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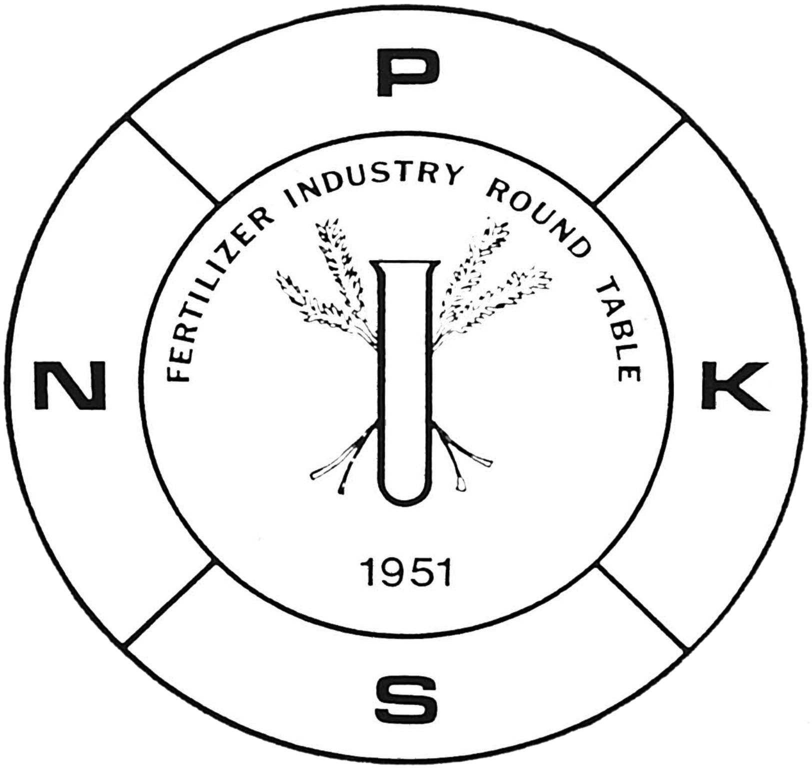
OF THE
43rd ANNUAL MEETING
FERTILIZER INDUSTRY
ROUND TABLE
1993



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THE FERTILIZER INDUSTRY ROUND TABLE AWARD OF MERIT

Presented to Paul J. Prossor, Jr.
By David W. Leyshon

The Fertilizer Round Table Award of Merit is awarded to outstanding individuals who have devoted most of their career to our industry and are recognized by their peers as having made a positive difference. This year we honor Paul Prosser, who for the past twenty years has truly been "Mr. Round Table."

Paul did most of his growing up in Baltimore, where he graduated from Loyola College in 1942. He spent World War II in the U.S. Navy as an Officer on a destroyer in the Pacific from 1942 to 1946.

In 1946, Paul entered the fertilizer industry joining the Baugh Chemical Company. He started at a small plant in the rural community of Keymar, Maryland. He was active in all phases of the business. He rapidly rose in the company ranks and left in 1964 as Executive Vice President, shortly after Baugh was purchased by Kerr McGee.

He joined the Prosser Company in 1964 as an Officer and Stockholder. This engineering company had been formed by Paul's brother Joe in 1960 as a machinery supplier and contractor of chemical plants. After a long and productive career, Paul retired as Executive Vice President at the end of 1988.

The Round Table owes this man a debt of gratitude, the extent of which can only be rivaled by Vince Sachelli, the founder of the organization. During the first twenty years of the organization, it was run by scientists as a "Non-Profit Entity." It certainly was that. Back in the 50's and 60's with attendance booming to six hundred plus participants, the organization was always in the red.

In the late 60's, Paul became the assistant secretary of the Round Table. He brought a practical businessman's approach that the group had lacked previously. The financial stability of the organization improved dramatically even though attendance has never returned to the "Boom Times."

The Directors and Membership is proud to present to Paul Prosser:

"THE FERTILIZER ROUND TABLE AWARD OF MERIT"

Presented to PAUL J. PROSSER, Jr. in recognition of a lifetime of outstanding service and technical contributions to the fertilizer industry, farmers, and people of the world."

OPENING REMARKS

David W. Leyshon, Chairman

I am David Leyshon of Jacobs Engineering, Chairman of this year's Fertilizer Industry Round Table. I would like to welcome you the 43rd Annual Round Table and to New Orleans.

We hope to provide you with an interesting and informative meeting and to provide a forum for exchange of news, views and technology.

We are often asked to define the objectives of the Fertilizer Industry Round Table. It is not an easy task. The Round Table has become much more diverse than originally. In its inception, the Round Table provided technical information to those running granulation plants, help on nuts and bolts, the granulators and dryers.

Over the years, the Round Table has become much more commercial, as evidenced by the outlook papers in this morning session.

At the peak, there were over 200 NPK TVA-type granulation plants. There are only about 30 now, but they made over 1,6000,000 tons of product in 1992. That is not an insignificant amount and we hope to continue to represent their needs and other, what might be called, up-country facilities, for bulk blending and liquids.

We also propose to represent the "big" producers in Florida and the lower Mississippi on our program. That is one reason we are here today, in New Orleans, and next year in Orlando, Florida.

We also think of ourselves as a link between the technology of Europe and that of North America. We will be seeing an example of European infusion during our visit to the Arcadian phosphoric acid plant on Wednesday morning.

We would like to offer a special welcome to our foreign visitors from Brazil, Morocco, Greece, France, Mexico, Finland, Norway and other exotic lands.

Monday, October 25, 1993

Session I
Moderator:
Ole Lie

Keynote Address

Facing the Future: Opportunities and Challenges for the U.S. Fertilizer Industry

Fritz Corrigan

Cargill Fertilizer

I've chosen to talk about the status of and long-term outlook for our industry, plus the factors we at Cargill believe will influence the success each of us has in the future. Those factors include broader use of the futures market as a price-discovery and risk management tool, the importance of the North American Free Trade Agreement and our industry's need to balance environmental responsibility with productive capabilities. If we don't manage those aspects of our businesses, someone or something else will impose such disciplines on us.

There is a Chinese greeting that says: "May you live in interesting times." Our friends in China and India have certainly made that true for the fertilizer industry during the past 12-18 months.

The governments of both nations have reduced subsidies to domestic fertilizer producers and farmers. At the same time, currency devaluations and a decentralization of fertilizer purchasing have occurred. All of these activities have caused a sharp drop in import demand and contributed to the decline of worldwide fertilizer prices—and to 20-year lows for phosphates.

Statistics show how important China and India are in world fertilizer markets. Since 1988, those two nations have accounted for 40 percent of world urea trade and 45 percent of diammonium phosphate trade. Most industry observers believe that by year-end Chinese and Indian imports of urea and DAP will be down more than two million and one-half metric tons (Figure 1).

These market depressing short-term adjustments make it hard to focus on the long-term, positive impacts of reforms in both countries. Most of the reforms are designed to remove market distortions and stimulate agricultural productivity. Those factors are very constructive to future commercial dealings with China and India. Demand and prices already are beginning to rebound, and factors at work in those countries bode well for our industry long term.

In both nations, production and yields—while increasing—have not kept pace with demand. At the same time, harvested areas throughout Asia have remained relatively constant since the mid-1970s.

China must conquer several challenges to meet growing food demand. Its population is projected to reach approximately 1.3 billion by the year 2000. Prospects for its economy remain strong despite inflation and political unrest. Strong economic growth will boost demand for coarse grains, as people upgrade their diets with more meat, poultry and dairy products.

Ag reforms in China have stimulated production, but those gains have only narrowed the gap between use and production. As a result, Chinese grain reserves have fallen steadily since the late 1970s (Figure 2).

Grain stocks are projected to decline to less than 19 percent of use by the end of the 1993-94 crop year. That's down from more than 40 percent in the late 1970s (Figure 3).

Chinese coarse grain yields could increase more if farmers adopt currently available hybrids and technologies. More mouths to feed and increasing per-capita income there will drive grain demand and keep pressure on planners and farmers to boost ag production.

The situation in India is more critical. Grain stocks as a percent of use are expected to fall to about 10 percent by the end of the 1993-94 crop year (Figure 4).

That would be the lowest level since 1974-75. It would represent 17 million metric tons, or just over one month's grain use. That sharp drop in grain stocks has outpaced India's increased production.

Like China, India clearly must focus on improving agricultural productivity. Policies required by international aid and lending organizations will be critical to the success of these efforts. Those policies are aimed at boosting grain prices and reducing inefficiencies in production, procurement and distribution of farm inputs (Figure 5).

The challenge to Asian policy makers is to keep yields increasing at more than historical rates. More intensive agronomic practices—including fertilizers—must be part of this strategy. There are increasing signs that the fertilizer industry has weathered the current market storms. We believe the long run holds promise in this most significant fertilizer market.

The situation in world grain markets also is upbeat long term for fertilizer. On the basis of USDA's report Oct. 12, worldwide grain stocks are projected to fall to only 17.4 percent of use by the end of this crop year. That is the lowest level since the 1976-77 crop year and just a few percentage points above the level of the food crisis years in the early 1970s. Stocks are low by historical standards. They are not adequate to cope with a supply shock or demand surge.

World grain use has exceeded production in five of the last seven years. That happened while farmers around the world were producing the largest and second-largest grain crops in 1990 and 1992 and demand was flat the past four years. Bin-buster crops are needed today to meet current grain demand, even though use has remained virtually flat.

Farmers today are growing approximately double the amount of grain on virtually the same amount of land as they did in 1965. Total harvested area is only 20 million hectares—or 3 percent—more than in 1965.

That means that improved yields have been responsible for virtually all of the increase in grain production. And, most of the future increases in grain demand will have to be met by further yield increases on those same harvested areas.

To us at Cargill that means a high probability that fertilizer demand will increase. Experts predict that world population will exceed 6 billion by the year 2000. That's up from about 5.3 billion today. It means that between now and the end of the century, the world must find ways to feed added population equal to another India.

Most analysts are predicting that slow to moderate economic growth will continue during the decade. As reasons for slow worldwide economic growth, they cite large debt in many countries and a slow transition from planned to market-based economies in Eastern Europe and the former Soviet Union.

These population and income growth predictions mean world grain use will continue to climb steadily. This figure shows actual and projected world grain use as modeled by Dr. Mike Rahm of our staff (Figure 6).

The forecast uses population projections from USDA and moderate increases in per-capita income. The model predicts that grain use in the year 2000 will likely increase to just over 2 billion metric tons.

This figure summarizes conclusions from our model analysis (Figure 7).

First, world grain yields must continue to increase in order to meet projected demand.

Second, if yields increase at historical rates, low demand forecasts could be met on approximately the same harvested area as today. However, moderate demand increases would require a 4 percent—or 30 million hectare—increase in harvested area.

Third, if yields increase at about one-half the historical trend rate, low demand forecasts would require a 6 percent or 40 million hectare— increase in harvested area. Moderate demand forecasts would require an 11 percent—or 75 million hectare—increase in harvested area. This would exceed the 1981 peak of 734 million hectares by 28 million hectares.

Any way you look at it, the impacts on fertilizer demand are positive.

A similar model analysis for Asia predicted that grain use in that region will reach 850 million metric tons by 2000. Again, if we can survive the short run, the long run is promising.

The Asian model assumed moderate increases in per-capita income and population estimates from USDA. The results are reflected in this figure combining harvested hectares and yields required to meet low, moderate and high demand scenarios.

The analysis assumes that grain imports will account for just over 10 percent of projected use—which is the average between 1965-1992 (Figure 8).

These are the conclusions reached for the Asian model. First, grain yields must continue to increase in order to meet projected grain demand.

Second, if Asian yields increase at historical rates, low demand forecasts could be met on about the same land area as today. However, moderate and high demand forecasts would require 2 percent and 5 percent increases in harvested areas. Both would exceed the peak area of 1983, and additional grain imports likely would be necessary because of land constraints in Asia.

Third, if yields increase at about one-half the historical trend, it is highly unlikely that enough land could be planted to meet demand and the deficient would have to be made up by more imported grains.

World fertilizer use fell more than 13 percent—or 20 million metric tons—between 1988 and 1992. This was a result of the collapse of fertilizer demand in Eastern Europe and the former Soviet Union; and slowing in the increase of use in the rest of the world during the early 1990s. World use likely bottomed out in 1992. Most analysts expect world fertilizer use to rebound to about 150 million metric tons by 2000 (Figure 9).

Of course, grain prices will be a key determinant of fertilizer use and values for the remainder of the decade. Tightening of grain markets would boost fertilizer demand and add to the fundamental strength caused by recent adjustments in supply. Weather in the U.S. grain belt this past summer has increased the possibility of tight markets. The analyses and recent weather conditions I've outlined make Cargill believe that recent strengthening in DAP markets is the "tip of the iceberg" in terms of better times ahead.

The DAP market's upbeat direction has been reported recently by trade media. In my opinion, most publications were late in recognizing this fact. However, one publication has speculated that further market strengthening could dissolve if individual decisions by major producers expand production. As we've all learned in the volatile markets of the past 12-18 months, managing price risks and balancing production to market demand can be extremely challenging, and I dare say, painful.

Futures Markets

More accurate price-discovery and achieving balance between supply and demand are two areas where the futures market can help the industry exercise improved management (Figure 9).

Futures markets provide a single-point for price discovery of the actual values of commodities. During the past year, DAP futures markets and fertilizer export markets have been truer, more closely related indicators of value than spot domestic markets and published lists in trade publications.

With futures, price discovery is realized through the buying and selling of contracts that translate supply and demand factors into actual values. Unlike prices in industry publications, the futures market brings together the information and opinions of everyone in the marketplace. That process produces a price that is instantly available to everyone AND that price reflects actual trades—real money on the line.

The risk-management function of futures markets is achieved by enabling producers, distributors and end users to transfer unwanted flat-price risk to those willing to accept it. This hedging function greatly reduces—but does not eliminate—price risk. That's because of variation in the basis. However, in most cases, variation in the basis is much less than the variation in the flat price. Hedgers exchange flat-price risk for basis risk.

The basis is the difference between the flat price for delivery of a certain volume of fertilizer on a specific date and the futures market price for the same date and volume.

If on December 1, the March ammonia futures price is $120 per ton fob New Orleans and the spot price of ammonia fob the elevator at Garner, Iowa, is $155, then the basis for Garner, Iowa, is $35 over the ammonia March futures.

Elements factored into the basis are: 1. transportation and handling costs between the local cash market and the delivery date 2. storage and interest costs until the expiration date of the contract. This provides the hedger an opportunity to earn a return on storage and other distribution services.

Hedging through the use of futures is a risk management tool for producers, distributors and end users. It is not a substitute for current methods of selling or sourcing products. This risk management tool should enable a firm to focus primary resources on serving the customer and developing innovative pricing programs such as basis-priced contracts. Not hedging flat-price risks is the same as speculating.

Economic benefits of futures market trading include: 1. Improved ability to find real prices and to price products for future delivery 2. Management of price risk exposure 3. Ability to plan transportation/storage and production logistics 4. Contract integrity 5. Flexibility to reverse market positions 6. Lower inventory financing costs 7. Reduced storage or carrying charges

Because of our familiarity with other futures markets, Cargill has led efforts to establish DAP futures. Recently, we've been encouraged that other major producers have been warming to the concept of futures. For whatever individual reasons, they are realizing the improved price discovery, risk management and forward contracting flexibility of the system. I encourage others to examine and experience the benefits of futures markets.

