fertilizer materials quickly transform into an unmanageable, mud-like material that is very corrosive, slippery, and upsetting to the performance of the process equipment and work force.

The relative humidity of the ambient air at the plant site varies from about 70% at midday to nearly 100% at night. Likewise the temperature varies from about 27° to 32°C, depending upon the time of day. With these conditions it would be difficult to routinely operate the process without a humidity control system.

The FPM plant is equipped with two 756,000 kcal/hour capacity refrigeration units. These units can be operated separately or together. Operating experience has shown that the relative humidity and temperature within the process plant can usually be maintained at about 50%–55% and 29°C, respectively, by using only one of the refrigeration units.

With the dehumidification system, a makeup flow of ambient air is chilled to about 10°C; this causes about 50% of its contained water vapor to condense and be separated. The cool moist air (at essentially 100% relative humidity) is discharged throughout the process plant building by use of a distribution duct system. Normal heat from the process plant machinery (primarily the dryer and electric motors) together with solar heat is usually enough to heat the cool moist air sufficiently to decrease its relative humidity to about 50%.

An auxiliary reheat system (hot-water coil) is used to provide additional heat to the process plant to compensate for normal fluctuations in the solar heat load at nights and on cloudy days and to maintain a low relative humidity in the plant during periods when the granulation unit is shut down for maintenance or other reasons.

CONCLUSION

The successful implementation of the FPM project provides a practical model and should encourage others to undertake similar ventures. The project management strategy developed and used by FPM—from process development through plant startup—seems to be practical and cost effective and is likely to be adopted by others.

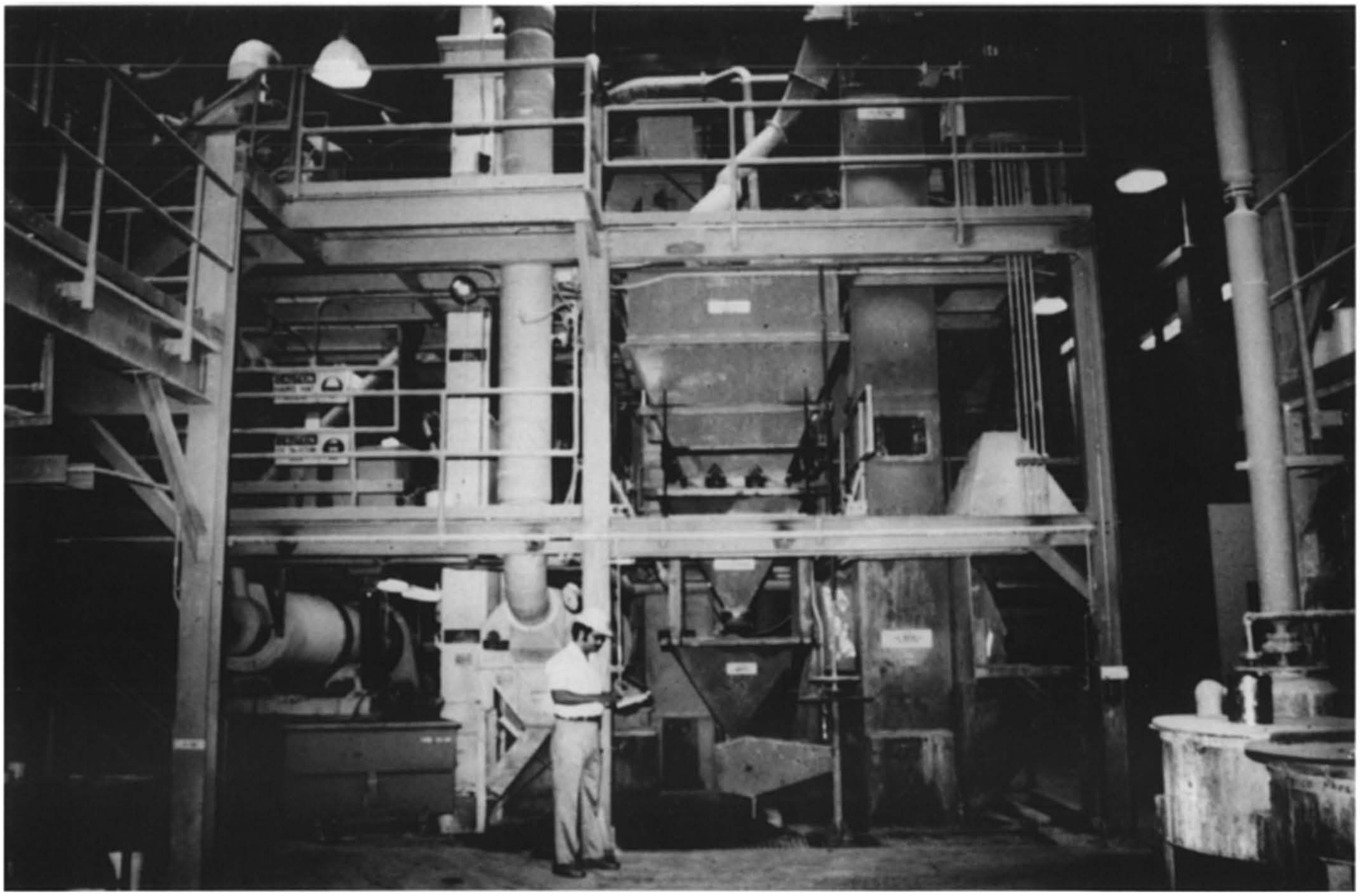

Figure 1. IFDC Pilot Plant Used to Perform FPM Granulation Trials.

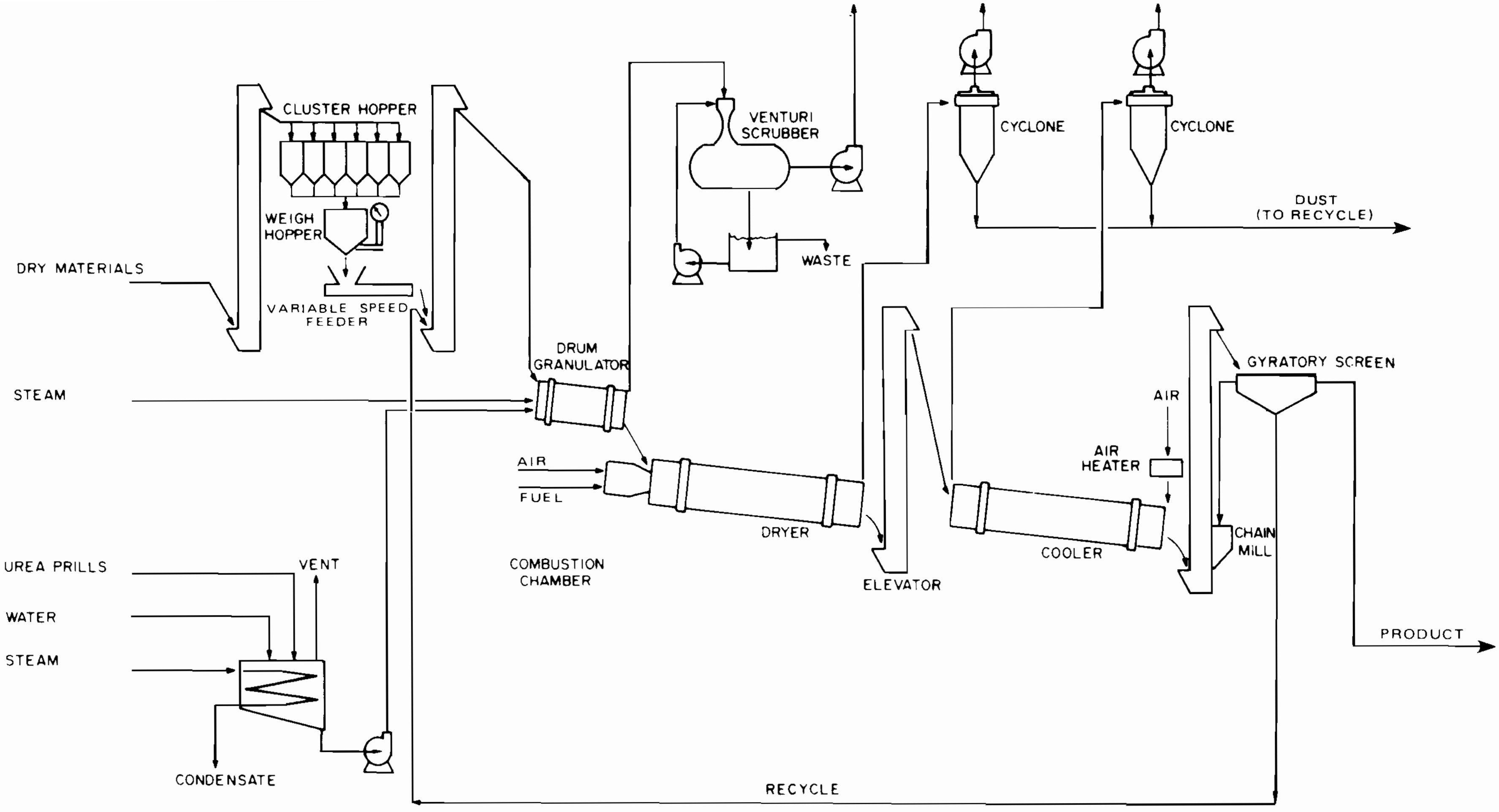

Figure 2. Process Flow Diagram--Urea-Based NPK Granulation.

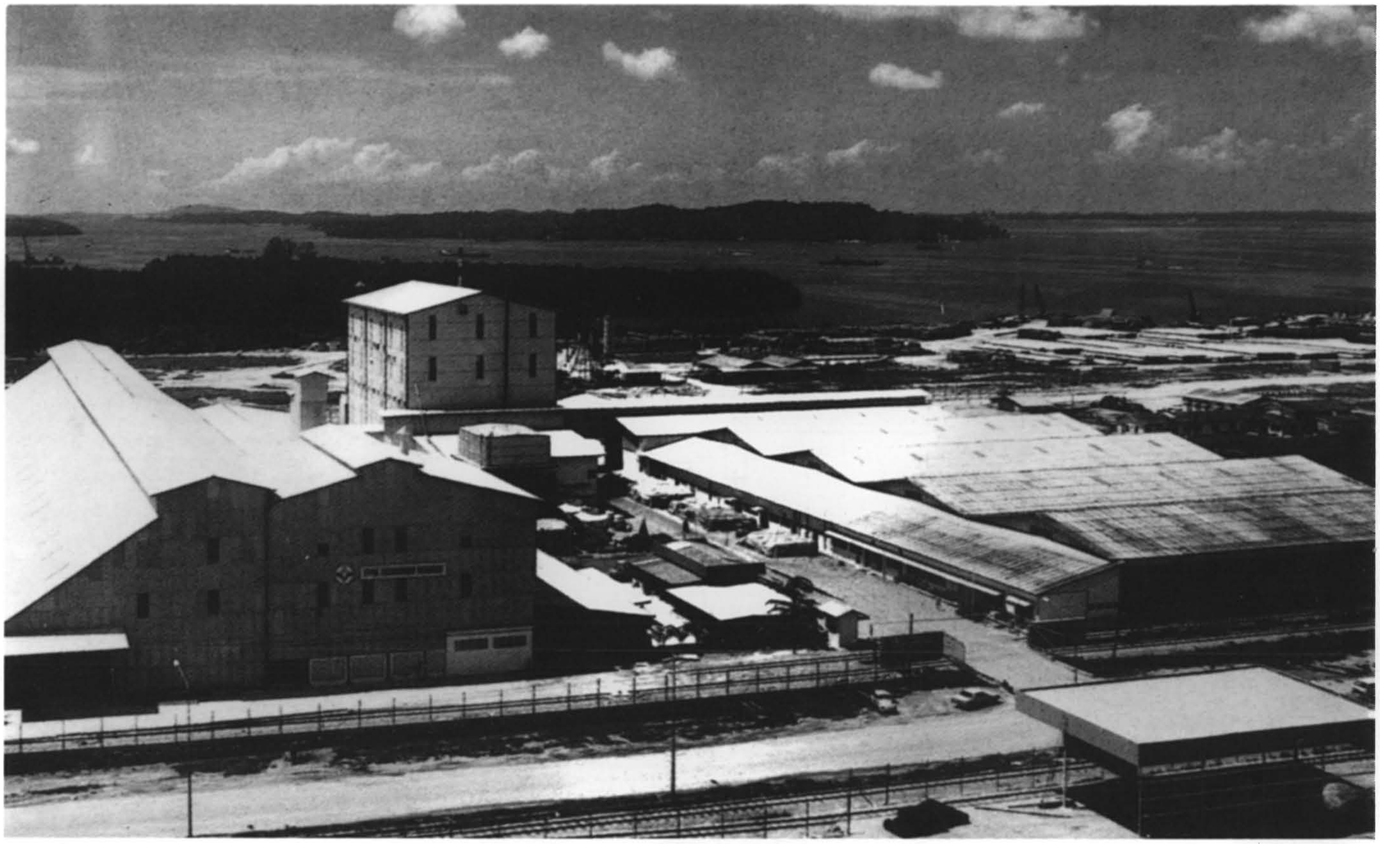

Figure 3. FPM Granulation Plant in Malaysia.

Figure 4. Drum Granulator in FPM Granulation Plant.

Manufacture of Urea DAP Based NPK Products in Developing Countries

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INTRODUCTION

In this paper we will describe the status of Urea-Ammonium Phosphate (UAP) granular fertilizer production in India. While India may be termed a developing country, it has made great strides, in both consumption and production of granular fertilizer as statistics presented in this paper will show.

On September 9, 1971 the first shipment of Merchant Grade Acid (MGA) was received at Madras Fertilizers. Since that time, eight granulation facilities, employing 18 lines have been constructed or are under construction for utilizing imported phosphoric acid.

The first ammonium phosphate complex, comprising a 25 TPD Prayon phosphoric acid plant and a 100 TPD Dorrco ammonium phosphate granulation plant, making 11-48-0 and 16-20-0 started up in 1960 at Fertilizer and Chemicals Travancore, F.A.C.T.

From this humble beginning, as the cliche goes, Indian fertilizer production has come of age through the 1970's to include some of the world's largest granulation facilities.

The strategy of manufacture of granular products from locally produced ammonia and urea and imported phosphoric acid has enabled the Indian fertilizer industry to make this impressive start, and shows the way for other developing nations to bring about efficient and economically sound fertilizer production.

PRODUCTION OF UREA-AMMONIUM PHOSPHATE AND OTHER SLURRY PROCESS

The growth in consumption and production of fertilizers including urea-DAP products in developing countries has been very inconsistent worldwide. However, India is an example of rapid and even spectacular growth, as denoted in Tables 1 and 2 and Figures 1 and 2.

Figure 1 plots the urea-DAP products made in India over a period covering 1974–75 to 1983–84. Figure 2 plots other non-urea grades over the same period. For the last three years the total of urea and non-urea grades has been about 2.2 MM tons.

Table 3 shows total N, P_2O_5 and K_2O consumption for current years as well as production in India. Shown also is a projection for future production.

Currently about 67% of the P_2O_5 consumed in India is produced there as granular products. Most of the imported P_2O_5 comes in as DAP, over 1.0 MM tons per year. Of the locally produced granular products about 60 to 65 percent of the P_2O_5 is imported as merchant grade acid.

By 1989–1990 it is projected that about 82% of the fertilizer P_2O_5 will be granulated locally. Almost 1.0 million tons more of P_2O_5 will be required by 1990 if these projections are correct. Most of this will be as imported merchant grade acid, although some new phosphoric acid production will begin during this period. India's first large phosphoric acid plant at Paradeep is due on stream in 1987, to add 250,000 TPY P_2O_5 from imported rock. India currently is importing about 750,000 TPY of P_2O_5 as merchant grade acid, about one quarter of the world's traded acid.

Having firmly established Urea-DAP grades such as 17-17-17 and 28-28-0, and with 19-19-19 and 14-28-14 also coming along, the general trend as shown in Figure 1 is upward for production of these grades.

Table 4 lists the granular ammonium phosphate plants currently in operation in India. It should be noted that the IFFCO complex at 800,000 TPY and the Paradeep project at 650,000 TPY rank with the world's larger fertilizer complexes. The capacity yet to startup on this list represents over 1,200,000 tons per year production.

PROMINENT USE OF IMPORTED ACID IN INDIA

One of the elements which has resulted in improved productivity in the developing Indian fertilizer industry is the practice of using merchant grade acid. This prevents upstream complex problems from reducing fertilizer production. It has proved to be a very sound strategy.

Typical Acid Handling System

Of the total phosphoric acid consumed by the Indian Phosphatic Fertilizer Industry, a significant percentage is imported (60%). Consequently, all the major DAP/NPK plants in India are shore based.

Phosphoric acid is imported from Florida, Iraq, Morocco, Jordan, Senegal etc. in bulk shipments of 28,000 MT. The surfaces exposed to acid are either covered with rubber or fabricated in SS cladded carbon steel to withstand corrosion. The acid in the ship's holds is normally pumped out by the ship's pumps to the shore based storage tanks. These pumps are generally capable of pumping at the rate of 1,000 TPH of acid at 9 kg/sq.m gauge pressure.

A typical 200mm dia. flexible hose connected to the pump discharge takes the acid to the shore based rubberlined carbon steel tanks through 250 mm dia. rubberlined carbon steel pipe installed on the ground. (Occasionally, FRP pipes have also been used). Conventional storage tanks have a holding capacity of 10,000 MT of acid (28m dia. x 10.3m dia. high). A top feed pipe with a distribution arrangement is provided with an impact plate to avoid damage to the rubberlining when filling empty tanks. A typical arrangement is shown in Figure 3.

A set of centrifugal acid pumps in Cd4MCu construction are used to recirculate the acid within the tank, transport to another tank, a road tanker or a plant use tank as the case may be.

In view of the large size of the storage tanks, they are fabricated in the field and field lined by prevulcanized rubber sheets using cold bonding technique. A safe life of about 10 years has been found to be practical after which the tanks may be required to be re-rubberlined. The bottom and the side of tank about a meter on the side are lined with 10mm rubber whereas the rest of the wall is lined with 5mm thick rubber.

Where one of the first such projects built in India had a provision for future addition of sludge raking arrangement and thus necessarily had a partially open top, in practice it was observed the imported 54% P_2O_5 acid did not have much solids (less than 1.0%) and most of these solids could be kept in suspension by recirculation. Consequently, all subsequently designed storage tanks were provided with covers. In one location roof-mounted agitators have been installed.

The centrifugal pumps are walled inside by a 1m high dyke with a drain leading into a reclaimed sump. The sump pumps could either return the spilled acid, if any, to the tank or pump out to a lime pit for neutralization before discharging to a chemical sewer.

The following points have been found to be useful for proper operation and maintenance of the storage tanks:

- The storage tank should have a sloping bottom towards the suction nozzles of the centrifugal pump. This will facilitate in emptying out the tank completely.

- The tank should be emptied out completely, cleaned after every 2 or 3 shipments. The rubberlining of the tanks should be spark-tested at regular intervals.

  If the tanks were cleaned after relatively long intervals, it was found that the sludge had hardened resulting in extended cleaning time and potential damage to the rubberlining.

- The recirculation pumps should have suction nozzles at 2 or 3 levels for ease of operation.

The plant use tank or a day tank is provided with an agitator to keep the acid homogeneous. The use tank is constructed with rubberlined carbon steel with agitator in 316SS construction.

Figures 4 and 5 show scenes of the acid and potash receiving area at the Madras Fertilizers plant, about 12 miles from the port. The acid is transported in 25 ton "Hippo" trucks.

UREA-DAP-NPK PRODUCTION IN INDIA—MADRAS FERTILIZERS

In developing countries like India, urea DAP based fertilizers have been in great demand because of very high nutrient analysis attainable with maximum availability of nutrients to the soil due to very high water solubility. This type of fertilizer has attracted both the producers and the end use-farmer. Urea ammonium phosphates are preferred over nitrate based fertilizers for paddy crops. If one looks at statistics, about 40% of total fertilizer production in India is constituted by urea-DAP based fertilizers.

Madras Fertilizers Limited, located in southern India has been the major contributor to the national production of UAP grades. It uses the conventional Dorrco slurry process to produce variety of grades like 24-24-0, 28-28-0 and predominantly 17-17-17. Although the Madras C-line is about a decade old, in last January 1984, production reported was 31000 MT which is 203% of design capacity. The other two lines produced 41115 MT in same month with 134% capacity utilization. Ever since 1971 when the first two lines went on stream and 1976 for the third line, the Madras plant has been the hallmark of successful UAP production. The production record at Madras is shown in Table 5.

Brief Process Description of Madras Fertilizers Granulation Plants

The basic raw materials used are imported 54% P_2O_5 acid from Morocco, Tunisia and Florida, ammonia and urea which are produced in other plants forming part of the complex.

Slurry is prepared in 316L SS preneutralizer and pumped to granulators, where prilled urea, filler and KCl are added in the recycle. The temperature of granulator discharge is maintained low enough (160–170°F) to limit urea melting and ammonia loss.

The three lines at Madras use a modified DAP circuit with relatively conventional granulation and ammoniation in either a Dorrco Blunger or a TVA drum granulator.

Drying high urea content fertilizers has been a well balanced act requiring close control of temperature. Larger dryer fan capacities than normally required for other DAP/NPK grades have to be used to limit inlet gas temperature in dryer. The problems encountered due to high temperature is dealt separately in following sections. The dried fertilizer which contains oversize, product size and fines is screened in 4 ft. × 20 ft. Tyler double deck screens, which are fitted with motorized vibrators. The chain mills have worked very satisfactorily except that cleaning is required at least once a day but the scale is not as hard as that produced in TSP processing or some other granular products. This type of preventive maintenance has enhanced the plant on-stream factor considerably. One important thing to note here is that crushing of oversize material is more or less mandatory in order to maintain proper sieve analysis in granulator and to limit formation of lumps which are difficult to dry.

The product size fraction is delivered to product cooler depending on "product take out" rate and rest goes back to recycle along with crushed oversize and fines. The ambient air induced countercurrently is heated with the help of steam to reduce the relative humidity and prevent moisture absorption by the product in the discharge end of the cooler. The cooled fertilizer is coated with coating agent in a coating screw to improve its storageability and shelflife. The coated fertilizer is polished further in Tyler motor vibrated type double deck vibrating screens to give closely sized product. The product is directly bagged in a bagging plant. Over the period of years it has been found that this directly bagged product can be stored satisfactorily for 4–5 months.

Bagging directly off the line, without storage and aging, requires the product be relatively non-caking. Such is the case at Madras even with minimal coating with a local clay. The storage of products in bags has eliminated the requirement of dehumidified air for bulk storage in one of the most humid, tropical climates in the world. It also reduces "shrinkage", the handling losses which occur in moving bulk products, which can run 2% or more.

Major Problem Areas

Associated with UAP production there are several problem areas which need to be taken care of during design stage itself and during operation of plant to ensure sustained production run. Major problems center around high humidity prevalent around coastal areas.

Dryer fan capacity has to be larger than that normally required for other DAP/NPK grades for two reasons. The inlet gas temperature to dryer has to be limited in order not to cross the fertilizer melting point and to avoid softening of the material. Also larger air volume is helpful in producing less than 1 percent moisture in the final product, which is required for these grades.

Dryer retention time is longer than required for DAP, so as to achieve the low moisture levels required for proper product quality. This aspect should be taken care of during design stage itself.

Steam heating of ambient air for cooling is a common practice used to decrease relative humidity of cooling air. This has helped considerably in improving the storage property of UAP fertilizers. Steam space heaters in recycle conveying equipment and in screen room were envisaged as another precautionary measure to reduce moisture pick up by fertilizers. In practice it was found that steam leaking from valves and piping caused more problems than benefits, makes the equipment surfaces sticky increasing scaling and maintenance problems on equipment like elevators and flight conveyors.

The high humidity problem suggests dehumidification of the entire plant building and having a relatively closed building. At Madras no dehumidification is used. However, an efficient way of dehumidification would be to use liquid ammonia for air chilling and to use the generated vapor ammonia in the process allowing less concentrated phosphoric acid to be used and more quantity of fresh water into the plant. The closed plant building demands efficient dust removal system covering all dust generation points.

In India fertilizer demand has always been a seasonal demand despite the fact that crop rotation and suitability of UAP to a variety of crops smooths out the demand pattern. Due to seasonal demand, however, producers of UAP grades have to ensure good shelflife of product to maintain their market share. Coating of UAP grades has been the standard practice all over the world. At Madras, coating oil is not used because of polythylene lined jute bags which are reused many times. The soiling of the bags with coating oil is unacceptable.

It has been mentioned above that Madras plant does not use bulk storage but directly bags the product. However, in other plants, located in Goa, again a coastal area bulk storage has been a standard practice. It is worthwhile mentioning here that use of slight quantity of coating oil will certainly improve and enhance shelflife of urea DAP type fertilizers.

Another important aspect of UAP production is cleanliness and housekeeping of the plant. It is common knowledge at Madras that the double deck screens need constant attention and cleaning to keep screening efficiency at it's maximum. Use of single deck screens will help to solve the cumbersome cleaning problems usually encountered with double deck screens. Also judicious control of granulation and drying will result in low screening surface requirements for the scalping screen which is no longer dependent on product screen surface area requirment, in single deck screening system.

Continuous screen analysis for checking the tendency of overgranulation is a most important process control requirements. Calibration of solid raw materials feeders has to be done regularly to maintain correct nutrients ratio.

A frequent and common problem encountered while handling UAP is of overgranulation and drying of these oversize granules. Since it is very difficult to remove entrapped moisture in the lump, the tendency to overgranulation must be curbed. It is to be noted that the Madras plant is a relatively conventional slurry process plant. It does not use a recycle cooler which is relatively inefficient in terms of heat utilization, and is an expensive addition. In the Dorrco process for producing urea-DAP granular products proper temperature controls throughout the granulation loop prevent excessive ring and lump formation and produce granules of exceptional quality.

Conclusion

UAP being agro-economically superior product has gained wide acceptance in India. The flexibility offered by UAP route makes it an excellent product for India which requires concentrated nutrients because of low fertilizer usage per hectare of agricultural land. However, various problems encountered during operation and production must be taken care of during design. Proper care and engineering experience in designing such plants make the UAP route suitable for Indian conditions, and many other developing countries.

DORRCO PROCESS FOR UREA-AMMONIUM PHOSPHATE GRADES

Producing MAP Grades

The grades produced in India are urea-DAP grades. They have the economic advantage of using the maximum ammoniacal nitrogen and include formulas like 19-19-19 and 35-17-0, which are not possible using MAP. Figure 6 is a current flowsheet for the Dorrco Urea DAP process. The flowsheet is virtually the same for urea-MAP grades which may be preferred in certain areas for agronomic reasons.

Forms of Urea Utilized

Urea is likely to be available as prills, urea dust, crystalline urea, urea melt or granulated and hardened urea. The Madras plant uses prills which have no hardener. This is one of the less desirable forms, actually, since the prills are soft and tend to make the bed in the granulation viscous and floppy rather than fluid and rolling. The prills are not crushed prior to addition to the recycle. However, because of the soft nature of the prills and the high solubility of urea the product is quite homogeneous in appearance.

Urea melt can also be used and has the advantage that there is no cooling effect as would normally be encountered when mixing solid urea with ammonium phosphate slurries.

Tests have recently been conducted using urea granulated by the Spherodizer Process, wherein a hardener is used giving the urea a granule hardness of about 7 to 8 pounds. This form of urea appears to be easier to handle, being less mushy in the bed and making harder NP and NPK products.

PROCESS FEATURES

Single Deck Screening

Figure 6 shows the two stage single deck screening used in the Dorrco process. Single deck screening is highly recommended for processing urea—ammonium phosphate grades.

Pulverizing

Chain mills with rubber lining are used for pulverizing. Our experience is that these mills are preferred to cage mills because they are less likely to have vibration problems, are easy to clean and maintain. Ultimately particle size is maintained by the process control of moisture and temperature conditions.

Drying

Urea-DAP formulas require longer dryer detention. This is basically not for the normal sized particle with its thin film of new slurry. These dry very rapidly. The added detention is to cope with lumps and agglomerates which dry very slowly. It should be noted also that urea NPK products are much more difficult to dry than urea NP materials. The addition of potassium chloride lowers the critical relative humidity to about 45% and increases the hygroscopicity and difficulty to dry. This can lead to increased lump formation, screening and pulverizer problems and even dryer ring formation.

Formulations

Table 6 shows formulations for 28-28-0. This grade can be made at a mole ratio as low as about 1.4 as shown. This requires about 6% more urea in the formula. These formulas, it is to be noted, do not take into consideration the hydrolysis of urea which will occur in the scrubbing system and where conditions of high temperature and high acidity exist. Some hydrolysis is relatively difficult to avoid, but it is minimized by certain process conditions including avoiding the addition of either unneutralized phosphoric acid or sulfuric acid to the granulator.

Tables 7 and 8 show formulas for 19-19-19, 35-17-0 and DAP, based on Merchant Grade Acid of a purity of 64.8% P_2O_5 in anhydrous acid, typical of imported MGA. The products are estimated to contain a maximum of 0.8% moisture, 1.0% coating agent and 0.5% coating oil. From a grade point of view it is substantially more difficult to make 19-19-19 and 35-17-0 than DAP.

Pipe Reactor Processing

There are advantages to using a TVA type pipe reactor on certain urea grades, particularly those with high moisture input like 28-28-0. Also grades which do not require extremely high mole ratios in the product like 17-17-17 are candidates for pipe reactor processing. In using the pipe reactor it's possible to raise the temperature in the granulator, use less moisture, save some fuel, add capacity, and so forth, the well known advantages the pipe provides. Another technique for increasing heat in the granulator is to use gaseous ammonia. Both the pipe reactor and gaseous ammonia will be used in the urea-DAP-NPK facility employing the Dorrco process now being constructed by Jacobs Engineering near Port Harcourt, Nigeria. Grades such as 28-28-0, 19-19-19, 35-17-0 and DAP will be made.

Many plants using imported phosphoric acid do not have sulfuric acid available. Grade adjustment is with urea and filler. Many plants in the USA also use urea for grade adjustment when processing phosphoric acid containing a high quantity of impurities. In fact, with today's high cost of sulfur and low differential between urea and ammoniacal nitrogen, it is less expensive to use urea than ammonium sulfate from sulfuric acid.

Table 8 shows two formulas for DAP made from acid of 64.8% P_2O_5 in anhydrous acid. The top formula is a conventional high mole ratio product. The lower formula shows a DAP with only a 1.5 mole ratio and a pH of about 6.8. The latter formula is possibly because of the high purity of normal Merchant Grade Acid. This formula is particularly well suited for pipe reactor processing. It also serves to illustrate the rather substantial effect of acid purity on mole ratio for DAP.

Scrubbing System

The use of the pipe reactor and the making of high mole ratio grades such as 35-17-0 and 19-19-19 require extremely efficient and effective scrubbing. The Dorrco process employs multi-stage, countercurrent scrubbing for the granulator and preneutralizer fumes. Variable throat venturi scrubbers are used with relatively high liquid to gas ratios. We avoid using spray towers for all but tailgas scrubbers since nozzle maintenance is high and spray patterns are inconsistent due to nozzle wear, scaling and plugging. There is no liquid effluent from the plant.

Other Methods of Making UAP Products Using MAP Powder or Melt

The UAP products made in India are via the slurry process. Similar grades can be made using powder MAP or MAP as a melt. Ammoniation of these materials in the granulator is generally considered difficult and normally only low mole ratio products are made this way.

We believe the handling losses using powdered MAP are significantly higher than generally recognized; they can be 3% or more. Also, the products are usually softer than products made with slurry. Such powder or melt processes generally rely on using very low quantities of water so that adequate gas scrubbing is very difficult, or the plant has an effluent.

One of the supposed advantages of the powder or melt granulation process is relatively low recycle and some consequent energy savings. Recycle rates at Madras Fertilizers on grades like 17-17-17, 28-28-0 and 14-18-14 are in the 2.5:1.0 to 4:1.0 range, not very high but still allowing drying at detentions substantially less than required for powder granulated (agglomerated) products. The energy savings for the very low recycle used in powder or melt processes is essentially negligible since the dryer, granulator screens, and fan sizes are not reduced in size.

Urea-DAP-NPK's by Bulk Blending

The use of bulk blending in the USA has resulted in production of granular urea, a material somewhat larger than prilled urea and more compatible sizewise with DAP. Urea NPK's are normally bulk-blended by mixing granular urea, DAP and granular potash.

Sometimes these mixtures tend to segregate due to the irregular potash shape. A premium bulk blend 19-19-19 can be made by using granular urea and a 10-26-26 grade which is DAP plus potash.

Such bulk blend products can be coated and bagged, with good storage and handling properties and provide an alternative to powder process granulation for areas where little or no granulation technology exists, or where no local ammonia production is possible.

SUMMARY

The growth of the Indian Fertilizer Industry sets a significant example of accomplishment. In the initial plant built in 1960, described in the Introduction, virtually all of the engineering and equipment was imported. In the current plants being constructed all of the engineering and all the equipment and materials, except for a few items of specialized nature, are being supplied from India itself.

The authors wish to thank the Fertilizer Association of India for providing production statistics for India and the management of Madras Fertilizers Ltd. for production figures for their operation.