Let me offer an example from our spring 1993 experience that demonstrates how futures options can benefit all aspects of the market. Hopefully, it will de-mystify the futures-market process (Figure 10 and 11).

This is a forward-pricing option we offered on DAP delivered to North Dakota between March 1 and June 1 at the buyer's option. With futures, buyers were able to forward price their inventories for the busy season prior to its start. The cash market did not allow that.

As a producer, Cargill wanted to establish a forward price so it could plan transportation and other logistics related to producing and delivering a set amount of DAP into markets where it is used. It could price product on the futures market from day one—if it liked that price, or convert it to a flat-price sale anytime it wanted.

As a buyer, customers could lock-in a cash price from day one if they liked what the futures offered, or the forward contract gave them the flexibility to speculate on price movements throughout the term of the contract. They were free to lock-in a price anytime from February through May 31. They also could plan and anticipate their logistics needs.

For those who chose to trade the basis risk, the February cash market price was $145. The futures price was $111. Therefore, the basis was $34.

In March, the futures price dropped to $104 while cash price was $144. That meant that the basis contract could have been priced at $138, with a resulting savings of $6.

In April, futures moved up to $114, while the cash market was $150. That allowed a seller to sell futures at a price of $114. Add the $34 basis and he received $148 rather than the $145 he would have received from the February cash sale. That's not as good as $150, but it was $3 better than the original cash price.

Then in May, the futures option dropped to $109, while the cash market remained at $150. The basis contract could have been priced at $143, saving $7 versus cash spot prices.

There were several points throughout the contract period where both buyer and seller could liquidate their positions and realize benefits from having someone else assume the flat price risk of the products they produced or purchased.

Trade Liberalization

Another key to the long-term positive outlook for our industry is congressional passage of the North American Free Trade Agreement, or NAFTA. Ratifying NAFTA will bring Mexico into the free trade zone that already links the United States and Canada. This would create a 6.5 trillion dollar market, with nearly 370 million people.

NAFTA will further open the Mexican market to U.S. goods, including fertilizers. Mexican tariffs against U.S. products currently average 10 percent. U.S. tariffs on Mexican goods are about two percent. Despite high tariffs on U.S. products, Mexico already is our nation's third largest export market—after Canada and Japan. In fact, Mexico is the second largest market for U.S. manufactured goods—Canada is first.

Mexico already is a major customer for U.S.-grown grains and oilseeds. A further reduction in Mexican tariffs under NAFTA is expected to spark~ added export demand for those crops. As the standard of living and infrastructure improve within Mexico, crop and fertilizer demands will increase, which will effect our industry positively.

Since 1986, when Mexico began liberalizing and opening its economy, U.S. exports to Mexico have grown 228 percent—from 12.4 billion dollars to 40.6 billion dollars last year. That's over 5 billion dollars worth of goods more than Mexico exports to the United States.

Opponents of NAFTA claim that large numbers of American jobs will move to lower-wage Mexico. What critics don't say is that U.S. factory productivity is six to seven times greater than Mexico's. What really counts is unit labor cost—which makes U.S. jobs very competitive. Businesses' decisions about where to build plants are based on more than just cheap labor. Worker productivity, access to markets and raw materials and infrastructure to support industries, plus countless other factors go into deciding where a plant is located.

Actually, the agreement will create about 200,000 new jobs here, while preserving the 700,000 U.S. jobs that already depend on exports to Mexico. Those jobs will be needed to keep up with increasing Mexican demand for U.S. products.

Perhaps the most important reason for Congress to pass NAFTA is the statement it makes to the rest of the world. Failing to approve NAFTA would send a message that the United States is not serious about liberalizing trade under the General Agreement on Tariffs & Trade (GATT) and other international trade talks. NAFTA should serve as an addition to, not a substitute for, the freer trade promised by efforts to improve the GATT. We can't ask others to dismantle trade barriers against our goods and services while we refuse to do so with Mexico.

If you have not done so already, I urge you and each of your managers and employees to write or phone your respective congressional delegations to register support for NAFTA. We are doing so throughout the Cargill family of businesses. Broad grassroots support for the positive impact of NAFTA on local industries is needed in each congressional district. We must offset the claims of vocal opponents to the agreement, who are serving their own agendas and ignoring what is right for the nation and improving the standard of living throughout North America.

Environmental Responsibility

Another cornerstone of our industry's ability to control its own future will be its willingness to embrace increased environmental responsibility. If we *ALL* do not continue to upgrade our facilities in ways that safeguard the environment and our neighbors, there are plenty of volunteers eager to help various government agencies impose changes.

I can tell you from personal experience that being in the sights of environmentalists and the government, as we were soon after acquiring our Tampa operations, is not an enviable position. It does concentrate your attention on those issues. And, we have responded with sincere dedication to improvement.

Since 1988, Cargill has led the way in designing safeguards and efficiencies that improve our ability to protect the environment. Those efforts have been directed at eliminating potential releases of hazardous chemicals, managing stormwater and protecting groundwater. The current investment total exceeds 125 million dollars.

We've renovated and improved our production equipment. We've installed new control and monitoring systems that head off problems and assure that our work is done in ways that are safe for the environment. We've engineered and installed tank-containment and storm water recirculation systems. Additionally, automated control systems with redundant alarms and acid-neutralization systems were added. This has not eliminated all problems. However, it has shown the communities where we operate that we are serious about and committed to environmental responsibility. Through open communications with our neighbors, even when there is an incident, we are building credibility with them.

Tampa managers also created a 25-member Citizens' Environmental Advisory Committee. That group is engaged in a wide-ranging education program with local schools and supports area environmental groups and projects. Awards and commendations include the "Governor's Environmental Education Award."

All these initiatives have resulted in Cargill being recognized and commended by federal, state and local regulatory agencies in Tampa. We have begun applying the same environmental integrity to the Bartow facilities acquired earlier this year.

The Florida Phosphate Council also is emphasizing for its members the importance of environmental responsibility. I applaud its efforts. The Executive Committee of that group has developed and implemented environmental standards that phosphate producers must meet to maintain their status as members.

But, our commitment to the environment cannot stop at the front gate of our facilities. We must help educate our customers and farm producers about Best Management Practices in application technology. Cargill is doing so to help assure responsible usage on the farm. Not providing such education ignores the very real threat that rural groundwater issues may pose to future demand for fertilizer products.

The name of the game within industry environmental circles is: innovate or governments will legislate. We have the ability to lead the way. We should do so first because guarding the environment is the right thing to do. It also is in our enlightened self-interest to prevent our farm customers and ourselves from becoming a focus of legislative attention directed at restricting production, distribution or farm-use levels of our products.

To summarize my main points:

We believe the outlook for fertilizer producers is upbeat, but there will always be bumps in the road. Recent worldwide economic doldrums and tough markets slowed the pace of new facilities coming on stream, but also prompted the shutdown of inefficient plants in Western Europe (Figure 13 and 14).

Economics also have forced the governments of Australia, China and India to stop protecting uncompetitive local industries. Those developments favor the North American fertilizer industry, which has a comparative advantage

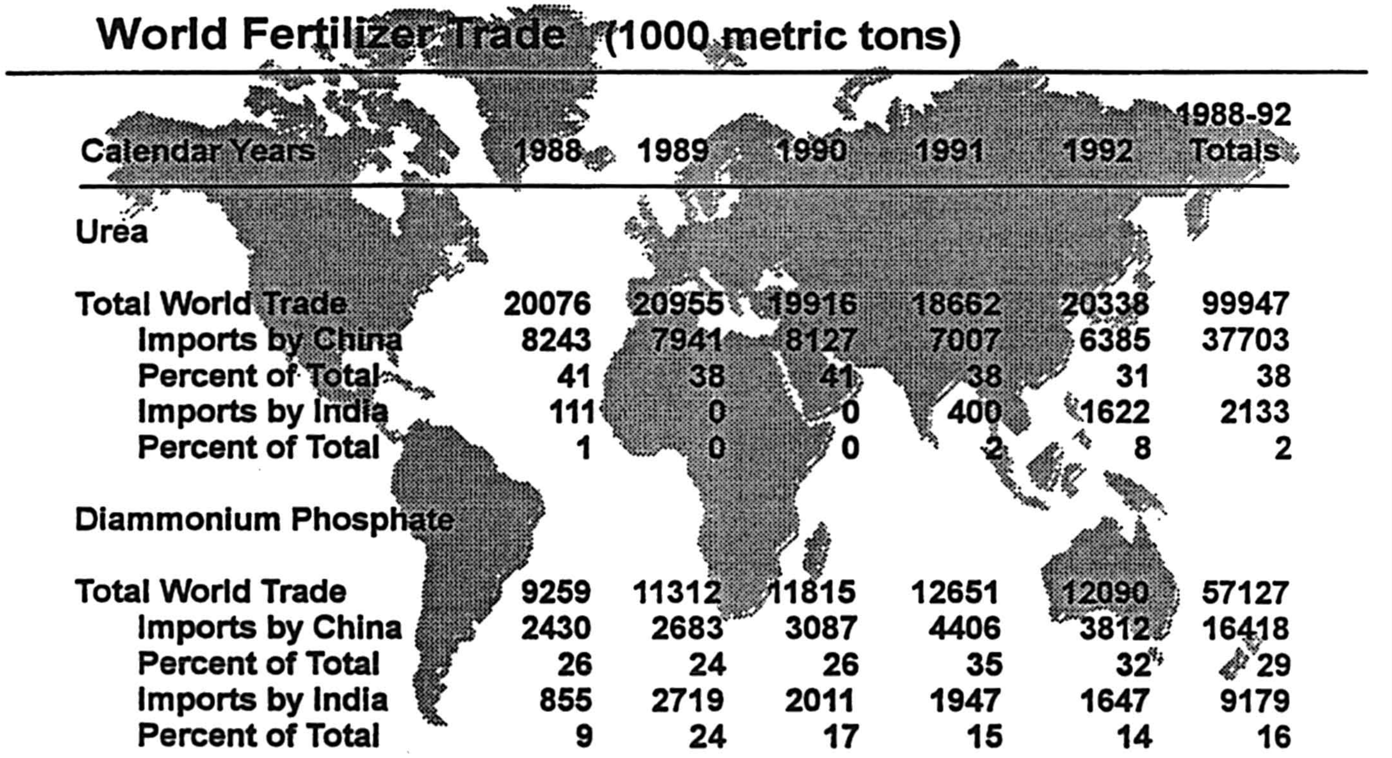
Similarly, currency devaluations in China and India, those nation's decentralization of purchasing and increased crop production are positive for the industry. Once currency problems can be stabilized, China in particular should become an even larger force in fertilizer demand.

Second, greater use of futures market contracts will aid the industry's efforts to improve price discovery and better manage the risks of balancing what it produces with demand for those products. Futures markets enable forward pricing, logistics and transportation flexibility. Perhaps, they can even help moderate the volatility of markets.

Third, trade liberalization initiatives such as NAFTA and GATT deserve our support in Congress. They will enable us to increasingly serve growing North American and export markets.

Last, as an industry we need to remain focused on cleaning up our own environmental houses. If we *ALL* don't voluntarily improve, federal, state and local governments will dictate in greater detail the tools we must use and how fast we must do it.

I hope my remarks challenge all of us to examine the industry today and the brighter prospects ahead. Those of us who have the discipline to manage the topics I identified will enjoy the industry's brighter future. Thank you for inviting me to be with you today.



World Fertilizer Trade (1000 metric tons)

Calendar Years	1988	1989	1990	1991	1992	1988-92 Totals
Urea						
Total World Trade	20076	20955	19916	18662	20338	99947
Imports by China	8243	7941	8127	7007	6385	37703
Percent of Total	41	38	41	38	31	38
Imports by India	111	0	0	400	1622	2133
Percent of Total	1	0	0	2	8	2
Diammonium Phosphate						
Total World Trade	9259	11312	11815	12651	12090	57127
Imports by China	2430	2683	3087	4406	3812	16418
Percent of Total	26	24	26	35	32	29
Imports by India	855	2719	2011	1947	1647	9179
Percent of Total	9	24	17	15	14	16

Figure 1: World Fertilizer Trade

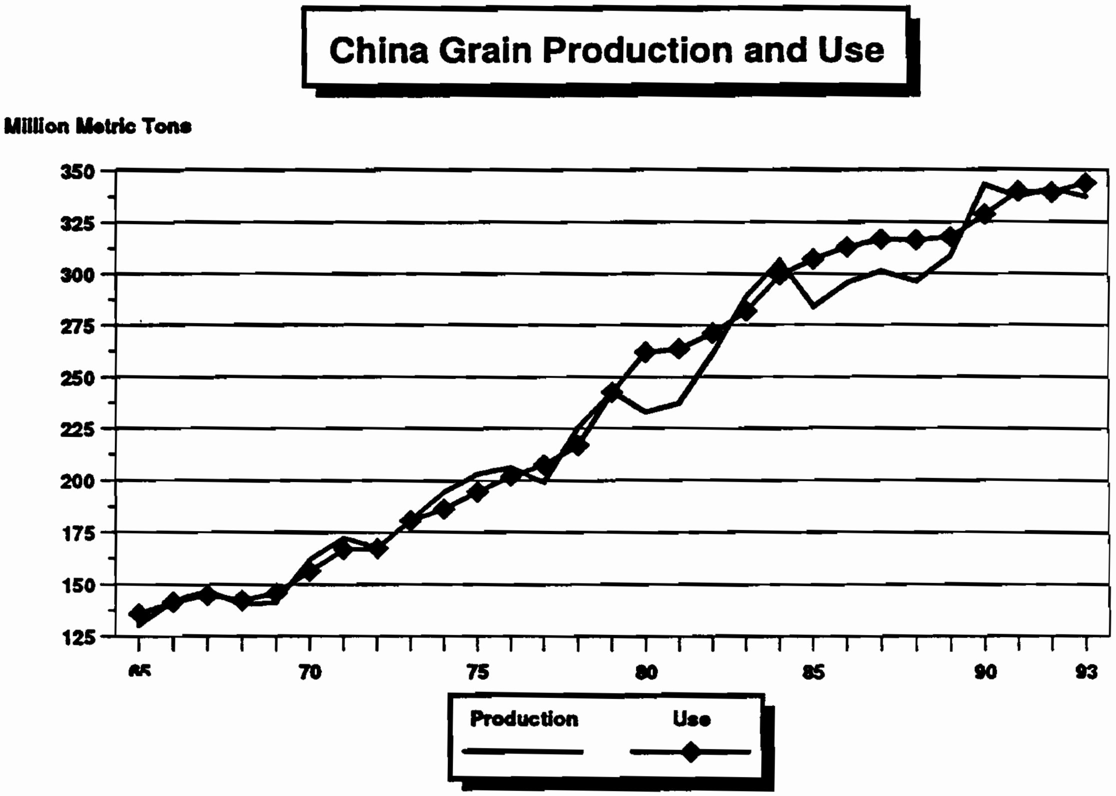


Figure 2: China Grain Production and Use

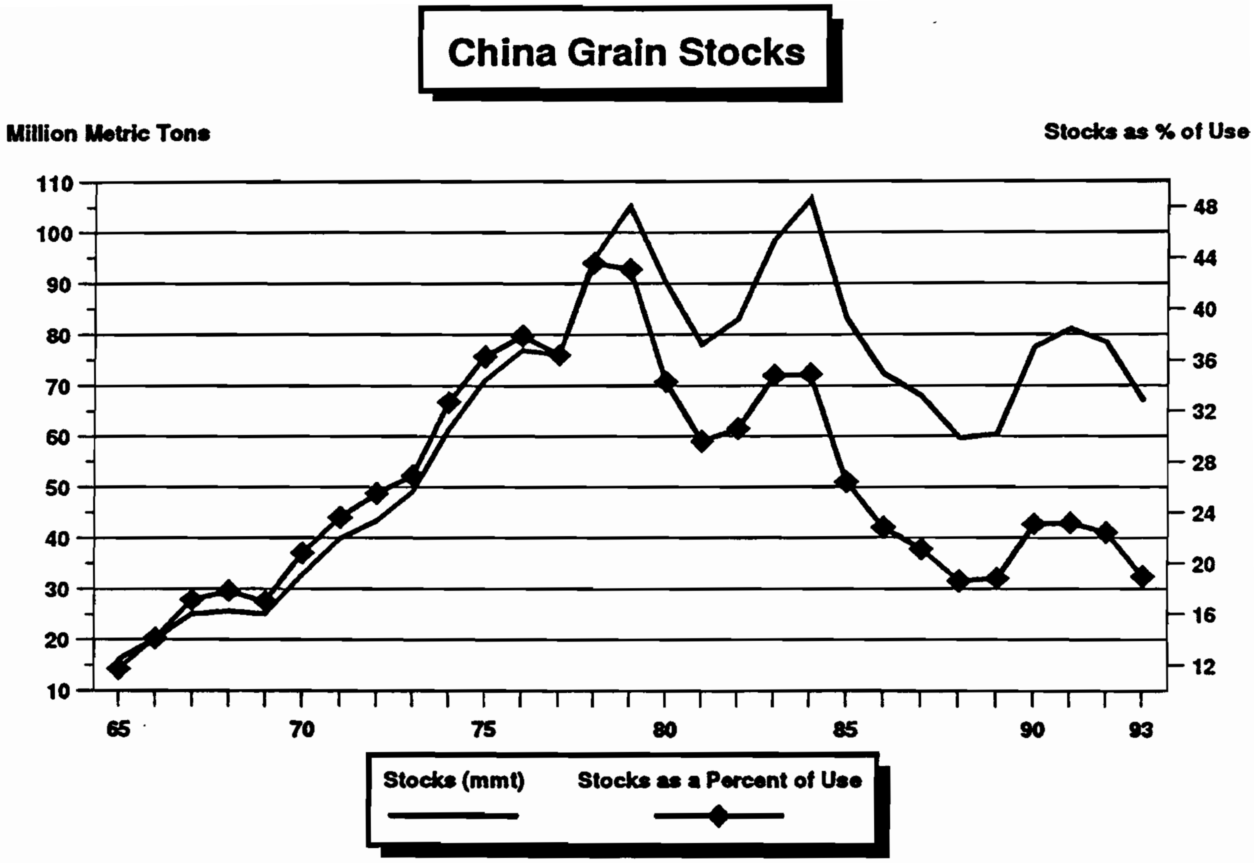


Figure 3: China Grain Stocks

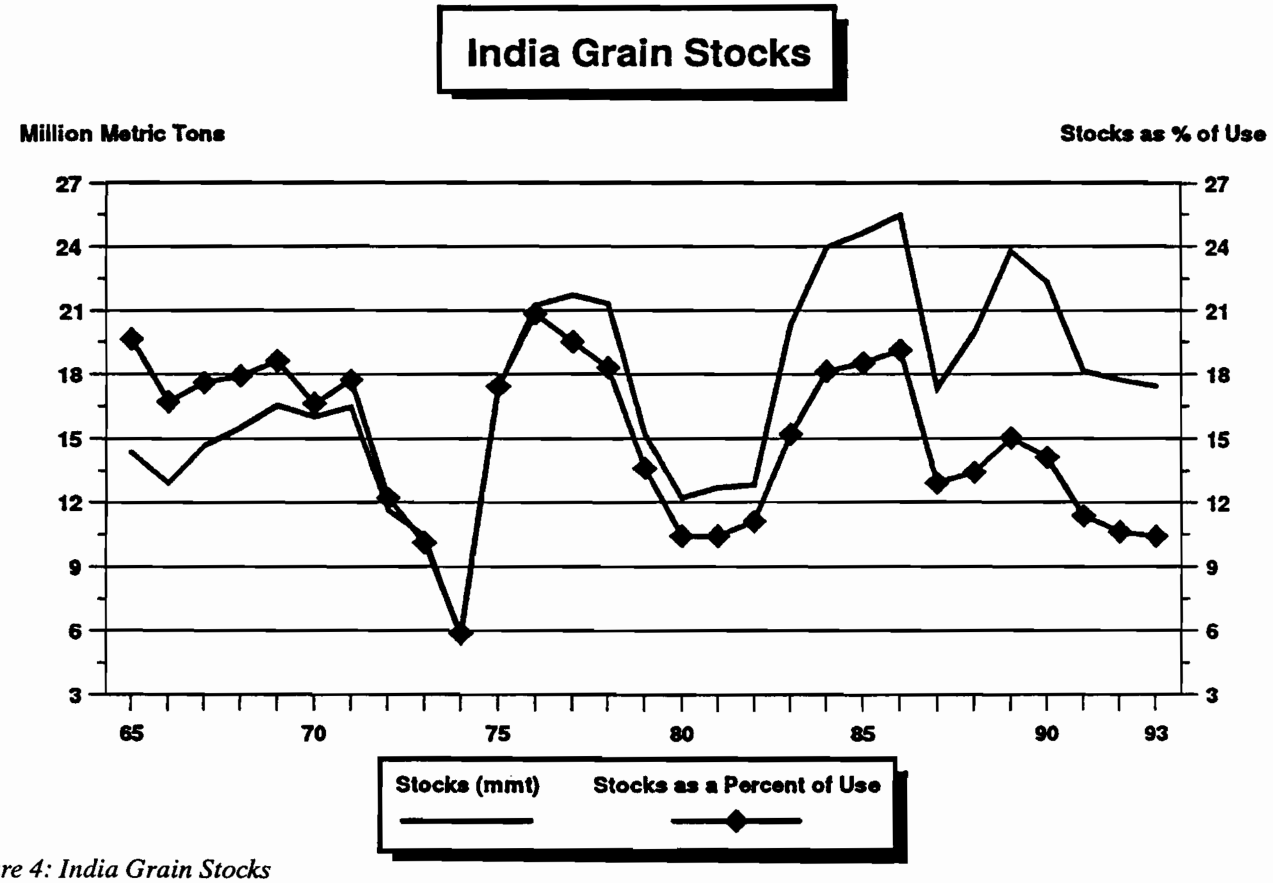


Figure 4: India Grain Stocks

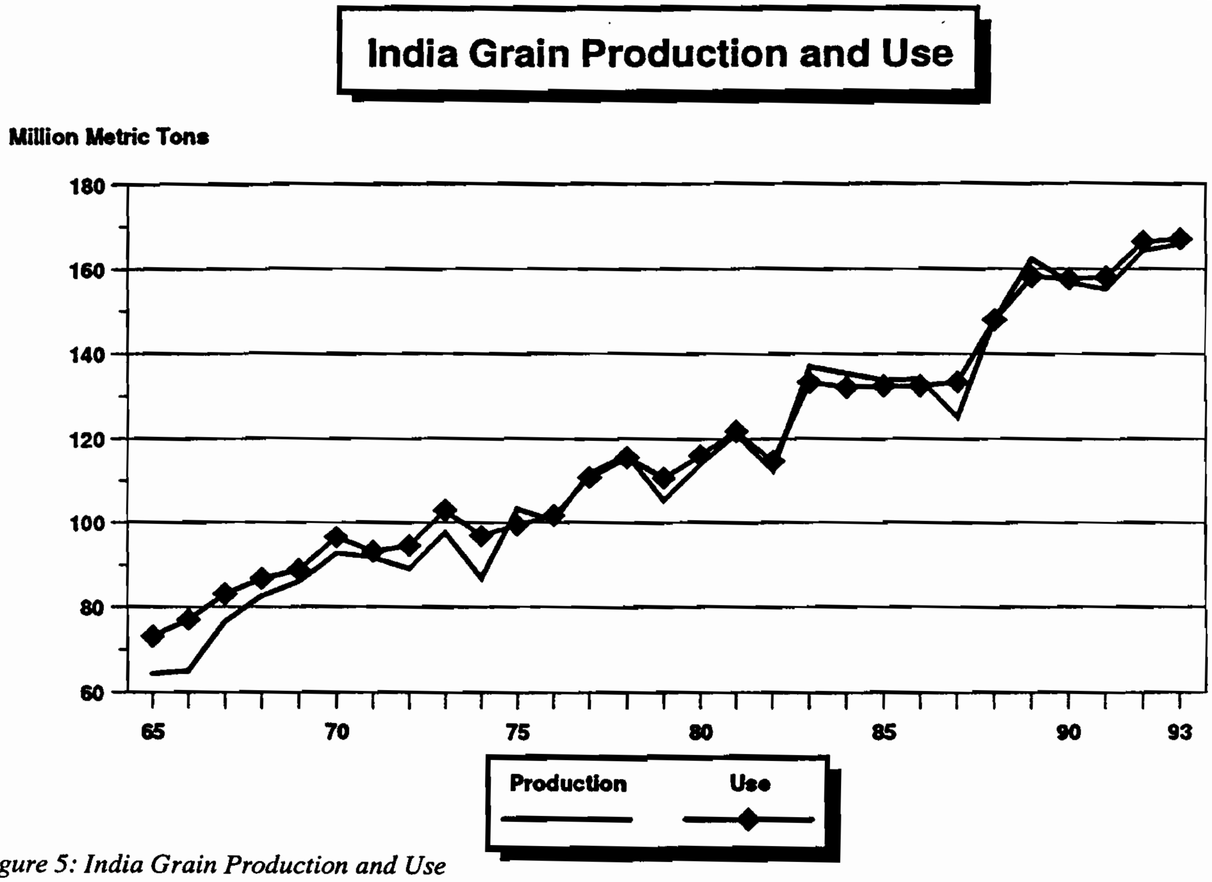


Figure 5: India Grain Production and Use

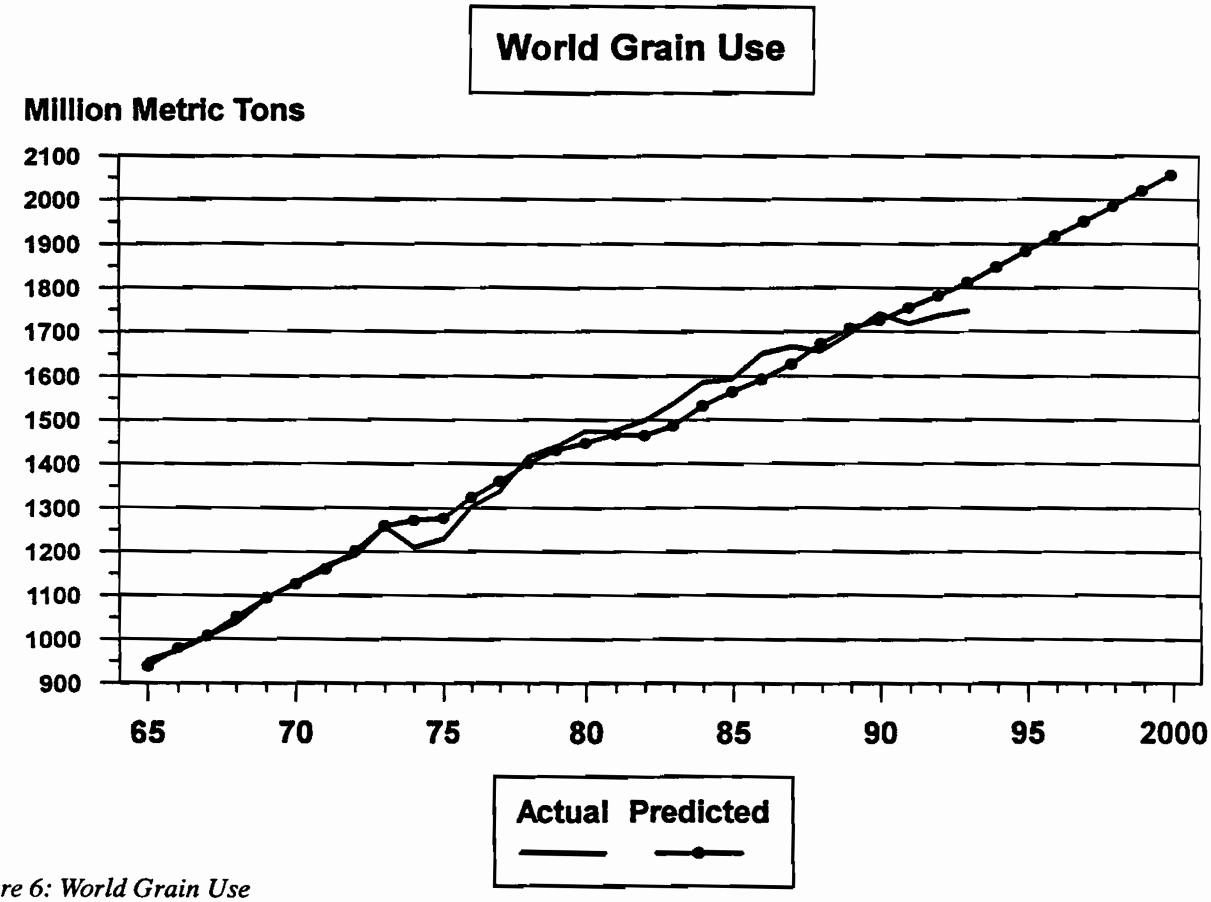
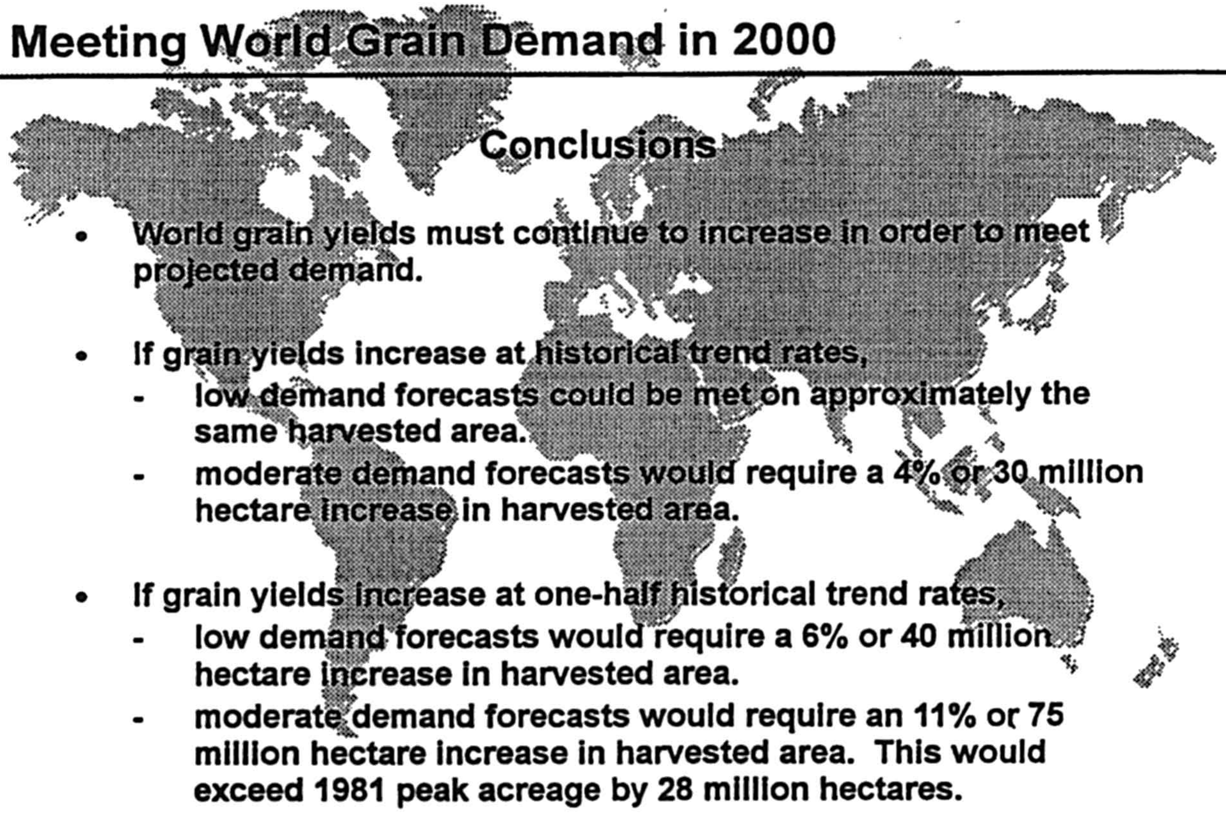