FIGURE 1

PRODUCTION STATISTICS

ALL INDIA PRODUCTION OF UAP FERTILISER

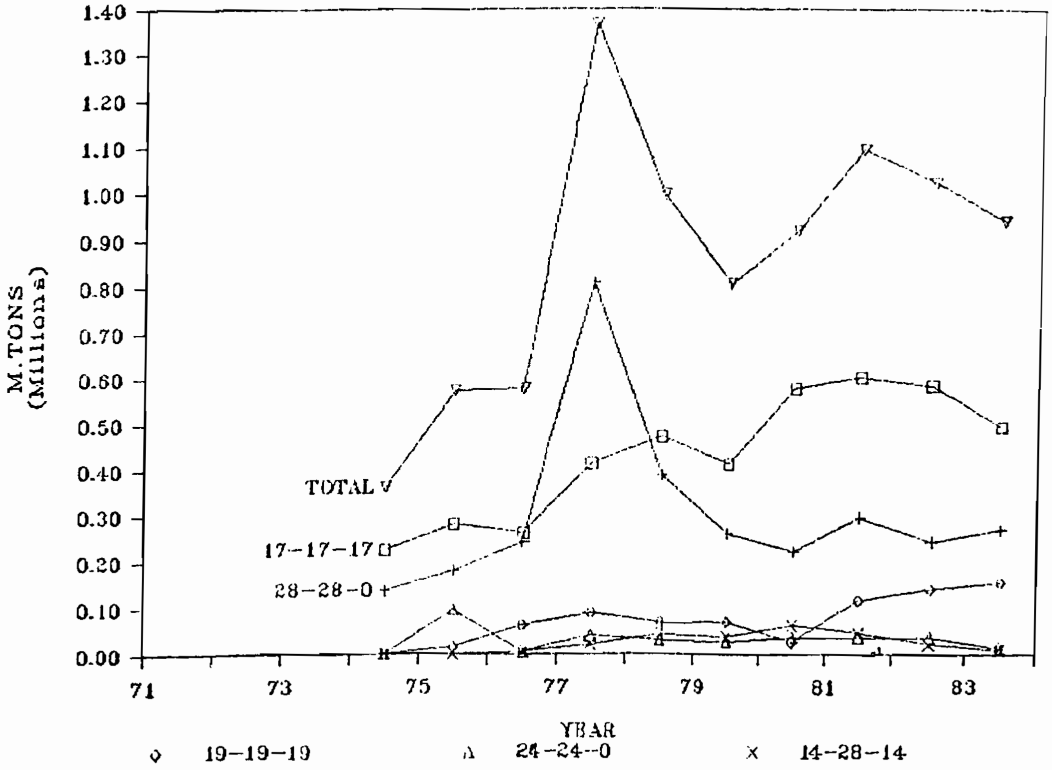


FIGURE 2

PRODUCTION STATISTICS

ALL INDIA PRODUCTION OF NPK FERTILISER

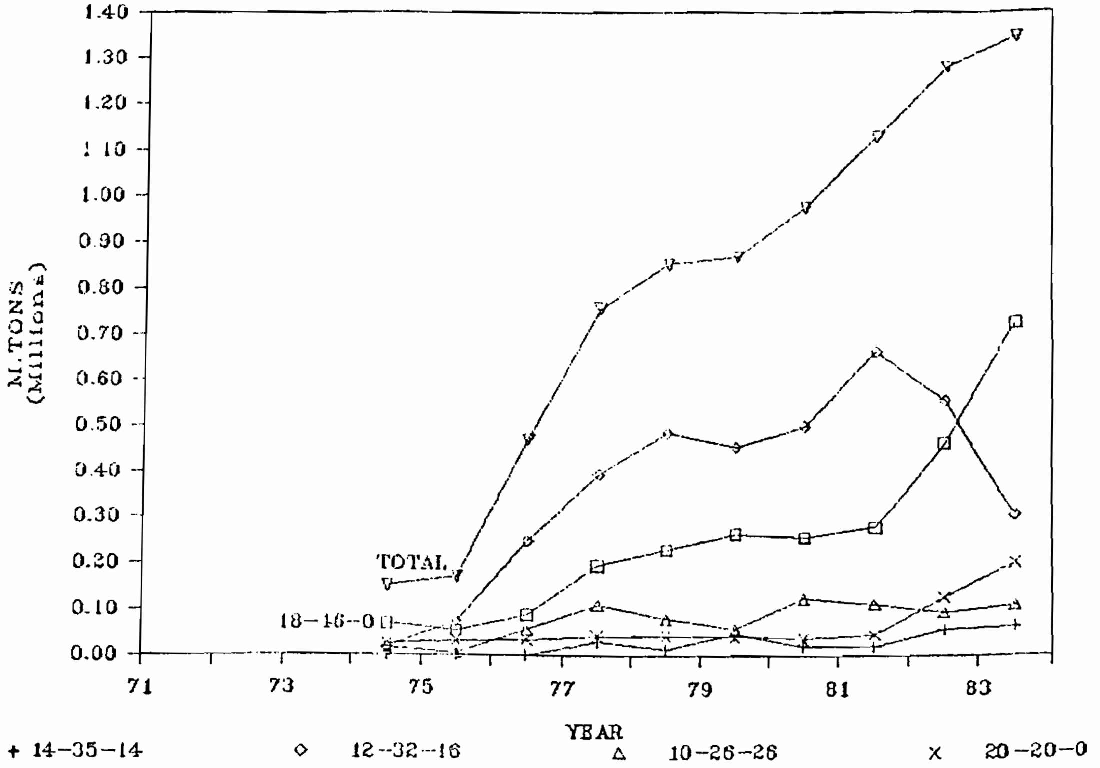
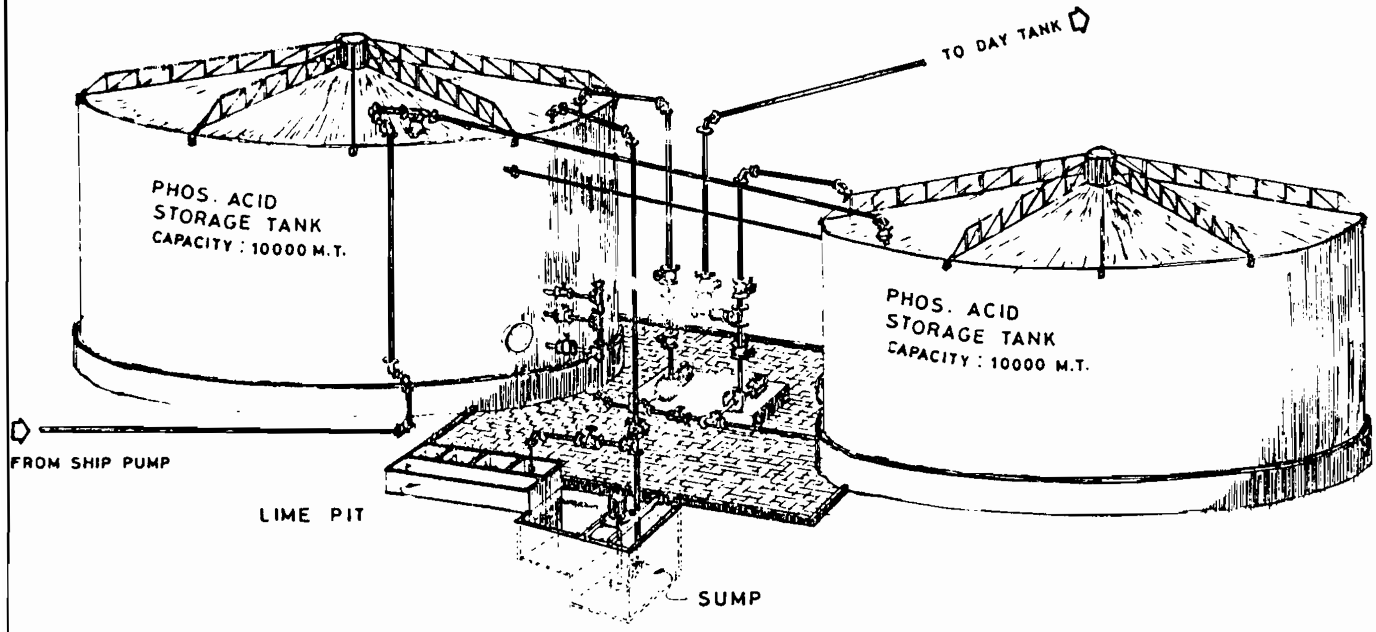


FIGURE 3

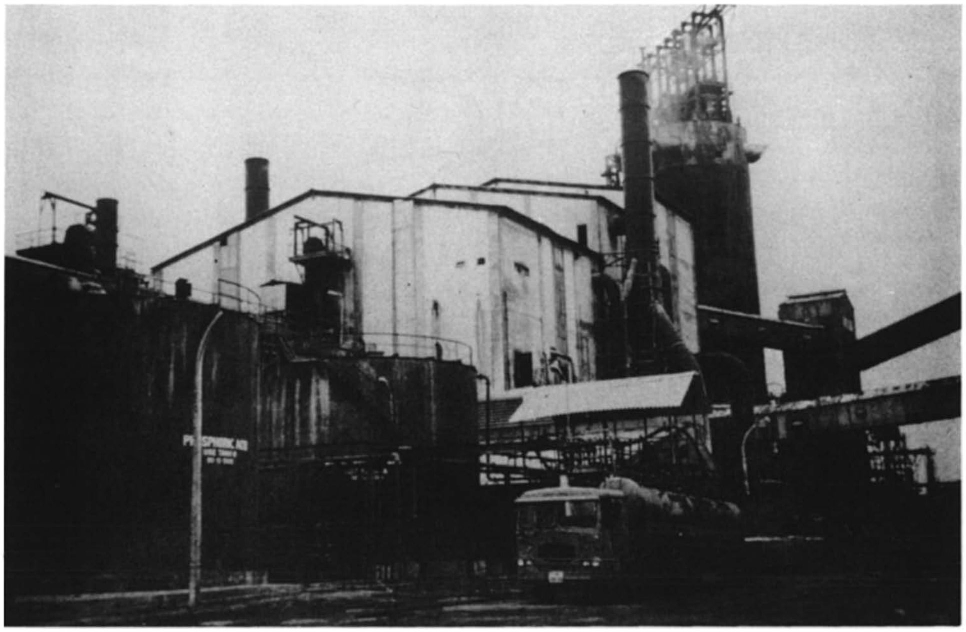


A TYPICAL IMPORTED PHOSPHORIC ACID HANDLING AND STORAGE SYSTEM

FIGURE 4

Phosphoric Acid and Potash
Receiving - Madras Fertilizers

FIGURE 5



Phosphoric Acid Tankage with Madras Fertilizers

A & B Lines

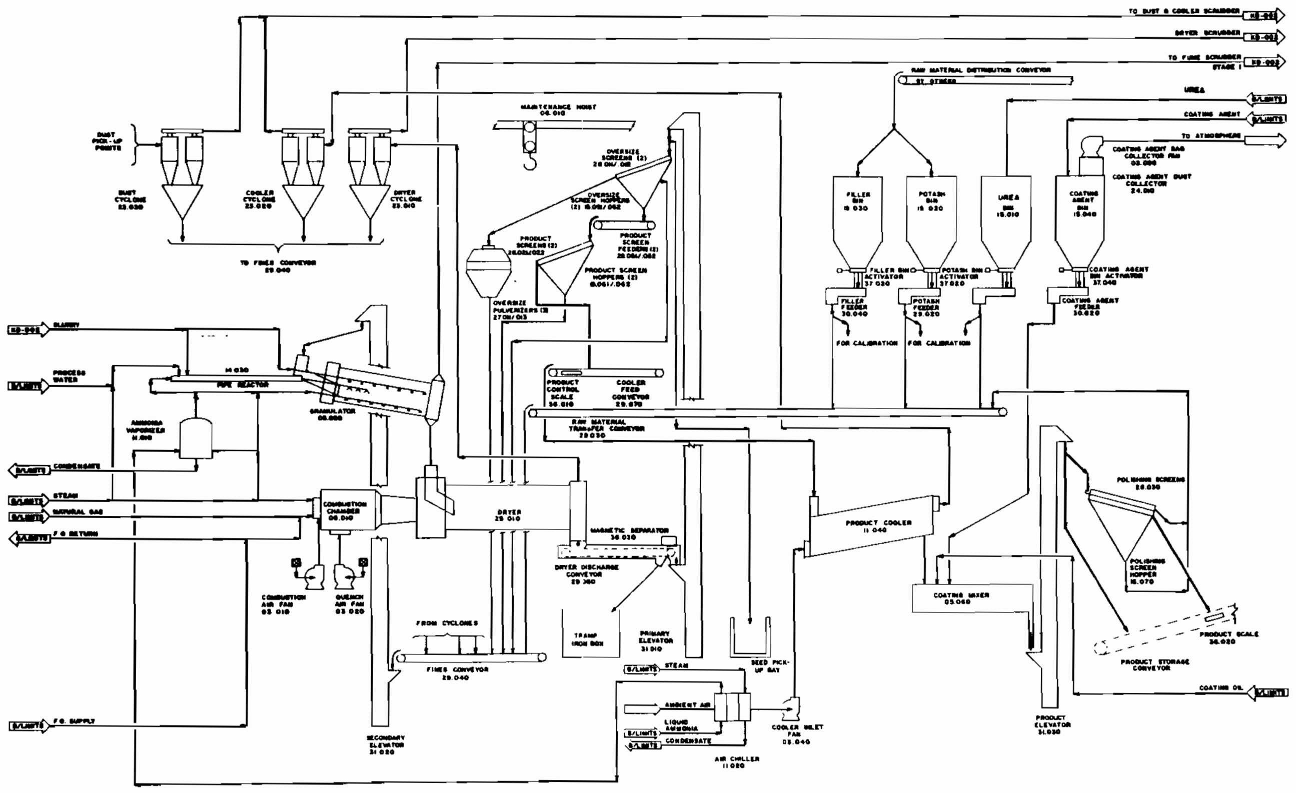


FIGURE 6

Table 1. PRODUCTION STATISTICS

All India Production of UAP Fertilisers

Year	17-17-17	28-28-0	19-19-19	24-24-0	14-28-14	Total
1974–75	226,400	136,900	—	—	—	363,300
1975–76	282,100	181,100	15,300	95,400	—	573,900
1976–77	261,900	244,100	61,400	5,000	5,000	577,400
1977–78	414,800	807,600	87,700	38,300	20,000	1,368,400
1978–79	472,400	388,200	66,500	28,000	42,100	997,200
1979–80	412,500	261,500	68,800	25,700	36,800	805,300
1980–81	577,100	222,300	25,200	35,100	60,800	920,500
1981–82	602,800	297,300	115,700	35,400	44,700	1,095,900
1982–83	583,300	244,200	140,000	35,400	20,300	1,023,200
1983–84	493,400	269,500	156,100	13,100	8,900	941,000

Source: Fertiliser Association of India
Fertiliser Statistics

Table 2. PRODUCTION STATISTICS

All India Production of NPK Fertilisers

Year	18-46-0	20-20-0	14-35-14	12-32-16	10-26-26	Total
1974–75	67,500	23,800	28,200	16,000	14,400	149,900
1975–76	52,900	30,200	12,200	72,300	3,100	170,700
1976–77	87,000	33,000	44,900	247,500	54,900	467,300
1977–78	195,100	40,100	19,800	392,200	108,900	756,100
1978–79	229,000	42,700	18,000	484,400	78,600	852,700
1979–80	263,400	40,600	55,200	453,300	56,800	869,300
1980–81	256,200	35,800	61,900	498,800	123,400	976,100
1981–82	277,900	43,800	33,700	661,500	111,100	1,128,000
1982–83	461,000	126,300	44,100	554,700	92,800	1,278,900
1983–84	722,600	201,700	7,600	304,200	108,500	1,344,600

Source: Fertiliser Association of India
Fertiliser Statistics

Table 3. PROJECTED CONSUMPTION AND PRODUCTION OF FERTILIZER NUTRIENTS IN INDIA, MM TONS*

	Consumption			Production		GAP	
Year	N	P_2O_5	K_2O	N	P_2O_5	N	P_2O_5
1984–85	5.64	1.87	0.87	3.92	1.26	1.73	0.60
1989–90**	7.73	2.69	1.36	6.93	2.19	0.80	0.49

*Fertilizer Focus Magazine
**VIIth Plan

Table 4. GRANULAR AMMONIUM PHOSPHATE PRODUCTION IN INDIA

Table of Installations

Plant	Location	Date of Operation	Process	Design Capacity (MTPH)	Grade
Coromandel Fertilisers Limited	Vizag[1]	1968	Wellman	347500	28-28-0
	(Andhra Pradesh)		Lord	in 2 Lines	14-35-14
The Fertilisers & Chemicals Ltd.	Ambalamedu[1]	1976	Wellman	485000	17-17-17
	(Cochin)		Lord	in 2 Lines	28-28-0
	Kerala				18-46-0
					20-20-0
Gujarat State Fertilisers Ltd.	Baroda[1]	1967	Chemico	108000	18-46-0
	Gujarat		Hitachi		
Gujarat State Fertilisers Ltd.	Sikka[2]	1987*	Dorrco	328000	18-46-0
	Gujarat			in 2 Lines	
Hindustan Lever	Haldia[1]	1985*	Fisons	160000	18-46-0
	West Bengal				
Indian Farmers Fertilisers Co-Op	Kandla[2]	Phase I—1975	Dorrco	800000	10-26-26
	Gujarat	Phase II—1981		in 4 Lines	12-32-16
					14-36-12
					18-46-0
Madras Fertilisers Ltd.	Madras[2]	A&B—1971	Dorrco	360000	17-17-17
	Tamilnadu	C—1976		in 3 Lines	24-24-0
					18-46-0
Mangalore Chemicals & Fertilisers Ltd.	Mangalore[2]	1985*	Toyo-Fluid	138000	18-46-0
	Karnataka		Bed Process		
Paradeep Phosphates Ltd.	Paradip[1,2]	1986*	Dorrco	650000	18-46-0
	Orissa			in 4 Lines	
Southern Petrochemical Industries Corp. Ltd.	Tuticorin[1,2]	I—1976	Hitachi	310000	28-28-0
	Tamilnadu	II—1983	Zosen	in 2 Lines	10-26-26
					18-46-0
Zuari Agro Chemicals Ltd.	Zuarinagar	1975	Toyo	150000	28-28-0
	Goa				19-19-19
					14-35-14
					18-46-0
Zuari Agro Chemicals Ltd.	Zuarinagar	1985	Dorrco	150000	19-19-19
	Goa				28-28-0
					18-46-0

Source: Fertiliser Association of India
Fertiliser Statistics

*To be commissioned

[1] Local acid

[2] Imported acid

Table 5. MADRAS FERTILISERS LIMITED PERFORMANCE DATA

A & B and C Trains

	A & B Trains		C Trains	
Year	Production in MT	% Capacity Utilization	Production in MT	% Capacity Utilization
1972–73	286200	80	—	
1973–74	267700	74	—	
1974–75	259400	72	—	
1975–76	330200	92	—	
1976–77	211000	59	79000	Commissioned in Oct. 1976
1977–78	252000	70	221000	123
1978–79	287000	80	269000	149
1979–80	236000	65	249000	138
1980–81	312000	87	246000	136
1981–82	339000	94	243000	135
1982–83	325000	90	279000	155
1983–84 (anticipated)	284000	79	223000	124*

*Severe power and water constraints shutting down plant for 5 months in 1983.
Source: Madras Fertilisers Limited

Table 6. 28-28-0 FORMULATIONS

	N	P	
18.7-50.1 *(1.9 MR pH 7.65)	10.56	28.28	56.45
Urea	17.72		38.53
H_2O, C.A., Oil			2.30
Filler			2.72
	28.28	28.28	100.00
14.6-53.3 *(1.4 MR pH 6.6)	7.75	28.28	53.06
Urea	20.53		44.64
H_2O, C.A., Oil			2.30
	28.28	28.28	99.95

*64.8% P_2O_5 in anhydrous acid

Table 7. UREA DAP FORMULATIONS

19-19-19

	N	P	K	Total
18.7-50.1 (1.9 MR)	7.16	19.19		38.30
Urea	12.03			26.15
KCl 60			19.19	31.98
Moisture, C.A., Oil				2.30
Filler				1.27
	19.19	19.19	19.19	100.00

35-17-0

	N	P	K	Total
18.7-50.1 (1.9 MR)	6.41	17.17		34.27
Urea	28.94			62.92
Moisture, C.A., Oil				2.30
Filler			-	0.51
	35.35	17.17		100.00

Table 8. DAP

(High Mole Ratio)

	N	P	K	Total
18.7-50.1 (1.9 MR)	17.34	46.46	—	92.73
Urea	.84			1.83
Moisture, C.A., Oil				2.30
Filler			-	3.14
	18.18	46.46		100.00

DAP PIPE REACTOR

(Low Mole Ratio)

	N	P_2O_5	Total
15.9-52.3 (1.5 MR-6.8 pH)	14.12	46.46	88.83
Urea	4.06		8.82
Moisture, C.A., Oil			2.30
	18.18	46.46	99.95

Production of Monoammonium Phosphate Sulfate with TVA Pressure Pipe-Cross Reactor

David G. Salladay
Manager of Cooperative Ventures
and
Mary S. Traweek
Chemical Engineer
National Fertilizer Development Center
Tennessee Valley Authority
and
Nicholas H. Louizos
Chemical Engineer
Hellenic Chemical Products & Fertilizers Company
Athens, Greece

Introduction

In 1982 and 1983 TVA engineers worked with Hellenic Chemical Products and Fertilizers Company of Athens, Greece on the design of a TVA pipe-cross reactor (PCR) for their granulation plant in Piraeus, Greece. In 1984 a TVA engineer helped in the first operation of this TVA PCR, which was fabricated and installed by a U.S. engineering company. This paper will correlate experience in the United States with weak and strong phosphoric acid used to produce monoammonium phosphate sulfate granular fertilizers. Nicholas Louizos of Hellenic Chemical Products and Fertilizers was the project engineer for his company.

Discussion of Previous Related Work with Western United States Phosphate Granulation Plants

Tables 1 and 2 summarize detailed operating data for producing 16-20-0-13-/14S granular monoammonium phosphate sulfate fertilizer in these western granulation plants. General experience during the last eleven years with the development of these pipe-cross reactor/melt granulation processes has yielded much information about design criteria and operating parameters. But the work in the Western United States combined with results last year in Athens, Greece, has provided new insight. The operating data in table 1 were obtained for a standard 10-foot-long by 6-inch-diameter (original PCR design) pipe. The data in table 2 were obtained with a lengthened 20-foot-long by 6-inch-diameter PCR. Tests in table 1 and table 2 show that the shorter pipe, although operating under conditions very similar to those shown in table 2, had a much lower ammonia loss. It lost only about 1.5 percent of the ammonia fed while the longer pipe lost 9.4 percent of the ammonia fed. While the N:P mole ratio in both pipes was about 1 and the sulfuric acid was converted to ammonium sulfate, the large quantity of water present in the longer pipe greatly affected ammonia loss. The reaction rate constants for ammonia reacting with sulfuric and phosphoric acid are relatively fast. But the physical barrier of large quantities of water converted into steam by the heat of reaction has had a significant effect on the operation of the pipe. (Table 2.) The large quantity of steam molecules inhibits the ability of ammonia molecules in this steam phase to find unreacted acid in the melt portion of the two-phase composition in the pipe.

Discussion of Granulation Work in Greece

Table 3 summarizes the results obtained in the production of 16-20-0-14S in Hellenic Chemical Products and Fertilizers granulation plant, Pireaus, Greece. As in the work discussed in tables 1 and 2, this granulation plant contained a 10-foot-diameter by 20-foot-long TVA-type rotary ammoniator-granulator. A newer TVA designed pressure pipe-cross reactor was used in this work, however. A 20-foot-long, 8-inch-diameter inclined section of reactor pipe feeds into an 11-foot-long by 8-inch-diameter transition section of pipe. This entire pipe reactor was made of Hastelloy C-276. Figure 1 shows the pressure PCR used in a Florida granulation plant, while Figure 2 shows the modification of this design for the Greek plant.

In this granulation test work, this pressure pipe reactor was operated simultaneously with a conventional tank preneutralizer. About 28 short tons per hour were produced in each of these pieces of equipment giving a total production rate of about 56 tons per hour. When the anhydrous ammonia and dry ammonium sulfate fed to the bed of the ammoniator granulator are included, this process has ten feed streams. At the time of the tests, the production facility in Pireaus did not include phosphoric acid concentration facilities. To be able to granulate with 28% P_2O_5 filter grade phosphoric acid, large quantities of 98% sulfuric acid are used. Ammonium sulfate solution is used whenever possible in all the granulation production to consume this by-product produced by an adjacent production plant. The imported dry ammonium sulfate is economical and is used to the greatest extent possible in these fertilizer grades.

As in the work discussed in table 2, the ammonia loss with the high quantity of water fed into the pressure pipe reactor is high. Losses of 7% or more of the ammonia fed to the process were encountered.

Comparison of Western United States and Greek Granulation Experience

Table 4 compares the results shown in tables 1, 2, and 3. This table shows N:P mole ratios, pipe temperatures, ammonia loadings, and concentration of water in the PCR by weight percent and volume percent. Ammonia losses increased rapidly because as high percentages of water in the PCR make it increasingly difficult for the ammonia to contact the acids. TVA engineers have often said that from the standpoint of removing the most water from incoming acid and by-product or scrubber streams, including water in the pipe reactor portion of the formulation is desirable. However, recent work in Florida has shown many benefits to spraying the by-product water streams or scrubber slurry streams onto the bed of granules in the granulator. While the theoretical vaporization of a pound of water requires about 970 Btu's, experience continues to indicate that about 1300 Btu's per pound of water should be allowed when formulating. This empirical relationship continued to yield good granulation results in Greece.

Discussion of Granulator Air-Flow and Maximum Water Removal from the Granulator

This retrofit project in Greece necessitated the use of maximum air velocity through the granulator with maximum water removal while providing satisfactory granulation. If this had not been a retrofit project, a 12-foot-diameter by 24-foot-long granulator would have been specified for producing 50 to 55 tons per hour of 16-20-0-14S from feed streams containing large quantities of water. The initial test work in this European designed and built granulation plant was conducted with countercurrent airflow in the granulator. When the tank preneutralizer was used, the countercurrent mode of operation was satisfactory, although granules were carried by the exhaust air from the solid material feed. These solids were conveyed back into the system with a screw conveyor. Attempts to use countercurrent airflow with the melt-granulation pipe-reactor process were not satisfactory during the start-up. The granulator was modified for concurrent air and fertilizer flow. Countercurrent airflow would not be recommended in an ammoniator granulator pipe-reactor system.

Experience in this Greek plant compared well with experience in the U.S. granulation plant, discussed in table 2. A granulator 10 feet in diameter by 20-feet long using melt granulation to produce monoammonium phosphate sulfates can handle about 23,000 lbs/hr maximum water input, not including water in the fertilizer recycle stream. The maximum airflow which could be handled in this system was about 5.5 cubic ft/sec. The exhaust airflow from this granulation system exceeded 150% of saturation.

Further calculations were made to determine the phosphoric acid concentration necessary to produce 50 metric tons per hour of 16-20-0-14S in the 8-inch-diameter pressure pipe-cross reacctor. These calculations were based on about 1300 Btu's chemical heat of reaction per pound of water in the pipe reactor and 600,000 Btu's/(in^2)(hr) cross-sectional area heat flux. N:P mole ratio of 1.1 was assumed for the phosphoric acid, and liquid anhydrous ammonia was used in the heat of reaction calculations. The following wet-bases formulation (2000 lb/ton) was obtained:

16-20-0-14S

	lb/ton
Anhydrous ammonia (liquid)	201.2
Phosphoric acid (38.6% P_2O_5)	1037.0
Sulfuric acid (98%)	284.0

If Hellenic Chemical installed phosphoric acid concentration facilities, it could blend filter grade acid and 54% acid to produce about a 40% phosphoric acid.

Summary

Review of the granulation test work in the Western United States and Greece has provided much useful information which will be included in a melt granulation computer simulation being developed by NFDC. The data can be used with other operating results to predict ammonia slip from the process. This work in Greece has also demonstrated the maximum water loading and airflow velocity which can be used in a 10- by 20-foot ammoniator-granulator. If Hellenic Chemical Products and Fertilizers installs phosphoric acid concentration equipment, they can produce 16-20-0-14S using only the 8-inch pipe-cross reactor and the 10- by 20-foot rotary ammoniator-granulator.

Table 1. PRODUCTION OF MONOAMMONIUM PHOSPHATE SULFATE USING TVA PRESSURE PIPE-CROSS REACTOR

Western United States Granulation Plant

Test	1	2
Nominal grade	16-20-0-14S	16-20-0-14S
Operating time, hr.	9	25
Average production rate, tons/hr. (mt/hr.)	29(26.3)	25(22.7)
Granulator size, D × L, ft (m)	10×20(3×6)	10×20(3×6)
PCR diameter, in (cm)	6(15.2)	6(15.2)
PCR length, ft (m)	10(3)	10(3)
Formulation, lb/ton of product (kg/mt)		
Pipe-cross reactor (PCR)		
Ammonia	246(123)	246(123)
Sulfuric acid (98% H_2SO_4)	494(247)	494(247)
Phosphoric acid (52% P_2O_5)	627(314)	627(314)
Water	102(5)	102(5)
Total water to PCR	212(106)	212(106)
Granulator		
Ammonium sulfate	505(252)	505(252)
Phosphoric acid (52% P_2O_5)	158(79)	158(79)
Ammonia	20(10)	20(10)
Total water to bed	25(12)	25(12)
Temp, °F (°C)		
Dryer outlet gas	250(121)	242(117)
Product from granulator	214(101)	220(104)
PCR skin	263(128)	281(138)
Dryer gas	On and off	Off
Estimated recycle rate, kg/kg product	4	4
pH of granulator product	3.5-4.5	4.2
PCR heat flux, 10^6Btu/(hr.) (in^2 cross section)	0.56	0.56
Total chemical heat, 10^3Btu/ton (10^3kcal/mt)	670(186)	670(186)
Ammonia loss, % of ammonia fed	—	1.5
Average back pressure in reactor, psig (kg/cm^2)	50(3.5)	50(3.5)
Product		
Chemical analysis, % (average)		
N	15.8	15.9
P_2O_5	22.7	22.8
Screen analysis (Tyler), %		
+4 mesh	0	—
−4 + 8 mesh	57.5	40.7
−8 + 16 mesh	42.4	59.0
−16 mesh	0.1	0.3

Table 4. COMPARATIVE SUMMARY PRODUCTION OF MONOAMMONIUM PHOSPHATE SULFATE

	Grade	N:P Mole ratio	Pipe temp., °F	Ammonia loading, lb. NH_3/(in^3)-(hr)	Concentration water PCR Weight %	Concentration water PCR Volume %[1]	Ammonia loss, % of ammonia fed
Table 1 (Western USA)	16-20-0-14S	1.0	263	1.02	14	65	1.5
Table 2 (Western USA)	16-20-0-13S	1.0	260	0.73	30	99	9.4
Table 3 (Piraeus, Greece)	16-20-0-14S	1.0	284	0.83	31	99	7.0+

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[1] Assume two phases: Saturated steam at 267°F and 40 psig and 1.5 specific gravity monoammonium phosphate sulfate melt.

Table 2. PRODUCTION OF MONOAMMONIUM PHOSPHATE USING TVA PIPE-CROSS REACTOR WITH MEDIUM STRENGTH PHOSPHORIC ACID

Western United States Granulation Plant

Nominal grade (mt/hr.)	16-20-0-13S
Production rate, ton/hr	25(22.7)
Granulator size, D × L, ft (m)	10×20(3×6)
PCR diameter, in (cm)	6(15.2)
PCR length, ft (m)	20(6)
Formulation, lb/ton product (kg/mt)	
PCR	
Phosphoric acid (43.5% P_2O_5, 30% H_2O)	789(394.5)
Byproduct ammonium sulfate liquor (7% N, 8% S, 67% H_2O)	430(215)
Sulfuric acid (93% H_2SO_4)	924(462)
Ammonia	364(182)
Water	175(87.5)
Scrubber seal tank slurry (60% H_2O)	140(70)
Total water PCR (calculated)	849(424.5)
Granulator	
Weak acid slurry (23% P_2O_5, 25% $CaSO_4$, 43% H_2O)	265(132.5)
Ammonia	31(15.5)
PCR operating conditions	
Skin temperature, °F (°C)	260(127)
Total, 10^3 Btu/ton (10^3Kcal/mt)	964(268)
Ammonia loading, lb NH_3/hr. in^3	0.73
Mole ratio slurry to PCR	0.4
Mole ratio melt from PCR	1.0
Granulator operating conditions	
Temperature material, °F (°C)	200(93)
Recycle rate, tons/hr (mt/hr)	95(86)
Recycle ratio	3.8
Granulator	
N:P mole ratio	1.0
Airflow, cfm (estimated across bed) (m^3/hr)	15,000(25,485)
Air velocity, ft/sec (m/s)	4.6(1.4)
pH	4.8
Electricity, 10^3 Btu/ton (10^3kcal/mt)	317(88)
Dryer fuel, 10^3 Btu/ton (10^3kcal/mt)	200(55)
Dust loss from granulator (recovered in scrubber), lb/hr (kg/hr)	230(104)
% of total product ton/hr (mt/hr)	0.46(.42)
Ammonia loss from granulator (recovered in scrubber, lb/hr (kg/hr)	930(422)
% of ammonia fed	9.4

Table 3. PRODUCTION OF MONOAMMONIUM PHOSPHATE SULFATE

Hellenic Chemical Products and Fertilizers, Piraeus, Greece, July, 1984

Nominal grade	16-20-0-14S
Actual (formulated) grade	16.4-21.6-0-14.4S
Production rate	
Pressure PCR ton/hr (mt/hr)	28.1(25.5)
Tank preneutralizer ton/hr (mt/hr)	28.1(25.5)
Combined production ton/hr (mt/hr)	56.2(51.0)
Granulator size D × L, ft (m)	10×20(3×6)
PCR diameter, in (cm)	8(20.3)
PCR length, ft (m)	20(6)
Formulation lbs/ton (kg/mt)	
Pressure PCR	
Anhydrous ammonia (liquid)	180.4(90.2)
Phosphoric acid (28% P_2O_5)	670(335)
Sulfuric acid (98% H_2SO_4)	398.3(199.2)
Ammonium sulfate solution (6.3%)	30(15)
Total water to PCR	392.2(196.1)
Tank preneutralizer	
Anhydrous ammonia (liquid)	135.4(67%)
Phosphoric acid (28% P_2O_5)	780(390)
Sulfuric acid (98% H_2SO_4)	305.8(152.9)
Phosphate rock (31.5% P_2O_5)	84(42)
Bed ammoniator granulator	
Dry ammonium sulfate	240(120)
Anhydrous ammonia (vapor)	21(10.5)
Operating conditions	
N:P Mole ratio PCR	1.0
PCR temperature, °F (°C)	284(140)
PCR ammonia loading, lb NH_3/(in^3)-(hr)	0.83
Heat fluxes, Btu/(in^2)-(hr)	
X sectional area	569,000
Slot (¾″ × 48″)	794,000
Ammonia loss, % of NH_3 fed	7.0