Figure 6: World Grain Use

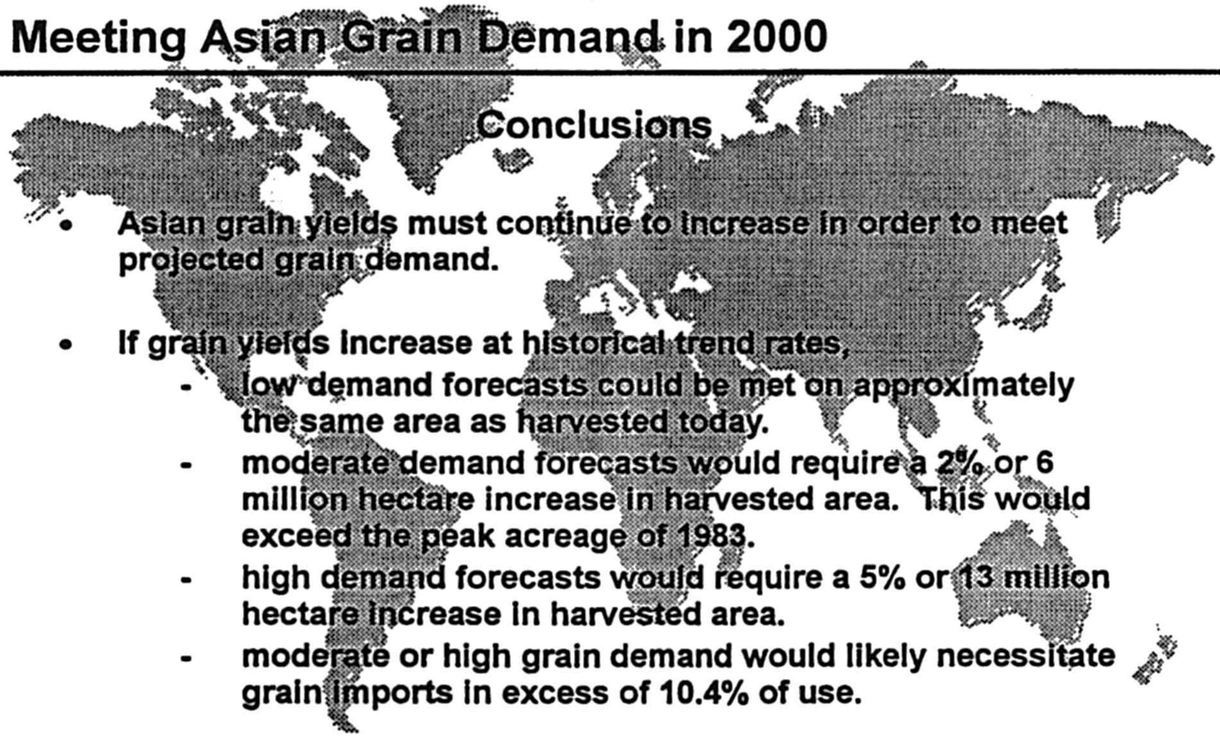


Meeting World Grain Demand in 2000

Conclusions

- World grain yields must continue to increase in order to meet projected demand.
- If grain yields increase at historical trend rates,
  - low demand forecasts could be met on approximately the same harvested area.
  - moderate demand forecasts would require a 4% or 30 million hectare increase in harvested area.
- If grain yields increase at one-half historical trend rates,
  - low demand forecasts would require a 6% or 40 million hectare increase in harvested area.
  - moderate demand forecasts would require an 11% or 75 million hectare increase in harvested area. This would exceed 1981 peak acreage by 28 million hectares.

Figure 7: Meeting World Grain Demand in 2000



Meeting Asian Grain Demand in 2000

Conclusions

- Asian grain yields must continue to increase in order to meet projected grain demand.
- If grain yields increase at historical trend rates,
  - low demand forecasts could be met on approximately the same area as harvested today.
  - moderate demand forecasts would require a 2% or 6 million hectare increase in harvested area. This would exceed the peak acreage of 1983.
  - high demand forecasts would require a 5% or 13 million hectare increase in harvested area.
  - moderate or high grain demand would likely necessitate grain imports in excess of 10.4% of use.
- If grain yields increase at below trend rates, it is unlikely that enough land could brought into cultivation to meet grain demand. The deficit would have to be made up by additional grain imports.

Figure 8: Meeting Asian Grain Demand in 2000

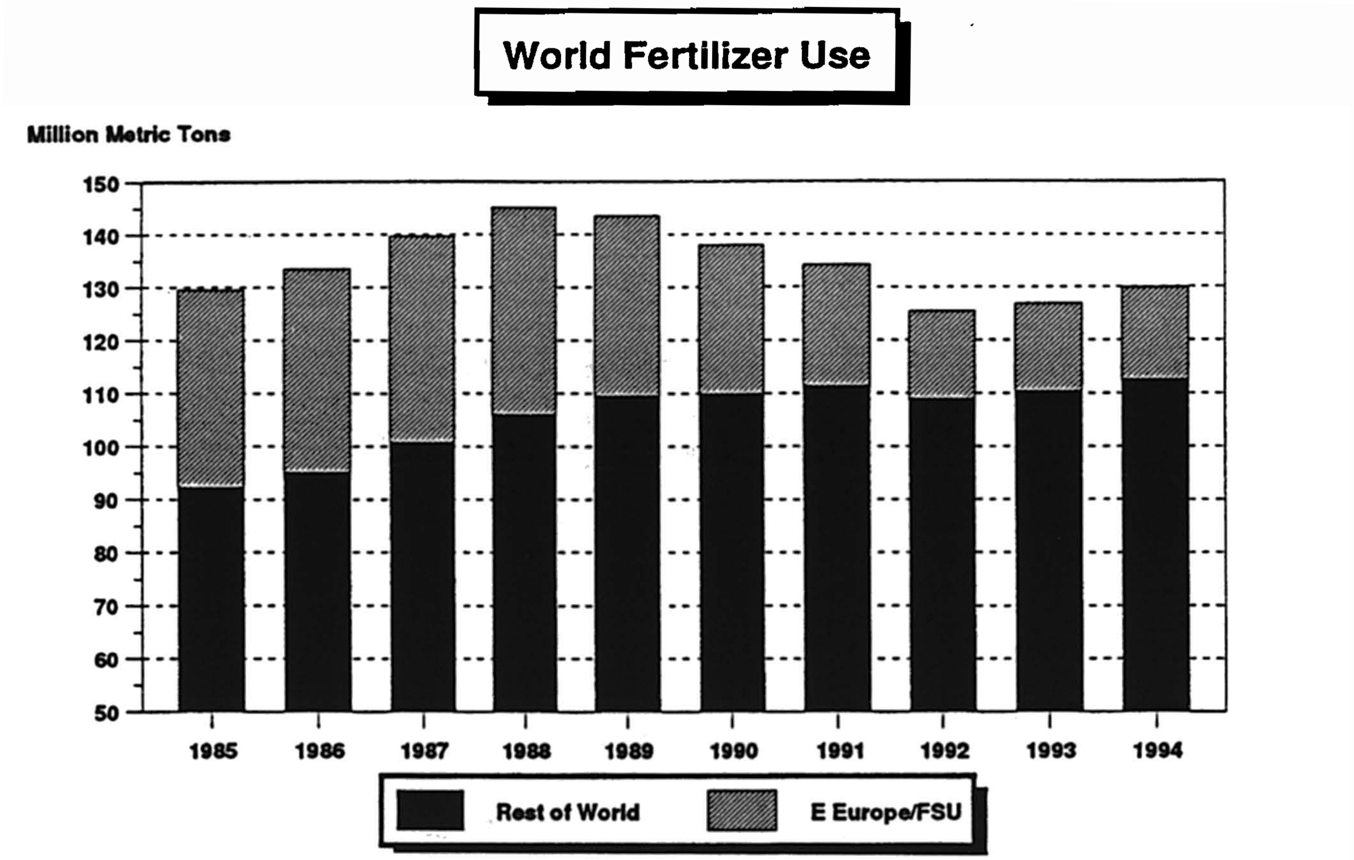
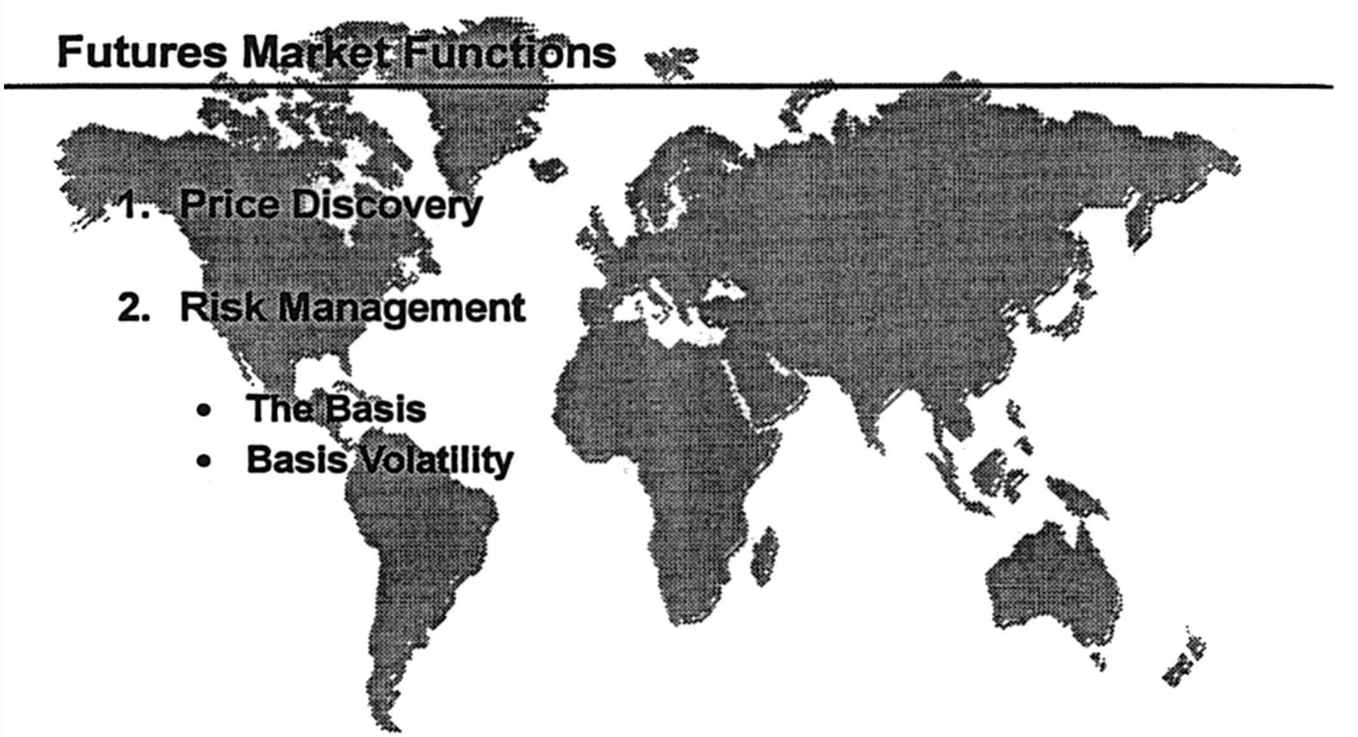


Figure 9: World Fertilizer Use

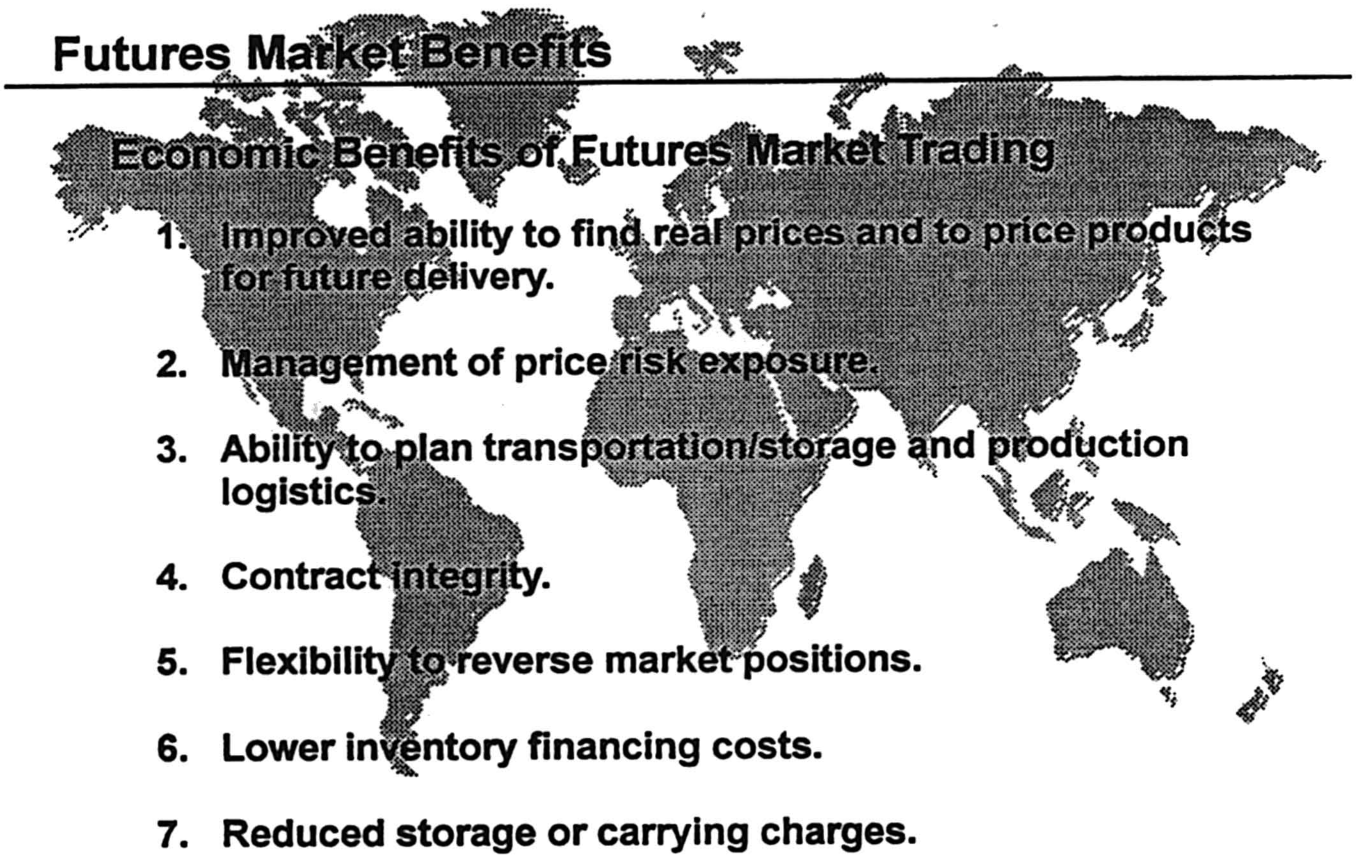


Futures Market Functions

1. Price Discovery

2. Risk Management
   - The Basis
   - Basis Volatility

Figure 10: Futures Market Functions

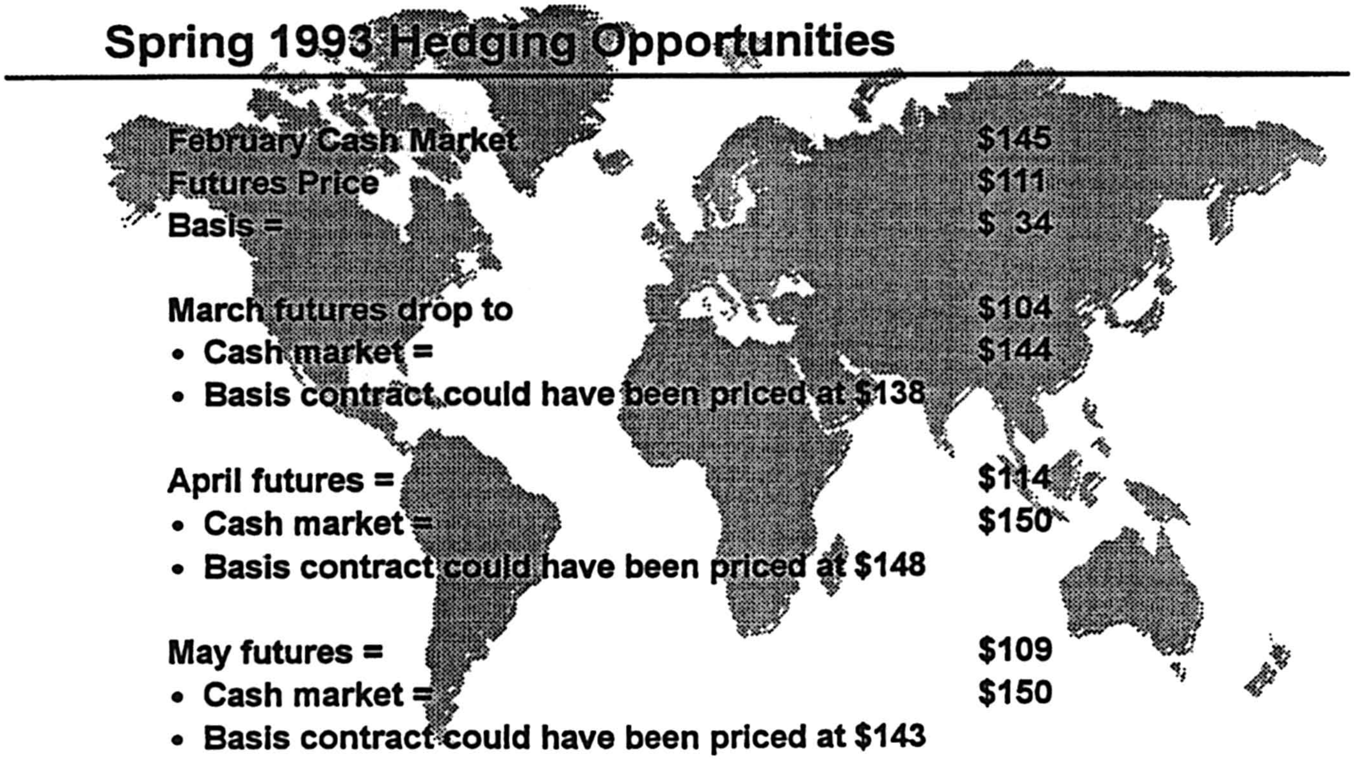


Futures Market Benefits

Economic Benefits of Futures Market Trading

1. Improved ability to find real prices and to price products for future delivery.
2. Management of price risk exposure.
3. Ability to plan transportation/storage and production logistics.
4. Contract integrity.
5. Flexibility to reverse market positions.
6. Lower inventory financing costs.
7. Reduced storage or carrying charges.

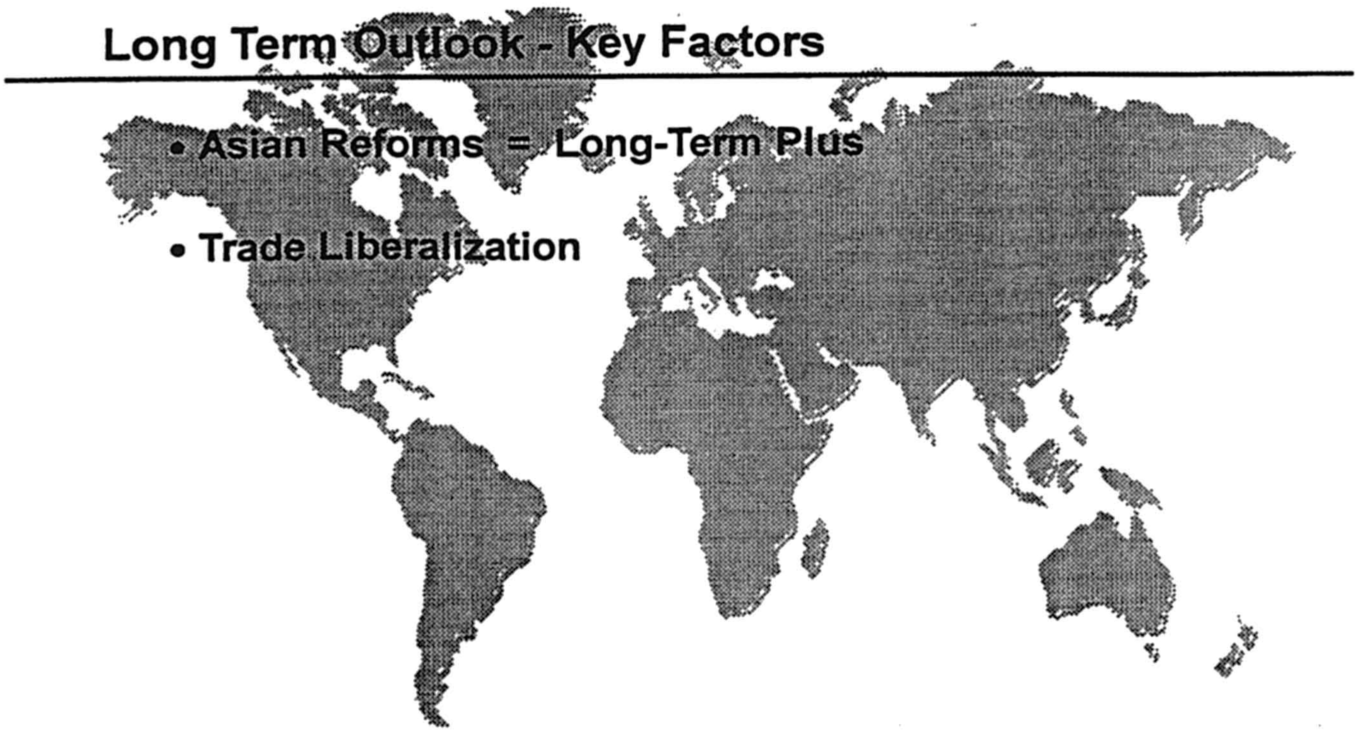
Figure 11: Futures Market Benefits



Spring 1993 Hedging Opportunities

February Cash Market	$145
Futures Price	$111
Basis =	$ 34
March futures drop to	$104
• Cash market =	$144
• Basis contract could have been priced at $138	
April futures =	$114
• Cash market =	$150
• Basis contract could have been priced at $148	
May futures =	$109
• Cash market =	$150
• Basis contract could have been priced at $143	

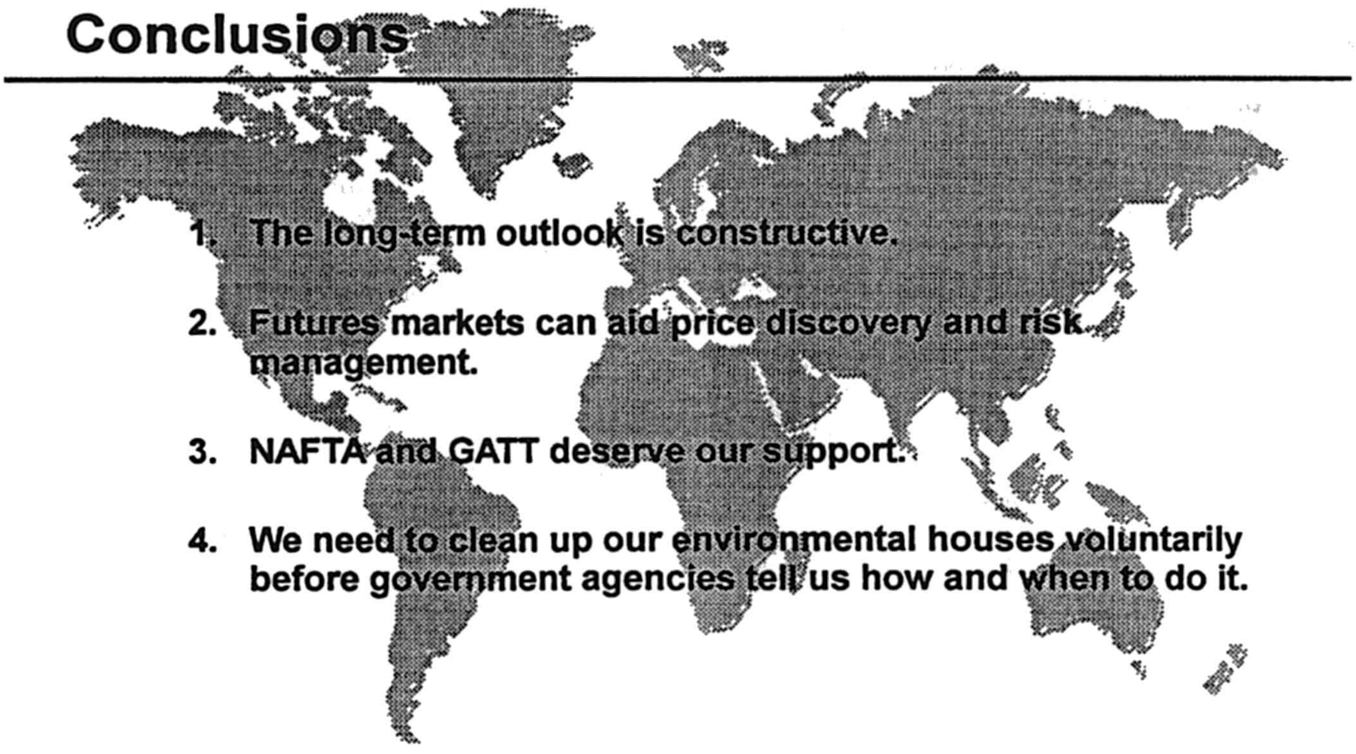
Figure 12: Spring 1993 Hedging Opportunities



Long Term Outlook - Key Factors

- Asian Reforms = Long-Term Plus
- Trade Liberalization

Figure 13: Long Term Outlook - Key Factors



Conclusions

1. The long-term outlook is constructive.
2. Futures markets can aid price discovery and risk management.
3. NAFTA and GATT deserve our support.
4. We need to clean up our environmental houses voluntarily before government agencies tell us how and when to do it.

Figure 14: Conclusions

Outlook for Nitrogen

Joe Dillier

CF Industries

World Industry – Overview

The world supply/demand balance for the nitrogen industry is expected to tighten over the next five years. The speed and extent of the tightening will depend primarily on plant closures in Europe and the former Soviet Union. The outlook for world demand has been reduced because of declining consumption in recent years.

The Outlook For World Nitrogen Consumption

World consumption of nitrogen fertilizer fell 2.5% in FY92/93 to 73.3 million metric tons N, according to June '93 estimates of the International Fertilizer Industry Association (IFA). Sharp cutbacks continued in the Former Soviet Union, where consumption fell an estimated 21% from a year earlier, and in East Europe, where consumption fell 13%. FY92/93 marks the fourth consecutive year of decline in world consumption.

IFA forecasts world consumption of nitrogen fertilizer will rise approximately 2% annually through the late 1990s (Figure 1). Even though that's about the same rate of growth as indicated in earlier forecasts, the current outlook is significantly less optimistic: A year ago the Industry Fertilizer Working Group projected world consumption in FY97/98 would be more than 10% above IFA's current forecast. Earlier forecasts missed last year's large declines in Central Europe and the FSU.

The bright spot for consumption is in the developing countries, particularly in Latin America and Asia (Figure 2). Relatively fast growing populations and rising per capita incomes should boost food demand. As food demand and diets improve, demand for grain — especially for cereals used in livestock feed — is expected to grow substantially. To meet that demand, application rates should rise and modest increases in area can be expected.

- Latin America's consumption is expected to rise 5% per annum, with Mexico the driving force. The Mexican economy has been restructured since the debt crisis of the early 1980s. Growth has been strong in recent years. Passage of the North American Free Trade Agreement would further enhance economic prospects.

- Consumption is forecast to rise 5% per year in the Near East. Egypt's use has declined recently, due to structural changes, but should resume its uptrend. Support for fertilizer use will likely continue in Iran. In Turkey, increased irrigation should raise demand.

- South Asia, dominated by Pakistan and India, is forecast to see growth of slightly over 3% annually.

- For East Asia, demand in is expected to be stagnant to declining in Japan and Taiwan but grow strongly in Indonesia, Malaysia, Philippines, and Thailand.

In China, the world's largest consumer of fertilizer nitrogen, growth is expected to be relatively slow, 1% annually. Fertilizer application rates are already relatively high. Plus, massive rural-urban migration may constrain availability of farm labor. However, China's volatile economic and political environment make it difficult to forecast future consumption levels with much confidence.

Africa has the potential to see relatively high growth in the future, as currently nutrient removal far exceeds application. IFA projects use will rise 5% annually through FY97/98. For that to occur, however, Africa's economic prospects must improve.

In Central Europe/FSU, consumption is expected to bounce back somewhat, but the process will likely be slow (Figure 3). Since FY89/90 consumption has fallen 60% in East Europe and 40% in the FSU and it is expected to remain well below previous highs through the late 1990s. Farms in the region will continue to be affected by the cost-price squeeze brought on by economic reform — increased prices for farm inputs and reduced prices for farm output.