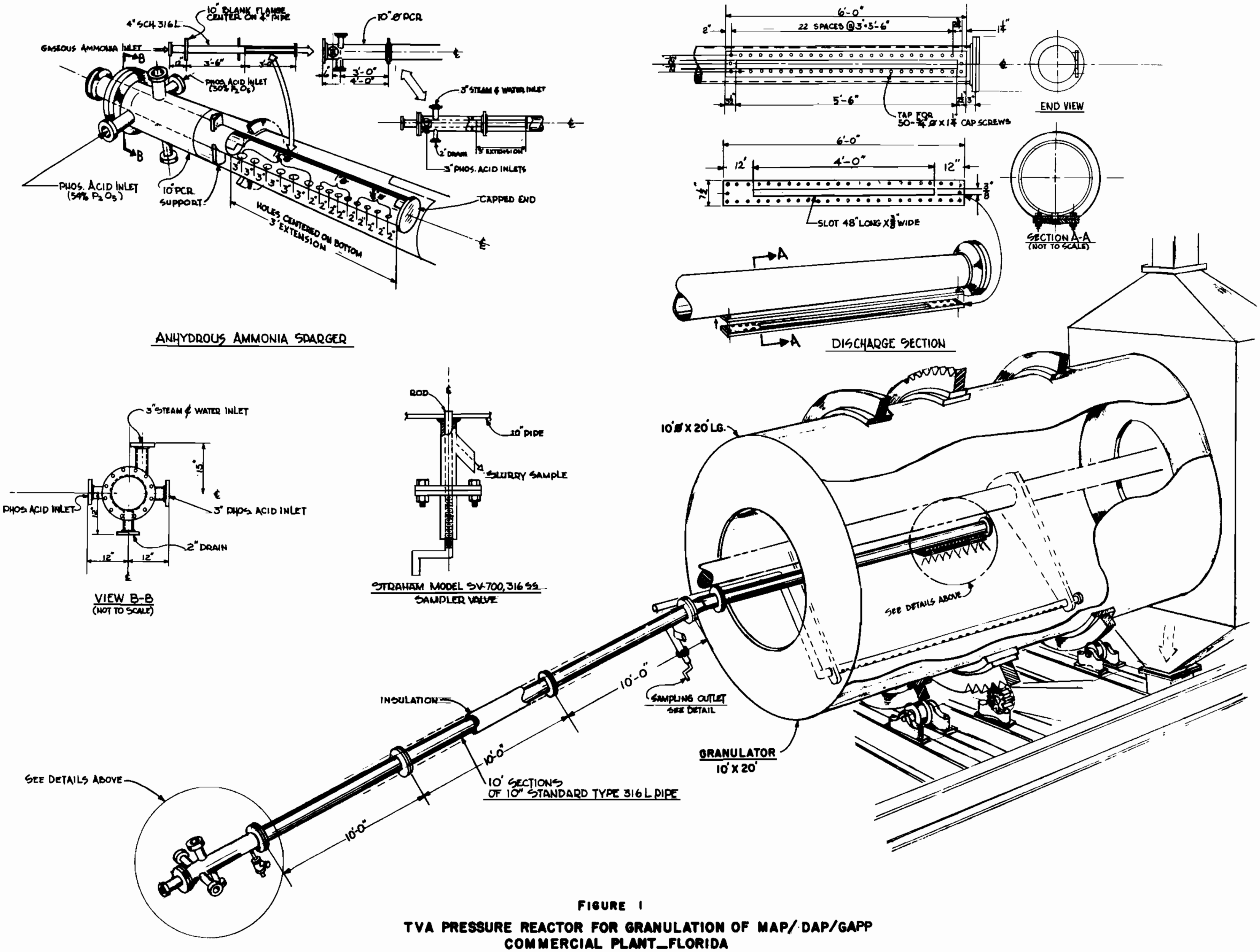

FIGURE 1

TVA PRESSURE REACTOR FOR GRANULATION OF MAP/DAP/GAPP COMMERCIAL PLANT—FLORIDA

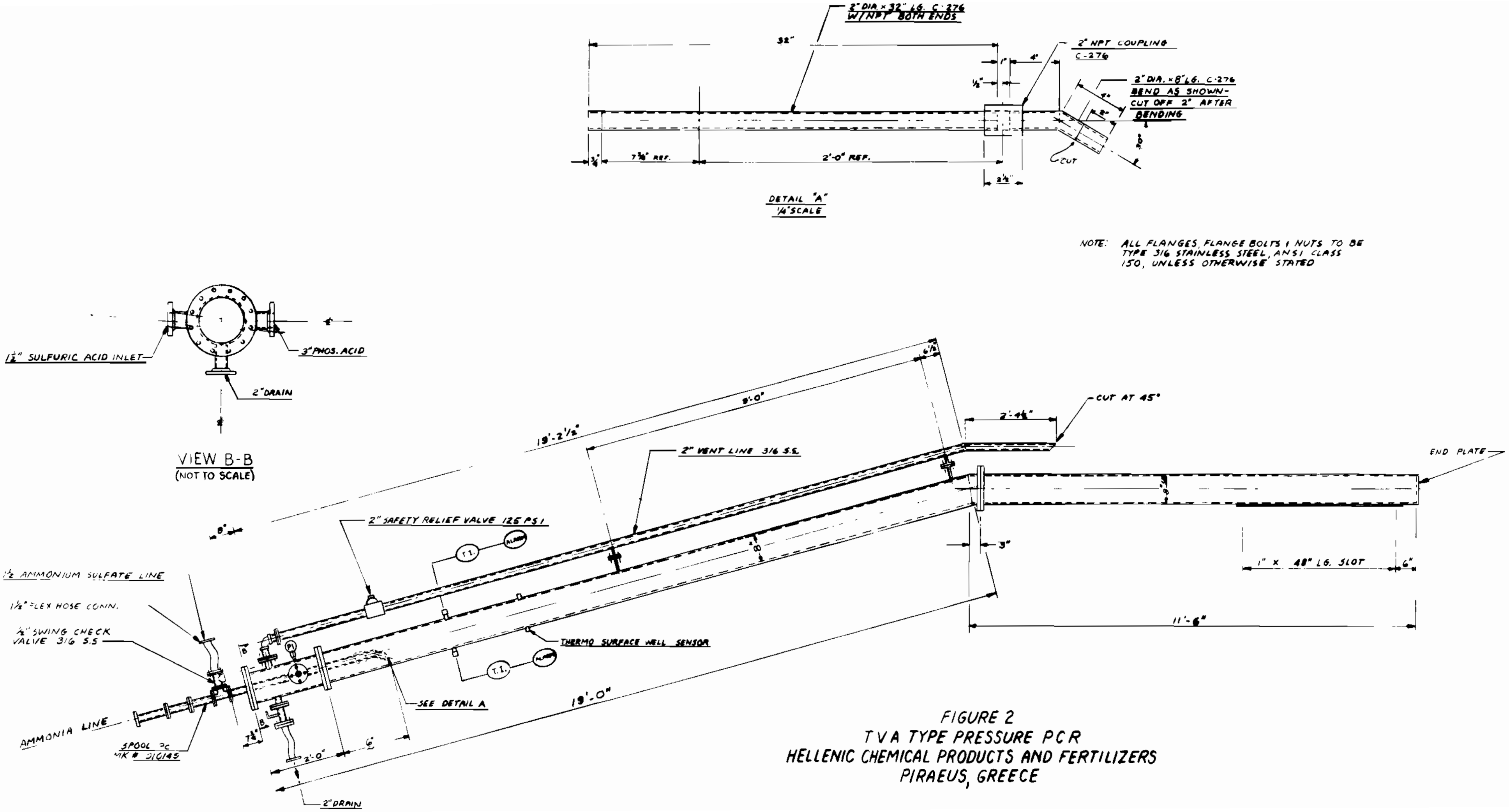

FIGURE 2
TVA TYPE PRESSURE PCR
HELLENIC CHEMICAL PRODUCTS AND FERTILIZERS
PIRAEUS, GREECE
]

Granulation by Computer Simulation A Case Study for DAP-Production by Pipereactor

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The best method to demonstrate the effects of the use of pipereactor is to let it replace the preneutralizer in a conventional T.V.A-type granulation plant. When this is done for the production of DAP, the results are not beneficial at all.

The two major effects of the introduction of a pipereactor are

—a granulation temperature which increases with between 10 and 25 degrees centigrade

—an instability in the ammonia-balance.

The first effect—an increased granulation temperature—is caused by the fact that the pipereactor produces not only a hot slurry, but also water vapour, which has to pass through the granulation drum.

The unstable ammonia-balance is caused by the high temperatures in pipereactor and granulator. Small changes in operating parameters such as water consumption or NH4/PO4-molar ratio on the pipereactor have as a consequence large fluctuations in the amount of ammonia escaping to the scrubber.

Uhde ran into such a situation in 1980 when we started up our first pipereactor plant, with a capacity of 500 MTPD, to produce DAP. The plant was conventional otherwise, except for the fact that the design recycle ratio was 3.0:1.

The plant and the modifications made are described, from the operator's point of view, in a recent paper (1).

One of the authors started at that time a project to prepare heat—and material balances by computer. Five years later Uhde has a granulation process simulation model (GPSM) that with good accuracy predicts operating conditions in granulation plants. The program is described in some detail in reference (2) and some applications are shown in reference (3).

A first version, ready by mid 1981, was used to help us solve the problems in our troubled plant and to help us with the process design and optimization of equipment for a new granulation plant.

It also was used to do consultancy work on a series of plants which, in turn, gave us valuable data.

Here we would like to duplicate the experiment with which we started by a computer simulation.

We take a standard 1000 MTPD DAP-plant (producing 44,5 MTPH) with a granulator of 3.5 × 7.5 m, a drying drum of 4.2 × 33 m and a conveying capacity through the drying drum and over the coarse screens of 250 MTPH, which gives a recycle ratio of 4.5. The air flow through the granulator is assumed to be 10.000 kg/h. This plant has to adhere to a European product specification—93% between 2 and 4 mm—, which makes the drying drum slightly larger than is usual in the USA to reach 1.5 percent moisture in the final product. The feedstocks are phos acid on basis of Jordan Rockphosphate, liquid ammonia, 48 kg/mt sulfuric acid to reach a nutrient content of 18% N and 46% P205 and a specific water feedrate, including the water in the phos acid, of 450 kg per metric ton of product.

The NH4/PO4-molar ratio (MR) in the preneutralizer is kept constant at 1,45 (after the ammonia fixed to sulfate is deducted from total ammonia). The molar ratio ex granulator has to be MR = 1,75.

The most important operating parameters for preneutralizer, granulator, drier and recycle stream as shown in the first column of table 1.

The preneutralizer slurry contains 17.4 percent water, the granulate exit granulator 3.5 percent.

Of the incoming ammonia 81 percent is fed to the preneutralizer, 19 percent to the sparger. Ammonia losses to the scrubbers amount to just over 10 percent. The granulator temperature is 97 degrees centrigrade, 3150 kg water vapour is formed here.

The granulate has a mean particle size of 2.7 mm. The granulation factor

$$\alpha - 50 = \frac{\text{d50 - Granulate}}{\text{d50 - Feed}}$$

is 1.46. Moisture content of product is 1.5 percent.

We now change the preneutralizer into a pipereactor and leave the feeds, including the quantity of process water, as they were. The pipereactor is very wet, with 21.1 percent water at 3 bar pressure and 147 degrees centigrade. This explains the relatively low ammonia loss from the pipereactor. The granulator temperature is, with 106 degrees centigrade, still acceptable, but the moisture content in granulate has increased to 4.8 percent.

This is responsible for the very high granulation factor of 2.4. The mean particle size would, when there were still proper granulation, be some 8 mm. The full set of data is shown in the second column of table 1.

We decide to reduce the process water feedrate, in small steps, to 350 kg of water per metric ton of product.

In reducing the water consumption from 450 to 350 kg/ton the granulator becomes dryer and hotter, increasing from 106 to 115 degrees centigrade, but the granulation factor comes down only slowly. In this operation the ammonia losses to the scrubber increase steeply, making the system more prone to fluctuations.

Nowhere stable operating conditions are obtained.

At a specific water feedrate of 350 kg/ton the conditions change from non-autothermal to autothermal operation, which means that no external heating energy is required for product drying.

The autothermal operation lets the granulator temperature go down with 10°C to 105°C.

Also, otherwise the data look good, with the exception of the granulation factor, which is 1.73. We decide to reduce water further to 310 kg/ton. Now the temperature level increases rapidly, leading to an unstable ammonia-balance (table 1, 3 rd column). Therefore, variations in the ammonia distributions do not lead towards more stable conditions.

All this was done with a specific drier air consumption of 2 kg/kg of final product. We have the impression, that we will do better, when we reduce the airflow to ultimately 1 kg/kg. Now we run into another trap. The drying drum looses in efficiency, since the relative humidity of the drier off gases approaches the critical relative humidity for DAP (75%).

Thus the ability of evaporating water is impaired and as a consequence the moisture content increases throughout the granulation loop (table 1, column 4).

We give up and decide to run the plant at 80 to 90 percent of its nominal capacity, with a higher-recycle ratio, to adjust the granulation factor. The ammonia-balance remains very sensitive, but otherwise conditions are good with a recycle ratio of 5.0:1 (table 1, column 5).

Summarizing

The effects of a pipereactor in the granulation drum are of great complexcity, affecting the design-rules for individual equipment items, such as the granulator and the drying drum. Also, the quantitative effects of one parameter on another are sometimes very surprising. We therefore investigate in somewhat more depth the operational stability of granulation plants.

Stability Considerations

Every operator is regularly reminded of the fact that granulation is an equilibrium process. Even in a well-conceived plant it may happen that the equilibrium parameters are outside the specifications of the equipment or outside the specification of a commercial product.

In the past, granulation plants were designed by using design rules for individual equipment items. Of course were the material—and heatbalance governing the overall design, but interactions in operating conditions were hardly considered.

With our Granulation Process Simulation Model we now can consider such interactions quantitatively. We can calculate the effects of changes in drier dimensions or crushing capacity. But we can also simulate the effects by varying process parameters. By doing this, one at the time and small steps, we can determine the operational stability of a granulation plant. Also it is possible to determine differences between plant concepts.

When we compare the effect of a variation in the molar ratio in the reactor, of a preneutralizer plant and a pipereactor plant we achieve very different results (figure 1). An increasing MR gives a continuously decreasing granulation factor α S/B 50 in a preneutralizer plant. This permits, at the same specific water consumption, a lower recycle ratio—that is a higher production rate. This may be the most important reason, together with viscosity effects, why American producers, over the years, have steadily increased the MR in the preneutralizer.

For the pipereactor plant the granulation factor is relatively constant up to a MR = 1.5, where autothermal operation becomes impossible. In the range from MR = 1.5 to 1.7, where the drying air requires heating, the granulation factor α is again constant, but at a lower level.

We have found four measures to be beneficial in stabilizing a pipereactor plant to produce DAP.

—a separate liquid circuit for the granulator scrubber

—the use of liquid ammonia in the pipereactor

—an "oversized" granulating drum

—control of ventilation air through the granulating drum

In an Uhde brochure (4) a series of process parameters are investigated in detail for a 1000 MTPD-plant designed in accordance with the above mentioned guidelines. They include: pipe reactor pressure, air to granulator, specific process water consumption and ammonia distribution pipereactor / sparger. The interested reader is referred to this paper.

Here we will discuss some of the more salient points. Figures 2 and 3 show the effect of ventilation air through the granulator. It is found that by increasing the amount of air the granulate temperature initially falls rapidly, then declines slowly. With small amounts of air the granulator bed is also too wet, leading to unmanageable granulation factors (figure 3). With excessive amounts of ventilation air the bed is blown dry, which leads to fine and dusty granulation. In this example the preferred range is 10.000 to 20.000 kg/h.

In figures 4 and 5 the distribution of ammonia over the pipereactor and the sparger is varied. Figure 4 shows the effect of the granulate temperature where figure 5 shows the corresponding granulation factor. The conclusion from the data is that, provided that measures are taken to stabilize operation, it is advisable to send as much ammonia to the pipereactor as is compatible with autothermal operating conditions.

Figures 6 and 7 show the differences in some operating conditions when liquid ammonia is replaced by gaseous ammonia. The specific water consumption has been selected to give optimum granulation conditions. The ammonia—distribution changes. The losses from pipereactor and sparger increase. The losses in the case of gaseous ammonia are between 30 and 50% higher, given the same MR's exit pipereactor and granulator. Especially at higher MR-values at non-autothermal conditions, the ammonia efficiency of the pipereactor decreases. In figure 6 the horizontal line indicates a ammonia efficiency of 100%, where the inclined line indicates a ammonia efficiency of 0%, in other words, where all additional ammonia to the pipereactor is lossed to the scrubber. Note also that the ammonia efficiency can be over 100%, as in the case with liquid ammonia at lower MR's.

Figure 7 shows the granulation factor for both cases. Using gaseous ammonia, the steep increase at the lower MR-values is an indication for unstable operating conditions. When operating with gaseous ammonia, the advise for autothermal operation is for the highest possible MR-values, 1.45 to 1.55.

Operation with gaseous ammonia is very sensitive to the waterbalance. One ton of water per hour makes the difference between coarse and fine granulation. Proper control of the density of the feed acid to the pipereactor is a necessity for control over granulating conditions.

Regularly the question is asked: can Uhde's GPSM be used to design a process control system?

We think so. It would require the development of a dynamic version, incorporating response times specific for the plant under consideration.

Such a version would be able to calculate intermediate conditions between equilibrium points, on a time scale. It could be instructed to counteract in order to keep the system operating at or near optimum conditions. It would require sampling and autoanalyzer equipment, which is in part available.

It would take a disproportionate amount of time to conceive such a process control system and it would be costly.

The effect of it could, in our views, not compete with the effect of the stabilizing measures which we have listed above.

Future Developments

We believe to have solved most of the questions concerning the factors that govern granulation. By combining the relevant parts of the granulation theories of Sherrington (5) and van der Leek (6) with our own work, we are able to predict accurately phenomena occuring in the granulation device. Our work concentrates on the relationship between available liquid phase, granulation temperature and the resulting granulation factor.

We have also developed equations to predict mass- and heat transfer in the granulator. From literature and a considerable amount of data taken from a series of granulation plants, we have now a data base for a wide range of fertilizers.

This includes ammonium phosphates, ammonium sulfate-phosphates, ammonium phosphate-nitrates, mixtures of ammonium phosphates with superphosphates and mixtures of ammonium nitrate with superphosphates as well as ternary fertilizers on basis of the raw materials mentioned above.

Our work will lead to a generation of granulation plants with lower recycle ratios and, consequently, smaller handling equipment. When we focus on DAP, we believe that a next generation of granulation plants, equipped with a pipereactor, will operate with a recycle ratio of 2.5 and will have greater operational stability than the present-day preneutralizer plants.

Nevertheless, some questions are still to be answered. The most important one is that of the granulator efficiency.

Granulator efficiency is defined here as the percentage by weight of onsize material available ex granulator. For various types of granulation devices and products it ranges from 30 to 80 percent. For drum granulators and pugmills the particle size distribution over the important range of 15 to 85 weight percent can be fitted accurately by a log-normal distribution function (7):

$$\log y = a_0 + z * a_1$$

where y = the particle diameter
a_0 = log of the mean particle diameter
a_1 = distribution coefficient
z = the number of standard deviations.

(Similarly, particle size distributions produced in a prilling tower or pan granulator fit a normal distribution:
$y = a_0 + z * a_1$):

Unsolved yet is the question which factors influence the value of a_1. An obvious factor is the particle size and the shape of the distribution curve of the recycle material.

An important clue is given in an also otherwise interesting paper by Baykal (8):

> "In the first half of 1982, the screen size of the bottom deck of the product screen was 1.5 mm and 60-65% of the granules was between 1-2 mm. To improve the product quality it was decided to decrease the percentage between 1-2 mm and increase the percentage between 2-4 mm. To do this, the screen size of the bottom deck gradually increased to 2 mm. At the beginning, we thought that the increase in the screen size of the bottom deck will increase the product quality but also decrease the production capacity. But the result was on the opposite side, in other words, our

> production capacity increased by 20%. We understood that, the reason was the increase in the screen size of the bottom deck increased the size of fines which is fed back to the granulator increased the granulation efficiency. As a result, the recycle ratio of the system decreased from 2:1 to 1.5:1, in other words plant capacity increased together with the help of barries which were installed on the top deck as explained above from 1000 tons/day to 1200 tons/day."

We have made the same experience in two recent consultancy jobs on granulation plants with low recycle ratios.

At present we estimate a value of a_1 from actual plant data, obtained from plants engineered by ourselves or from consultancy work done in the last three years.

Values of a_1 are usually in the range of 0.25 to 0.33, but we have operated plants under stable conditions with values as low as 0.20. Figure 8 gives an impression what the effect is on the granulation efficiency. The figure shows that with an a_1 of 0.20 about 55 wt.-% is in the desired range of 2 to 4 mm. This would lead to a recycle ratio of 1.5. At a distribution coefficient of $a_1 = 0.33$ the granulation efficiency decreases towards 35 wt.-% and a resulting recycle ratio of 3:1.

For a future generation of granulation plants the impact may be considerable.

It concerns design and functioning of crushers and product screens. The presently so popular crusher types like flail type crushers and double cagemills may have had their best time.

The predominant reason for their popularity is their performance during upset-conditions.

The reason why they will be abandoned is that they produce an irregular recycle stream with far too much fines.

The first company that had the courage to have their new granulation plant designed with the aid of our computer program, Omnia Fertilizer Ltd. of South Africa, decided to install two hammer-roller crushers. The plant is designed to produced an extremely wide range of fertilizer products, from LAN to high-P205 NPK's.

On Uhde's request the crushers were designed in such way that they could easily be converted to doubled roller crushers. The first crusher was modified six months after initial start-up, the second one somewhat later.

The results show that the modification has a beneficial effect both on output and product quality.

The other large fraction of recycle material originates from the product screens.

In the past we were mostly concerned about the fraction of fines in the product. We are presently involved in setting up a concept that allows the recycle of the smaller granules on the lower end of the product range back to the granulator.

To an audience of predominantly fertilizer producers, one negative aspect of our development work should be mentioned.

In a new generation of granulation plants, designed by Uhde, it will not be possible to double output by debottlenecking and improving operating parameters, as many of the American producers have done with their plants built in the sixties.

The usual safety factors in design and in the specification of handling equipment will permit in future plants to exceed their design capacity by only 15 to maximum 25 percent.

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Table 1. REVIEW OF OPERATING CONDITIONS FOR A GRANULATION PLANT EQUIPPED WITH PRENEUTRALIZER, OR ALTERNATIVELY, PIPE REACTOR

Column		1	2	3	4	5
Type		PN	PCR	PCR	PCR	PCR
Capacity	MTPD	1000	1000	1000	1000	900
Autothermal/Non-autothermal		N	N	A	A	A
Recycle Ratio		4.5:1	4.5:1	4.5:1	4.5:1	5.0:1
Spec. Water Feedrate[1]	kg/mt	450	450	310	350	340
Spec. Airflow to Drier	kg/kg	2	2	2	1	1,13
NH_3 to Scrubber[2]	wt.-%	10.4	15.7	23.0	19.8	20.4
NH_3 to Reactor[2]	wt.-%	81.1	77.1	78.9	76.2	79.2
NH_3-Loss[2]	wt.-%	6.1	8.5	16.2	12.6	14.2
Reactor Temp.	°C	119	147	160	154	156.5
Moisture in Melt	wt.-%	17.4	21.1	12.0	15.3	14.0
Granulator Temp.	°C	97	106	107	106	105
NH_3 to Sparger[2]	wt.-%	18.9	22.9	21.1	23.8	20.8
NH_3-Loss[2]	wt.-%	4.0	6.9	6.5	7.0	6.1
Moisture Ex Granulator	wt.-%	3.54	4.82	2.70	4.24	2.95
Gran. factor α-50	—	14.6	2.37	1.46	2.05	1.49
Drier Air Inlet Temp.	°C	150	158	25	25	25
Moisture Ex Drier	wt.-%	1.50	2.10	1.33	2.75	1.44
Prod. Temp. Ex Drier	°C	80	80	69.0	71.4	73.5
Rel. Humidity Off-gas	%	23	28	26	41	37

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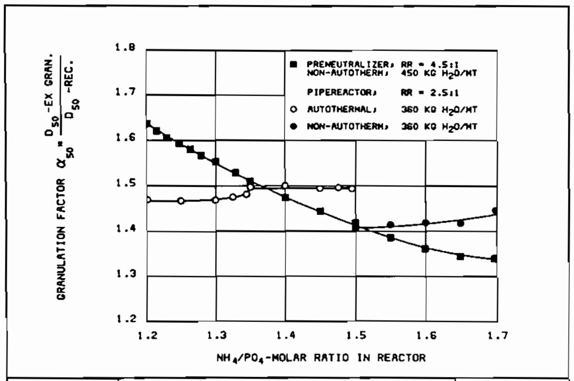
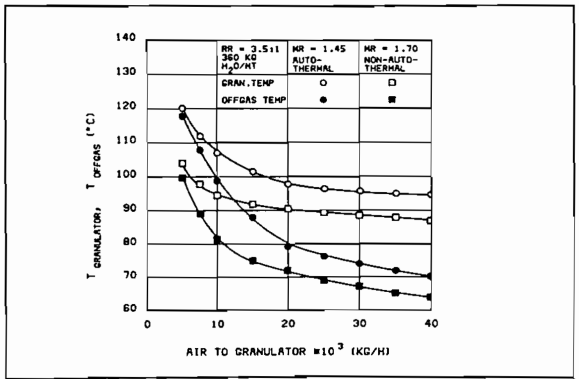
[1] Including water content of phos acid and additional process water.

[2] The ammonia-balance is expressed as a percentage of total ammonia feedrate to plant.



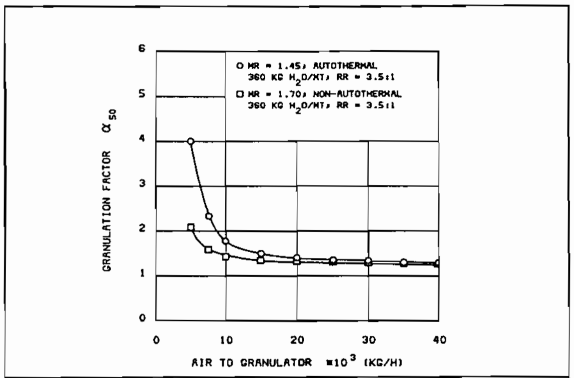
EFFECT OF VARIATION OF THE REACTOR MOLAR RATIO ON THE GRANULATION FACTOR

FIGURE 1



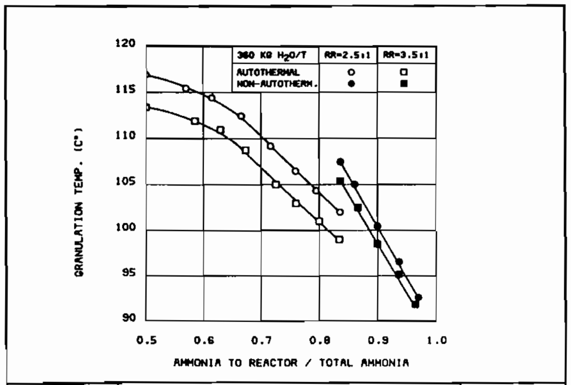
EFFECT OF VARIATION OF AIRFLOW THROUGH THE GRANULATOR ON THE GRANULATION TEMPERATURE

FIGURE 2



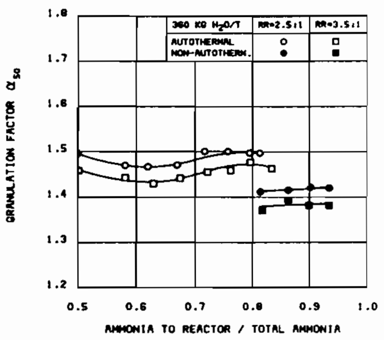
EFFECT OF VARIATION OF AIRFLOW THROUGH THE GRANULATOR ON THE GRANULATION FACTOR

FIGURE 3



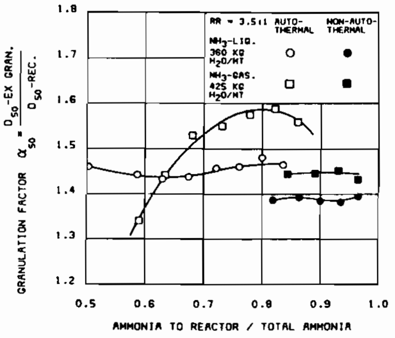
EFFECT OF AMMONIA DISTRIBUTION ON THE GRANULATION TEMPERATURE

FIGURE 4



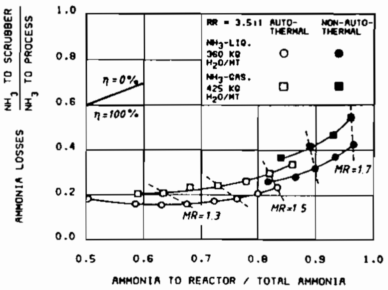
EFFECT OF AMMONIA DISTRIBUTION ON THE GRANULATION FACTOR

FIGURE 5



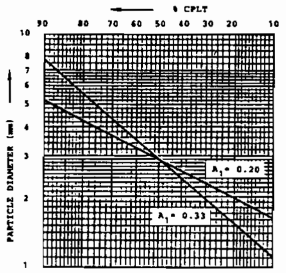
EFFECT OF AMMONIA DISTRIBUTION ON THE GRANULATION FACTOR α USING GASEOUS/LIQUID AMMONIA

FIGURE 7



EFFECT OF AMMONIA DISTRIBUTION ON THE AMMONIA LOSSES TO THE SCRUBBER

FIGURE 6



EFFECT OF DISTRIBUTION COEFFICIENT A_1 ON THE PARTICLE SIZE DISTRIBUTION FOR LOG-NORMAL CURVE

FIGURE 8

Wednesday, October 30, 1985

Afternoon Session
Moderator:

James C. Brown

Fertilizer Application Methods

Rich Fee, Sr.
Crops and soils editor, *Successful Farming*
and
Larry Reichenberger,
Great Plains Regional Editor, *Farm Journal*

By: Rich Fee

I happened to see a segment on television the other night about the retirement of veteran CBS reporter Richard C. Hottelet, one of Edward R. Murrow's original team of broadcasters. Hottelet described his job this way—"Just find out what is going on and tell people about it."

I share that with you hoping it explains why I stand here before you even though I possess no particular expertise about your industry. What I do to support my family—and my addiction to farming—is visit a lot of farmers and agribusiness people each year and sit through scores of meetings. Then I write stories explaining what is going on.

Over the past five or six years, a lot of those stories have dealt with fertilizer placement. A story I wrote last fall on deep placement of dry fertilizer led to an invitation to be here with you today.

I was asked to deal primarily with the equipment aspects of dry placement, so I won't get into the agronomics of fertilizer placement. I would like to say one thing, however. Fertilizer placement was a lot easier to keep abreast of when fertilizer was either broadcast or put on as starter.

The intense interest that's developed in precision placement of nutrients over the past few years has given rise to a host of new terms—dual application, knifed, deep banding, deep placement, preplant banding, surface banding, stripping and dribbling, to name some.

While farmers, equipment manufacturers and fertilizer dealers are scrambling to develop equipment for fertilizer injection and surface banding, researchers are scrambling to find out where it fits and to develop application guidelines.

Although I'm going to concentrate on dry application, I'll open the equipment segment with some slides of liquid injection rigs. They're from a story I did in 1982.

When surface banding and deep placement of P and K started catching the eye of corn growers three or four years ago, liquids quickly became the material of choice. There were several reasons for that. For one, liquid dealers are aggressive marketers. For another, it was relatively easy for local fertilizer dealers and individual farmers to make their own liquid injection rigs by outfitting tillage tools or old anhydrous ammonia applicators with pumps, tanks and modified knives.

Although liquid interests had a head start, people in the dry fertilizer industry are gearing up for more precise fertilizer application. While suspensions are competitively priced in many areas, by and large dry fertilizer is less expensive in most corn-growing regions. That simple fact has some farmers asking dealers for dry injection units. And, it has some dry dealers looking for units which they can either sell or rent to farmers.

As the following slides will demonstrate, there have been a multitude of dry application units introduced recently. There are chisel plow units for fall and spring deep placement with primary tillage, toolbar applicators for minimal disturbance in soybean stubble in the fall or with no-till and ridge-till, planter attachments for spring one-pass systems, and tag-along units for applying urea or even P and K while cultivating. Plus, several fertilizer dealers have purchased floaters equipped with surface banding and injection equipment.

DMI

This is the prototype of a unit DMI, Goodfield, Illinois, is now manufacturing. It consists of a chisel plow and a 7,000-pound-capacity hopper.

Fertilizer is gravity-fed to a ground-driven metering auger. The fertilizer is then metered into large tubes connected to special points attached to the chisel shanks, and knifed-down six to nine inches. (slide unavailable)

This photo shows Iowa farmer Keith Kuhn injecting dry P and K along with NH_3 in the spring of 1983. Kuhn told us he wanted to use the cheapest forms of fertilizer and put them down where they're needed. (slide unavailable)

These next two slides (photo #1) show a similar DMI deep-placement machine set up for no-till, ridge-till or fall use in soybean stubble. Instead of chisel shanks, it is equipped with a coulter and knife assembly for minimal soil disturbance.

These units require 12–15 horsepower per shank.

DMI first began making liquid injection units, but saw that 80% of the market was dry, and there was no way to inject dry when they started testing their machine. That fact, along with requests from people in the dry fertilizer business, prompted them to develop the dry application equipment.

GANDY

Gandy Company, Owatonna, Minnesota, just introduced this air delivery system (photo #2) that can be used with a chisel plow or field cultivator to inject dry fertilizer. The air to move the fertilizer across the implement is supplied by a blower powered by a hydraulic motor. Metering wheels are activated by a ground-wheel drive, so the application rate remains constant regardless of field speed. Capacity ranges up to 4,000 pounds, and more than 300 pounds per acre can be supplied. Gandy also makes a skid-mounted applicator for broadcasting fertilizer as well as granular chemicals and seed. A trailer-mounted version is also available.

CONCORD

Concord of Fargo, North Dakota, makes this air system (photo #3) designed to be used with tillage tools. It has two, 75-bushel tanks so the farmer can apply both fertilizer and seed in the same trip, or a combination of two kinds of fertilizer. The blower unit can be powered by either a diesel engine or a hydraulic motor. In normal situations, the unit can apply up to 400 pounds per acre. Concord also makes a smaller, less expensive two-wheeled version, plus a wide axle model which can be pulled behind a row-crop planter.

THURSTON MANUFACTURING COMPANY

Thurston Manufacturing Company, Thurston, Nebraska, makes this unit (photo #4) for simultaneously injecting dry P and K and anhydrous ammonia. The unit can apply up to 1,000 pounds of fertilizer per acre. It relies on a high volume, but low velocity, stream of air to move fertilizer out to the shanks of the tillage implement. It's powered by a pto-driven hydraulic system. The unit shown holds 3-1/2 tons; both smaller and larger models are available.

This air system was originally developed by Dave Long, an entrepreneur in Ohio. I believe Dave Long helps individual farmers adapt the system to existing tillage tools and planters.

WIL-RICH

This air seeder (photo #5) is a product of Wil-Rich, Wahpeton, North Dakota. It's part drill, part fertilizer applicator and part field cultivator.

Seed and/or fertilizer are metered from the tanks into seed cups. High volume/low pressure air passes through the bottom of the seed cups drawing both the seed and fertilizer through 3/4-inch lines and placing them into the ground behind the shovel points on the field cultivator.

TYLER

Tyler, Benson, Minnesota, started working with pneumatic delivery systems five or six years ago, and have several models on the market.

This wagon-style unit (photo #6) can be pulled behind chisel plows, field cultivators and planters. It costs about $21,000. Tyler hopes fertilizer dealers will purchase these and rent them to farmers.

This unit hooks to the tractor, and has a 3-pt. hitch in back to pull tillage implements. In this slide, it is being used to simultaneously inject dry fertilizer and anhydrous ammonia.

With both units, fertilizer is divided into eight compartments before entering the air stream.

Tyler also makes a pneumatic fertilizer cart with a 40-foot boom for broadcasting fertilizer, including materials impregnated with herbicides. The unit can be converted to surface banding also.

Tyler makes this floater (photo #7) with a mid-mounted 60-foot boom. Tyler says the unit has an overlap spreading pattern that eliminates the need for double-spreading when applying fertilizer impregnated with herbicides.

DEMPSTER

Dempster, Beatrice, Nebraska, just introduced this pneumatic machine (photo #8). Fertilizer is augered from the hopper to a couple of metering boxes near the front of the unit, then moved by air to the outlets on the boom, which are 36 inches apart. It's strictly a broadcast unit, although I suppose those fans or deflectors at the end of the tubes could be removed so that the machine would surface band.

Dempster also makes a trailer-mounted *liquid* unit for deep placement, and believes that ease-of-handling will continue to give liquid the edge in the injection market.

LOR-AL

This unit (photo #9) is made by Lor-Al Corporation, Benson, Minnesota. I believe they were the first U.S. company to offer a pneumatic truck-mounted fertilizer spreader.

I don't have a slide of it, but in 1983 Lor-Al introduced a trailer-mounted model to be pulled with a farm tractor. That unit can be used alone to broadcast or surface band dry fertilizer, or in combination with tillage tools hooked to the back of the trailer.

BIG WHEELS

Big Wheels, Paxton, Illinois, has made pneumatic systems since 1983. I believe they make the only truck-mounted deep placement machine for *dry* fertilizer. This rig (photo #10) is designed to perform secondary tillage while injecting dry fertilizer. It can also be equipped to simultaneously inject anhydrous ammonia.

Big Wheels also makes this pneumatic unit (photo #11) for applying dry fertilizer on the surface. I believe this unit can also be equipped with a 400-gallon tank to simultaneously apply liquid herbicide.

Big Wheels says their pneumatic offers two advantages over the spinners. One, it doesn't cause as much product segregation and, two, it gives more uniform coverage. However, the dry boom can be dropped off and spinners put on to spread lime or high rates of fertilizer where precision isn't as important.

HAWK EYE, INC.

Hawk Eye, Inc., of West Lafayette, Indiana, developed this unique banding unit (photo #12) in 1983, but I don't believe they're making any now. It was able to lay down four-inch wide strips of fertilizer at 16 miles per hour. Because of a slit running diagonally the length of the conveyor trough, each pocket on the conveyor chain dropped its cargo at a different spot, theoretically overcoming segregation problems.

HARLAN

Harlan Manufacturing Co., Harlan, Iowa, began marketing this heavy-duty counter/knife assembly (photo #13) for injecting dry fertilizer below the seed in minimum tillage and no-till planting situations this year. A similar liquid unit was available last year. Many of the conventional starter fertilizer assemblies simply won't penetrate hard ground more than an inch or two, whereas this unit will place dry material down 4–5 inches. These units cost approximately $225 per row.

YETTER MANUFACTURING

Yetter Manufacturing, Colchester, Illinois, also makes a heavy-duty unit (photo #14) for applying dry fertilizer with the planter. Besides placing the fertilizer deeper than is possible with most conventional double-disk start attachments, they also disturb less soil. These units list for approximately $250 per row.

M & H SERVICES

M & H Services, Mount Pleasant, Iowa, manufacture this farmer-designed coulter-knife assembly for deep placing dry starter in no-till conditions. (slide unavailable)

SOIL TEQ, INC.

Soil Teq, Inc., a Waconia, Minnesota, consulting firm, has developed a system that uses computerized soil maps and radar guidance to adjust fertilizer rates and blends as the applicator crosses the field. First, digitized soil maps are made from infrared photographs of fields. Then soil samples are taken from the three major soil types in each field. At application time, the custom operator enters the desired fertilizer rates for each soil type into a computer. Two radio repeaters are set in the field to give the microprocessor coordinates for the machine's location.

From these coordinates and the digitized map, the microprocessor deciphers which blend or rate of fertilizer is needed for the particular soil it is passing over and meters it over the field.

CENEX, a regional cooperative in the northern Corn Belt, helped developed the system, and several CENEX co-ops plan to use the system this fall. The service was expected to cost $1–$2 an acre more than current custom application rates. (slide unavailable)

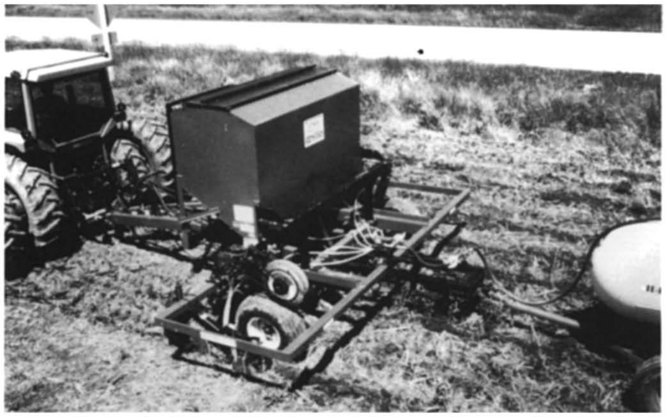
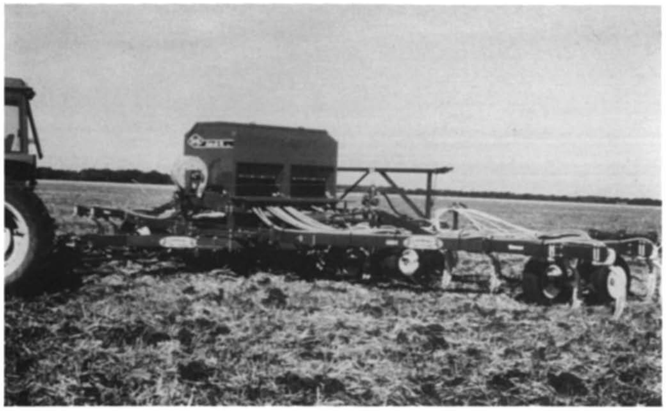


Photo #1



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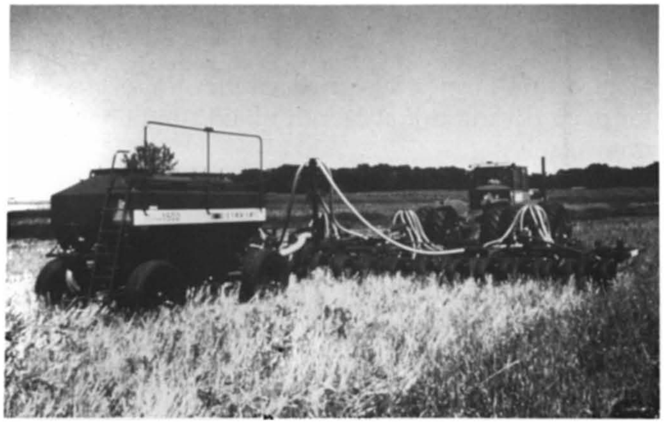


Photo #3

Photo #4

Photo #5

Photo #6

Photo #7

Photo #8

Photo #9

Photo #10

Photo #11

Photo #12

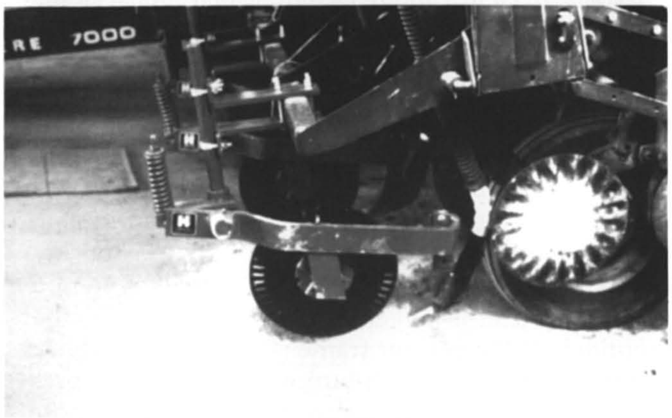


Photo #13

Photo #14

By:Larry Reichenberger

Though my topic is fertilizer placement, I'm going to talk first about no-till and conservation tillage because of the key part they play in the growing practice of precision fertilizer placement. A national survey by the Conservation Tillage Information Center indicates that nearly 100 million acres of crop land are now farmed under some type of conservation tillage. No-till is the fastest growing of all these conservation tillage practices. It increased by 20% from 1983 to 1984 to a level of roughly 5% of total crop acres.

That trend is likely to continue according to a recent survey of several thousand farmers. In that study, 80% of the respondents admitted to having reduced tillage operations in the past five years. Another 45% plan to reduce tillage operations even further in the next three years.

Farmers are making those changes for three major reasons, either to reduce soil erosion, cut fuel costs or save soil moisture.

The concerns over soil erosion appear to be well warranted. We're losing more soil now than we did in the Dust Bowl years of the '30's. Erosion robs us of enough soil every year to cover the state of Missouri with a layer an inch thick.

The average erosion loss to water excedes the tolerance level of five tons per acre in 18 states. Tennessee leads the list with annual losses of 14 tons per acre. To put that in perspective, that's slightly less than one cup of soil per square foot. Wind erosion is also wrecking havoc. Soil losses to wind erosion excede the five ton per acre tolerance level in 10 Great Plains states.

There's a growing realization among farmers and crop researchers that, under no-till or conservation tillage programs, immobile crop nutrients tend to accumulate on or near the soil surface compared to conventional tillage where they're physically mixed to the depth of tillage.

(Slide 1) The white bars on these graphs indicate the concentrations of phosphorous and potassium found at various depths in the soil under different tillage programs. Note that with the moldboard plow, nutrients are distributed relatively evenly through the profile while under less intensive tillage programs the nutrients, shown again by the white area of the charts, concentrate nearer to the surface. Finally, under no-till, nearly all the nutrients are concentrated in the top few inches. There's growing agreement among researchers that this stratification of crop nutrients causes greater root density at the surface of soils under no-till or conservation tillage, but whether these different rooting patterns cause a difference in yield is where the agreement ends.

In the northern Great Plains and the Northwest yield response to deep banded fertilizer has been consistent on spring wheat grown under no-till. Results have shown yield increases ranging from 15 to 50% on wheat and barley.

(Slide 2) Agronomists cite the low levels of available phosphorous generally found in Western soils for some of this response. Nutrients placed in the root zone are less likely to be tied up in the soil before they can be absorbed into the plant. Responses have been so significant, in fact, that some agronomists credit deep fertilizer placement with 60% of the success of no-till small grain production.

In other areas of the country, however, the relationship between fertilizer placement and crop yield is more complex. While results with winter wheat are often favorable, they are generally less significant than spring wheat. Results in the Corn Belt are even more controversial.

Despite the controversies, farmers and machinery manufacturers have forged ahead with innovative designs and modifications to deep place fertilizer in concentrated bands either below or beside and below the seed. To date, most of this development has been with liquid application, primarily because it has proven to be more adaptable to inexpensive modification. However, the growing interest in fertilizer placement is spuring innovators to design equipment capable of deep placing dry crop nutrients as well, thereby taking advantage of their generally lower cost.

(Slide 3) Here, for example, is a homemade deep placement rig built by a farmer in Iowa that we recently featured in Farm Journal. This unit injects dry fertilizer in the fall. The farmer uses a controlled traffic pattern in his field so he can plant directly over the fertilizer bands the following spring. The 4,000 pound hopper gravity feeds fertilizer to tubes that run down deep V-shanks mounted on the back of the unit.

(Slide 4) In contrast, here's a homemade liquid system that accomplishes a similar task. Liquid fertilizer is pumped through distribution pods and then piped into the ground behind the shanks of this toolbar. Fertilizer solutions and aqua ammonia can be applied at the same time.

(Slide 5) Most of the enthusiasm over fertilizer placement, however, is for planting time applications. Here's a farmer designed system built around the planter. It injects cold flo NH3 between 30-inch spaced rows.

(Slide 6) Liquid fertilizer is injected four inches deep—roughly two inches below the seed, which is planted in the same operation, and from this same shank. Some innovators are even injecting the NH3 directly below the seed with liquid P and K.

Deep injecting dry fertilizer at the planter or drill presents a couple of challenges. In contrast to liquid systems, dry systems require a wider drop tube for high application rates, capacity is generally more restrictive and transport flexibility is limited. Here's how farmers and manufacturers are solving those problems.

(Slide 7) An Iowa farmer built this shank/coulter arrangement on his 8-row planter to deep place dry fertilizer and found he could use a smaller diameter injection tube if he screened the fertilizer as he filled the hoppers. This smaller tube caused less draft and didn't wear as fast as larger tubes he had used. Tube diameter is approximately 3/4ths an inch.

(Slide 8) Here's another example of a similar design that's built entirely of components readily available off the shelf of local suppliers.

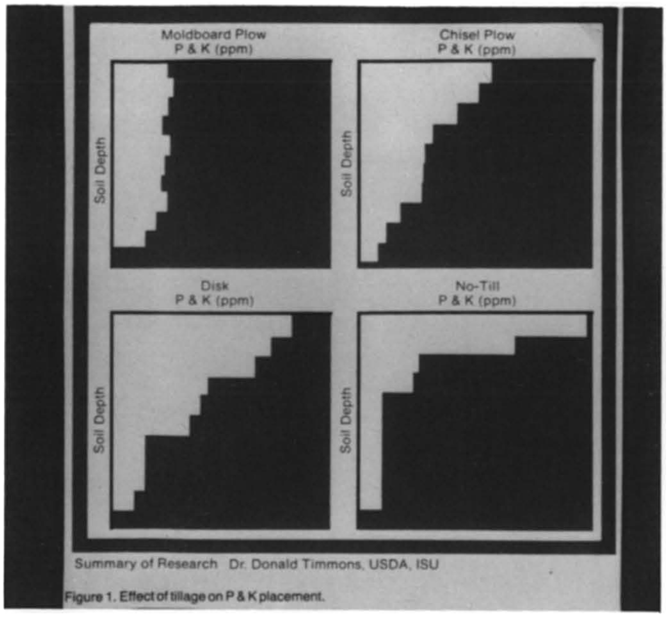
(Slide 9) Dry fertilizer presents a problem to planter transport because the hoppers and augers generally used in gravity flow systems don't fold easily and that's a major problem on row crop planters larger than 8-rows. One alternative is to use an air system, like this Minnesota farmer. Fertilizer is carried in a two wheeled cart pulled behind the planter. Periodically, fertilizer is augered forward into a hopper mounted on the planter frame. From there, fertilizer is augered up into a distribution pod where air pressure blows it to individual rows through flexible hose. To date, however, this practice has met with only limited success because of uneven distribution.

(Slide 10) Here's why farmers remain excited about deep placement. The root system on the right is from a plant receiving deep placed fertilizer. The other received a surface broadcast application. While many agronomists struggle to find consistent yield benefits to deep placement in may areas, proof like this is hard for farmers to ignore.

(Slide 11) Here's a wheat drill that features inexpensive modifications for deep placing liquid fertilizer below the seed. A squeeze pump on this unit delivers fertilizer to a point three inches below the seed release point on the seeding shank.

(Slide 12) The list of commercially available drills capable of deep placing dry or liquid fertilizer is growing rapidly. The Yielder drill, which some of you are probably familiar, is an expensive but very effective example of a drill capable of placing liquid, dry, anhydrous and seed in a single pass.

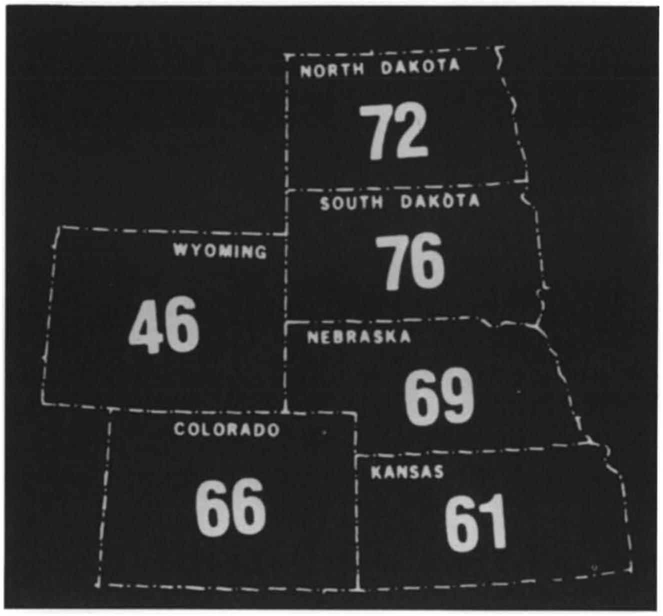
Though Yielder virtually pioneered this technology in the West, a number of manufacturers have now jumped on the bandwagon with perhaps more affordable drills capable of similar applications. And airseeders have also demonstrated their merit as combination seeder/fertilizer placement rigs.



Summary of Research Dr. Donald Timmons, USDA, ISU

Figure 1. Effect of tillage on P & K placement.

Slide 1



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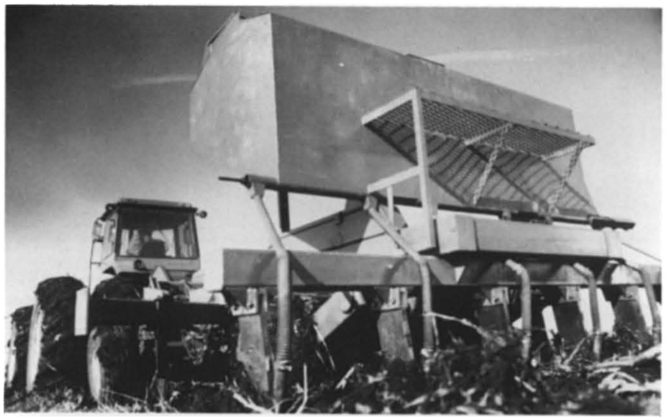

Slide 3

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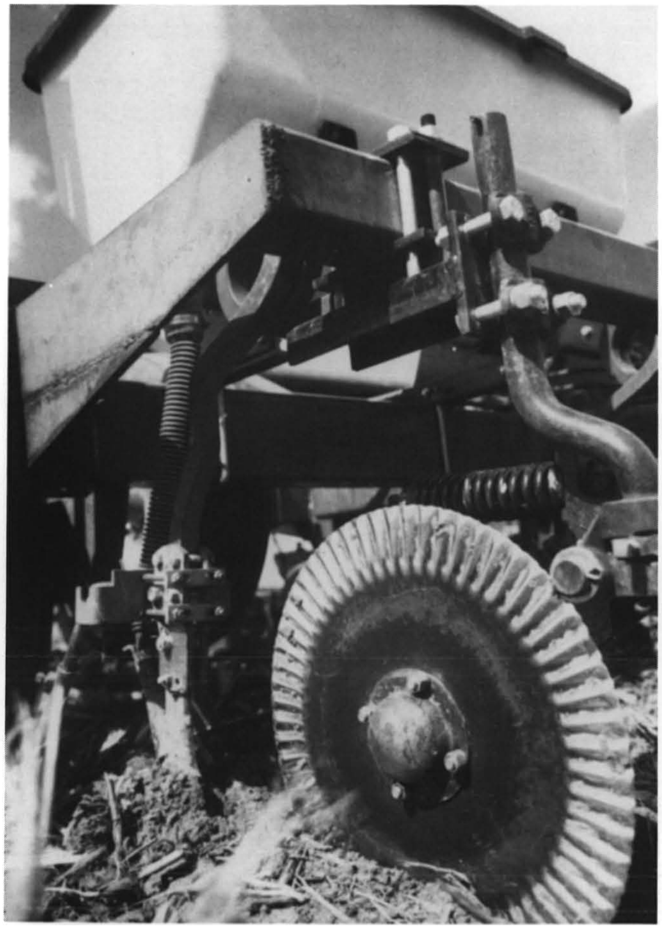

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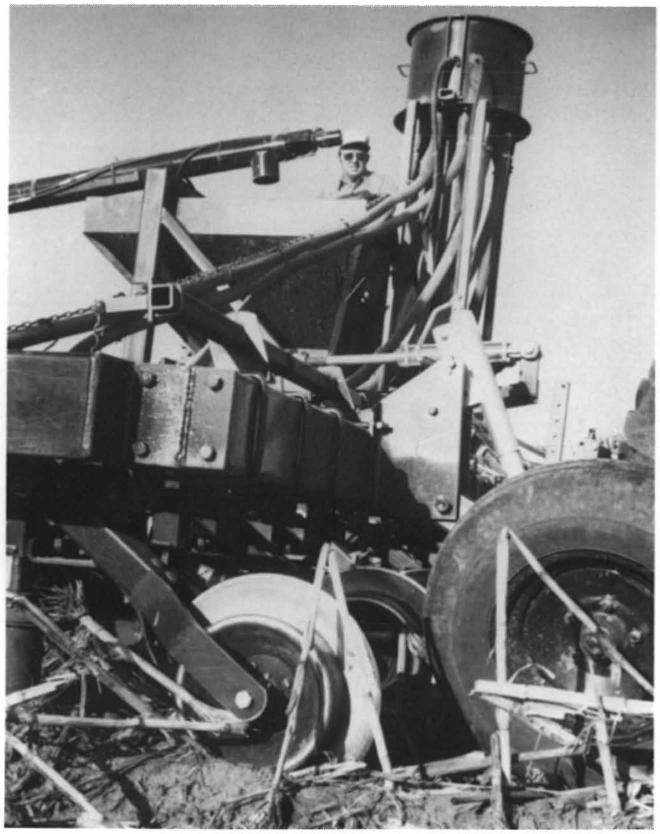

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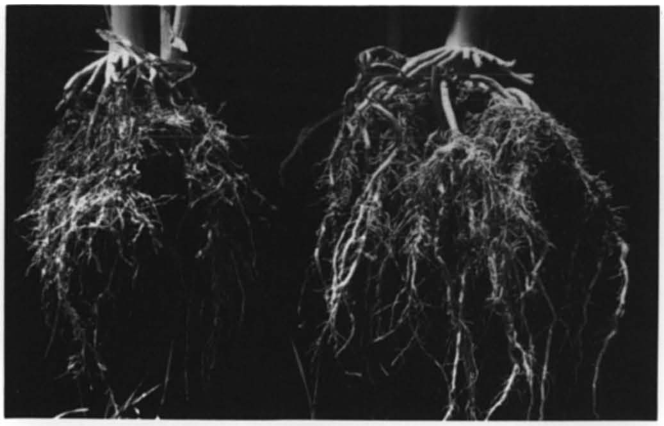

Slide 10

Slide 11

Slide 12

Fertilizer Blending in Ireland*

J.E. Leonard & T.M. Young
Grassland Fertilizers Limited

Introduction

In the Republic of Ireland, 83% of all mixed fertilizers are blended in plants having an annual throughput of up to 250,000 tons and almost 100% of all fertilizer used is distributed in 50 kilo heat-sealed plastic bags which are palletized in 2 ton unit loads and covered with a shrink-wrap plastic film for storage out-of-doors. Due to this unique development for outside storage of finished product, bulk storage capacity for raw materials averages 20%—and in some instances is as low as 6%—of total annual distribution, (i.e. between 5 to 17 transits through store p.a.). Product formulations are standardised and the manufacturer/blender does not provide a spreading service—all fertilizer is sold to merchants and co-operatives, who retail to the farmer.

AGRICULTURE IN THE IRISH ECONOMY

Ireland is an island located on the Western extremity of Europe. Latitude 51 to 55 degrees North. Climate is temperate with no extremes of heat or cold. Soil is generally fertile; rainfall is high and occurs throughout the year.

The population in the Republic of Ireland is 3.5 million; total labour force is 1.3 million, of which 83% are at work, and 16% of the workforce (183,000) are employed in Agriculture.

Land Use

Total land area is 6.89 million hectares (17.0 million acres). Land utilization naturally reflects the type of agricultural activity. Out of a total utilisation of 5.71 million hectares, pasture accounts for 2.93 million hectares (51.3%); hay and silage (for winter feed) 1.24 million hectares (21.7%); arable crops (mainly barley, wheat, sugar beet and potatoes) 0.50 million hectares (8.8%); the remainder being rough grazing and forestry. (Table 1).

Farm Size

The number and size of farms remain fairly constant, a notable feature being the number of small holdings, the average size being 23 hectares (55 acres). Out of a total of 223,300 farms 61% are holdings of less than 20 hectares (50 acres) and only 9% are greater than 50 hectares (125 acres). (Table 1). A further feature is the number of permanently fenced fields—approximate size 2 to 5 hectares (5 to 12 acres).

Agricultural Output

Gross Agricultural Output in 1983 was valued at U.S. $2,690 million, of which livestock and livestock products amount to U.S. $2,290 million (85%). Arable crops (mainly barley, wheat, and sugar beet) account for the remaining 15%.

Production of milk, dairy products, and beef cattle account for 70.3% of G.A.O. (Table 2).

THE FERTILIZER MARKET IN IRELAND

Fertilizer Use:

Fertilizer usage in the Republic of Ireland is approximately 1.7 million tons of product annually—all in the form of dry granular material. One million tons are P.K. and N.P.K. mixes, loosely referred to as "Compounds", of which 83% are blends and 17% are imported complete granular (High Nitrogen) compounds. "Straight" products (mainly Nitrogen in the form of Calcium Ammonium Nitrate and Urea)—account for the remainder.

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*Republic of Ireland (26 Counties).

The "Compounds" (mixes) may be conveniently divided into three product groups, namely:

"P.K." (Binary—containing no Nitrogen).

"N.P.K.—Low N Compounds" (containing less than 20 units of Nitrogen).

"N.P.K.—High N Compounds" (containing more than 20 Units of Nitrogen).

Furthermore, only eight standard formulations account for over 90% of total compounds used. The remainder are mainly "special" N.P.K. grades incorporating Sulphate of Potash (for potatoes) or Boron as trace element. (Table 3). This "standardisation" of products (which owes its origin to the time when Government subsidies were paid on fertilizers and formulations were controlled by the Ministry for Agriculture) facilitates overall planning and efficiency within the industry.

Fertilizer nutrients used during Season 1984/'85 are set out in Table 3. Nitrogen usage, which has steadily increased from 87,000 Tons of N in 1970, reflects intensification in the Beef and Dairy Sector on Ireland's accession to the European Economic Community. This is predicted to level off in the future owing to controls on milk production imposed by E.E.C. Agricultural policy. Following peak demand in 1978 (184,000 m.t. P_2O_5, 221,000 m.t. K_2O) Phosphorus and Potassium usage has fallen and should now remain relatively static at current levels.

Almost 80% of total fertilizer consumption in Ireland is used on grass (pasture, hay and silage), the remainder being applied mainly to cereals, sugar beet, and potatoes.

FERTILIZER BLENDING IN IRELAND

Definition

The definition of 'blended fertilizers' in the Republic of Ireland would be as follows:—

'Blended fertilizers (or "multi component mixes") in Ireland may be defined as the mixing together of evenly sized granular materials (or intermediates), including screened granular Potash, to produce binary or ternary compounds.

These compounds are treated with conditioning agents (to preserve their free-flowing characteristics) and packed in 50 kg. plastic bags which are palletized in 2 ton unit loads and stored out-of-doors for long periods (of up to nine months) before final application on the land.'

Development of Blending in Ireland

Blending had its origin in the late 1960's when corrosion and pollution problems, coupled with the availability of screened granular Potash, made it more economic to blend Granular Triple Superphosphate with Potash to obtain P.K. formulations, rather than granulating the powdered materials.

Furthermore, three chemical N.P.K. plants were commissioned by the established producers in Ireland during the mid-1960's which produced high quality Concentrated Compound Fertilizers (C.C.F.'s).

Grassland Fertilizers Limited, which commenced operations in 1964 by mixing powder compounds (Ammonium Sulphate, Single Superphosphate and Potash), built a small steam-granulation plant (based on dry input materials) in 1969, when powder mixing became obsolete. Increased demand for high quality granular fertilizers saw this company developing the technique of producing granulated N.P.K. "bases" on their Granulation Plant, for blending with granular M.A.P., D.A.P., and N.P. intermediates, which effectively competed with the C.C.F.'s. In the mid-1970's, following the world oil and phosphate commodity price crises, the Irish Market suffered a sharp decline in fertilizer demand, particularly in Phosphate. As the decade progressed, most of the C.C.F. capacity was shut down for economic reasons and blending became the logical alternative. The last remaining chemical compound plant was closed in 1983.

There are now eight blending plants in the country, with annual output ranging between 50,000 to 250,000 metric tons. These are operated by six companies, three of whom supply over 70% of the market.

TYPICAL BLENDING OPERATIONS IN IRELAND

A typical blending operation in Ireland consists of the following facilities:

—Multi-bay raw material storage, some with automatic intake equipment.

—Continuous batching system, fed by front-end loader.

—Coating, mixing, screening.

—Bagging Plant—one or two 60 T.P.H. lines (some with automatic bag presenter), and heat sealer.

—Automatic palletizer and shrink-wrap oven.

—Out-door storage facilities for palletized finished product.

(Figures 1 & 2).

Raw Materials

The finished products are mostly standard formulae.

The materials (all granular) used in blending include:—

Ammonium Phosphates—D.A.P./M.A.P.
Superphosphates—T.S.P./S.S.P.
Ammonium Phosphate Nitrates—N.P. Bases, e.g. 30.10.0; 26.14.0. etc.
Calcium Ammonium Nitrate—C.A.N. 27½% N,

Ammonium Sulphate Nitrate—A.S.N. 26% N; 14% S.
Potash, Screened—M.O.P./S.O.P.
Granular Urea.
Trace element: Boron (usually incorporated in a granulated base).

Problems of segregation will occur if U.S. size materials (e.g. T.S.P./D.A.P.) are mixed with European or North African size materials so the blender tends to obtain materials from a constant supply source. With the exception of Calcium Ammonium Nitrate from the domestic state-owned Nitrogen producer, all materials used are imported from Northern and Western Europe, North Africa and the U.S.

Blending plants are located at—or convenient to—ports, and ships of 2,500 to 3,500 T.D.W. are preferred, the exception being larger vessels of 10,000 to 15,000 T.D.W. from the U.S.

Following is a description of a 60 T.P.H. Blending Unit in Ireland

Ships are discharged by grab crane to a quayside hopper and into suitably covered trucks for transport to the factory.

Raw Materials intake system (optional)

A typical system consists of a hopper at ground level into which a truck of 30 ton capacity discharges. The intake hopper is covered by a 2 inch grid to separate large lumps of material to prevent blockage of the system. The material is elevated by a positive discharge chain and bucket type elevator on to a conveyor belt with throw-off unit to discharge into selected bays in the store.

One of the advantages of this type of external intake system is that the discharging raw material trucks are kept outside allowing the payloader unhindered access when feeding the plant inside the store.

Batching System

Most blending plants have a continuous batching system, there are three main types in use namely:

(i) Volumetric,
(ii) Continuous Belt Weighers, and
(iii) Constant rate feeders.

(i) *Volumetric System*

In this system the various materials are measured out volumetrically from separate hoppers, the discharge gate openings of which are set in fixed position to deliver the correct weight of materials onto a collector belt. The opening is determined by the percentage required in the formulation and the bulk density of the material. This system is not regarded as the most accurate, since bulk density can change with granule size, but such systems are successfully used in Ireland.

(ii) *Continuous Belt Weighers*

Materials are fed from hoppers onto fixed speed weighbelts. These belt weighers can sense weight changes and transmit a signal to adjust the hopper gate opening to compensate thus, they are continuously and automatically self adjusting. Such a system, whether controlled pneumatically or electronically, is very accurate—normally ± 1%, and safeguards can be built in to automatically shut down the system if, for some reason, the correct weight of material is not being delivered, for example, lumps blocking the discharge gates, or the feed hopper emptying.

(iii) *Constant Rate Feeders*

The hopper gate opening is fixed and the belt speed is continuously variable, (unlike continuous belt weighers where the gate opening is variable and the belt speed fixed). The control system (normally electronic) measures the required output by weighing the amount of material on the belt and adjusting belt motor speed to give the required output. This system is the most accurate of those described (±0.5%). The controlling mechanism consists of an electronic load cell to provide continuous data on weights of material to a controller. Each belt has its own separate controller and these are set to give the desired blend ratio. All are tied in to a "group controller" which may be preset to give a range of plant outputs.

Experience has shown that at least four hoppers are needed to give adequate flexibility with regard to raw material/product formulations.

From the collector conveyor, which is common to all systems, the proportioned mix is normally fed through the coating unit for further mixing and conditioning to prevent the blend from caking during subsequent storage.

Coating Unit

The coating unit consists of a simple rotary drum (approximate dimensions 16 ft. × 6 ft. diameter at speeds of 6–10 r.p.m., at an angle of 5 degrees) with no flights and no ribs in which the product is gently rolled in a continuous motion. Oil, at 80°C, is sprayed on followed by application of a very fine inert clay which is introduced into the drum by screw conveyor. Typical application rates would be 0.3% Oil plus 1.0% Clay.

Traditionally, fuel oil was used but its limitations are gradually becoming apparent, together with adverse farmer reaction to undesirable side effects (colour, odour, etc), consequently the industry in Ireland is changing to single fraction lubrication oils, which are much more effective, and easier to handle and apply.

Three types of clays may be used—China Clay, Ball Clay, and Talc. All are very fine, in the range 1 to 10 microns, and when applied with good quality oil gives the storage properties required for long term storage in bags. If the product is stored for a long period of time, there is a tendency towards clay fall-off, which in turn gives rise to farmer complaints concerning dusty products. Fertilizer granules are porous and each raw material used has a different porosity, therefore, oil is absorbed to a varying degree by different materials, resulting in varying rates of clay fall-off. The choice of coating oil is, therefore, critical—if clay fall-off is excessive then the product becomes "dusty", the anti-caking efficiency is affected, and the products free-flowing properties can be impaired.

Blended oils are not recommended as the lighter oil fraction will be absorbed quickly. Neither can heavy single fraction oils (or waxes) be used as these cannot be uniformly applied because they solidify too quickly when sprayed onto cold granules. The best compromise is a medium single fraction oil which can be applied uniformly onto cold granules, even if some absorption does occur with time.

Screening

From the coating/mixing drum, material is elevated onto one end of a horizontal vibrating screen. Product passes down into a holding hopper (over the bagging plant) and oversize (above 5 mm) travels to full length of the screen and down an "oversize" chute. Screen size required for a 60 tonne per hour plant is 8 ft. × 4 ft. The screen is mounted on springs and vibrated by means of two motors attached to the screen sides. These motors have eccentric weights attached which may be altered to change the intensity of vibration.

Fines are not screened out—the imported blend ingredients are purchased to specification and are screened at source, therefore, fines are not normally present in sufficient quantity to warrant further screening.

Bagging Unit

The bagging unit consists of a product hopper (10 to 30 tons capacity), feeding one (or two) 50 kg. weighers which discharge into one bag spout. Practically all product is bagged in 50 kg. bags.

The more modern weighers can achieve outputs of up to 20 weighments per minute (60 T.P.Hour), and are extremely accurate (±20 grams in 50 kgs. or 0.04%). The weighbucket is mounted on a load cell which is connected to an electronic controller. These weighers are self checking and self correcting; they can be set to check any range of weighments. In this way, the operator can control both accuracy and speed of operation, i.e. a fast operation with few weight checks or a slower operation with totally accurate weights. When two of these weighers are used discharging alternately on a 60 T.P.H. plant then the rate for each weigher is only 10 weighments per minute or half its capacity. This means that up to half the number of weighments can be checked, resulting in extremely accurate weighing.

From the weighers, material may be discharged directly into bags, or into a bag spout where the weighment can be held before discharge into the bag. The advantage of the latter system is two fold—(1) the material is dropped from a shorter height into the bag and (2) the discharged weigher can be refilling while the previous weighment is held in the bag spout or being transferred from the spout into the bag. Such bag spouts are normally fitted with a dust extraction system to reduce dust levels generally and, of equal importance, to reduce the rate of dust adhesion to the inside of the plastic bag, so that heat sealing can be more effective.

Automatic machinery is available for placing bags onto the bag spout and subsequently feeding to the heat sealer. But these machines demand a "feed" of well packed empty bags with no faults such as blocking, sticking, etc. Their speed of operation tends to be much slower than can be achieved manually, and they require regular maintenance.

Therefore, in general, manual bagging is still preferred in Ireland, and apart from the use of some bag placing machines, there are no sophisticated automatic bagging machines in operation.

Bags used are polyethylene. Thickness varies from 700 to 1,000 gauge (175 to 250 microns) depending on the product and the application. Once filled, each bag is vibrated (to "settle" the material and expel air) and then fed to a heat sealer where bags are sealed by squeezing between two heated bands. Seal cooling is normally by water cooled blocks or air blowing.

Palletizing

All bagged product in Ireland is palletized on wooden pallets (5 ft. × 4 ft.). In the past this was done manually but the modern requirements of pallet stability and better presentation together with high wage costs have resulted in complete changeover to automatic palletization.

There are many types of palletizers on the market but all have essentially similar features.

All pallet loads in Ireland with the exception of Urea, are two tonnes—eight rows of five bags. (Urea is palletized in 1½ tonne loads). The five bags are positioned by a turning head or other similar device. Each layer consists of three bags at right angles and two bags lengthwise. Some manufacturers like to position these bags so that all top seals face inwards. This results in better presentation and also protects against product spillage in the event of there being any weakness in the top seal.

Each layer of bags is transferred onto the pallet in one operation. Each alternate layer is the mirror image of the previous one so that when placed on the pallet one bag overlaps two bags above and below thereby creating an interlocking effect and improving pallet stability. Bags contain microholes and it is common to pass these through a bag press prior to palletizing and to press each layer when placed in position on the pallet. Some manufacturers also use a press to compress the finished pallet. The application of all this pressure at various stages ensures that all trapped air is driven out through the microholes, resulting in a very stable pallet. This is absolutely essential as the pallets are subsequently driven over uneven yard and road surfaces.