Consumption also is expected to be weak in West Europe. After declining an estimated 11% to 8.9 mmt in FY92/93, it is forecast to trend down to 8.6 mmt by FY97/98. Reform of the EC's Common Agricultural Policy, through reduced agricultural subsidies and land idling programs, will both lower application rates and trim acreage. Environmental concerns over nitrogen and groundwater may also dampen application rates in West Europe.

World Nitrogen Supply Capacity

In contrast to world nitrogen consumption, nitrogen supply capacity has been increasing, albeit modestly. Total world ammonia capacity is estimated at approximately 117 million tons N for FY92/93, up from 116 a year earlier. Modest capacity reductions in West Europe and Central Europe/FSU have been more than offset by increases in Asia, including the Near East (Figure 4).

In Europe, aside from the dramatic reduction in nitrogen use, the major factor behind capacity closures has been gas costs. In West Europe, high gas prices, tied to the price of oil, have made imported nitrogen fertilizers cheaper in many instances. In Central Europe, Russia's 1991 decision to charge its former Soviet-bloc trading partners market prices for gas caused production costs to rise dramatically.

Gas prices have also been a factor behind closures in the FSU, even though prices remain well below international levels. Russia's market reforms have pushed domestic gas prices to an estimated $0.50/MMBTU currently. Russia also raised its price for gas exported to Ukraine. However, through its control of the nitrogen export facility at Odessa (an important outlet for Russian nitrogen), Ukraine has been able to bloc the full increase. The Russia-Ukraine gas situation is still in dispute and when it will be settled, and how high prices to Ukraine will go when it is settled, is not clear at this point.

What does seem clear is that the cost-price squeeze in the region will lead to additional closures (some of which may be showing up already). The question is how quickly will additional capacity be closed. Production economics would dictate closure for old, inefficient plants in the region. (Many plants would fall into that category; nearly 40% of Central Europe's capacity was in operation prior to 1970, according to the World Bank's 1992 World Nitrogen Survey.) However, many plants remain under government control, so the prospect of hard currency earnings via export sales is an offsetting consideration.

Most capacity expected to come on stream between now and FY97/98 will continue to be in Asia, including the Near East. Nitrogen fertilizer demand is expected to grow and the region has ample reserves of natural gas. India will increase its ammonia capacity by over 3 million tons by the mid-1990s. Pakistan and Indonesia are expected to continue to add capacity. China is also expected to add capacity, but its projects are dependent on foreign aid and have suffered substantial delays.

What will be the net impact of all of this on world ammonia capacity? Its difficult to forecast with confidence, but assuming shutdown decisions in Europe/FSU proceed relatively unimpeded by governments, closures should largely offset new supply (Figure 5). Overall, world capacity will edge up slowly under this scenario, less than 0.5% per year.

World Nitrogen Balance

The world ammonia operating rate is estimated at a relatively low 77% for FY92/93. The balance is expected to tighten over the outlook period as the growth in nitrogen demand is forecast to outstrip net capacity additions. By FY97/98, the operating rate is forecast to be near 83%, slightly above the previous peak in FY89/90.

U.S. Nitrogen Market — Overview

U.S. nitrogen demand is expected to increase significantly this year. Industry operating rates will be high and the supply/demand balance will likely be fairly tight.

Longer term demand will trend up only modestly, as application rates should be relatively flat. The U.S. industry will continue to operate at relatively high capacity utilization rates. Competition from imports may lessen moderately in the years ahead as the world balance tightens. Still, import competition, coupled with continuing environmental regulations, will keep profit margins modest.

Short-Term Demand

Nitrogen demand is expected to increase in FY93/94, because of substantially higher crop acreage. Acreage planted to the 8 major crops is forecast to be the highest since the mid-1980s (Figure 6). Acreage Reduction Programs for most crops will be down compared to a year earlier; thus farmers will idle less and plant more. Total nitrogen consumption is forecast to rise 3% to 11.5 million tons N, the highest since FY84/85 (Figure 7).

The corn supply/demand has tightened considerably because of this year's short crop. Excessive rain/flooding reduced yields to an estimated 110 bushels per acre, down from over 131 last year. End-of-year inventory levels for the 1993/94 marketing year are expected to be less than half the prior year (Figure 8). The season average corn price will rise to $2.40 per bushel, according to USDA's most recent forecast, compared to the year-earlier price of $2.07 per bushel. Acreage can be expected to rise to near 78 million acres compared to less than 74 million acres last spring. Corn accounts for approximately 43% of all nitrogen fertilizer consumption.

For wheat, the supply/demand situation is less bullish (Figure 9): Inventories are rising compared to last year; prices are weak; and acreage will decline slightly. Demand is relatively weak because of low export demand.

Cotton, because of the increased Acreage Reduction Program for 1994, will also decline. But soybean acreage will be strong — the highest since 1985 — as production and inventories are down and prices are higher . Sorghum acreage is also forecast to rise.

While the acreage outlook appears relatively straightforward, the outlook for application rates is anything but straightforward. Reports of nitrogen deficiencies were relatively widespread this year, and that could mean higher application in FY93/94. On the other hand, nitrogen application rates, especially on corn, have been trending down slightly (Figure 10). Plus, some producers may face financial constraints. Given the offsetting factors, probably the most likely outcome for FY93/94 is that rates will stay relatively flat.

In terms of product forms, direct applied ammonia is expected to see the biggest increase in FY93/94, up 9%. (That's not as high as it may look since direct ammonia was down nearly 10% in FY92/93; compared to FY91/92, direct ammonia usage is expected to be down marginally.) Urea use is expected to be up 4%. UAN demand may actually fall somewhat, because weather caused last year's demand to jump an estimated 9%.

Short Term Supply/Demand Balance

The U.S. ammonia market has tightened considerably in recent weeks. December futures at the Chicago Board of Trade jumped from around $105/ton in late August to about $120/ton currently. A number of factors are responsible: Imports are tight because of production cutbacks in Trinidad, the FSU and Mexico (all are at least partially due to reduced gas supplies). Production cutbacks by domestic producers earlier this year tightened the balance. Finally, the outlook for this year's corn crop has repeatedly been scaled back in recent weeks, fueling ever-increasing expectations for FY93/94 ammonia demand.

The current import-availability problems appear to be mainly temporary. Assuming imports increase, the current tightness will ease. Nonetheless, because of the significant increase in demand for nitrogen this year, the domestic industry will operate at close to full capacity and the balance will probably stay relatively tight (Figure 11).

The U.S. urea market is anything but tight. Urea prices, at approximately $115/ton in mid-October, are nearly $15/ton below year ago levels and $20/ton below October 1991. The weak world supply/demand situation is affecting the U.S. market as import availability has increased substantially. Offshore imports into North America tripled last year. Part of the problem lies in China. Import demand there has been weak because of currency devaluations. China accounts for as much as 40% of total world urea imports.

The world supply/demand may be strengthening modestly. Thus import availability should decline. That, coupled with increased spring demand, should tighten the U.S. balance (Figure 12).

For UAN, prices continue to be high. At midmonth, UAN, basis the Corn Belt, was $0.20-$0.25/unit higher than last year. The supply/demand balance may weaken somewhat from the current situation,, but UAN demand for FY93/94 is expected to be fairly strong (even if somewhat lower than last year). Thus, the supply/demand balance will stay fairly tight (Figure 13).

Longer-Term Outlook

Demand for nitrogen fertilizer is expected trend up modestly, rising less than 1% annually through FY97/98. That would keep total N demand below FY80/81's record level of 11.9 million tons throughout the period. Acreage may increase slightly, but environmental concerns and cost pressures on farmers will keep application rates relatively flat.

On the capacity side, some plant reconfigurations will occur, but no new grass roots plants are expected. The industry will likely continue to operate at high capacity utilization rates.

Import availability may decline somewhat as capacity closes in Central Europe/FSU and the world supply/demand balance tightens. However, imports will continue to play a significant role in the U.S. market.

Environmental regulations/costs will likely continue to escalate. Those costs, coupled with competition from imports and the endless drive for efficiency and productivity, mean industry margins will probably be modest. The industry's long term trend toward consolidation will continue at all levels of the business — producer, distributor, and retailer.