Storage

The final palletised load is shrinkwrapped, i.e. covered with a plastic hood—normally 300–400 gauge (75–100 microns) which is then heat shrunk in an oven or tunnel at 120 degrees Centrigrade. This treatment gives weather protection during subsequent outside storage as well as giving added stability during transit. Some manufacturers also use a bonding agent to hold the layers of bags together but this is not widespread. (It also presents difficulties to farmers removing the bags later).

As Irish blending plants are operated practically all year round and the offtake season is very short, very high stock levels are built up. It would be impractical and very expensive to have covered storage for such high volumes, therefore, all product storage is outside. Even though weather conditions are variable and sometimes very wet and windy, there is no deterioration of product. This is largely due to the fact that the packaging system employed is geared towards this subsequent storage, and the protection provided is adequate for our winter conditions.

Some problems arise when weather conditions are abnormal or longer storage is required. Ammonium Nitrate containing materials are widely used and these are subject to breakdown in warm weather. Although air temperatures in Ireland never reach the transition temperature (Phase III to Phase II) of Ammonium Nitrate, heat can be concentrated inside the bags, and the temperature inside the bag can be substantially higher than the outside air temperature. Therefore, even in a country like Ireland, with maximum temperature of 27 or 28°C, protection against a breakdown is necessary. This is normally achieved by the use of opaque bags and white or UV inhibited shrink wrap covers. These treatments in themselves weaken the plastic and leave it more susceptible to degradation with time, so the extent of protection is normally a compromise between protection and longevity. The idea would be to protect the material well and hope it will be used before plastic degradation can occur.

DISTRIBUTION NETWORK

All fertilizer is sold by the manufacturer to Wholesale Merchants and Co-Operatives who, like the manufacturer, invariably have fork-lift equipment to handle palletised goods. The pallet is charged out to the customer, who receives credit on its return. Approximately 80% of the fertilizer is dispatched to the farm on pallets where the bags are usually removed from the pallet on arrival. At present almost all fertilizer is handled on the farm in 50 kg 'free bags'.

Advantages and disadvantages of this system of 50 kg. plastic bags, palletised in 2 ton unit loads, may be summarized as follows:

Advantages:

1. The manufacturer can 'convert' dry granular raw materials directly from the plant to the 'bagged state' without incurring the expense of intermediate bulk storage.
2. The system of handling and distribution can be 'streamlined'. A greater volume can be handled and stored with less labour thus improving overall productivity and efficiency.
3. This method is most suitable for our climatic conditions. The conventional heat sealed plastic bag offers sufficient protection from the atmosphere to obviate moisture pick-up by the material—thus prolonging the shelf-life of the product.
4. There are no segregation problems once in the bag and blend components are evenly sized.
5. The product can be packed two tonnes per pallet which can be safely stacked 3 (in some cases 4) pallets high. Pallets measure 5 ft. × 4 ft. thus 6 to 8 tonnes can be stored in an uncovered area of 20 square feet.
6. Storing the bagged product in the open saves the expense of covered storage. The product can also be moved to Merchants/Co-Operative's premises and onto farm headlands outside the peak season.
7. This method facilitates transport by road and rail.
8. As far as the retailer and farmer are concerned, the 50 kg. bag, pellet, and mechanical handling equipment are largely 'conventional' when other types of farm supplies and products are considered.
9. Having regard to farm size and activity at farm level this system is most suited to Irish conditions.

Disadvantages:

1. The manufacturer has to invest in pallets, and maintain specialized equipment for palletizing and handling.
2. The pallet is returnable and problems associated with its consignment and eventual return to, and repair by, the manufacturer must be faced. Thus cost of administration is high.
3. The modern pallet is heavy for the farmer to handle and the cost of specialized equipment for handling bags on pellets is prohibitive to most farmers.
4. The human (physical) and time (cost) factors in handling 50 kg. bags on the farm and into the spreader.

In short, having regard to the 'seasonality' of the industry and the high volume/high output plants (approximately 75% of fertilizers are applied over a 10 week period during February to May) this system has proven to be an ideal intermediate storage medium between manufacturer and farmer-user. Furthermore, the distribution network of the Irish fertilizer industry is based on the two-ton (returnable) pallet system and any major change—for example, to bulk or big bags ('I.B.C.'s)—would require considerable investment in intermediate storage and handling equipment, the cost of which would inevitably be passed on to the farmer.

Application

On the grassland, the fertilizer is broadcast by "spinner" (Centrifugal Broadcaster); on grain crops this is normally carried out by combine drill. The quality of the blend must be good. The blend components must be of similar size otherwise segregation can occur during application by spinner resulting in subsequent "striping" in the crop. Spreading tests were carried out to assess the spreading characteristics of blended products. The results of recent trials (Figure 3) clearly show that over the standard 40 ft. spread good blends and C.C.F. fertilizers show similar spreading patterns. Figure 4 shows the uniformity of nutrient spread of two blended fertilizers.

The blend cannot contain oversize which would block the screen on the drill nor can there be too much dust which would build up and restrict the drill hole, particularly in humid conditions.

QUALITY

Quality control standards for manufacture and analysis of fertilizers are rigidly enforced by the Irish Ministry for Agriculture since 1955. (A Government subsidy was paid on fertilizers until 1977). Stringent rules continue to be applied under European Economic Community Regulations. For example, when bagged product is sold to E.E.C. standards the form and quantity of each nutrient must be clearly stated on the bag for control purposes and analyses of the product must conform to specification within narrow tolerances. Furthermore, the Irish fertilizer market is highly competitive and product is sold on price, quality, and service.

Our raw material specifications, to which our suppliers adhere, pay particular attention to the following characteristics:

Moisture,
Granule size and shape,
Granule hardness,
Chemical analysis,
Colour and general appearance.

Stores are not air conditioned and bulk material heaps (all indoor) are covered with plastic sheeting to minimize moisture uptake.

Particular care is taken to ensure that materials when blended will be compatible to avoid deterioration in storage. Test stacks are constantly under surveillance, and, as already mentioned, every bag is date coded to facilitate investigation in the unlikely event of farmer complaint.

In Conclusion:

Ireland is the only country in Europe where compound fertilizer manufacture is 100% based on Blending and the Irish fertilizer industry has devel-

Table 1. REPUBLIC OF IRELAND LAND USE AND FARM SIZE

Land Use

	Hectares (million)	
Total land area	6.89	
Arable crops	0.50	
Hay & Silage	1.24	73%
Pasture	2.93	
Other (incl. rough grazing & forestry)	1.04	
Total utilized area	5.71	

Farm Size

Size Hectares	**Number of Farms (000)**	**%**	
1– 5	33.9	15	61%
5–10	35.4	16	
10–20	67.7	30	
20–50	66.6	30	
Above 50	19.7	9	
Total	223.3	100	

(One Hectare = 2.47 acres)
Source: The Agricultural Institute, Ireland.

oped a most advanced, sophisticated, and inexpensive method of handling bagged fertilizer from factory to farm. Hopefully the experience gained from the Irish system will be of benefit, particularly to those countries where a fertilizer industry and distribution network are required or are in course of development.

Table 2. REPUBLIC OF IRELAND

Agricultural Output—1983

	U.S.$ Million*	%	
1. Livestock & livestock products			
Milk and dairy products	957	35.5	70.3
Cattle	936	34.8	
Pigs	194	7.2	
Other	203	7.5	
Total livestock & livestock products	2,290	85.0	
2. Arable crops			
Barley	135	5.0	
Wheat	46	1.7	
Sugar beet	64	2.4	
Potatoes	32	1.2	
Other crops	123	4.7	
Total crops	400	15.0	
Total gross agricultural output	2,690	100.0	

*Currency conversion: IR.Punt 0.90 to 1 U.S. dollar.
Source: Central Statistics Office, Dublin.

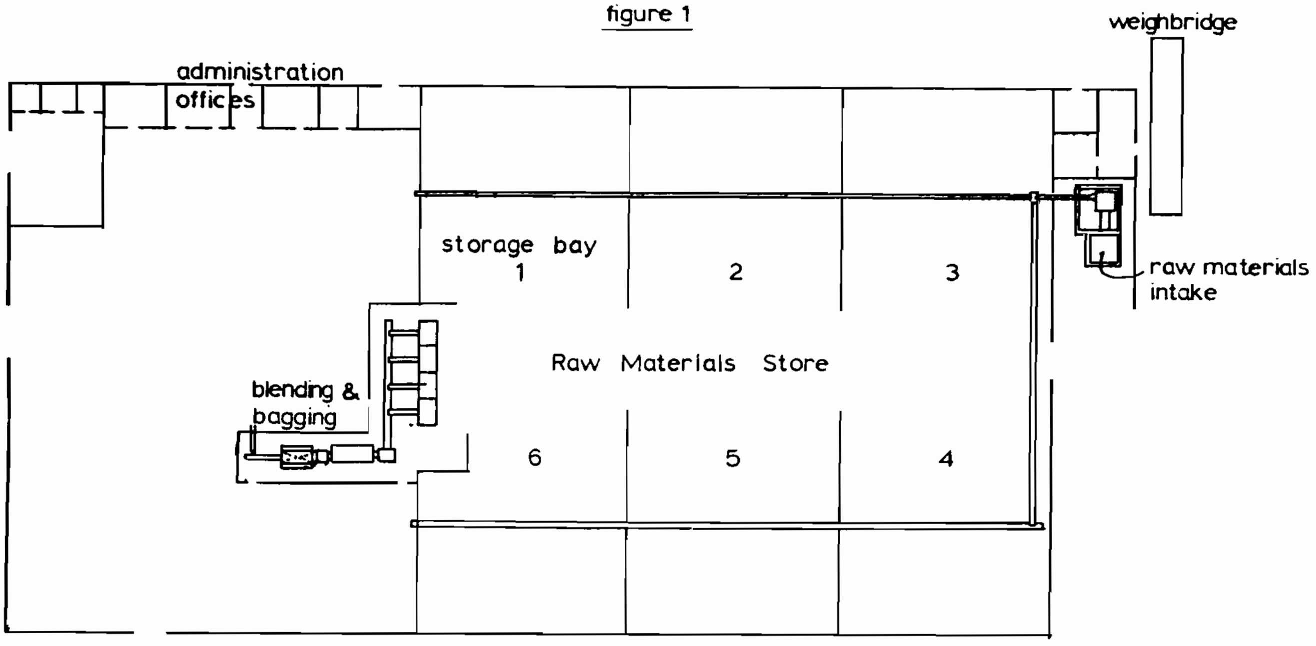
Table 3. REPUBLIC OF IRELAND FERTILIZER USE—1985

Tons of Product

Product Group	M Tons (000)	Products
Compounds & Blends:		
P.K. (binary)	275	*Two*—0-16-36 & 0-23-24
N.P.K. (containing less than 20 units of nitrogen)	470	*Four*—18-14-14; 14-16-16; 10-23-24 & 9-14-18 +B account for 85%.
High N (containing more than 20 units of nitrogen)	280	*Two*—24-6-12 & 27-6-6 account for 98%.
Total compounds & blends	1,025	83% blends
'Straight' products	660	Mainly calcium ammonium nitrate & urea
Total tons of product	1,685	

Tons of Nutrients	M Tons (000)
Nitrogen—	
In form of 'straight' fertilizer	192.0
In compounds & blends	135.7
Total nitrogen	327.7
P_2O_5	151.2
K_2O	196.6
Total nutrients	675.5

figure 1



FERTILIZER BLENDING/BAGGING PLANT

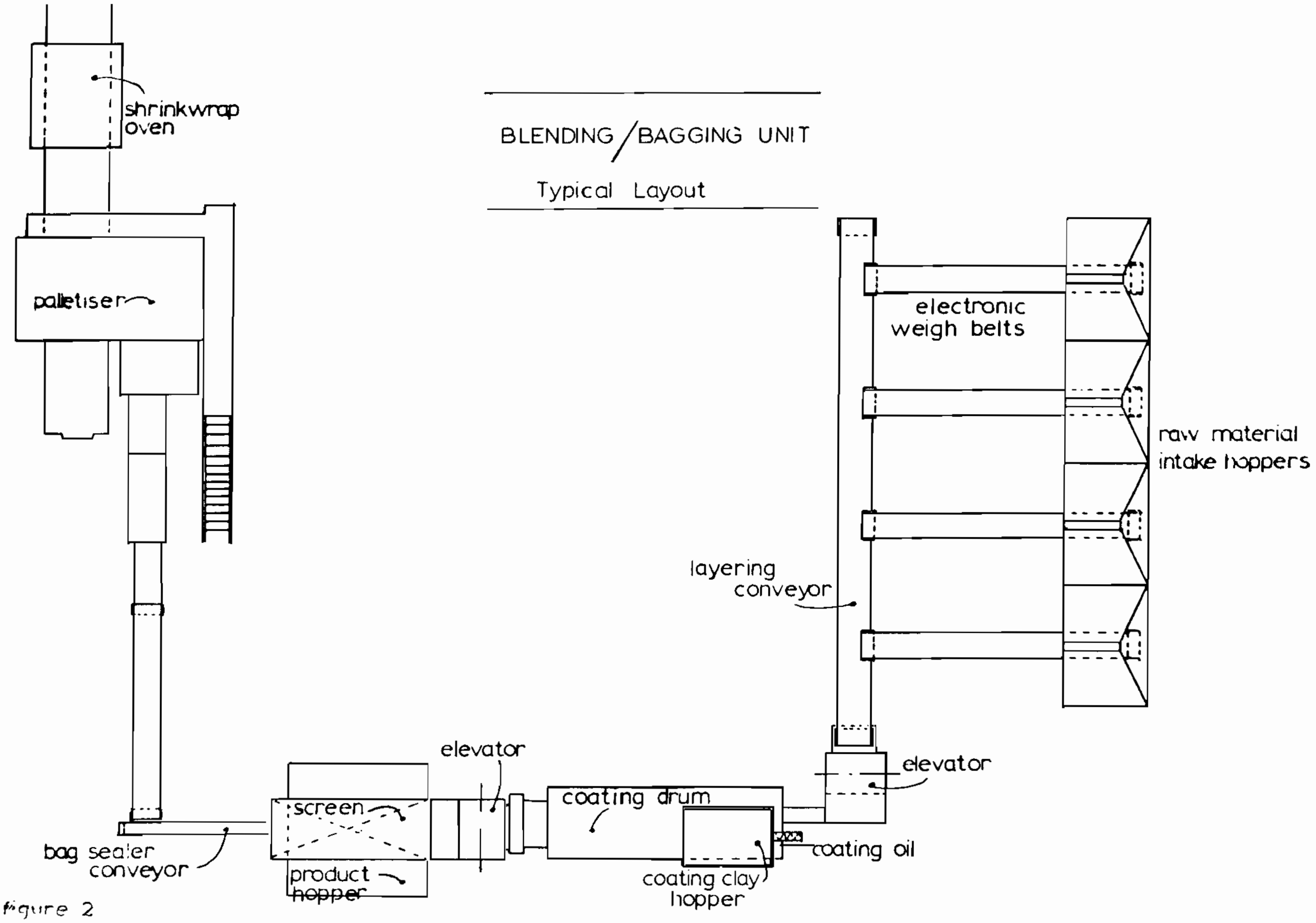


figure 2

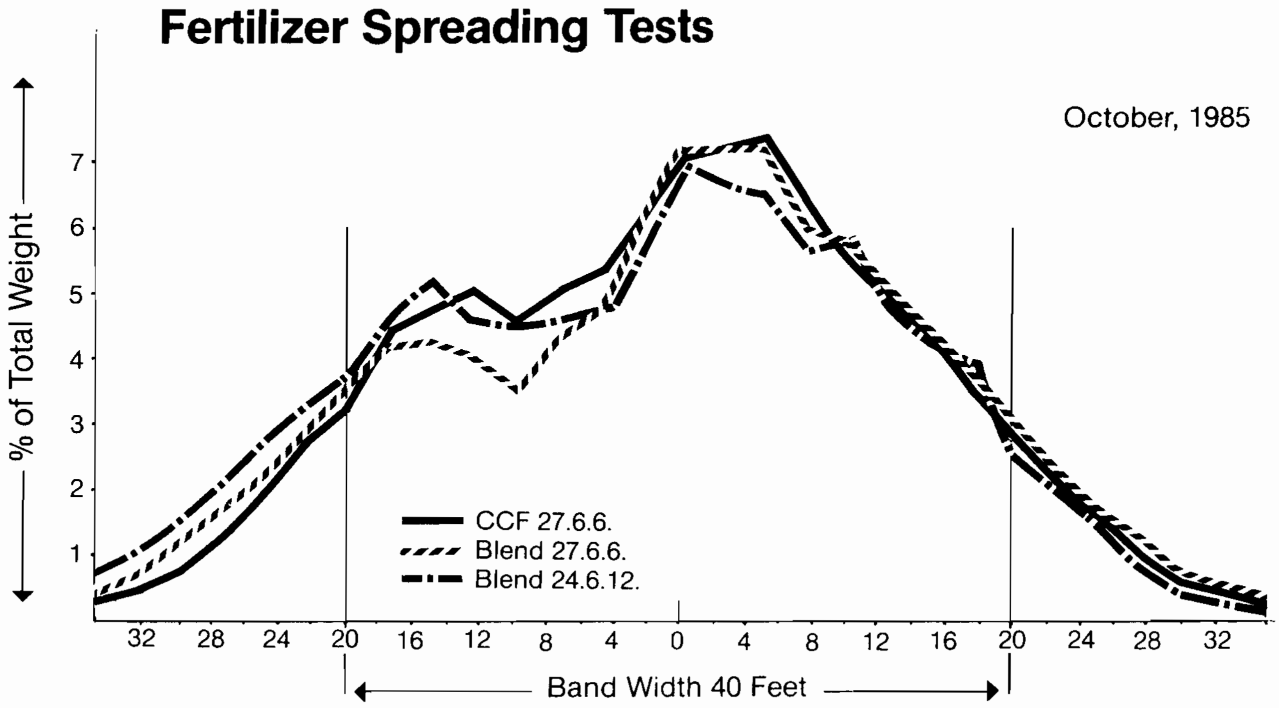


FIGURE 3

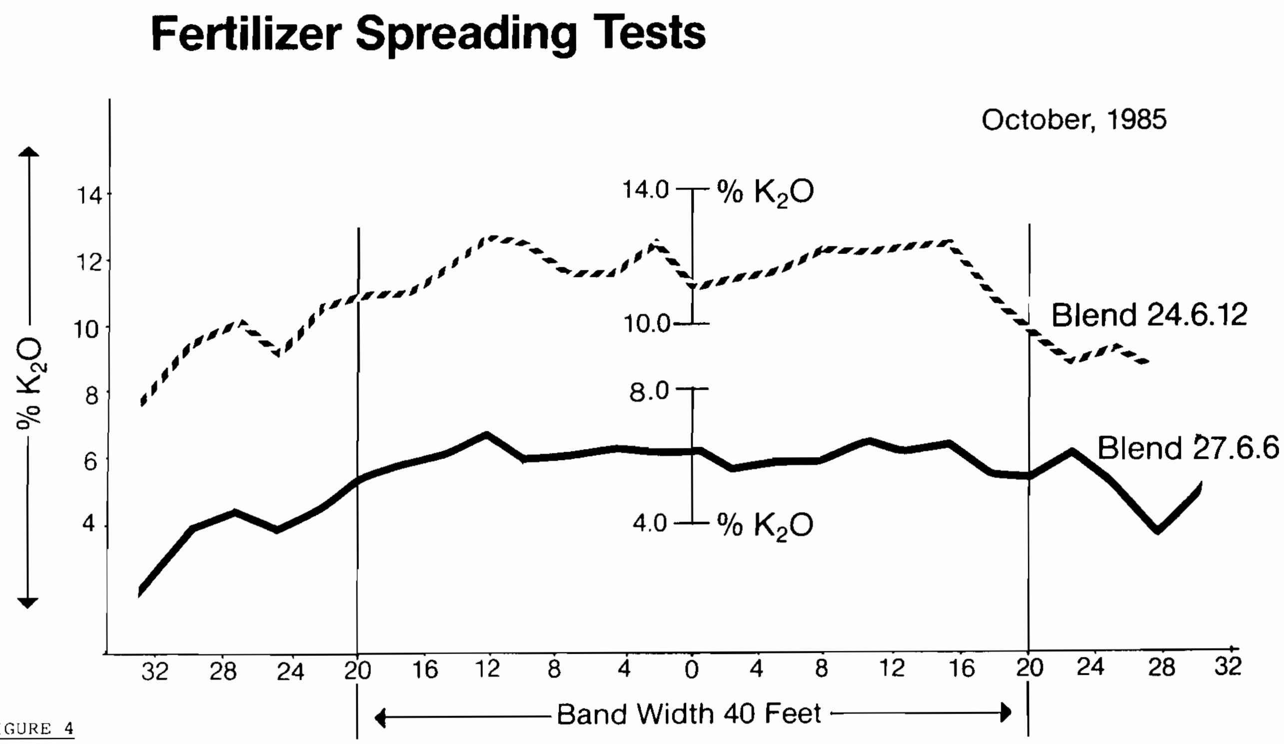


FIGURE 4

Bulk Blending-Mixing Efficiency Tests

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Introduction

In 1982 TVA performed mixer efficiency tests on a concrete mixer and a cylindrical rotary mixer. Results of this work were reported at the Fertilizer Industry Round Table in 1982 (1). To provide more data on mixers used widely in the industry, we decided this year (1985) to test two other types of mixers—a 5-ton paddle mixer and a 5-ton shaft-mounted drum mixer. The latter mixer appears similar to the cylindrical mixer, but the cylindrical mixer turns on trunnions while the shaft-mounted drum mixer turns on a shaft through the center of the mixer. The shaft-mounted drum mixer also has a unique flight design.

Test Procedures

The procedures used in the 1985 tests closely resembled those used in the 1982 tests. Fertilizer materials were obtained from private suppliers and TVA. Monoammonium phosphate (MAP) was substituted for diammonium phosphate (DAP) because of availability. The remaining materials, triple superphosphate (TSP), urea, and granular potash, were the same as in 1982. In the 1982 previous tests, raw materials were riffled into two segments to ensure that size distribution of the granules was as similar as possible for all tests. Because of the larger scope of the current tests, further riffling was required. Four-thousand pounds of each raw material was riffled into eight separate 500-pound lots using the same riffle used in the 1982 tests. During the riffling procedure the materials were temporarily stored in Roura hoppers (figure 1). Samples were taken from each hopper with a Missouri "D" probe using AOAC sampling methods. These samples were sieved for cumulative size distribution and analyzed chemically for total N, P_2O_5, and K_2O. Only seven of the eight samples were used in the tests. The cumulative size distribution for each of the seven lots used is shown in figures 2, 3, 4, 5, 6, 7, and 8. Chemical analyses of the seven samples used are shown in tables 1, 2, 3, and 4. The theoretical grade to be produced from these raw materials was the 14.3-25.3-15.2. The formula used is shown in table 5.

Raw materials were then bagged and weighed using International Fertilizer Development Center's (IFDC) Electronic Flexure Base Platform Scale (model 4848, manufactured by Electronic Scales Corporation, Santa Rosa, California) to ensure the correct weight for each lot. This scale has an accuracy guaranteed to 1 part in 5,000. The separate components, 500 pounds each of urea, MAP, TSP, and KCl, were bundled together for each test lot. Two lots were shipped to each test site. Altogether, six of the eight 2,000-pound lots were used in the initial tests and part of a seventh was used in a subsequent test.

We decided that rather than test the mixer twice using the same mixing time as was done in 1982, one test would be made using the recommended mixing time and a second at twice the recommended mixing time. This was done to determine the effect of mixing time on analysis. All other procedures were the same.

The raw materials were placed by hand into the closest possible entry point for each mixer. Materials could be placed directly into the mixing drum for the cylindrical mixer, but the others required emptying the preweighed bagged material into a Payloader bucket for placement in the mixer.

Sampling Procedures and Results

Paddle Mixer—The paddle mixer was installed just before the 1985 fertilizer season and had been used for one season. The mixer was, therefore, still new enough to be in excellent mechanical condition. The mixer is shown in figure 9.

The 1-ton preweighed batch was loaded into the mixer and mixed for 60 seconds (the mixing time recommended by the manufacturer) then discharged. As the mixer discharged, AOAC procedures for stream sampling were used to obtain twelve samples. These samples were submitted to the National Fertilizer Development Center (NFDC) General Analytical Laboratory for chemical analyses. Results are shown in table 6. Means of the samples were 14.5% nitrogen, 25.9% P_2O_5, and 15.5% K_2O. Standard deviations were 0.6 for nitrogen, 1.2 for P_2O_5, and 0.9 for K_2O. Coefficients of variation were 4.0% for nitrogen, 4.6% for P_2O_5, and 5.5% for K_2O.

The second 1-ton preweighed batch was loaded into the mixer and mixed for 120 seconds, twice the manufacturer's recommended mixing time. Sixteen samples were obtained as the mixer discharged. Results are shown in table 7. Means of the samples were 14.3% nitrogen, 25.8% P_2O_5, and 14.9% K_2O. Standard deviations were 0.6 for nitrogen, 0.7 for P_2O_5, and 0.7 for K_2O. Coefficients of variation were 4.2% for nitrogen, 2.8% for P_2O_5, and 4.9% for K_2O. This was a slight improvement over the 60-second mixing time.

Shaft-Mounted Drum Mixer—The shaft-mounted drum mixer had been used for about three seasons. The owner had had some trouble with analysis which he believed was caused by the mixer. A sketch of a similar mixer is shown in figure 10. The owner and TVA had attempted to solve this problem before the tests, and the mixer manufacturer had modified the flights in the mixer. The changes apparently improved mixing efficiency. We assume the manufacturer will make similar changes in its mixer design.

Two mixing times were used to test the mixer—180 seconds, as recommended by the manufacturer, and 360 seconds. Thirteen samples were obtained as the mixer discharged after the 180-second mixing time. An analysis of these samples is shown in table 8. Means of the samples were 14.2% nitrogen, 25.4% P_2O_5, and 15.5% K_2O. Standard deviations were 0.3 for nitrogen, 0.4 for P_2O_5, and 0.4 for K_2O. Coefficients of variation were 2.3% for nitrogen, 1.7% for P_2O_5, and 2.4% for K_2O.

Results of the 360 second mixing time are in table 9. Thirteen samples were obtained. Means of the samples were 14.1% for nitrogen, 25.2% for P_2O_5, and 15.4% for K_2O. Standard deviations were 0.5 for nitrogen, 0.7 for P_2O_5, and 0.5 for K_2O. Coefficients of variation were 3.7% for nitrogen, 2.9% for P_2O_5, and 3.4% for K_2O. A decrease in mixing efficiency was obtained by doubling the mixing time.

Cylindrical Mixer—The cylindrical mixer at IFDC (figure 11), which was used in the 1982 tests, was tested using the same raw materials used for the paddle mixer and the shaft-mounted drum mixer. The cylindrical mixer also was tested at two mixing times—90 seconds, the time recommended by the manufacturer, and 180 seconds. Ten samples were obtained after the 90 second mixing time. The chemical analysis is shown in table 10. Means were 14.0% for nitrogren, 25.6% for P_2O_5, and 15.2% for K_2O. Standard deviations were 1.7 for nitrogen, 1.8 for P_2O_5, and 4.0 for K_2O. Coefficients of variation were 12.0% for nitrogen, 7.2% for P_2O_5, and 26.5% for K_2O. The 0.2 ton results are for a subsequent test described later. They are compared in tables 10 and 11.

Eleven samples were obtained at the 180 second mixing time. The chemical analyses are shown in table 11. Means were 14.4% for nitrogen, 25.5% for P_2O_5, and 15.1% for K_2O. Standard deviations were 0.3 for nitrogen, 2.0 for P_2O_5, and 1.7 for K_2O. Coefficients of variation were 2.2% for nitrogen, 7.6% for P_2O_5, and 10.7% for K_2O. This was an improvement over the 90-second mixing time and much more of an improvement than obtained with either the paddle mixer or the shaft-mounted drum mixer by increasing the mixing time. Also the results, even at 180 seconds, were worse than those from either of the other two mixers at any mixing time.

Results were worse for the cylindrical mixer than for the others and worse than the results in our 1982 tests. One possible reason was the load capacities of the different mixers; the cylindrical mixer has a 1-ton capacity, whereas, the other mixers have 5-ton capacities. All samples blended were 1-ton batches, which is equivalent to full-load capacity in the cylindrical mixer but only one-fifth capacity in the other mixers. To evaluate this, the cylindrical mixer tests were repeated with 400-pound samples (one-fifth capacity). Again, the tests were made with mixing times of 90 and 180 seconds—the recommended mixing time and double the recommended mixing time.

Eight samples were taken at the recommended mixing time. Chemical analyses for the one-fifth capacity test (0.2 ton) are also shown in table 10. Means were 14.4% for nitrogen, 25.4% for P_2O_5, and 14.8% for K_2O. Standard deviations were 0.2, 0.6, and 0.7, respectively, and coefficients of variation were 1.2% for nitrogen, 2.4% for P_2O_5, and 4.5% for K_2O. Seven samples were taken at double the recommended mixing time. Chemical analysis is shown in table 11. Means were 14.3% for nitrogen, 25.5% for P_2O_5, and 15.0% for K_2O. Standard deviations were 0.4 for nitrogen, 0.4 for P_2O_5, and 0.25 for K_2O. Coefficients of variation were 2.7% for nitrogen, 1.6% for P_2O_5, and 1.7% for K_2O.

Means, standard deviations, and coefficients of variation of all eight tests are shown in table 12. For comparison, results obtained with the cylindrical mixer in 1982 are included, even though the maximum difference between sizes of particles of the materials used was higher (32%) than those used in 1985 (25%). Coefficients of variation are plotted in figures 12 and 13 for the recommended mix time and for double the recommended mix time.

Conclusions

The paddle mixer and the shaft-mounted drum mixer, gave good results based on their coefficients of variation. That is assuming (arbitrarily) that a coefficient of variation under 10% indicates good results. The cylindrical mixer performed fairly well but did not do as well as expected and did not do as well as in 1982. We don't know the reason for this inconsistency. However, results were improved when the mixer was loaded to only one-fifth its capacity.

Flight design of the shaft-mounted drum mixer was modified by the manufacturer just before the tests. Only a long-term improvement in the record of the blends produced by this mixer will show if these modifications were responsible for the good results produced by this mixer.

The test data indicate that at full capacity the recommended mixing time for the cylindrical mixer is apparently inadequate, and even doubling the mixing time does not improve mixing efficiency enough to make it equal to the mixing efficiencies of the paddle and shaft-mounted drum mixers. When the loading factor was reduced to one-fifth, the results from this mixer were comparable to the paddle mixer and the shaft-mounted drum mixer. Unfortunately we did not have time to investigate the effect of fully and partially loading the other mixers. We plan to test one of these mixers partially and fully loaded.

According to the AAPFCO table of investigational allowances, the paddle mixer produced only three deficient samples, if considered separately, at the recommended mixing time, 60 seconds. This increased to six when the mixing time was doubled. This indicates that the recommended mixing time is probably the optimum mixing time even though the coefficients of variation improved slightly when the mixing time was increased.

The shaft-mounted drum mixer had no deficient samples at the recommended mixing time of 180 seconds. This increased to four deficient samples at double the mixing time of 360 seconds. Apparently the recommended mixing time is the optimum mixing time for the shaft-mounted drum mixer. The increase in mixing time also produced an increase in the coefficient of variation.

In the first series of tests, the cylindrical mixer was operating at capacity while the other mixers were not. This suggested the possibility that tests of these mixers, partially and fully loaded, might provide further insights into the reliability of the data presented in this paper. Results of the tests of the cylindrical mixer at one-fifth capacity showed improved performance of the mixer at both mixing times. This indicates that any mixer manufacturer should know how his mixer operates partially and fully loaded. Owners interested in making a good blend should know this too, even if they must invest some time and money to find out.

Apparently all three of the mixers can do a good job if proper mixing times and loading procedures are followed and if the fertilizer used has a reasonably matched granule size.

Reference

1. Balay, H. L., C. A. Cole, Jr. and D. W. Rutland. 1982. "Bulk Blending Mixing Efficiency Tests," *Proceedings of the 32nd Annual Meeting of the Fertilizer Industry Round Table*, pp. 143–154, Atlanta, Georgia.

Table 1. CHEMICAL ANALYSIS OF UREA USED FOR TESTS OF BULK BLENDING MIXERS

Sample No.	% N
1	46.4
2	46.2
3	46.2
4	46.2
5	46.3
6	46.2
7	46.0
$\overline{X}$	46.2

Table 2. CHEMICAL ANALYSIS OF MAP USED FOR TESTS OF BULK BLENDING EQUIPMENT

Sample No.	% N	% Total P_2O_5
1	11.0	54.1
2	11.1	54.3
3	11.0	54.1
4	11.0	54.0
5	11.1	54.3
6	11.0	54.0
7	11.0	54.0
X	11.0	54.1

Table 3. CHEMICAL ANALYSIS OF TSP USED FOR TESTS OF BULK BLENDING MIXERS

Sample No.	% Total P_2O_5
1	46.9
2	47.2
3	47.2
4	47.2
5	47.1
6	47.1
7	47.0
X	47.1

Table 4. CHEMICAL ANALYSIS OF POTASH USED FOR TESTS OF BULK BLENDING EQUIPMENT

Sample No.	% K_2O
1	60.6
2	60.8
3	60.7
4	60.7
5	60.8
6	60.6
7	60.8
X	60.7

Table 5. FORMULA FOR 14.3-25.3-15.2 USED FOR TESTS

Material	Lb/Ton Product	Lb N	Lb P_2O_5	Lb K_2O
Urea (46.2-0-0)	500	231	—	—
MAP (11.0-54.1-0)	500	55	270.5	—
TSP (47.1-0-0)	500	—	235.5	—
Potash (0-0-60.7)	500	—	—	303.5
Total	2000	286.0	506.0	303.5

Table 6. ANALYSIS OF 14.3-25.3-15.2 BLENDED FERTILIZER FROM PADDLE MIXER

Mixing Time—60 Seconds[a]

Sampling Time (sec)[b]	% N	% P_2O_5	% K_2O
6	14.4	25.7	15.6
12	14.0	28.3	15.4
18	14.2	27.1	14.6
24	14.1	26.4	15.3
30	14.8	26.0	14.2
36	14.3	25.3	15.3
42	14.7	25.9	14.8
48	14.5	26.1	15.3
54	15.0	24.4	15.6
60	15.8	26.6	16.3
66	13.5	23.5	17.7
67	15.2	25.3	15.8
Empty	—	—	—
$\bar{X}$	14.5	25.9	15.5
s_x	0.6	1.2	0.9
COV (%)	4.0	4.6	5.5

[a] Mixing time recommended by manufacturer
[b] Elapsed time after starting mixer discharge

Table 7. ANALYSIS OF 14.3-25.3-15.2 BLENDED FERTILIZER FROM PADDLE MIXER

Mixing Time—120 Seconds[a]

Sampling Time (sec)[b]	% N	% P_2O_5	% K_2O
6	13.5	26.1	15.5
12	13.1	26.9	15.0
18	13.8	26.0	15.4
24	14.0	25.2	15.6
30	13.8	26.1	15.0
36	14.3	26.6	14.2
42	14.3	26.2	14.4
48	14.4	26.9	13.8
54	15.7	26.0	13.2
60	14.7	24.5	15.6
66	14.3	25.6	15.3
72	14.4	25.9	14.9
78	15.1	25.8	14.0
84	14.6	24.6	15.7
90	14.5	25.5	15.1
96	14.6	24.8	15.6
Empty	—	—	—
$\bar{X}$	14.3	25.8	14.9
s_x	0.6	0.7	0.7
COV (%)	4.2	2.8	4.9

[a] Twice mixing time recommended by manufacturer
[b] Elapsed time after starting mixer discharge

Table 8. ANALYSIS OF 14.3-25.3-15.2 BLENDED FERTILIZER FROM SHAFT-MOUNTED DRUM MIXER

Mixing Time—180 Seconds[a]

Sampling Time (sec)[b]	% N	% P_2O_5	% K_2O
5	14.1	25.2	15.8
10	14.2	25.4	15.3
15	14.1	25.3	15.6
20	14.7	24.9	15.4
25	13.8	25.5	15.6
30	14.4	25.8	14.8
35	14.7	25.6	14.7
40	14.0	25.2	15.8
45	14.9	24.6	15.6
50	13.8	26.1	15.4
55	14.2	25.4	16.0
60	14.0	26.0	15.4
65	14.4	24.9	15.8
70 (empty)	—	—	—
$\bar{X}$	14.2	25.4	15.5
s_x	0.3	0.4	0.4
COV (%)	2.3	1.7	2.4

[a] Mixing time recommended by manufacturer
[b] Elapsed time after starting mixer discharge

Table 9. ANALYSIS OF 14.3-25.3-15.2 BLENDED FERTILIZER FROM SHAFT-MOUNTED DRUM MIXER

Mixing Time—360 Seconds[a]

Sampling Time (sec)[b]	% N	% P_2O_5	% K_2O
6	14.2	25.0	15.8
12	14.1	25.0	15.8
18	14.1	25.8	15.4
24	14.0	25.9	14.8
30	13.5	25.2	16.4
36	13.8	26.0	15.2
42	14.1	26.1	15.0
48	14.0	26.1	15.0
54	14.4	25.0	15.6
60	14.2	25.3	15.6
66	14.8	24.4	15.6
72	13.0	23.7	14.3
78	15.2	24.4	15.7
84 empty	—	—	—
$\bar{X}$	14.1	25.2	15.4
s_x	0.5	0.7	0.5
COV (%)	3.7	2.9	3.4

[a] Twice mixing time recommended by manufacturer
[b] Elapsed time after starting mixer discharge

Table 10. ANALYSIS OF 14.3-25.3-15.2 BLENDED FERTILIZER FROM CYLINDRICAL MIXER

Mixing Time—90 Seconds[a]

	% N		% P_2O_5		% K_2O	
Sampling Time (sec)[b]	1-Ton	0.2 Ton	1-Ton	0.2 Ton	1-Ton	0.2 Ton
8	16.4	14.6	26.9	24.6	10.5	15.3
16	15.0	14.1	27.2	25.8	12.2	14.3
24	15.0	14.3	26.8	26.4	13.1	13.9
32	15.6	14.3	26.9	25.3	11.8	15.1
40	15.2	14.6	27.4	26.0	11.8	14.0
48	14.5	14.4	25.9	25.1	13.7	15.1
56	13.3	14.5	25.5	24.8	16.4	15.8
64	12.3	—	24.2	—	18.9	—
72	12.0	—	22.5	—	21.0	—
80	11.0	—	22.2	—	22.4	—
Empty						
$\bar{X}$	14.0	14.4	25.6	25.4	15.2	14.8
s_x	1.7	0.2	1.8	0.6	4.0	0.7
COV (%)	12.0	1.2	7.2	2.4	26.5	4.5

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[a] Mixing time recommended by manufacturer
[b] Elapsed time after starting mixer discharge

Table 11. ANALYSIS OF 14.3-25.3-15.2 BULK BLENDED FERTILIZER FROM CYLINDRICAL MIXER

Mixing Time—180 Seconds[a]

	% N		% P_2O_5		% K_2O	
Sampling Time (sec)[b]	**1-Ton**	**0.2 Ton**	**1-Ton**	**0.2 Ton**	**1-Ton**	**0.2 Ton**
5	14.3	13.6	27.8	25.9	12.7	15.5
13	14.3	14.2	26.5	26.0	14.1	14.6
22	14.5	14.6	26.4	25.2	13.9	14.9
30	14.1	13.8	26.0	26.0	14.7	14.8
37	14.9	14.6	28.4	24.8	14.3	15.2
43	14.1	14.4	25.8	25.3	14.6	15.1
50	14.2	14.6	26.3	25.5	14.1	15.0
58	13.9	14.7	25.7	25.2	15.2	14.9
65	14.2	—	23.8	—	17.0	—
73	14.9	—	22.4	—	17.4	—
78	14.7	—	21.9	—	18.2	—
Empty						
$\bar{X}$	14.4	14.3	25.5	25.5	15.1	15.0
s_x	0.3	0.4	2.0	0.4	1.7	0.25
COV (%)	2.2	2.7	7.6	1.6	10.7	1.7

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[a] Twice mixing time recommended by manufacturer

[b] Elapsed time after starting mixer discharge

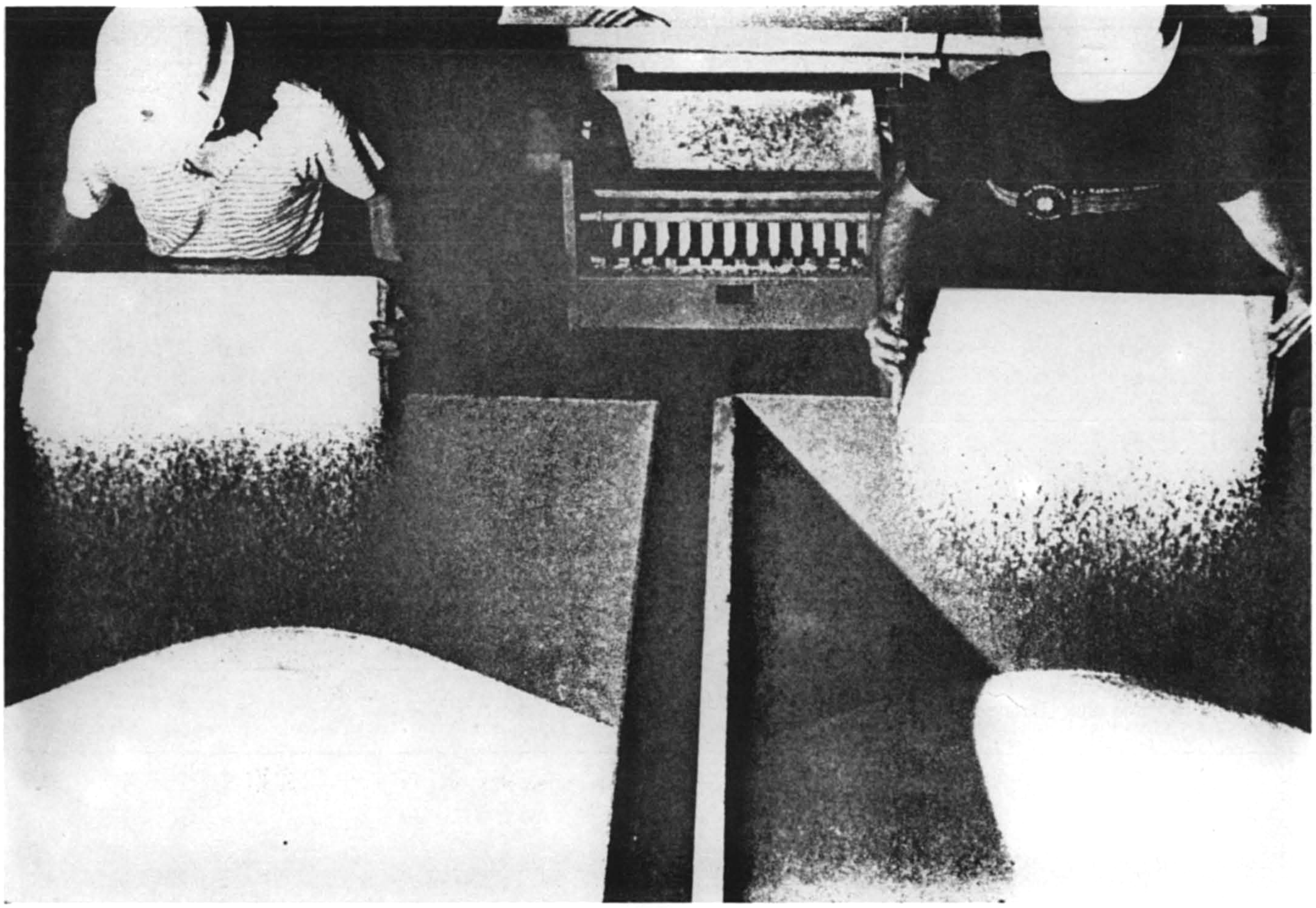

FIGURE 1 RIFFLING RAW MATERIALS INTO ROURA HOPPERS

Table 12. SUMMARY OF STATISTICAL VALUES FOR MIXING EFFICIENCY TESTS

	Paddle Mixer					
	Recommended Mixing Time (60 sec)			Double Recommended Mixing Time (120 sec)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Mean ($\bar{x}$)	14.5	25.9	15.5	14.3	25.4	14.9
Standard deviation (s_x)	0.6	1.2	0.9	0.6	0.7	0.7
Coefficient of variation (COV)	4.0	4.6	5.5	4.2	2.8	4.9

	Shaft-Mounted Drum Mixer					
	Recommended Mixing Time (180 sec)			Double Recommended Mixing Time (360 sec)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Mean ($\bar{x}$)	14.2	25.4	15.5	14.1	25.2	15.4
Standard deviation (s_x)	0.3	0.4	0.4	0.5	0.7	0.5
Coefficient of variation (COV)	2.3	1.7	2.4	3.7	2.9	3.4

	Cylindrical Mixer (1-Ton)								
	Recommended Mixing Time (90 sec)			Double Recommended Mixing Time (180 sec)			Double Recommended Mixing Time[a] (180 sec)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Mean ($\bar{x}$)	14.0	25.6	15.2	14.4	25.5	15.1	15.4	24.0	14.7
Standard deviation (s_x)	1.7	1.8	4.0	0.3	2.0	1.7	0.4	0.4	0.6
Coefficient of variation (COV)	12.0	7.2	26.5	2.2	7.6	10.7	2.9	1.7	4.1

	Cylindrical Mixer (0.2-Ton)					
	Recommended Mixing Time (90 sec)			Double Recommended Mixing Time (180 sec)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Mean ($\bar{x}$)	14.4	25.4	14.8	14.3	25.5	15.0
Standard deviation (s_x)	0.2	0.6	0.7	0.4	0.4	0.25
Coefficient of variation (COV)	1.2	2.4	4.5	2.7	1.6	1.7

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[a] From 1982 test; calculated grade 15.9-23.2-15.0. Particle size difference 32%.

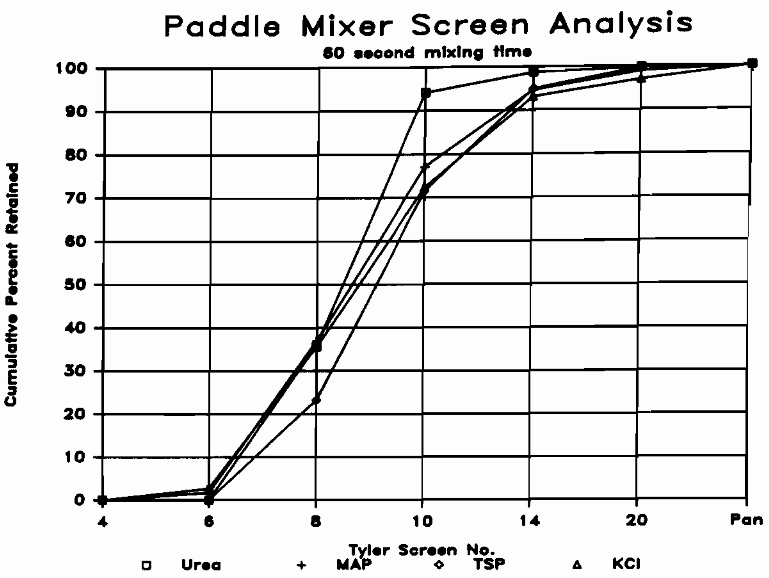


FIGURE 2

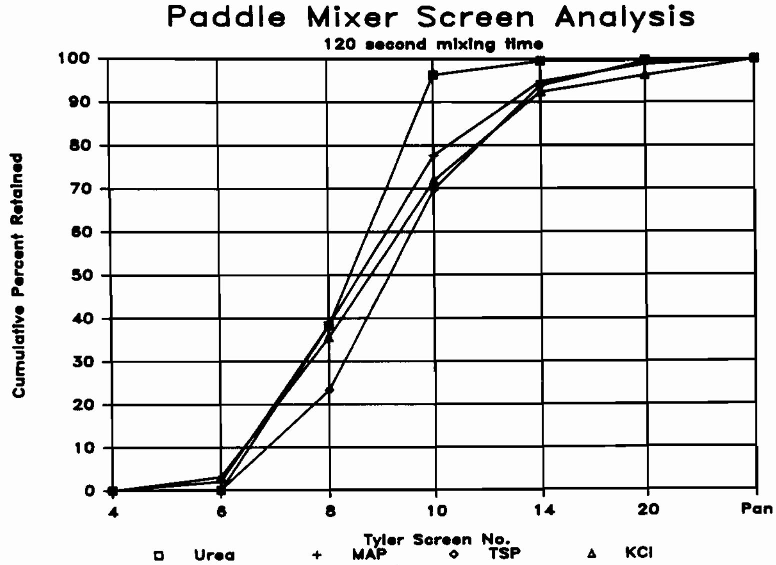


FIGURE 3

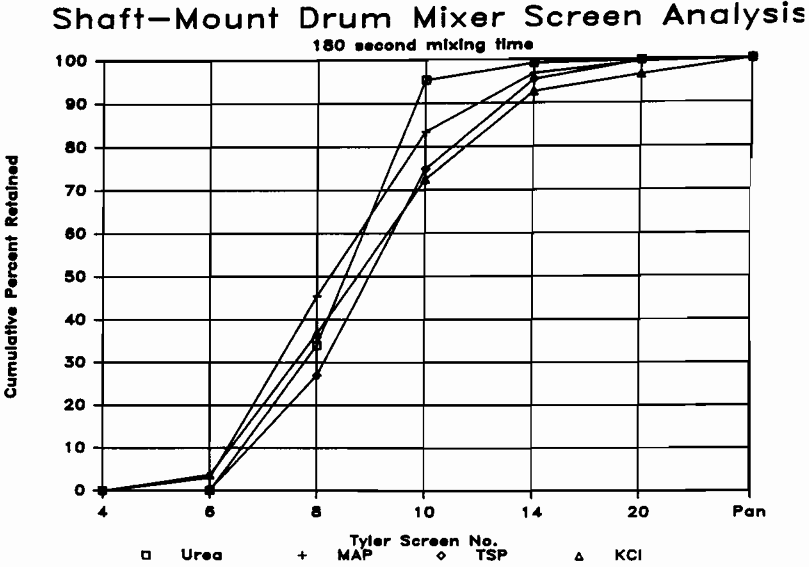


FIGURE 4

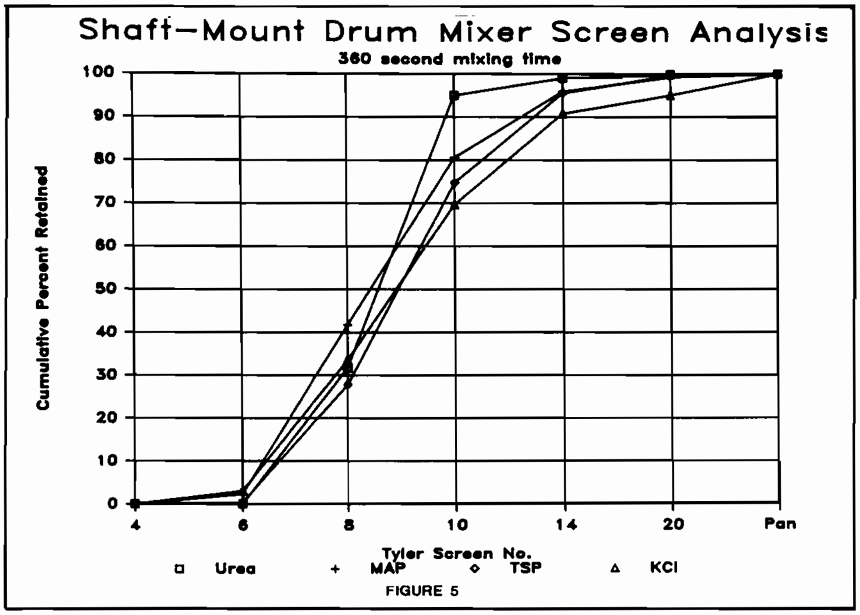


FIGURE 5

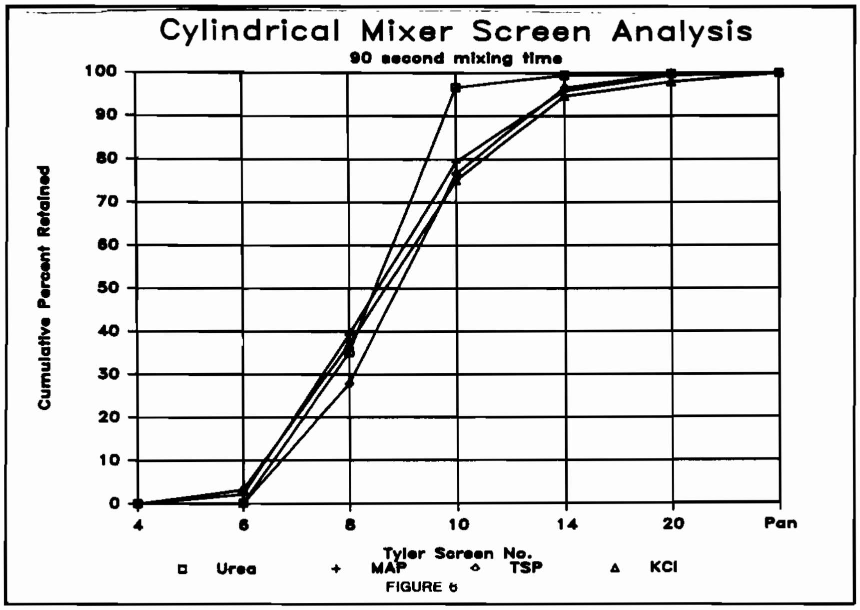


FIGURE 6

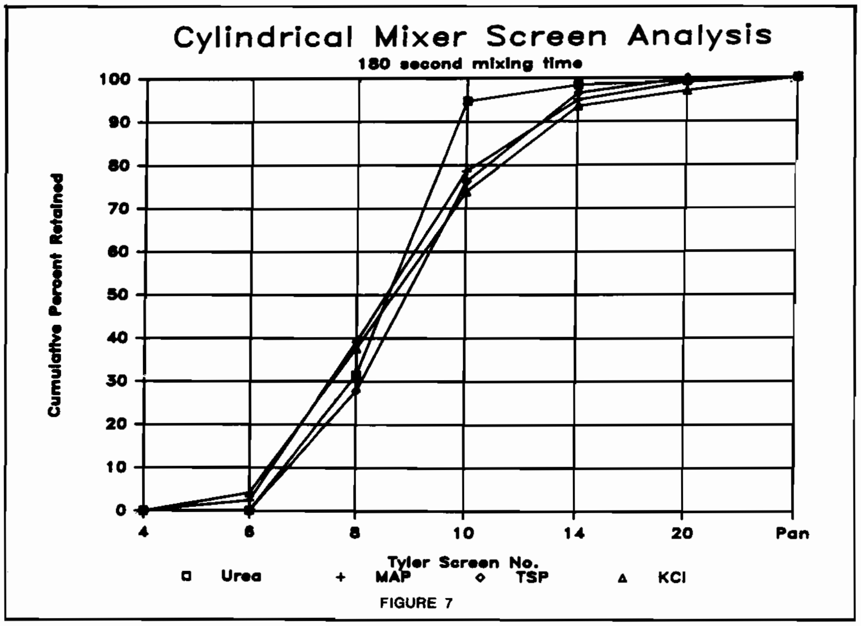


FIGURE 7

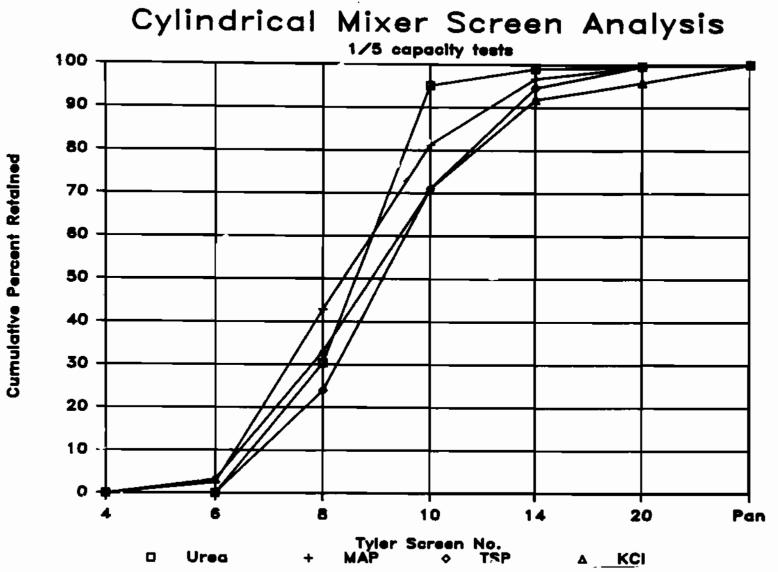
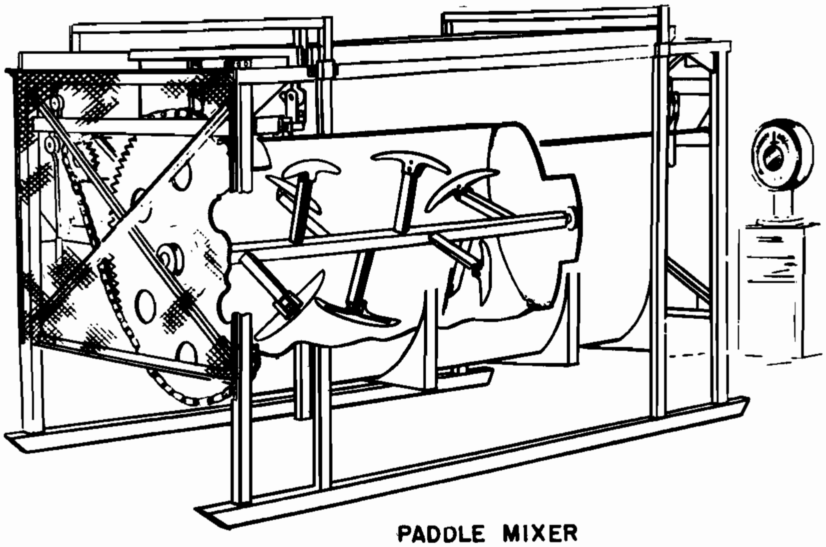
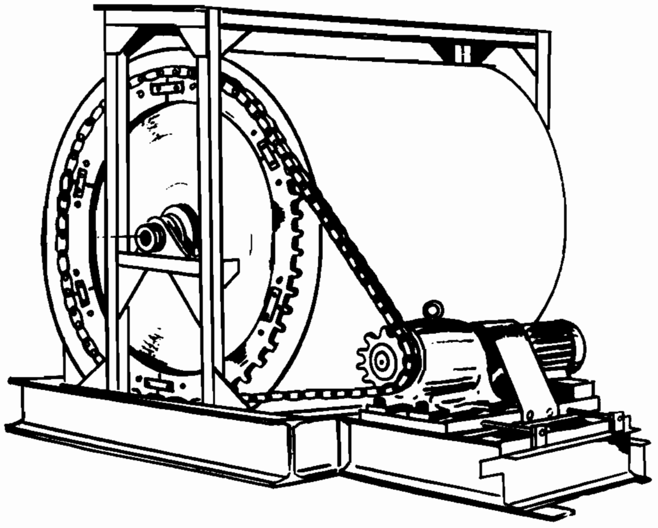


FIGURE 8



PADDLE MIXER

FIGURE 9



SHAFT MOUNTED DRUM MIXER

FIGURE 10

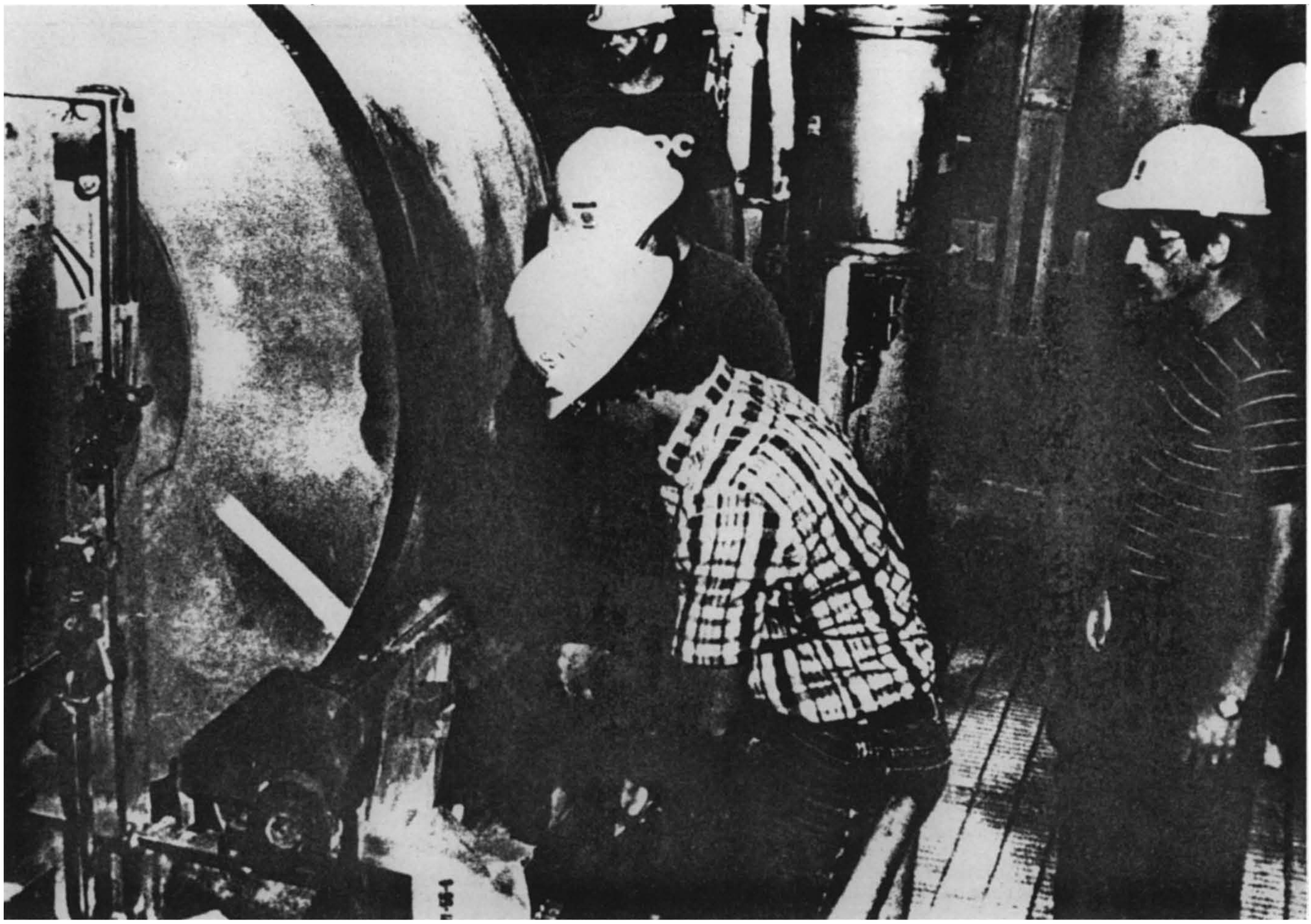


FIGURE 11 CYLINDRICAL MIXER

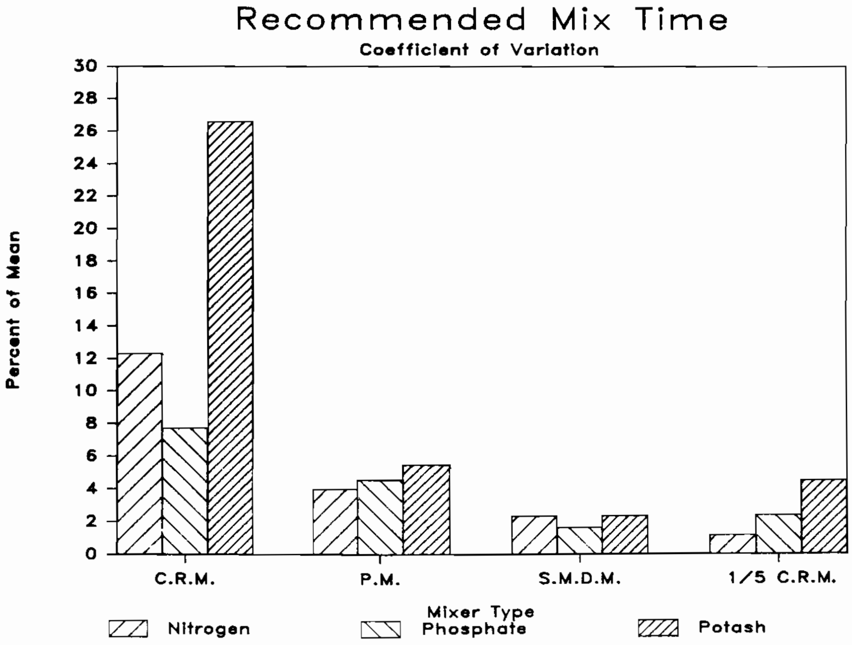


FIGURE 12

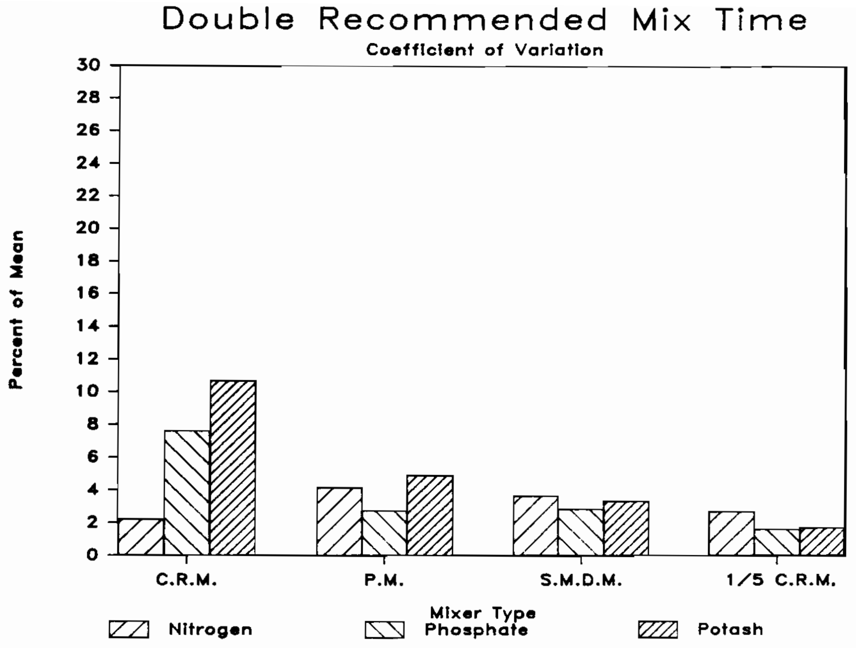


FIGURE 13

Growth Potential for Nonpressure Fluid Fertilizers in the United States

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Only nonpressure fluid fertilizers will be discussed and considered in this paper. These include urea ammonium nitrate (UAN) solution and suspension (28 to 36 percent N), solution mixtures, and suspension mixtures. Statistics for 1984 show that 18 percent of all plant nutrients consumed in the U.S. were applied in these forms. The same statistics show that 25 percent of the total nitrogen, 15 percent of the total P_2O_5 and 8 percent of the total K_2O were applied as fluids. Data presented in figure 1 show that consumption of nitrogen solutions has steadily increased at an average rate of about 6.8 percent per year since 1970. Data also show that there was a significant growth rate in use of fluid mixtures between 1970 and 1980, but it decreased slightly from 1980 to 1984. Consumption of solid mixtures, however, also decreased during this period.

Nitrogen Solutions

Most nitrogen solutions are produced in plants that produce ammonia, urea solution, and ammonium nitrate solution. These nitrogen solutions are usually produced from urea and ammonium nitrate solutions plus water. They usually contain a corrosion inhibiting agent and can be stored in mild steel (carbon steel) tanks. Although they can be applied with equipment made of mild steel, applicator tanks usually are stainless steel (type 304) and have plastic booms. Usually stainless steel nozzles and mild or stainless steel pumps are used. Solutions sold in the U.S. have three concentrations: 32 percent, 30 percent, and 28 percent nitrogen. Chemical characteristics of these three nitrogen solutions are shown in the tabulation below:

PHYSICAL AND CHEMICAL CHARACTERISTICS OF UREA-AMMONIUM NITRATE NONPRESSURE NITROGEN SOLUTIONS

Grade, % N	28	30	32
Composition by weight			
Ammonium nitrate, %	40.1	42.2	43.3
Urea, %	30.0	32.7	35.4
Water, %	29.9	25.1	20.3
Specific gravity, 15.6°C (60°F)	1.283	1.303	1.32
Salt-out temperature, °C (°F)	−18 (1)	−10 (+14)	−2 (+28)

The solution salting out temperatures vary directly with their plant nutrient concentrations. Figure 2 shows the solubility system of ammonium nitrate, urea, and water; maximum solubility of the salts in solution is obtained when the urea nitrogen:ammonium nitrate nitrogen ratio is about 1.0:1. All nitrogen solutions and one of the newer nitrogen suspensions have $CO(NH_2)_2$,N:NH_4NO_3,N ratios between 1.0:1 to 1.10:1. The two leading corrosion inhibiting agents used in nitrogen solutions are ammonia (0.5%, pH 7.0 to 7.5) and ammonium polyphosphate solution or an ammonium orthophosphate solution (0.06—0.2% P_2O_5).

Recently, several small U.S. companies with small ammonia plants that have been outdated by large efficient plants have shut down their plants. They rely on imported ammonia and prilled urea as sources of nitrogen for these solutions. Ammonia is converted to nitric acid which is then neutralized to form a hot ammonium nitrate solution. Urea prills are added to the hot ammonium nitrate solution in the proper proportions. There is enough heat in the hot ammonium nitrate solution to dissolve the solid urea in a reasonable length of time. Many small plants can use this procedure to produce nitrogen solutions competitively with the large plants. Some plants on navigable rivers use this procedure and receive urea by barge and ammonia by pipeline or barge. The urea barges can be used to backhaul grain to the point where the urea was originally loaded. This reduces freight costs for both the urea and grain. Sometimes grain is traded for urea which usually results in further lowering of urea costs. Most solid urea used to manufacture these solutions is considered inferior for manufacturing dry mixes.

Nitrogen solutions are produced either by a batch (figure 3) or continuous process (figure 4). In the batch process a relatively large batch tank mounted on scales is used to weigh ingredients used in the solution. A small quantity of ammonia is added as the inhibiting agent and the solution is cooled before it is pumped to storage. The mixture is mixed sufficiently during pumping and transporting. In the continuous process the ammonium nitrate solution, urea solution, inhibiting agent, and water are metered in the right proportions to a static mixer. Solution from the static mixer is cooled before it is pumped to storage.