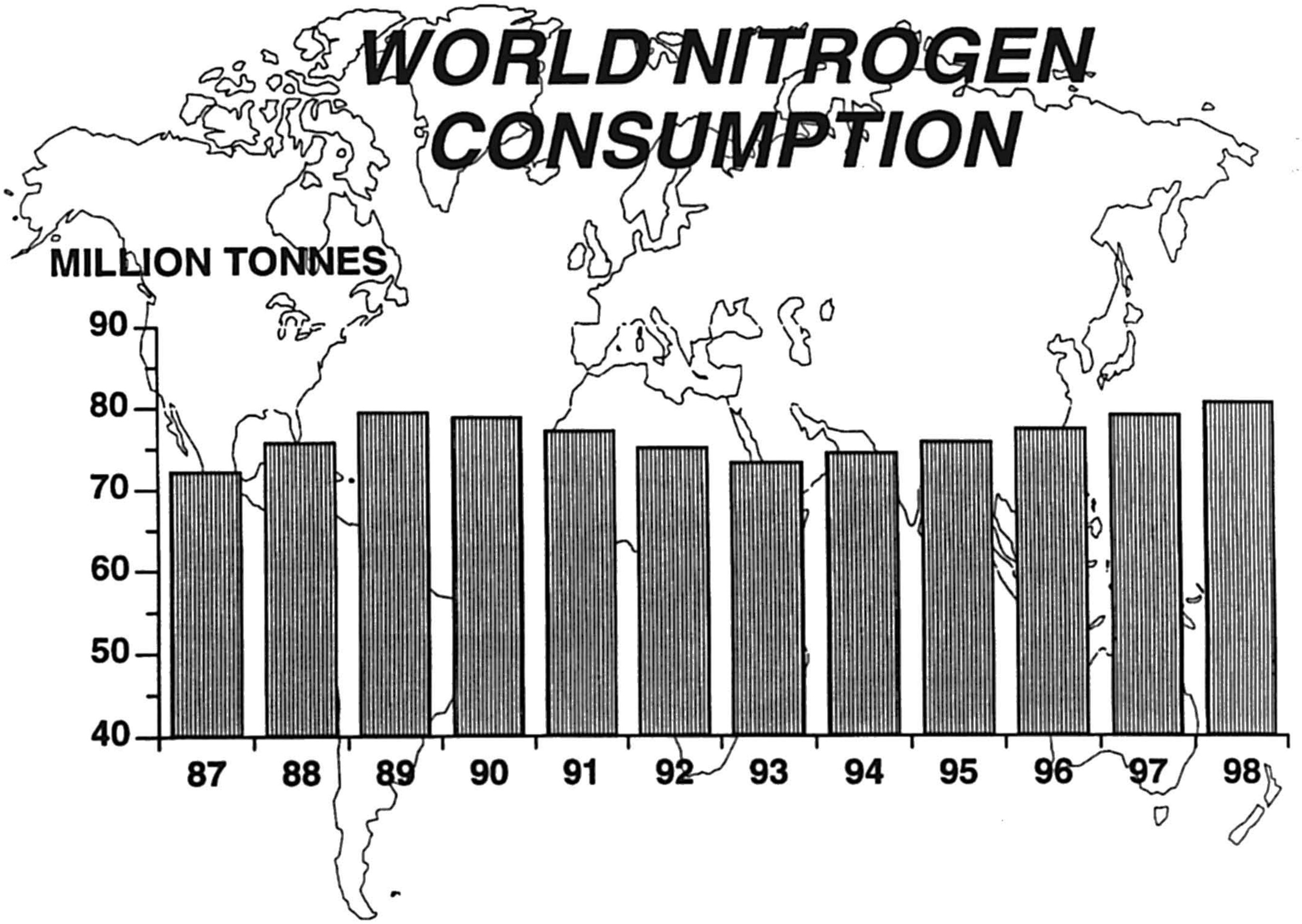


Figure 1: World Nitrogen Consumption

REGIONAL NITROGEN CONSUMPTION

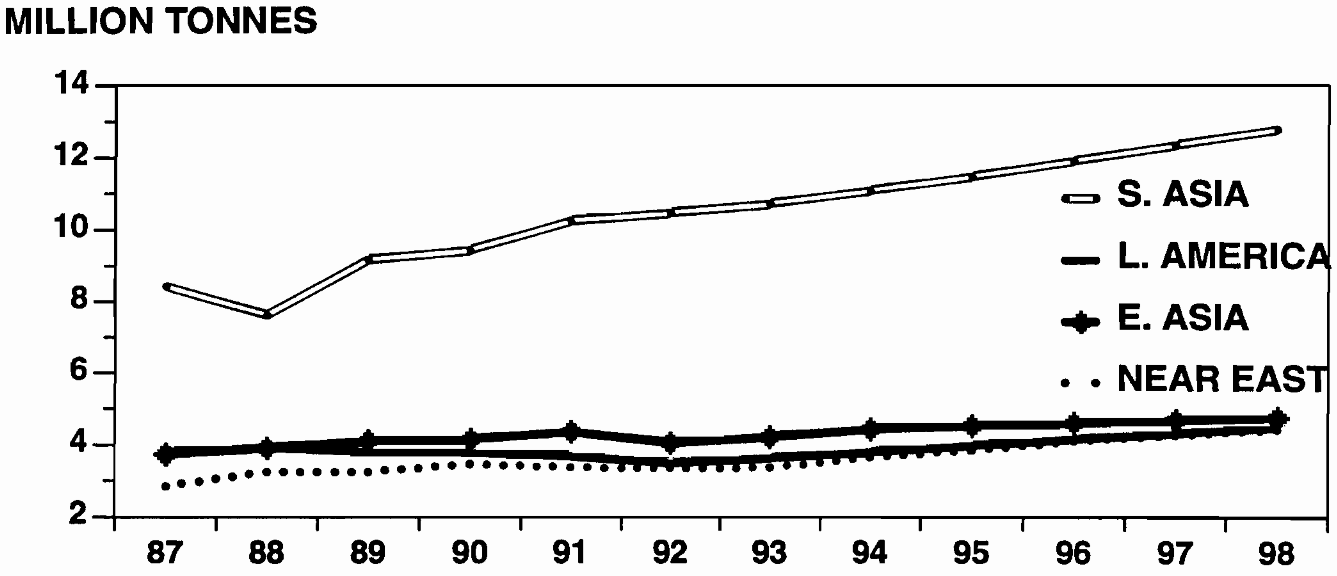


Figure 2: Regional Nitrogen Consumption —Latin America & Asia

REGIONAL NITROGEN CONSUMPTION

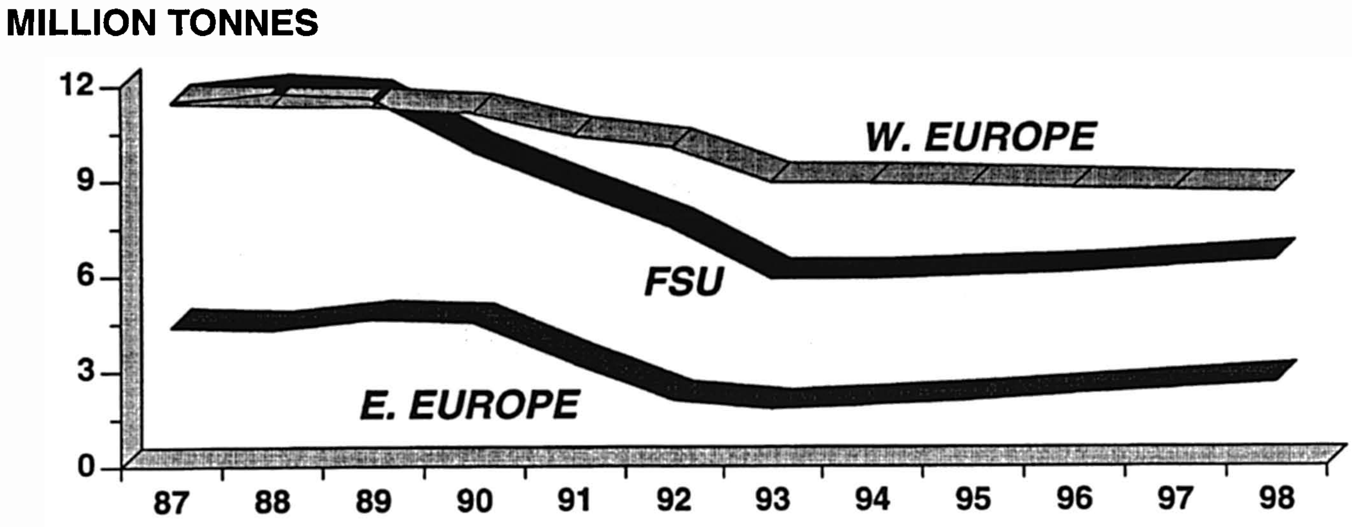


Figure 3: Regional Nitrogen Consumption —Central Europe

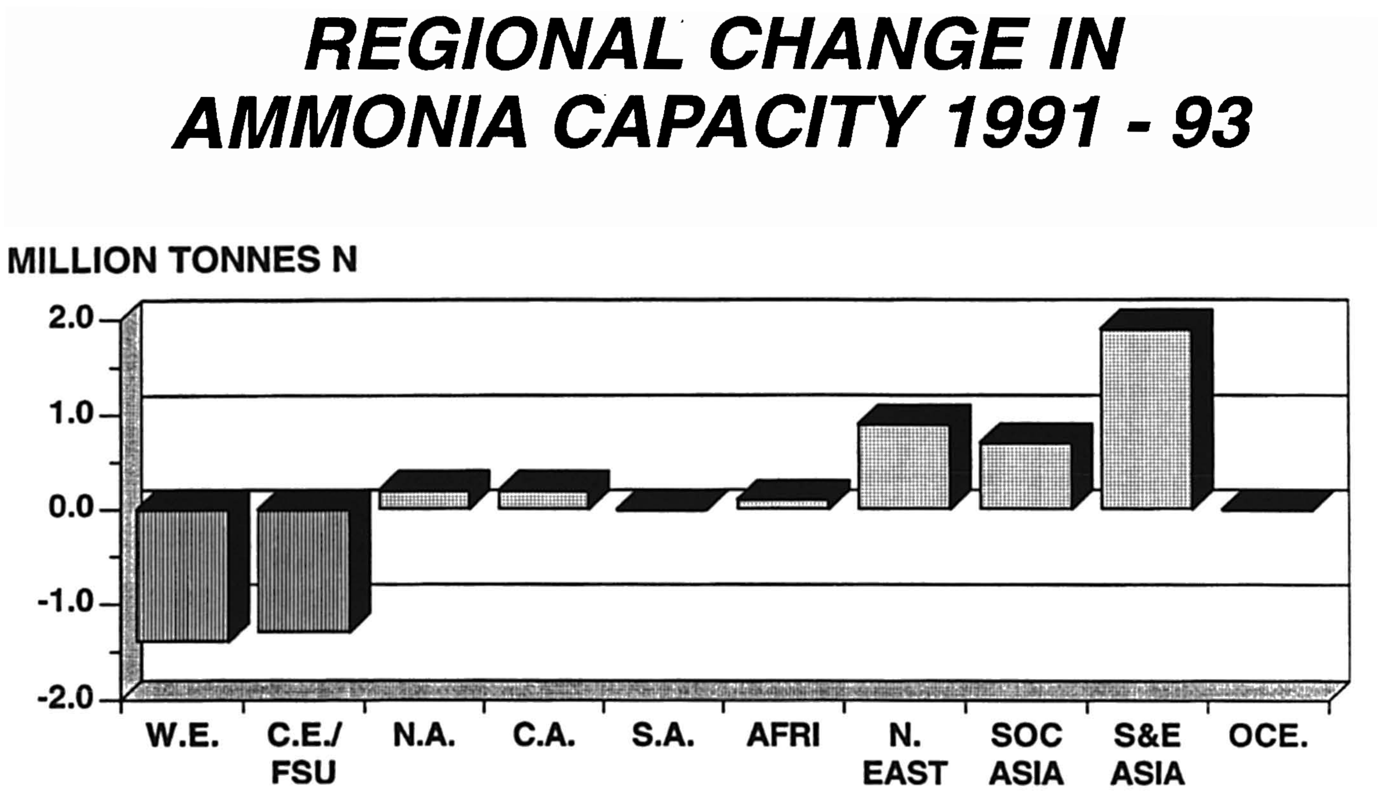


Figure 4: Regional Change in Ammonia Capacity 1991-93

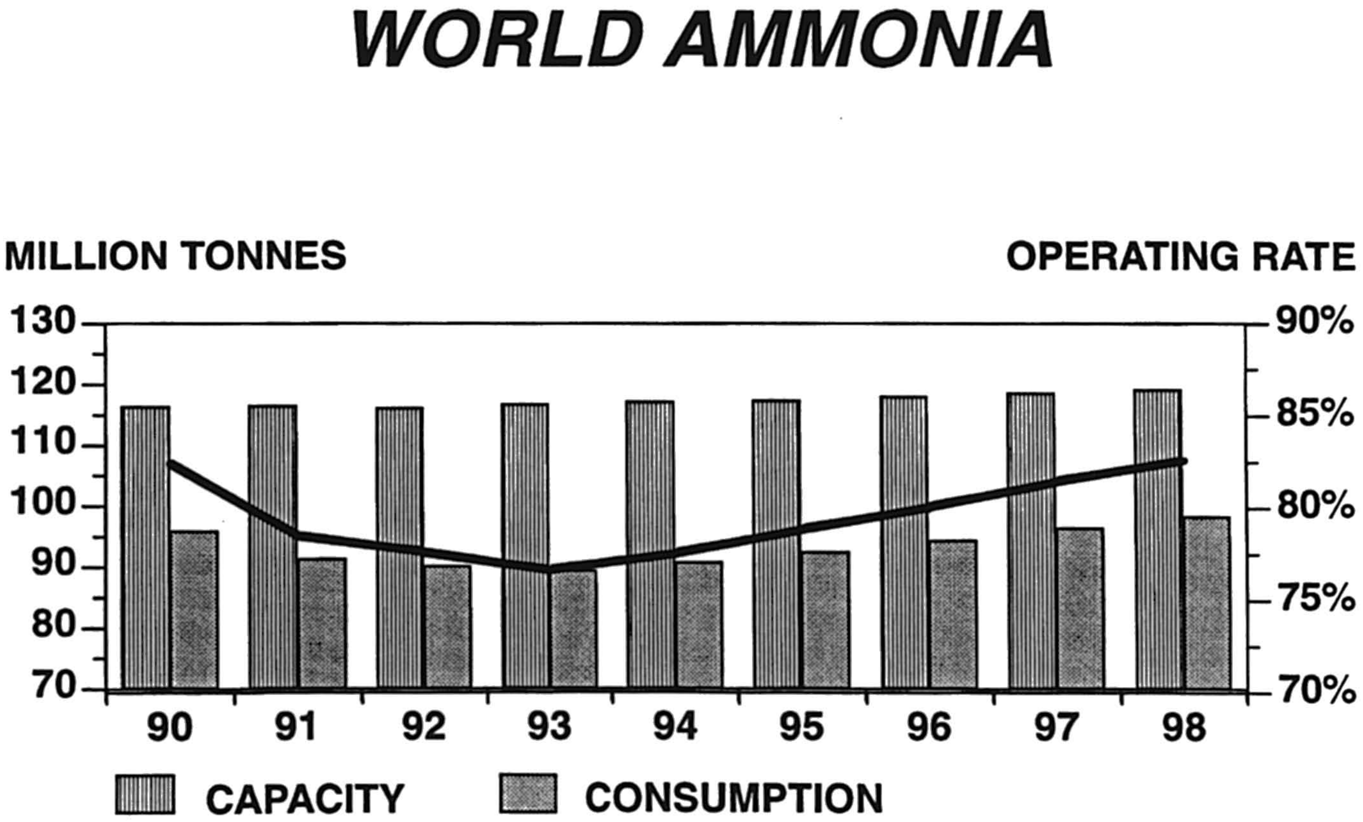
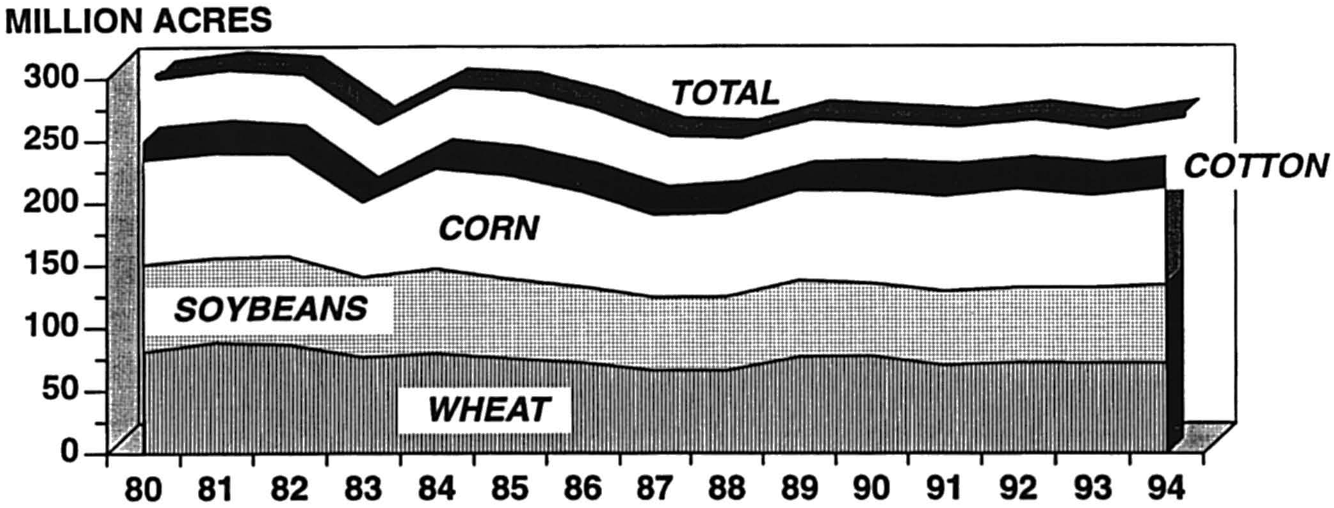


Figure 5: World Ammonia

U.S. PLANTED ACREAGE



MILLION ACRES	1992	1993	1994	% CHANGE 1993-94
WHEAT	72.3	72.1	71.8	-0.5%
SOYBEANS	59.3	59.5	62.3	4.8%
CORN	79.3	73.7	77.8	5.6%
COTTON	13.2	13.7	12.9	-5.6%

Figure 6: U.S. Planted Acreage

U.S. NITROGEN CONSUMPTION

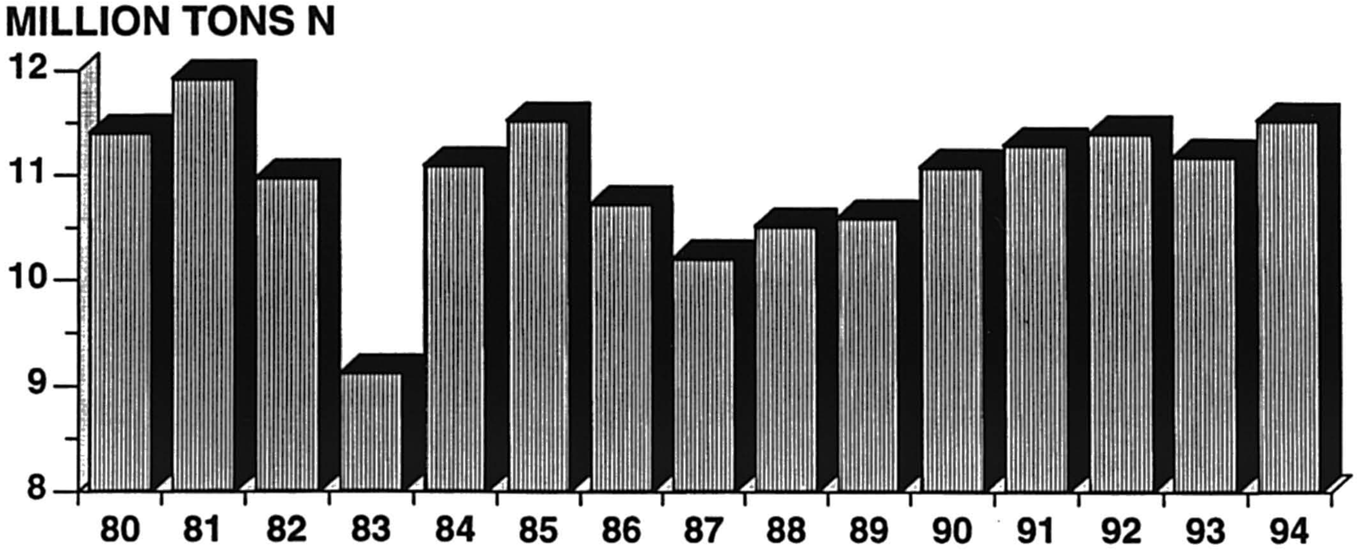


Figure 7: U.S. Nitrogen Consumption

USDA CORN SUPPLY/DEMAND

	1991/92	1992/93	1993/94
	(BILLION BUSHELS)		
BEGINNING STOCKS	1.521	1.100	2.113
PRODUCTION	7.475	9.479	6.962
TOTAL SUPPLY	9.016	10.585	9.085
FEED USE	4.878	5.250	5.050
FOOD/IND/SEED USE	1.454	1.510	1.550
EXPORTS	1.584	1.675	1.400
TOTAL USAGE	7.916	8.435	8.000
CARRYOVER	1.100	2.150	1.085
AVG. FARM PRICE	$2.37	$2.07	$2.40

Figure 8: USDA Corn Supply/Demand

USDA WHEAT SUPPLY/DEMAND

	1991/92	1992/93	1993/94
	(BILLION BUSHELS)		
BEGINNING STOCKS	0.866	0.472	0.529
PRODUCTION	1.981	2.459	2.422
TOTAL SUPPLY	2.888	3.001	3.026
FEED USE	0.254	0.196	0.275
FOOD/IND/SEED USE	0.883	0.829	0.835
EXPORTS	1.280	1.354	1.125
TOTAL USAGE	2.416	2.472	2.329
CARRYOVER	0.472	0.529	0.697
AVG. FARM PRICE	$3.00	$3.24	$2.90