Usually a batch mix tank is mounted on scales when solid urea is used. Mixing is accomplished by recirculating the mixture in the tank with a large pump.

Most of the following reasons for the popularity of nitrogen solutions are the same as those for other fluid fertilizers.

1. They are safe to handle in transport.
2. The cost of manufacture is usually competitive with other types of fertilizers.
3. They can be uniformly applied; for this reason, herbicides are frequently incorporated in them and the mixture can be used in a weed and feed program.
4. Micronutrients can be dissolved and suspended in them and uniformly applied.
5. They can be easily metered and pumped into irrigation systems so that fertilizer can be efficiently added several times during the growing season.

TVA is introducing a new nitrogen suspension containing 31 percent N and 2 percent clay. It has about the same $CO(NH_2)_2$,N:NH_4NO_3,N ratio as commercial solutions. This product will produce a high analysis nitrogen suspension for storage in the colder regions of the U.S. Also, since this product contains clay it can be cold mixed with other suspension products to produce high-analysis suspension mixtures. Fluid fertilizer dealers have designated this procedure as fluid blending to correspond to bulk blending of granular materials. This suspension plus a phosphate suspension (10-30-0 from MAP) makes possible the prescription blending with crystalline potash and accurate metering and uniform application to meet soil test requirements. This is almost impossible to accomplish with a dry bulk blend.

In a further attempt to increase the analysis of fluid nitrogen products, TVA has developed a process for producing UAN suspension containing 36 percent nitrogen. This product has a $CO(NH_2)_2$,N:NH_4NO_3,N ratio of 2.6:1, which is substantially higher than in commercial nitrogen solutions. Producing and shipping this suspension instead of the commercial nitrogen solution (28-0-0), saves about 29 percent in freight. Since freight is now a substantial part of the total delivery cost of nitrogen solutions, use of this new material may significantly decrease the cost of delivering fluid nitrogen fertilizer. Also, by using this high-nitrogen suspension, storage tanks can hold about 1/3 more nitrogen. Preliminary storage tests indicate that the products can be stored in the colder regions and ready for use during the early spring season.

Solution Mixtures

Solution mixtures are defined as those mixtures in which all of the plant nutrients are in solution. Most solution mixtures are produced from nitrogen solutions, ammonium polyphophate (APP) solutions (10-34-0), and solution grade potash (0-0-62). Nearly all 10-34-0 is produced from wet-process superphosphoric acid. Superphosphoric acid is produced in six U.S. plants that have a production capacity of about 0.9 million tons P_2O_5. Almost all of this acid is used to produce APP solution. A typical plant for producing this solution is shown in figure 5. Superphosphoric acid and ammonia are reacted in a pipe reactor to form a melt at temperatures ranging from 600° to 700°F. Reaction products, melt and steam, are quenched and mixed into a cool solution of 10-34-0. The pH solution is adjusted to 6.0 to 6.5 by adding ammonia. By this method the polyphosphate level is increased as a result of dehydration and polymerization of the phosphates in the pipe reactor. Superphosphoric acid containing only 10 to 20 percent of the P_2O_5 as polyphosphoric acids (nonorthophosphate) can be used to make solutions with polyphosphate levels above 50 percent and often as high as 75 percent.

The quality of 10-34-0 solutions depends on the impurities in the acid. The most troublesome are carbonaceous matter and magnesium. Carbonaceous matter forms a black flocculant precipitate in a solution. This is objectionable mainly because farmers expect the 10-34-0 to be clear. Magnesium forms a precipitate which plugs application equipment and is difficult to remove from storage tanks.

Nitrogen solution, 10-34-0, and potash are usually cold mixed in a plant such as the one shown in figure 6. This is a simple mixing process in which usually no chemical heat is released. The product becomes cool because of the negative heat of solution of the potash in the other liquids. Solution mixtures are of particular interest where there is a short growing season. These mixtures are often applied as starter fertilizers such as 7-21-7 and 8-25-3. The mixture is injected to the side and at the same level or below the seed. Farmers report they have superior results when these starter fertilizers are used this way. Sometimes a split application is used in which a part of the solution is applied on the seed with the remainder to the seed's side. Solution mixtures are also used in minimum tillage programs. Also, solution grades often are mixed with pesticides and applied in a single application. Because liquids can be easily handled and can be accurately metered, they may be increasingly used by farmers in minimum tillage programs.

The main disadvantage in using solution mixtures is that their cost is usually significantly higher than that of dry bulk blends and homogeneous granular NPK mixtures. The reason is that solid materials can usually be hauled in a transportation system that uses backhauling to reduce shipping costs. Also, superphosphoric acid has a higher production cost because impurities must be removed from the acid and the acid concentrated to 68 percent P_2O_5 as compared to the 54 percent P_2O_5 of merchant-grade phosphoric acid.

Solution mixtures are expected to continue to be a significant part of the fertilizer marketing system in the U.S. Some researchers have predicted that by 2000, 70 percent of all farms will use some form of minimum tillage program. Because solution mix fertilizers fit well into these types of systems, these types of mixtures are expected to increase in use as minimum tillage programs increase.

Suspension Mixtures

Suspension mixtures became a significant part of the industry in the early 1970's and their use grew rapidly until about 1980. Since then, there has been little increase. Annual use is about 2 million tons. Some of the reasons for their popularity are the same as for other types of fluid fertilizers. However, for the following reasons, they are more popular than solution-type mixtures:

1. Lower cost because less pure materials can be used to produce suspensions.
2. Higher analysis grades can be produced.
3. Usually larger quantities of micronutrients can be suspended in suspensions than can be dissolved in solution fertilizers.
4. Powdered herbicides and insecticides, not normally soluble in solutions, can be suspended in a suspension.

With suspensions high-analysis potash grades can be produced for use in regions requiring potassium. The most popular high K_2O suspension type grades are 7-21-21, 3-10-30, and 4-12-24. Other popular grades are 14-14-14, 20-10-10, 21-7-7, and 24-8-0. Plant nutrient concentration of these suspensions is about double the average concentration in solution mixtures.

At first, the main source of phosphate for producing suspensions was APP solution, 10-34-0 grade. However, in the 1980's use of solid phosphate materials such as monoammonium phosphate (MAP) became popular. The main advantage in using MAP for producing suspensions is that it can be ammoniated with low-cost ammonia. The delivered cost of P_2O_5 as MAP is much lower than the delivered cost as phosphoric acid or superphosphoric acid. When using MAP as a source of phosphate, the fluid fertilizer dealer can produce suspension mixtures with about the same cost and in some instances less cost than that of materials in a comparable bulk blend.

Figure 7 is a sketch of a typical mix tank for producing suspensions from commercial granular ammonium phosphates. This is a stainless steel batch mix tank mounted on scales. A mix tank of this type must have a large recirculation pump. This pump is used to help fluidize the solid materials and gel the clay used in the suspension. The ammonia can be added either as aqua or as anhydrous ammonia. Phosphoric acid usually is added when diammonium phosphate (DAP) is used as a source of P_2O_5. Best results occur when about 30 percent of the product P_2O_5 is supplied by phosphoric acid and the remainder is supplied by DAP. Phosphoric acid is not required when MAP is used. Chemical heat released by the reaction of MAP and ammonia usually is sufficient to help fluidize the MAP granules. Most operators produce a base suspension which has a grade of 10-30-0 or 11-33-0. After the product is produced in the batch mixer, it should be cooled in an evaporative type cooler such as shown in figure 8. This cooler does not have packing because the packing would plug during operation. Cooling occurs when some water from the suspension is passed through the air stream of the cooler. Operators using the cooler report that quality of their suspension is superior to that of hot suspension pumped to storage and allowed to cool slowly. When the cooler is not used, large crystals sometimes form during storage.

Another problem reported by operators is formation of thick gels in the 10-30-0 and other phosphate-based suspensions produced from MAP. Microscopic examinations indicate these gels are caused by the formation of NH_4-Fe-PO_4 compounds. Other impurities such as Al, Mg, SO_4, and Ca promote formation of these gels. Adding fluorine compound will increase the $F : R_2O_3$ ratio in the product which tends to decrease formation of these gels. Gels cause difficulty in pumping the material from the storage to application tanks. It also tends to cause viscosity to be too high (>800 cPs) which in turn causes nonuniform broadcast application. TVA research tests and field demonstrations have shown that polyphosphate in the final mixture helps to solubilize part of the iron and other impurities so that gel formation is avoided. These test data indicate that about 10 percent of the product P_2O_5 needs to be in the polyphosphate form.

Based on this data TVA has developed several processes for the production of APP suspensions (9-32-0 and 12-36-0 grades) and one process for the production of granular APP. Figure 9 is a sketch of a fluid fertilizer plant for producing APP suspensions. This process uses a pipe reactor in which merchant-grade phosphoric acid (54% P_2O_5) is reacted with ammonia to form a melt at about 450°F. This melt is dissolved in cooled recycle fluid and the clay is added to cooled product. Usually attapulgite clay is used; however, preliminary tests indicate that a sodium bentonite clay can be used.

TVA has a cooperative product with Royster Fertilizer Company in which a conventional granular DAP plant has been converted to produce granular ammonium polyphosphate (GAPP). Earlier this year about 3,000 tons of GAPP was produced and there are plans to produce substantial tonnages of the material. GAPP has a grade of 11-53-0-2S and contains between 11 and 15 percent polyphosphate.

In the process, phosphoric acid and a small amount of sulfuric acid are added to a TVA pipe-cross reactor. Usually phosphoric acid with a P_2O_5 concentration >52 percent is used. It is preheated to about 250°F. When this preheated acid is reacted with gaseous ammonia, the temperature of the melt increases to about 450°F and usually <475°F. A small quantity of sulfuric acid is added to the scrubber so that the pH of the scrubber liquor can be maintained at about 5.0. Gypsum pond water or fresh water is also added to the scrubber and this scrubber liquor is sprayed along with more gypsum pond water over the top of the bed in the granulator. This cools the material as it is granulated. About 1 gallon of gypsum pond water per ton of product is required to keep the temperature of the product from the granulator at about 255°F. At temperatures higher than 260°F, dust usually forms in the plant. By using pond water as a scrubbing medium, more F and P_2O_5 are added to the product. Recovery of P_2O_5 in the pond water more than offsets the cost of steam required to preheat the acid. Cost estimations show that GAPP can be produced for about what it costs to produce MAP.

Future of Fluids

The 9 percent growth rate for nonpressure nitrogen solutions is expected to continue during the next five years. However, during this period the growth rate of fluid mixtures probably is directly related to the health of the fertilizer industry. If the total consumption of fertilizer materials in the United States continues to remain relatively stagnant, then consumption of fluid mixtures will also remain in this condition. However, if the growth rate of the total consumption of fertilizers increases as it did before 1980, then we can also expect fluid fertilizer consumption to increase so that it will remain about 20 percent of the total mixtures consumed. Reasons for their growth will depend directly upon the advantages for fluids.

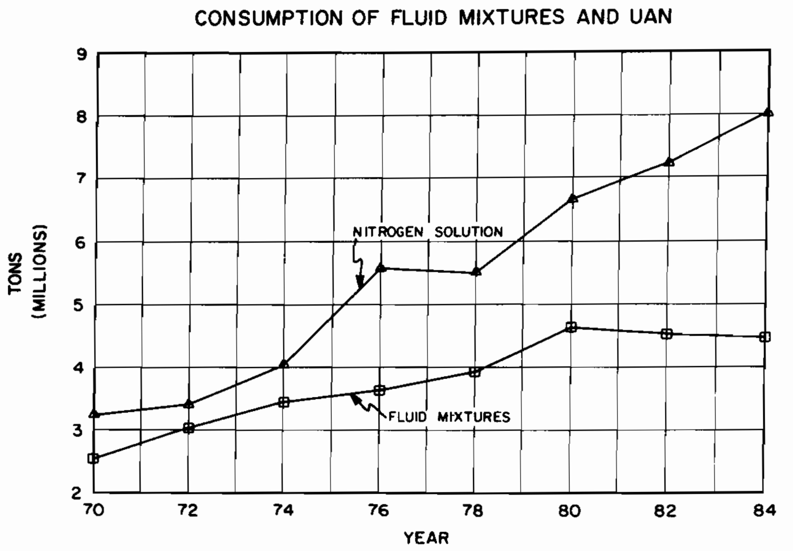


FIGURE 1

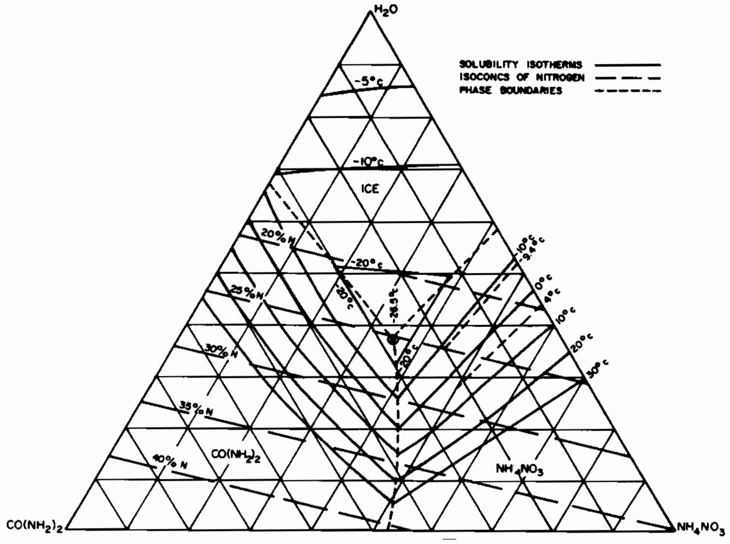


FIGURE 2
SOLUBILITY SYSTEM OF AMMONIUM NITRATE-UREA-WATER

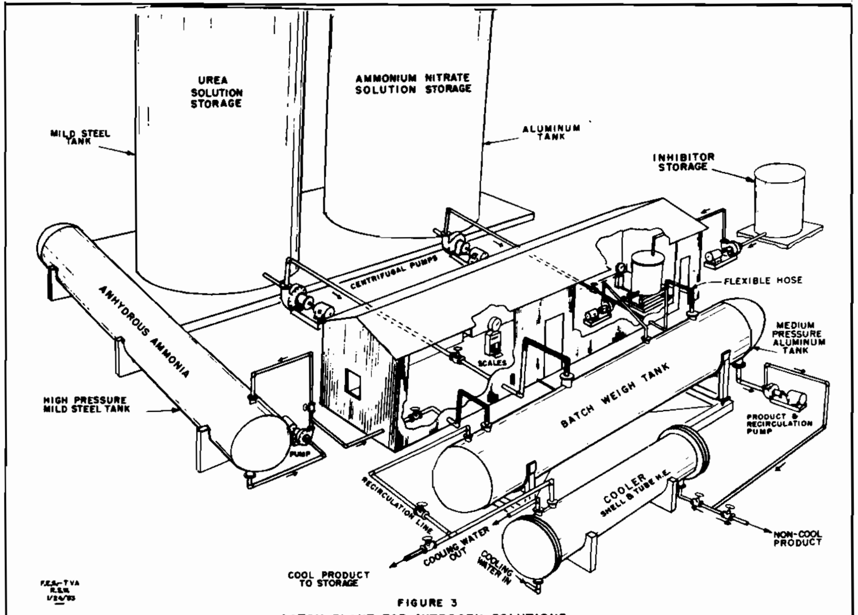
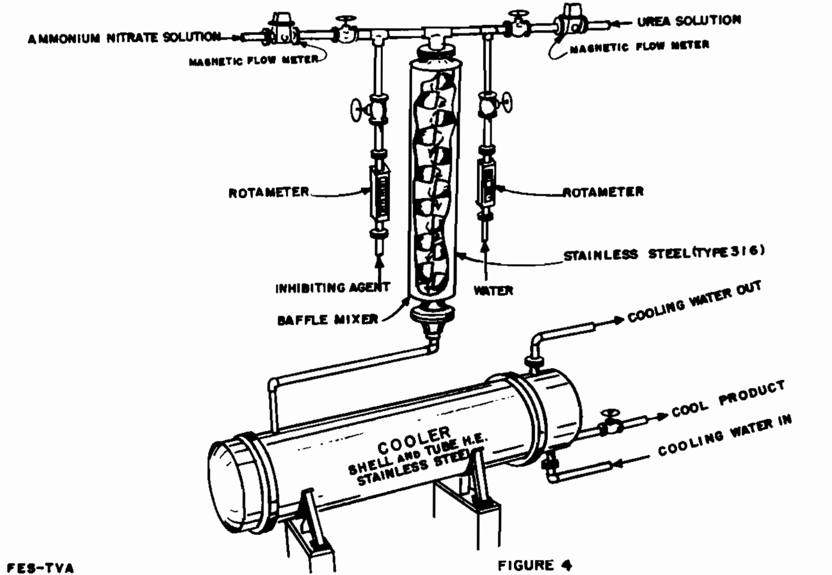


FIGURE 3
BATCH PLANT FOR NITROGEN SOLUTIONS



FES-TVA

FIGURE 4

TVA CONTINUOUS UREA-AMMONIUM NITRATE SOLUTION PLANT

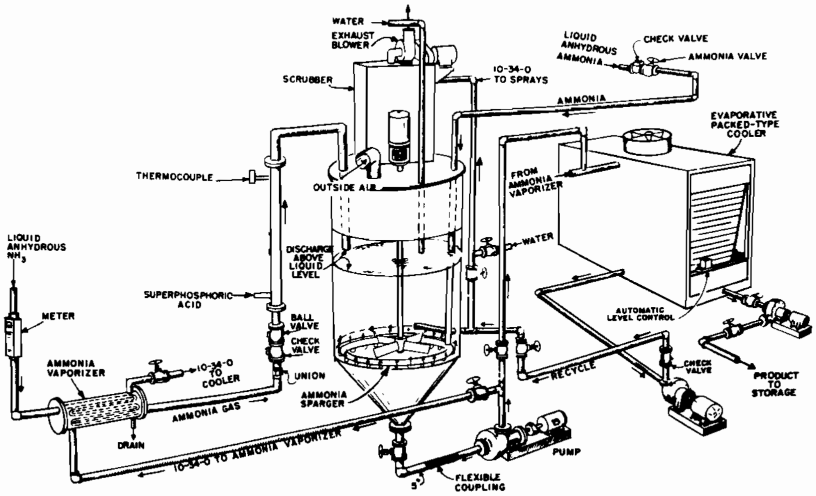


FIGURE 5

A FLOW DIAGRAM OF PIPE-REACTOR PROCESS
FOR AMMONIUM POLYPHOSPHATE SOLUTION

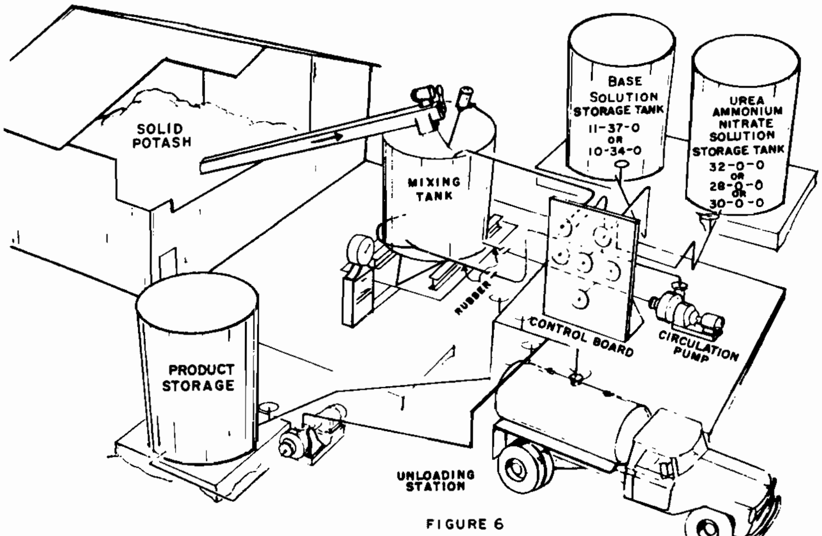


FIGURE 6

COLD MIX PLANT FOR SOLUTIONS

PPI SEC.-TVA

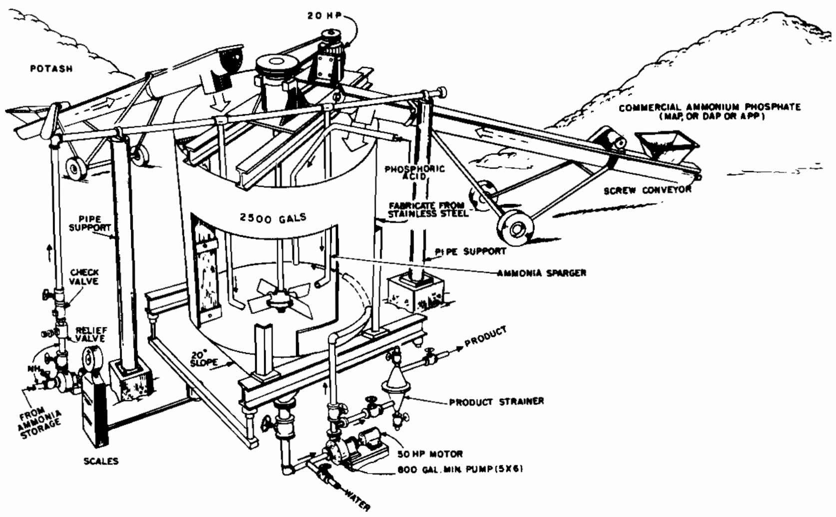


FIGURE 7

TYPICAL MIX TANK FOR PRODUCTION OF SUSPENSIONS FROM COMMERCIAL GRANULAR AMMONIUM PHOSPHATES

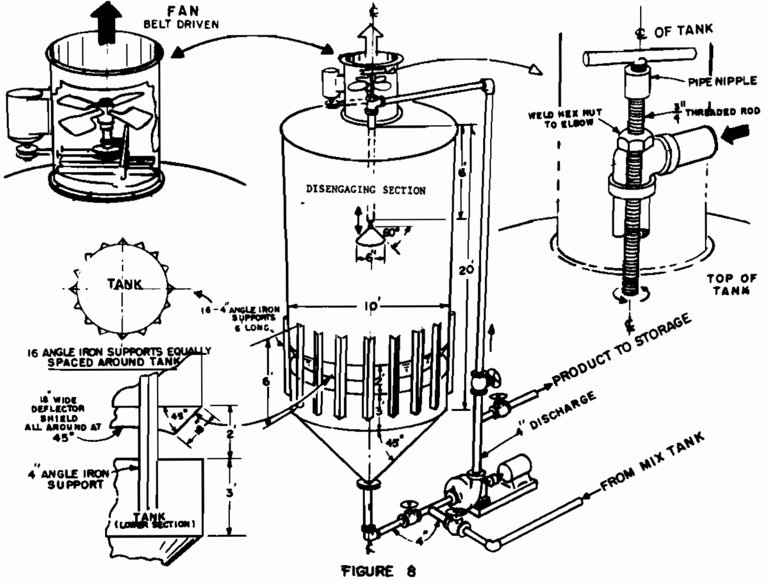


FIGURE 8

SUSPENSION COOLER (NO PACKING)

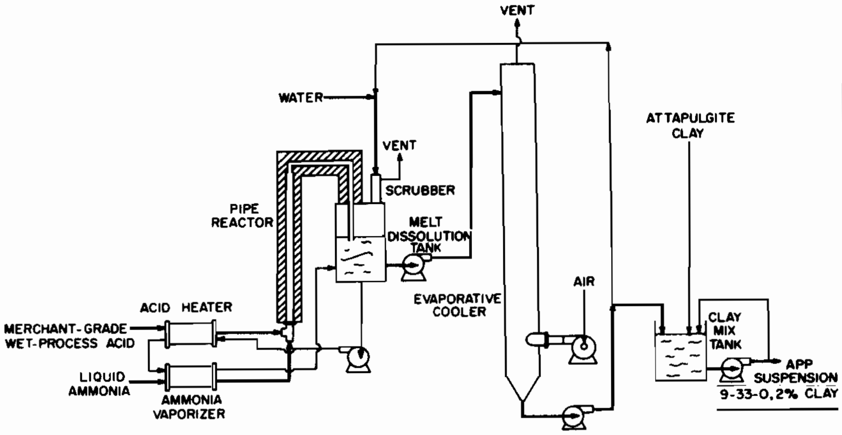


FIGURE 9

AMMONIUM POLYPHOSPHATE SUSPENSION-FLOW DIAGRAM

TROUBLE SHOOTING SUSPENSIONS

MAKING SUSPENSIONS TROUBLE-FREE

Sam H. Ferguson
Ferguson Industries

I prefer the subtitle given this paper because the best way to solve a problem is to avoid the problem. It is essential for the dealer and his plant operator to know the nature of suspensions, why they behave as they do, so they can be made properly the first time instead of correcting mistakes.

The Market Trend

Fertilizer consumption was down in 1982 after years of steady growth. All three types of fertilizer—dry, anhydrous ammonia and fluids followed the same general trend of the total. This was not the case of suspensions; they held steady. The use of monoammonium phosphate (MAP) has been a major contributor to this trend.

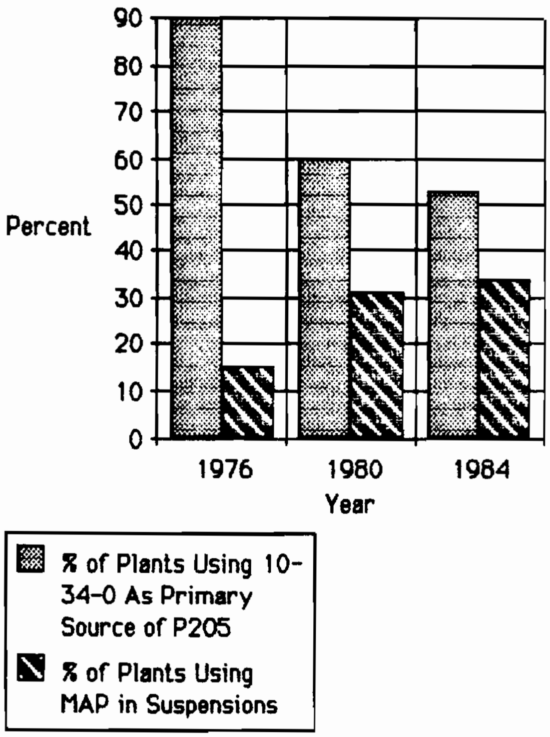
It is not possible to determine the amount of MAP used in suspensions because no state requires that information in reporting consumption. However, we can look at the figures and make some assumptions—

In 1976, 90% of the suspension plants reporting were using 10-34-0 as their primary source of P_2O_5. In 1980, only 60% and in 1984 only 53% of the plants reporting were using 10-34-0 as their primary P_2O_5 source. Let's look at the same survey for the numbers on MAP. In 1976 only 15% of the plants reporting were using any MAP in suspensions. In 1980, that number had grown to 31% and in 1984 to 34%. No figures are available on the tonnage of MAP used in suspensions, but the increase in the use of MAP compares to the decrease in the use of 10-34-0. In our daily contact with the market place, we find very few dry bulk blenders using MAP in lieu of DAP. Also, because of physical properties, some MAP such as 10-50-0, a powder-like material, is not suitable for dry blending. We can assume from this that the majority of MAP is used for suspension production.

In The Beginning . . .

The first mixed liquid fertilizers were solutions with all of the N-P-K dissolved. These were perfectly homogeneous mixtures that saved labor in handling. They were easy to spread accurately and uniformly, alone or with pesticides. Farmers were quick to see and appreciate the benefits—faster starts, more uniform growth and often higher yields. Higher costs, low analysis and inability to use nutrients that are not soluble were disadvantages that slowed the growth of these high performing fertilizers.

USE OF 10-34-0 AND MAP IN SUSPENSIONS



Source: AAPFCO Surveys

What are Suspensions?

Along came suspensions[1], *a saturated solution in which undissolved particles of fertilizer salts and impurities are suspended by the viscosity of the fluid.* Suspensions offer all the benefits of clear mixed liquids: less labor, homogeneity, and accurate uniform spreading, either alone or with pesticides. But that is not all. Suspensions offer rewards that are commensurate with the higher investment of management skills and capital. The orthophosphate suspension dealer enjoys plant food costs that are competitive with those of dry blenders—and often as much as $50 per ton or more below those of polyphosphate suspension dealers. Most nutrients can be supplied through a wide choice of raw materials and these materials do not have to be water soluble. In terms of product quality, there is considerable evidence that orthophosphate suspensions outperform dry blends and compete head on with polyphosphate fluids. Orthophosphate suspensions command premium prices, as do polyphosphates, and that adds up to higher profit margins. The plant food concentration can be increased by as much as 50% over solutions.

Suspensions offer important agronomic and economic advantages. Although they are cost competitive with dry blends, most suspension dealers elect to sell

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[1] In this article, the term "suspension" denotes suspensions based on orthophosphates (MAP, DAP and orthophosphoric acid.)

a complete program rather than competing on price alone. Complete agronomic programs are one reason for the success of suspension dealers and also for the remarkable acceptance by farmers. With proper planning, a dealer can capitalize on this acceptance.

Suspensions are Dynamic!

Before considering the fundamentals of formulating and marketing suspensions and how to maximize their opportunities, we must first understand that suspensions are quite different from dry blends and clear mixed liquids. *Suspensions are dynamic fluids. They are mixtures of reactive compounds that are not in chemical equilibrium.*

Suspensions have a maximum nutrient content of 45–50%, a maximum solid content of 75% and a minimum of 25% water.

They behave in accordance with Stoke's Law which states that in order to slow a rate at which suspended particles fall, one must make the particles smaller or make the viscosity of the medium thicker.

Suspensions will have a viscosity of 700–1000 SSU or about the consistency of 30-weight motor oil at 70°F. At this viscosity, suspensions are easily handled.

Steps to Suspensions Production

Let's look at some of the key steps to quality suspension production. The control of particle size—particles must be in the 20-mesh size range. With proper formulation the product will not be likely to grow troublesome crystals. A good clay gel is necessary to obtain the appropriate viscosity. This requires a properly designed high shear mixer. A mixer incapable of producing a good clay gel is an invitation to disaster. A clear liquid mixer will not make a suspension mixer without extensive modifications.

With this in mind, Ferguson Industries redesigned its clear liquid mixer to produce suspensions using these design criteria:

1) High quality, high analysis production.
2) High production rate.
3) The ability to use all fertilizer raw materials, limited only by their chemical properties.
4) Minimize energy, labor and maintenance.

The systems objective was to:

1) break, crush, or grind granular material
2) have high pump capacity
3) high shear agitation
4) fast clay gelling

This required a rugged, high capacity pump for hydraulic mixing and to assist in particle size reduction and gelling of clay.

Considerable research was conducted, and after much testing we determined that a modified Cowles-type blade produced a laminar flow that proved to be the most effective agitation system for the purpose. The horsepower required varies from 40–60 horsepower depending on tank capacity.

A 30° cone bottom mix tank prevents the build-up of solids on the tank bottom. In a shallow cone tank, solids build up on the tank bottom and cause the product to become contaminated with undegraded granules causing filter and applicator nozzle problems.

Since the mixer is only a part of the system, we find it highly advisable to give assistance to our customers in plant layout and design. Doing it right pays big dividends in time saved and in product quality.

The most commonly used products in the production of suspensions are water, MAP, anhydrous ammonia, clay, potash and nitrogen solution.

One of the most critical factors in producing a suspension is the 1:3 ratio of ammoniacal nitrogen to P_2O_5. This must be precise to avoid undue crystal growth and a product pH of 6.5. MAP has a pH of 4.1. As ammoniation increases the compound reaches the point of greatest solubility which is a pH of 5.8. With ammoniation at a 1:3 ratio of ammoniacal nitrogen to P_2O_5 a stable product is produced with a pH of 6.5. Nucleation or crystal growth would be small rectangular DAP crystals as opposed to long needle-like MAP crystals. If properly made and handled, a multitude of small DAP crystals or nuclei will be formed as the product cools. These very small crystals create no handling or application problem.

I would like to say again, DO NOT VIOLATE THE 1:3 RATIO OF AMMONIACAL NITROGEN TO P_2O_5. Do not use anhydrous or aqua ammonia as a supplement source of nitrogen. To do so invites disaster.

Reacting MAP and ammonia is the most common method of producing 10-30-0, an exothermic reaction with a theoretical heat rise of about 105°F. As a practical matter, the heat rise will be about 70°F, because of radiation and evaporation of water and other factors. This heat of reaction is of great benefit in accelerating the degradation of MAP granules and driving the reaction to completion. When the reaction is complete, heat is then detrimental. Since slow cooling promotes crystal growth, it is desirable to reduce the temperature as rapidly as possible to 130°F or less. This can sometimes be done by pumping the hot product into a heel of cool product in the storage tank and briefly recirculating to blend the hot and cool together.

DAP with a pH of 8.0 and phosphoric acid are also used to produce suspensions. DAP is over acidulated with phosphoric acid, then anhydrous ammonia is injected to neutralize the excess phosphoric acid generating heat to accelerate the chemical reaction. Usually about 30% of the P_2O_5 is derived from the phosphoric acid and the balance from DAP.

Since improper viscosity is one of the major problems for suspensions, I would like to discuss some of the factors affecting viscosity. Recalling Stoke's Law, viscosity must be sufficient to support the undissolved particles. The greater the viscosity, the heavier the suspended particles may be.

Viscosity is affected by solid content and the amount of clay. The higher the analysis of the suspension, the less clay required to attain the desired viscosity. As solids increase in a mixture, viscosity increases and suspending capability increases accordingly. Between 40 or 50% plant food, depending on the product being suspended, is the maximum concentration which can be easily pumped.

A graph developed by TVA demonstrates the relativity of plant food concentration to clay content. At 30% plant food, 2% clay would be required. At the opposite end of the scale, 45% plant food would require less than .75% clay. Since so many factors affect the viscosity there is no ironclad rule on the optimum amount of clay required to produce the proper viscosity. This will be determined based on operator experience. The amount of clay will normally vary between .5% and 2%.

The chemical reaction among nutrients can greatly affect the viscosity. This is particularly true when certain micronutrients are used. In some instances, no clay will be required such as when magnesium is part of the formulation.

The ineffectiveness of clay gel ranks as one of the most common problems in the production of a good suspension. A mixing system without adequate pumping and agitation is the most common cause of a poor clay gel. Another common cause is the addition of nitrogen solution to the suspension before clay is gelled. Ammonium nitrate salts in nitrogen solution will prevent the gelling of clay.

Gelled clay increases viscosity and forms a haystack like pattern to bind or suspend particles. Clay deters crystal growth by providing seats for small crystals to form, thus preventing the growth of large crystals. Clay also imbibes water reducing free water.

Having discussed some of the major principles involved in suspensions, let's make a brief review. The steps in the production of MAP and DAP suspensions:

1) Make a 1:3 ratio product
2) To the finished product, add clay and gel properly.
3) For N-P-K grades, add potash, then clay, then nitrogen solution.

The order of addition for a 10-30-0 suspension:

1) Water
2) MAP
3) NH_3
4) Clay

The order of addition for an N-P-K grade suspension might be:

1) Water
2) MAP
3) NH_3
4) Potash
5) Clay
6) Nitrogen solution
7) Secondary and micronutrients

This order of addition will vary depending upon the feedstocks, the grades being produced, the equipment used and the experience of the operator.

A good suspension has a proper formulation, small particle size, a good clay gel and a proper viscosity.

Problems with suspensions begin with the operator or the equipment. A skilled and trained operator with proper equipment will consistently produce a smooth, homogeneous, easily handled and easily applied suspension. He will know formulation and his feedstocks and will have a well maintained plant. There is no substitute for properly applied horsepower in producing suspensions.

Suspension Problems

Suspension problems may be classifed as either chemical, mechanical, or operator. In order of frequency the trouble calls we receive are:

Chemical Problems:

- Formulation problems
  - Violation of the 1:3 ratio
  - Order of addition
  - Improper clay gelling
  - Crystal growth

Mechanical Problems:

- Mixer limitations
  - Inadequate pump and agitation from either design or wear
  - Shape of tank—cone vs flat bottom
  - Poor manifold design
  - Scale design
  - Cross-contamination because of worn valve seats

Operator Problems:

- Problems may result from operator's failure to read scale stops correctly, or from inaccurate scales
- Slow addition of materials—One observed phenomenon for which we have no precise explanation is that the more rapidly materials are added to the batch mixer, the better the product quality.

Lastly, and as an invitation to those of you who are seriously interested in suspension, Ferguson Industries not only builds the finest equipment for producing suspensions but also conducts the only comprehensive suspension technology school we are aware of, and it is open to anyone who chooses to attend.

Appendix I. SUSPENSION TROUBLE-SHOOTING TABLE

Problem	Cause	How to Prevent or Cure
CLAY DOES NOT GEL	Insufficient shear.	Check pump impeller. Check agitator blades for wear. Recirculate/agitate longer. Change to high shear agitator.
	Wrong sequence.	The ammonium nitrate in nitrogen solution inhibits clay gel. Add UAN after clay has been gelled.
	Too much heat.	Clay temperatures should be kept below 160°F.
SOLIDS FALL OUT	Low viscosity.	Make sure clay is properly gelled. Use more clay. Make higher analysis grade, reduce water in formulation.
	Clay content diluted when mixing from base grades.	Add clay when using nitrogen solution to formulate NPK from base grades.* Gel clay before adding nitrogen solution. Recheck formulation.
	Particle size too large.	Agitate longer. Check agitator impeller for wear. Increase agitator horsepower. Add a wet mill to your mixer. Add MAP at minimum rate of 1½ to 2 tons/minute. Check analysis of raw materials. Check for feedstock contamination, e.g., granular potash in soluble potash.
	Improper formulation.	Run pre-production tests. Re-check formulation math. Did you consider the water in nitrogen solution and/or the base grade?*
	Improper formulation.	Review formulation with TVA, fertilizer supplier or other expert. Check MAP and other feedstock analysis.
	Wrong sequence.	See "Clay Does Not Gel" above.
	Materials are incompatible.	Check formulation with micronutrient supplier. (See "Secondary Micronutrients" Section of Ferguson Suspension Training Manual.)
SEDIMENTATION DURING STORAGE		
— SOFT	Failure to agitate.	Agitate or recirculate.
— HARD, GUMMY	Improper formulation.	Recheck formulation. Check clay gel.
	Acid fertilizer.	Clay gel strength weakens during storage of acid fertilizers. Check pH. Don't store for long periods if pH is less than 6.0. Check raw material quality.
	Particle size too large.	See above.
PRODUCT IS DIFFICULT TO PUMP	Viscosity too high.	Add water or nitrogen solution. Reduce clay. (Minimum of 25% water is required in suspensions.) Check for material compatibility.
	Too much clay.	Check math. Did you consider the clay in base grade?
	Intake lines from storage tank too small.	If pipe line to storage tank is smaller than pump intake, install larger pipes.
	Failure to agitate storage tank.	Check automatic timers. Schedule longer, more frequent agitation sequences.
	Line stoppage.	Clean out line.
	Pump impeller worn.	Check pump impeller. Replace if worn.
	Pump requires adjusting.	Refer to Owners Manual. If quick couplers are used, make sure connections are secure and pump is not pulling air.

Appendix I. SUSPENSION TROUBLE-SHOOTING TABLE
(Continued)

Problem	Cause	How to Prevent or Cure
CRYSTAL GROWTH*		
—MAP TYPE (needle like)	Under-ammoniation	Re-check formulation—1:3 ratio of NH_3 to P_2O_5. Test pH—should be 6.5. Send sample of product to laboratory for analysis. Check scales.
—DAP TYPE (cubes or rectangular crystals)	Over-ammoniation	Re-check formulation —1:3 ratio of NH_3 to P_2O_5. —For additional N use UAN, not NH_3. —Some UAN contains free ammonia. The amount of free ammonia must be calculated and offset other NH_3 used. —Check MAP analysis. Check pH—should be 6.5. Check scales.
	Slow ammoniation	Ammoniate at least 150 lb/min (30 gpm). Modify system if required.
—MAP or DAP TYPE	Slow cooling of phosphates in storage.	Pump hot phosphate product into a storage tank that contains a heel of cool material. Recirculate to blend and speed cooling.
	Weather related temperature changes.	Agitate thoroughly and often if temperature range is great.
	Failure to agitate stored material.	Check automatic timers. Schedule longer, more frequent agitation sequences.
—MAP or DAP TYPE	Complete change from previous cars of raw material.	MAP or DAP shipments may have varying analysis and impurities.
	Improper formulation.	See above.
BB OR PEA SIZE BALLS FORM IN STORAGE TANK	High calcium in MAP.	Check with MAP supplier.

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*28-0-0 contains 30% water.
32-0-0 contains 20% water.

**Crystals in suspension can be broken up with a Fluidizer or wet mill. If you don't have a wet mill, arrange with someone who has one to reclaim your product.

Thursday, October 31, 1985

Final Session

Moderators:
Cecil F. Nichols
Paul J. Prosser, Jr.

Methods of Handling Wastewater From Equipment Washing

R. Gordon Wells
The Fertilizer Institute

The last two years have brought renewed concern about adverse effects on environment quality from agricultural sources. Wastewater from washing fertilizer application equipment is often identified as a potential avoidable source of environmental contamination.

Wastewater from washing applications may contain corrosive chemicals, such as mineral acids or fluorides, nutrients such as nitrogen or phosphorous, or crop protection chemicals. Depending on local laws and regulations, wastewater containing such materials may be classified as hazardous and be subject to regulatory programs to protect the environment.

Past Practices

Earlier efforts to identify potential sources of pollutants from agriculture did not place much emphasis on wastewater from washing fertilizer applicators because of the small volumes and low concentrations of constituents in this water. As a result, historical practices of managing the wastewater often focused on readily available methods to clean the equipment and discard the water. In many cases, equipment was simply sprayed off in the parking lot or any drained area conveniently located near a clean water supply. Sometimes a rudimentary collection system such as an unlined pond would be constructed to control run-off of wash water from the property.

Recent Developments

The establishment of regulatory programs to control wastes accelerated the development of more sophisticated catchment systems for equipment wash down operations. These systems usually incorporate an impervious pad with a central collection system. The collection system consists of a lined impoundment or an underground tank. The collected wastewater must often be dicarded because it cannot be re-used in any of the on-site processes or products. As a discarded material, the wastewater may be subject to a substantial number of restrictions with respect to its treatment, storage and handling as well as disposal. The costs associated with handling or disposing or this wastewater increase dramatically under the regulatory programs.

Consequently, the fertilizer distributors are developing 1) methods of reducing the volume of wastewater from equipment washing and 2) systems to enable recycling of water from equiment washing. By minimizing waste generation at the distribution facility, fertilizer distributors avoid the difficulty of finding environmentally acceptable, cost-effective methods of handling wastewater.

While there are an almost infinite variety of means to minimize wastewater generation, four techniques can be applied to most fertilizer operations. First, planning applications of fertilizers to increase the uniformity in applications. Emphasis is placed on applying materials to a single crop before switching to a second crop. This reduces the number of times that an applicator must be washed. Second, reduce "haul-back" of unused materials. Less material remaining in the applicator requires less water to clean up *and* results in fewer pounds of contaminants in the wastewater. Third, reduce volume of wash water used to routinely clean applicators. Fourth, perform "in-field" washing of applicator and disposing of the wash water onto the crop.

For facilities which use water in the process, methods have been devised to maximize re-use of wastewater from equipment washing. Wash water from equipment washing is collected in separate catchment systems. That is, the wastewater from a corn application is segregated from wastewater from the soybean applicator. The wash water is then used as make-up water for the process. In most cases, the catchment systems may be a series of underground tanks or a sump with a manifold to above ground tanks.

Outlook for the Future

The regulatory agencies are becoming increasingly critical of wastewater storage systems which have a significant potential to leak. Efforts are under way to restrict the use of unlined ponds, requiring installation of liners and monitoring wells. Alternatively, a pond may be constructed with a double-liner with a leak detection system between the liners. Underground storage tanks are also considered a high risk to ground water. Federal law, however, prohibits the use of "bare steel" tanks in many situations. New underground tanks are required to have corrosion protection, and leak detection systems are under consideration.

Thus, the future for inexpensive storage of waste materials such as equipment wastewater contains few options. Many of yesterday's solutions, ponds and underground tanks, are under critical review and new facilities of this type are often discouraged, if not banned. The best solution is to not produce or store wastewater from applicator washing at the fertilizer site. Where field washing is impractical, it is important to develop management practices to reduce volume of wastewater generated.

Outline of the Federal Hazardous Communication Standard and Some of its Impacts on the Fertilizer Industry

Glenn A. Feagin
Manager of Fertilizer Technology
IMC Corporation

In 1980, I presented a paper to this group on the Federal Resource Conservation and Recovery Act (RCRA) and I said it was a time bomb. Today, I don't think many people would disagree with my assessment.

Now, I have another one for you. The Federal Hazard Communication Standard (29 CFR 1910.1200) administered by the Occupational Safety and Health Administration (OSHA), commonly referred to as the Right-To-Know Law. This standard has the capability of becoming the greatest paperwork proliferation device since the conception of the federal income tax.

The purpose of this standard is to ensure that all employees in the manufacturing sector are appraised of the hazards they work with through a hazard communication program, which includes container labeling, material safety data sheets (MSDS) and employee training.

OSHA states that implementing this standard will reduce the incidence of chemically-related occupational illness and injuries. They also state that the increased availability of information will allow employees to do a better job of protecting themselves.

This standard is described by OSHA as a "performance standard". That is, various methods can be used to meet the requirements. Results are what counts.

Briefly, it requires that:

1. *Chemical and Manufacturers and Importers*
    - A. Determine if their products are hazardous.
    - B. Label containers if hazardous, showing contents and type of hazard.
    - C. Provide material safety data sheets for hazardous materials.

2. *Distributors*
    - A. Provide their industrial customers with hazard information on the products they handle.

3. *Manufacturing Sector Employers*
    - A. Develop a comprehensive hazard communication program for their employees.

Sounds simple enough. Certainly we need to know the hazards of the materials we handle; however, let's look at a few of the details.

All chemicals must be evaluated and it is the primary responsibility of the manufacturers or importers to determine whether or not a chemical is hazardous.

Employers may rely on this information; however, employers are required to determine whether or not each material in their own workplace is hazardous. There are special provisions for evaluating hazards in chemical laboratories that makes this part of the job a lot easier.

The evaluation of consumer products is a grey area. OSHA in their final inspection procedure (Section (b) (4), states that it might not be necessary to have a material safety data sheet for a can of cleanser used to clean a restroom sink; but if the same chemical was used in large quantities to clean process equipment, it would have to be evaluated.

They have also publicly stated that when in doubt, the prudent course is to consider everything covered.

Materials can be considered hazardous because of their effect on human health or because of their physical properties.

Sources listing over 600 chemicals, which are to be considered hazardous, are referred to in the standard. These are called the "floor chemicals". In addition, any chemical which does not appear on the list has to be individually evaluated. Managnese is on this list as a health hazard—ammonium nitrate as a physical hazard. Another common fertilizer material that is considered hazardous is sand. Sand is silica and silica is a hazardous material.

However, as used in fertilizer, little or none of it is in a form hazardous to the health and this can be noted on the MSDS.

The regulation further states that if a mixture contains 0.1% or more of a chemical that is a carcinogen, or 1.0% if the material is a health hazard, the mixture is hazardous.

When materials considered hazardous because of physical qualities are added to a mixture, the ruling is not as clear. There is no percent cut-off as such; the manufacturer has to determine when the mixture constitutes a physical hazard.

If a material has been determined to be hazardous, all containers must be labeled identifying the contents and the hazard. This includes both shipping and workplace storage containers.

There are certain exemptions. In our case mainly for chemicals that have to be labeled under the Federal Pesticide Laws and for plant process piping.

No set form for labels is specified. However, they must not conflict with the Department of Transportation Labeling Regulations. Also the present D.O.T. labels do not meet the requirements of this standard.

The Fertilizer Institute (TFI) asked OSHA if this labeling requirement applied to fertilizer mixtures that had been classified as hazardous when they were sold to farmers or other consumers and not to manufacturers. The answer was that any container of hazardous material leaving the workplace must be labeled regardless of where it goes.

In addition to labels, the manufacturer must provide each customer, at the time of the initial shipment or before, with a document called a material safety data sheet usually referred to as a "MSDS".

These are detailed documents, usually 2 to 4 pages long, which describe the physical properties, health hazards and handling procedures. Each fertilizer manufacturer would have to prepare one for every hazardous mixture he produced.

Whether or not the MSDS has to be automatically supplied to farmers is not clear and I could not get a ruling on it before this meeting. They definitely would have to be sent to manufacturers and supplied to any other purchaser on request.

Many firms are making it a condition of purchase, that they be supplied a safety data sheet on all materials—hazardous or not.

The standard requires material safety data sheets only for hazardous materials. But how does a customer know that a material, especially a mixture, is not hazardous unless they have seen the data sheet? As I see it, sooner or later, we will have to include a data sheet with every shipment whether the product is hazardous or not.

OSHA also states that they intend, at a later date, to extend the requirements of this standard to other sectors of the economy and some states have already done so. In fact, a federal court has ordered OSHA to extend their coverage to anyone handling hazardous chemcials.

Paper! Paper! Paper!—Expensive Paper! OSHA estimates that it will cost the chemical sector over $408.09 per employee (pretty accurate estimate isn't it?) to initially implement this standard.

If you consider the value of management time, it will be much more than this for most locations. Remember, there are no size exemptions and the regulations apply to all fertilizer manufacturing plants, warehouses and retail outlets.

Last, but not least, the standard also requires that each employer:

A. Develop a written hazard communication program for each workplace.
B. Advise each employee of the existence of these regulations.
C. Advise each employee of the hazards in the workplace and how evaluated.
D. Make MSDS's available at all times and teach employees how to read them.
E. Thoroughly train each employee, prior to their initial exposure, on how to identify and safely handle each hazardous material in their workplace.
F. Retrain each employee whenever a new hazard is introduced into the workplace.
G. Maintain records for 30 years.

OSHA states that the written program need not be lengthy or complicated, but should adequately address each of the required components. Nice trick, if you can do it.

Sounds like a lot of work, doesn't it? and, it is. It's a tremendous job and we are now under the gun.

The final standard has been issued. It was published in The Federal Register, Volume 48, No. 223, Friday, November 25, 1983, Pages 53280–53348. The title is *Hazard Commmunication; Final Rule.*

As of November 25, 1985, the requirement for labeling and material data sheets go into effect and as of May 25, 1986, employers must be in full compliance with all provisions, including initial training for current employees.

Many states have passed, or are considering passing, their own Right-To-Know Laws. However, OSHA states that federal law will preempt state laws in the manufacturing sector, but makes no mention of other sectors.

Eventually, the courts will settle the matter, but until then, if your state has its own law, you should adapt your program to fit it as well as the Federal Law.

I have some copies of a generic hazard communications program available (Item I). I make no claim as to whether or not it is suitable for your use. However, it might give you some ideas you can use.

Thank you very much.

ITEM I

HAZARD COMMUNICATION PROGRAM
FOR ____________________ COMPANY

SCOPE

1. This document is designed to comply with the written program required for Federal OSHA 1910.1200 (e). It shall be made available to all affected employees and their designated representatives.

PURPOSE

2. The purpose of this Program is to ensure that the hazards associated with all chemicals produced, consumed or otherwise utilized within the workplace, are communicated to the affected employee.

CHEMICAL INVENTORY

3. A chemical inventory has been compiled for all hazardous chemicals present at the facility. This inventory will be updated as new chemicals/products are introduced into the workplace. ____________________ will request Material Safety Data Sheets with each new purchase.

4. (NOTE: INSERT INFORMATION AS TO LOCATION OF CHEMICAL INVENTORY AND WHO IS RESPONSIBLE FOR UPDATING THIS SECTION.)

MATERIAL SAFETY DATA SHEETS

5. Material Safety Data Sheets (MSDS) have been obtained for all chemicals listed in the Chemical Inventory, except as noted. The Master Chemical Inventory Library is kept in ____________________. Other copies are located in ____________________.

6. MSDS's for commonly-used chemicals are located in the ____________________. These MSDA's are available for employee use on all shifts. Other MSDS's are available upon request for chemicals not routinely utilized.

HAZARD DETERMINATION

7. It will be the responsibility of ____________________ to determine the hazards associated with newly-developed products. This determination will be made prior to the introduction into the workplace. The procedure for making this hazard determination is available upon request from ____________________.

8. For most raw materials and consumable supplies, the manufacturer's MSDS will be relied upon to state the hazards of the materials. MSDS's received from suppliers will be reviewed by ____________________ for content and completeness. If necessary, ____________________ will contact the manufacturer for any missing information.

LABELING

9. All hazardous products manufactured at the facility and destined for commerce will be properly labeled. Labeling will include the identity of the products and the proper hazard warnings. It will also include the name and address of the manufacturing site. Proper labeling will be issued through the ____________.

10. Incoming containers of consumables with proper labeling must not be defaced or removed. Shipments which are received without proper labels will be segregated and not used until proper labeling can be obtained.

IN-PLANT HAZARD I.D.

11. In-plant hazard identification will consist of several components.
    a. Fixed labeling may be used on dedicated storage space. This will include chemical name and appropriate warning labels.
    b. Production Sheets may also be used to identify the location of hazardous chemicals during processing.
    c. Removable Placards will be used in dry-product warehousng to designated product/bin.
    d. Tank Inventory Sheets will be used as necessary.
    e. Process flow diagrams may be used to show hazardous chemical flow in designated pipelines and vessels.
    f. The facility (Operating Manual) is the ultimate guide to chemical location and status in the process. These are located ____________________ and should be referenced when questions arise.

12. It should be noted that the labeling/placarding requirements of Federal OSHA'S Hazard Communication Program in no way supercede the requirements of any other State, Federal or Local regulation. (Ex.DOT, RCRA, TSCA, etc.)

TRAINING

13. The Hazard Communication Training Program will consist of the following components.
    a. Overview of this Hazard Communication rule.
    b. Location of Hazardous Chemicals in the various operating areas.
    c. Location and availability of the written program, the chemical inventory and Material Safety Data Sheet library.
    d. Methodology and hands-on training in sampling and detecting hazardous materials. Training will include ____________________.
    e. Physical properties and health hazards associated with chemicals will be handled via existing training programs as far as possible. These include the use of Protective Equipment and the Emergency Procedures and Contingency Plan.
    f. An explanation of the facility's various methods of compliance with the labeling requirements will be included.
    g. The use of Material Safety Data Sheets will be reviewed.
    h. Employee training will be documented and records kept in ______________. (SUGGESTION—Employee's Personnel File.)

NON-ROUTINE JOBS

14. The hazards (physical and chemical) associated with non-routine jobs will be reviewed prior to commencing any activity. Reference should be made to Confined Space Entry Procedures, Fire and Work Permits and Personal Protective Equipment and ____________________ for proper methods.

CONTRACTOR SAFETY

15. Refer to General Operating Standard on Contractor Safety for proper procedures.

16. A Company Representative will be assigned to work with each contractor. The contractor will provide a foreman to act as their representative. The Company Representative will review the Contractor Safety Checklist with each contractor prior to beginning of any work. This document will be signed by both the Company Representative and the Contract Foreman. (Contractor Safety Checklist attached.)

17. When the contracted work entails an exposure or potential exposure to hazardous chemicals, the Company Representative will provide the Contractor with the proper MSDS. The Contractor will provide the Company Representative an MSDS for any hazardous material he brings into the workplace.

ORIGINAL DATE: ____________________

REVISED DATE: ____________________

Fertilizer Quality Control Where We've Been-Where We Are-Where We Are Going

James R. Stevens

North Carolina Dept. of Agriculture

This is a topic we can talk and speculate on all day. I have 20 minutes and don't plan to run over. I have been in fertilizer control work for 35 years. When I started in North Carolina, there was no bulk fertilizer. There was no liquid. There was no bulk limestone. There were no nitrogen solutions. The mixed fertilizers were pulverized types sold in 200 pound burlap; and if companies really wanted to impress someone, they put it in 200 pound white cotton bags with fancy script. The only paper bags were 100 pound bags of bulldog soda and 20.5% ANL (Ammonium-Nitrate-Limestone). Limestone was in 100 pound paper bags. The predominent grades in our state were 3-8-3, 3-8-5, 3-9-6, 4-10-6 and 5-10-5. Sampling was simple. When we went into a place to sample, we carried a probe in one hand and case carrying our transcripts and containers in the other. We have always divided our samples in the field and still do. We probed the bags and emptied them unto oil cloth or clean paper and divided the aggregate sample into quarters. We then took one quarter and filled our container. If there was more fertilizer than our container would hold, we just left it. Prior to the introduction of granulated fertilizers, our penalty rate remained under 5%. I remember one company that went for years without a single penalty. Then one year, we had one sample that came up short. They hit the ceiling. That's how it was in the good old days.

Then came the granulated products, the nitrogen solutions, bulk limestone, blends and liquid formulations. We had to equip ourselves to handle sampling of liquid fertilizer including nitrogen solutions. With the coming of these products came mixed fertilizer in bulk. For many years, we sampled liquids by running it into a dipper and pouring it into our container. We used our bag probes for sampling bulk. Some states still do. We had no pattern for sampling bulk. Low pressure nitrogen solution 37 and 41% and anahydrous ammonia took the nitrogen market. The use of 30%, 28%, 21%, 19% and 16% was minute. We checked these non pressure products in the field by specific gravity and ran anhydrous by evaporation. When the liquid and blend plants started, some of them knew less about what they were doing than I did and I knew little. To show you how smart I am, I kept telling myself those people are stupid. These plants will never make it. Most of them made it and we found ourselves adjusting to their technology. Of course, our penalty rate jumped. Ammoniation plants began to close across the country. Two years ago we had 11 ammoniation plants located in North Carolina. Within the last two years, we have lost 6 of them.

Where are we today? In North Carolina, we have 130 blend plants and 50 liquid plants. I think the last figures I saw showed only 11 to 12% of the fertilizer sold nationally now is sold in bags. In North Carolina, over half of our mixed fertilizers are sold in bags and most of it in 50 pound paper bags. Even though only 11 to 12% of the fertilizer sold nationally is being sold in bags, about 40% of all samples are taken from bags. Deficiencies across the country have kept creeping up. Let's look at the monetary penalties being paid by the industry to the consumer and the states. While there are some variations, the rate of penalties are primarily 3 times the deficiency. There are several things that enter the picture at this point. Not all states have adopted the uniform investigational allowance. The tolerance is different. I dare say you will not find two states with the exact same relative values on which the penalty is based; and of course, there are the extremes from no monetary penalty to very expensive fines. Then there is another side. In North Carolina, we sample a higher percentage of tonnage sold than any other state. We have the uniform investigational allowances. Our relative value is probably higher than most, since we base relative values on retail prices of bulk fertilizer to the consumer. Thus we collect more dollars in penalties than any other state. I know you are thinking we are out of line. Are we? We only sample 10% of the tonnage sold in the state. If a fertilizer product is truly deficient, 90% of it is not being sampled. So every time a company pays us $3.00, they have made $7.00 on the shortage. I don't believe the penalty structure is out of line. Many believe the only way to cut the deficiency rate is to increase penalties. I do not agree. I believe the industry wants to make the best products possible. Recently, Kentucky, Florida and North Carolina reported a decline in deficiencies. Dave Terry in Kentucky and Vince Giglio in Florida attributed their decline to law changes. I attribute ours to an education program with the blenders.

Let's look at the plight of the blender. He really has problems. Some simply don't care. This is evidenced by the case in Canada where a company won its case in court. The company claimed the law only required them to mix a product to a given grade, not to keep it mixed. Florida has had some of these same problems. This indicates that the blender would simply dump the different materials into a truck and sell it as a mixed fertilizer if it were not for the requirements of law. Hopefully these are few. Most of our blenders are sincere and trying to sell a good mixed fertilizer. How can they do this? I don't know. Canada has the Size Guide Number and reports indicate this has helped. But what would the SGN accomplish in the states where practically all materials go through 1, 2, or 3 storage facilities before reaching the blender. A SGN of 210 might mean that this particular product would all pass a 6 mesh screen and be retained on a 16. Every time this product is placed into a storage facility, it segregates. So depending upon where the material is loaded from coming out of storage, it may be much closer to the 16 mesh or to the 6 mesh. To give you an example, we were trying to match materials to within 10%. The plant ordered a carload of urea directly from the manufacturer and a truck load of DAP directly from the manufacturer. The urea was unloaded by conveyer. When we screened the material in storage, the urea near the front of the pile was too large. We went to the top of the urea pile for a sample, it was too small. The DAP was too small. We sent back to the same manufacturer for another load of DAP. It came in and was too large. In order to match the materials to within 10%, we blended large and small urea together and blended the large and small DAP. We have been working with our blenders to get them to put anti-segregation devices in holding hoppers, have accurate formulas, accurate scales, good housekeeping, no cross contamination and buy the very best material available. It is difficult on the blender when major material suppliers import much cheaper standard and coarse potash and sell it to blend with granular DAP, Triple or Ammonium Sulfate. We all know that mixed fertilizers blended with materials with a wide range of particle size are going to segregate.

Earlier I referred to sampling equipment in good old days. Today, we have a specific pattern for sampling bulk; official equipment and methods for sampling all products. When we go to a location to sample, our inspectors have a tube for sampling bags, a tube for bulk, a stream sampling cup, a dipper and funnel for liquid mixing vats, a liquid sampling bottle, a gated riffle, a computer printout of manufacturers and products, tape for sealing holes in bags, transcripts and a case to hold samples. Each inspector is thoroughly trained in the proper use of all this equipment. Years ago, I rode around with a trunk full of cases for samples and my bag probe. Now our inspectors ride with a trunk full of equipment with their cases on the back seat. Presently the Association of American Plant Food Control Officials is working diligently to get uniformity among states in sampling and labeling. We encourage states to adopt the uniform fertilizer law. Our labeling committee is very active in assisting fertilizer companies and any state in uniform labeling. Our Inspection and Sampling Committee is ready to put on inspectors training seminars anywhere in the country to train inspectors in official sampling procedures and official equipment. The AAPFCO wants to assist the states and the industry in any way we can. The fertilizer industry has been and continues to be a very vital part of our association. Without the cooperation of the fertilizer industry, it would be difficult for us to survive.

Finally, where are we going? This one is easy. I have no crystal ball. I don't know where we are headed and I doubt many of you do. We all have ideas. There certainly will be changes in manufacturing and distribution. So the answer to the question "where are we going in the future in fertilizer control?" is; we are going where the fertilizer industry leads us. You develop the technology to produce quality product and we will develop the technology to sample and analyze them representatively and fairly. I thank you for allowing me to pinch hit for Past President, Charles Crober, and allowing me to ramble. After this presentation you may want to change your policy of inviting the immediate past president of AAPFCO or I might be back rambling again next year. Seriously, I do appreciate the opportunity to be with you at this round table. I regret that my schedule would not permit me to be here earlier. I invite you to join with us at our annual meeting next August in San Francisco. Thank you.

The Importance of Sulphur in Agriculture

Dr. William I. Segars
Extension Agronomist—Soils and Fertilizer
The University of Georgia

Sulphur (S) is considered as the fourth most important essential element in plant nutrition, ranking behind N, P and K. The quantities needed by plant is very similar to the requirements for elemental P. For many years, the importance of S was overlooked because adequate quantities were supplied to crops in the form of manures and low-analysis fertilizer manufactured using normal superphosphate and ammonium sulphate. Recently, the shift to high-analysis dry fertilizers and fluid suspension containing little incidental sulphur has prompted a necessary reemphasis on the need for this nutrient.

Plant Nutrition

Sulphur is required in many metabolic processes within the plant. It is a constituent of amino acids (methionine and cystine) and is consequently involved in protein metabolism. It functions in the activation of certain vitamins (Co enzyme A and glutathione). Sulphur is also important in the formation of glucoside oils in several *Allium* species and cruciferous plants. It has been linked to increasing cold resistance by increasing formation of sulfhydryl (-SH) groups. It is required for nitrogen fixation by leguminous plants and is part of the nitrogenase enzyme system.

Sulphur Deficiency

Sulphur deficiencies have been reported worldwide within the last decade. Crop responses to S fertilizers have been observed in the United States, Canada, Latin America, Europe, Africa, Asia and Australia. In the U.S., at least 37 states have reported responses to S.

There are several reasons why S deficiencies are being reported more frequently:

(1) Increasing use of high analysis fertilizers containing little or no incidental S.
(2) Improved air pollution control that reduces the amount of atmospheric S reaching agriculture land.
(3) Increasing crop yields and multiple cropping systems that require progressively greater quantities of S.

On most plants, S deficiency is observed as a general yellowing of leaves, usually occurring first in the young growth plant parts. In severe deficiency, the entire plant will appear yellow. The inexperienced observer may often confuse S and N deficiency symptoms. However, the symptoms vary in that N deficiency begins on the older leaves since N is translocated to the young active growing tissue. A plant analysis can be used to confirm the deficiency.

Soil Sulphur

Sulphur is present in soils in the soil minerals and organic matter. The vast majority of soil S is organically bound and must be converted to the sulphate ion ($SO_4=$) before it can be utilized by plants. This conversion is accomplished by soil bacteria. The conversion or oxidation of elemental S to the $SO_4=$ ion is accomplished by *Thiobacillus* (*thioxodams* and *thioparus* species) microorganisms. The speed of oxidation depends on soil pH, temperature, moisture and aeration.

Since the sulphate ion is an anion (negatively charged) it can be readily leached from soils with a low cation exchange capacity. The soil losses of sulphate are similar to those of the nitrate ($NO-3$) ion. The retention of sulphate ion by clay and organic matter is also reduced when the soil pH is near neutral or alkaline. This is the result of hydroxyl ($OH-$) ions competing with the $S0_4=$ ion for absorption sites.

Generally speaking, soils most likely to be low in residual soil S are soils:

(1) low in clay and organic matter
(2) in high rainfall or irrigated areas
(3) soils with a high pH (near neutral or higher)

Soils with these characteristics will often require annual S applications to maintain adequate plant available S. Soil testing for sulphur is not as reliable as tests for elements such as P and K. This is due in part to the fact that most soil sulphur is in the organic form, the availability of which is dependent on those environmental conditions which affect organic matter decomposition. Additionally, the topsoil of most low CEC soils contains relatively small quantities of S. There is little calibration data available for S tests on topsoil of low CEC soils. On these soils, soil test calibration data will be developed based on the S content of subsoil samples.

Although the sulphate ion will leach rapidly in many low CEC topsoils, it must be remembered that clay accumulated in the B horizon can attract the anion. Thus, on many low CEC topsoils, the growing plants may not exhibit S deficiency if the root system penetrates into the B horizon. This phenomena has frequently been observed in the southeastern United States.

Sulphur Fertilizers

There are numerous S-containing fertilizers that can be used to supply plant available S. Among the most frequently used are: (1) ammonium sulphate, (2) ammonium thiosulphte, (3) potassium—magnesium sulphate and (4) various forms of elemental S. When rapid plant uptake is required, water-soluble sulphate forms are used. Plant uptake from elemental S is delayed until the soil oxidation process converts it to the sulphate ion. This process requires several weeks or longer, depending on environmental conditions, soil pH, soil microorganisms population and particle size of the S.

Several recent developments in the U.S. regarding S fertilization include the use of S in banded starter fertilizers and the inclusion of S in nitrogen solutions. On high yielding irrigated crops such as corn, S is often applied in multiple applications with N to reduce leaching losses and improve fertilizer efficiency.

The selection of a particular S fertilizer will depend on the cropping situation, time of application, customer preference, cost, application equipment, compatability of S with base fertilizer and availability of the fertilizer.

Plant Analysis

The analysis of plant tissue for elemental content has proven to be a helpful diagnostic tool. It has been widely used in the United States to determine if adequate or sufficient levels of a given nutrient are present in quantities to maintain optimum plant growth. In Georgia, agronomists not only examine the content of sulphur but also examine the N to S ratio. Generally, this ratio is maintained in a range of 13:1 to 17:1. The use of excessive rates of nitrogen and induce of S deficiency by causing an imbalance in the ratio. Continuous refinements are being made in the use of plant analysis and undoubtly its use will increase throughout the world.

Summary of Business Meeting:

1) Secretary Treasurer Paul J. Prosser, Jr. read the following financial statement to the membership:

FINANCIAL STATEMENT

October 30, 1984 to October 24, 1985

CASH BALANCE—October 30, 1984		$12,175.94
Income October 30, 1984 to October 24, 1985		
Registration & Cruise Fees, 1984 Meeting	$11,775.00	
Sale of Proceedings	3,845.46	
Registration Fees, 1985 Meeting	7,670.00	
Total Receipts October 30, 1984 to October 24, 1985		$23,290.46
Total Available October 30, 1984 to October 30, 1985		$35,466.40
Disbursements October 30, 1984 to October 24, 1985		
1984 Meeting Expenses, including Cruise	$ 3,759.60	
Directors Meeting	1,365.20	
1984 Proceedings, including postage, etc.	13,666.57	
Miscellaneous Expenses including postage, stationery, etc.	459.17	
1985 Meeting Expenses	1,308.45	
Total Disbursements October 30, 1984 to October 24, 1985		$20,558.99
CASH BALANCE—October 24, 1985		$14,907.41

Respectfully submitted,

Paul J Prosser

PAUL J. PROSSER, JR.
Secretary/Treasurer

Mr. Prosser then announced that the official registration for the 1985 meeting was 242. He further indicated that funds available for the next year's operations were adequate.

2) Mr. Walter Sackett, chairman of the public relation's committee, expressed appreciation to all publications for their cooperation especially to British Sulfur Corporation and Mr. John French.

3) In the absence of Mr. Thomas B. Athey, it was announced that next year's meeting will be held in Baltimore, Maryland at the Sheraton Hotel near the Inner Harbor on November 17, 18, & 19, 1986 and that the 1987 meeting was scheduled for New Orleans.

4) Mr. Rodger Smith, reporting for Mr. Joseph Reynolds, chairman of the nominating committee, indicated that the current number of directors was down to thirty-eight, due to retirement, resignations and the like. Accordingly he read the following proposed slate of new directors:

Cameron Bowen—Royster Agricultural Company, Chesapeake, VA
William E. Byrd—Mississippi Chemical Corporation, Yazoo City, MS
Leo C. Cook—Agway, Inc., Syracuse, NY
Dick Fetter—Morral Chemical Company, Morral, OH
John French—British Sulphur Corporation Ltd, London, England
Bruce W. Karras—PCS Sales, Saskatchewan, Canada
Clyde Mader—Farmland Industries, Kansas City, MO
Ted Schulte—United Suppliers, Eldora, IA
James J. Schultz—IFDC, TVA, Muscle Shoals, AL
Robert Williams—C. E. Tyler, Ellicott City, MD

All were elected to the board of directors by majority vote. Further, Mr. Thomas Howe of Howe, Inc., Minneapolis, MN was elected vice-chairman to replace Mr. Al Malone of Agway, Inc., now retired.

After requesting that suggestions for future program topics and speakers be sent to Mr. Harold Blenkhorn, Chairman Medberry adjourned the 35th Annual Meeting of the Fertilizer Industry Round Table.