Figure 9: USDA Wheat Supply/Demand

CORN
AVERAGE APPLICATION RATE PER PLANTED ACRE

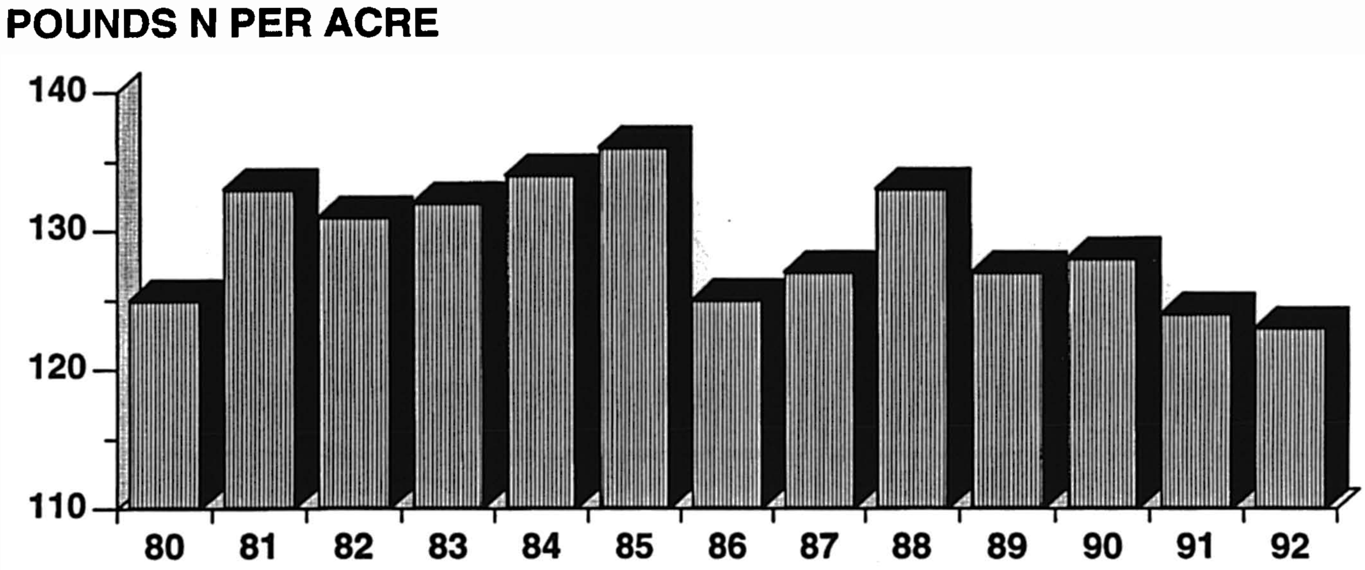


Figure 10: Corn Average Application Rate Per Planted Acre

U.S. AMMONIA SUPPLY/DEMAND

MILLION TONS	1991	1992	1993	1994
SUPPLY				
CAPACITY	18.099	17.881	17.436	17.479
OPERATING RATE	93.6%	98.4%	99.9%	98.6%
PRODUCTION	16.933	17.601	17.413	17.241
BEG. INVENTORY	1.322	1.035	1.118	1.270
IMPORTS	3.666	3.701	3.478	3.771
DEMAND				
DOMESTIC	20.034	20.645	20.266	20.441
EXPORTS	0.853	0.574	0.472	0.579

Figure 11: U.S. Ammonia Supply/Demand

U.S. UREA SUPPLY/DEMAND

MILLION TONS	1991	1992	1993	1994
SUPPLY				
CAPACITY	8.333	8.406	8.161	8.621
OPERATING RATE	96.3%	98.5%	100.8%	97.3%
PRODUCTION	8.027	8.281	8.229	8.388
BEG. INVENTORY	0.359	0.497	0.275	0.340
IMPORTS	1.980	1.682	2.651	2.420
DEMAND				
DOMESTIC	8.819	9.023	10.034	9.759
EXPORTS	1.050	1.163	0.782	0.939

Figure 12: U.S. Urea Supply/Demand

U.S. UAN SUPPLY/DEMAND

MILLION TONS	1991	1992	1993	1994
SUPPLY				
CAPACITY	11.419	11.669	11.421	11.958
OPERATING RATE	94.3%	95.5%	104.6%	95.4%
PRODUCTION	10.767	11.139	11.95	11.407
BEG. INVENTORY	0.819	0.731	0.736	0.845
IMPORTS	0.274	0.221	0.286	0.500
DEMAND				
DOMESTIC	10.650	10.931	11.914	11.565
EXPORTS	0.479	0.424	0.213	0.400

Figure 13: U.S. UAN Supply/Demand

Outlook For Phosphates

Maywood Chesson
Jacobs Engineering

Several months ago when David Leyshon was preparing the program for this conference, I agreed to present a paper discussing the *PHOSPHATE OUTLOOK* based on our past studies and a new analysis of the current world phosphate trade situation. At that time I was expecting our new study would be nearly complete and would provide current data on world P_20_5 demand; phosphate rock supply; and DAP costs. Unfortunately, we suffered delays in getting the new work started when we discovered many expected clients - world wide - were unable to subscribe because of their distressful economic situation.

Only recently have we secured the minimum-adequate number of clients to cover costs for traveling to Morocco, Tunisia, and Jordan to obtain current information concerning their phosphate rock and fertilizer industries to consolidate with U.S.A. industry data for preparing the world's status and outlook. Next week our study team departs on a four week fact finding mission to the three major foreign suppliers of the world export markets. The multi-client report, to be completed in December, will focus on the effects of changing costs and grade of phosphate rock over the next two decades on the competitive ranking of the four major exporters in DAP exports markets. The changes occur as existing mines in all competitive countries are extended to more distant locations from beneficiation plants to ultimately deplete available reserves and replacement and new mines are constructed to provide future P_20_5 demands of the growing world population.

To gauge competitive rankings of the four traditional major exporters, comparative DAP cost FOB producers' plant and CIF to the largest importing countries will be prepared. Other factors influencing DAP cost; e.g., sulfur, ammonia, and processing costs, will remain in constant 1993 dollars at each competitor's 1993 cost level, except for changes attributable to their future rock cost and grade changes.

Exporters with the lowest delivered DAP cost will be identified as the producers capable of economically justifying new investments in phosphate rock mines and fertilizer plants in future years. Producers in each of the major exporting countries are facing investment decisions. Using information we are currently collecting and our comparative phosphate rock and DAP cost models, we will predict where new mines most likely will be constructed.

Today, let me first share with you the dismal world Consumption-Demand outlook.

World P_20_5 Consumption

The total world P_20_5 consumption rate in 1 992 was about 36 million tons per year. Fertilizers used to enhance agricultural production for the world's increasing population and diminishing farming areas consumed about 89% of the total P_20_5. Other consumptions are **Industrial Phosphates** (6%) and **Animal Feed** (5%).

Table A shows World Total P_20_5 Consumption-Demand during the 1970s increased from 24 M tons at an average annual rate of 4.1%; during the 1980s the growth continued at an annual rate of 1.5% to a consumption of 40.4 M tons. This steady growth for two decades increased P_20_5 consumption about 67% as the world population increased 45%. Diets improved and there was less hunger on a global scale, although people in some world regions continued to suffer from inadequate food supplies. Then, disastrous changes began to disrupt the phosphate industry.

In the last two years of the 80s, P_20_5 consumption growth stopped; in the first two years of the 90s, consumption plummeted to levels attained in the mid-1980s. The major factors have been economic-political issues in the Former Soviet Union (F.S.U), Central Europe, and India, exacerbated by leveling consumptions in developed world regions, especially Western Europe and North America.

ZW's forecast follows IFA's recent prediction that the 1992 fertilizer P_20_5 demand would recover from 31.8 to 35.5 M tons over the next five years at an average annual rate of nearly 2%. Thereafter, we are projecting the average growth rate to 2010 at about 1.4%, which generally follows the predicted rate of world population increases.

Table A

World Total P_20_5 Consumption-Demand
(million tons P_20_5)(1)

	Fertilizers	Industrials	Feeds	Total
1970	21.2	1.8	1.0	24.2
1975	25.7	1.9	1.4	29.0
1980	31.9	2.2	1.9	36.2
1985	33.5	23.6	1.9	38.0
1988	37.6	2.5	1.9	42.0
1989	37.6	2.4	1.9	41.9
1990	37.1	2.4	1.9	41.4
1991	35.5	2.4	1.9	39.8
1992	31.8	2.4	1.9	36.1
1993	31.9	2.5	1.9	36.3
1994	32.8	2.5	1.9	37.2
1995	33.6	2.5	2.0	38.1
1996	34.6	2.6	2.0	39.2
1997	35.5	2.6	2.0	40.1
2000	37.8	2.6	2.1	42.5
2005	40.7	2.7	2.2	45.6
2010	43.8	2.8	2.3	48.9

(1) *Fertilizer statistics through 1997 compiled by IFA from companies/countries for fertilizer years and calendar years (e.g., 1970/71 and 1970); and other forecasts by ZW.*

Industrial and Animal Feed Phosphates

These markets are estimated to continue growing, although at a lower average rate than total population growth. The wet process phosphoric acid proportion of **Industrials**, compared to thermal acid, is expected to increase as recently demonstrated purification processes evidence acceptable quality products at lower cost. The world P2O5 consumption for **Industrials** and **Feeds**, as shown in Table A, is forecast to increase from 4.4 M tons in 1992/93 to 5.1 M tons in 2010, which is equal to about 1.0% per year.

Fertilizer P_20_5 Consumption-Demand

The myriad factors influencing fertilizer consumption change from year to year; they vary from country to country, and within countries; and are far too complex to describe and evaluate as to their influence in future years, and present in a report of this nature. Nevertheless, some comments seem necessary to justify the forecasts of demand, as shown in Table B, which provide the basis for estimating future sources of fertilizer supply and phosphate rock production.

U.S.A.

Fertilizer consumption increased during the 1970s to a peak of 4.9 M tons P_20_5 in 1980/81, then dropped to 3.8 M tons P_20_5 in 1985/86, and has remained in this range. Little change is expected for several years; however, to maintain the U.S.A. supply of agricultural products for domestic and export markets from reducing farm areas, a demand of 4.0 M tons is forecast in 2010. A return to the high levels in the 1970s is not predictable on the basis that export markets of U.S.A. agricultural products will not again be necessary because improved agricultural yields is predicted in other regions of the world.

India

Consumption increased steadily from 0.3 M tons in 1970/71 to 3.3 M tons in 1990/91, with an increase of more than 2 M tons per year during the 1980s. In 1992/93, government financial issues disrupted India's fertilizer production and export purchasing. This reduced consumption about 20% to 2.7 M tons, the rate of usage four years ago.

The forecast, based on an average 5% annual growth, is 3.5 M tons in 1 997/98 and 4.0 M tons in 2005. In the following five-year period, with an annual rate of growth at 2%, the consumption will reach 4.2 M tons in 2010. This forecast is somewhat more conservative than the IFA recent outlook of 4.5 M tons in 2002/03.

China

In the 1980s, China's consumption nearly doubled to 5.8 M tons P_20_5 in 1991/92 and agricultural production achieved record levels. In 1993, fertilizer imports were reduced abruptly, thereby diminishing consumption, although imported fertilizer prices were at a 20 year record low. China continues construction and engineering for new phosphate rock mines and fertilizer plants, but progress is slower than prescribed in their five-year plans. Fertilizer imports must be continued to support their required agriculture production.

The forecast is that consumption will increase about 3% annually to 6.8 M tons in 1995/96; then at a lower rate of about 1 % to 7.7 M tons to 2010. Imports are expected to return to the 1991 level of about 2.2 M tpy.

F.S.U.

The Former Soviet Union, during the late 1970s, began an aggressive program to improve farm yields. High investments were made to develop national gas fields and ammonia production, not only to dramatically increase domestic supplies, but for export. Simultaneously, long-term contracts were entered to import P_20_5 (SPA) and boost domestic fertilizer production quickly. Also, agreements were made for joint-venture development of Morocco's vast Meskala deposit to provide longer phosphate rock supplies to their eastern and southern regions.

Table B

World Fertilizer $P_2 0_5$ Consumption-Demand (million tons $P_2 0_5$)$^{(1)}$

	U.S.A.	China	Europe West	Europe East	F.S.U.	India	Others	World
1970	4.3	1.2	5.7	2.3	3.1	0.3	4.3	21.2
1975	4.7	1.8	5.6	2.6	4.7	0.4	5.9	25.7
1980	4.9	3.0	5.4	2.7	5.9	1.1	8.9	31.9
1985	3.8	3.0	5.2	2.8	7.6	2.1	9.0	33.5
1988	3.7	5.1	5.1	2.6	8.5	2.6	10.0	37.6
1989	3.9	5.2	5.0	2.5	8.2	3.0	9.8	37.6
1990	3.8	6.8	4.7	1.8	7.9	3.3	9.6	37.1
1991	3.8	7.2	4.1	0.6	7.0	3.4	9.4	35.5
1992	3.7	7.0	3.5	0.6	4.5	2.7	9.8	31.8
1993	3.8	6.5	3.5	0.7	4.5	2.19	10.0	31.9
1994	3.8	6.7	3.5	0.7	4.6	3.1	10.4	32.8
1995	3.8	6.8	3.5	0.8	4.7	3.2	10.8	33.6
1996	3.8	6.9	3.5	0.9	4.9	3.4	11.2	34.6
1997	3.8	7.0	3.5	1.0	5.1	3.5	11.6	35.5
2000	3.9	7.2	3.5	1.2	5.3	3.8	12.9	37.8
2005	3.9	7.4	3.5	1.7	5.9	4.0	14.3	40.7
2010	4.0	7.7	3.6	2.0	6.4	4.2	15.9	43.8

(1) *Fertilizer statistics through 1992 compiled by IFA from companies/countries for fertilizer years and calendar years (e.g.,1970/71 and 1970); and forecasts by ZW.*

Consumption climbed from 3.1 M tons in 1 970 to 7.8 M tons in 1990/91, but dropped to 4.5 M tons in 1992/93 as imports were curtailed and domestic production plummeted. Political and economic problems in the new Community of Independent States have created chaotic conditions. The farmers have no money to buy fertilizers - and no source of credit - and the newly independent fertilizer plant operators have no money - or credit - to buy raw materials and pay other operating expenses. They discovered hard currencies could be obtained by exporting fertilizers to Europe, North America and China, instead of supplying farmers in their state or neighbor states.

The outlook is continued economic distress in the F.S.U. with slight consumption recovery by 1998 to 5.1 M tons which will be 13% above 1993, but 35% below 1 990. Afterwards it is assumed consumption will increase about 2% per year to 6.4 M tons by 2010, significantly lower than the former rate despite the expected population increases.

Western Europe

Benefits from increased consumption of phosphate fertilizers in Western Europe peaked at about a rate of 6 M tons per year in the 1970s, as was the case in the U.S.A. During the 1980s, usage dropped to about 5.0 M tons; then diminished to 3.5 M tons in 1992/93 where it is expected to remain for the foreseeable future. Agriculture in this region is a mature industry and is limited by a multitude of political and environmental problems. The fertilizer usage per unit of production is among the highest in the world, so little growth is expected.

Eastern (Central) Europe

In Albania, Bulgaria, Czechoslovakia, Hungary, Poland, Rumania, and Yugoslavia, consumption peaked at about 3 M tons in the early 1980s and diminished gradually to 2.5 M tons in 1989. Political and economic turmoils through the region disrupted the fertilizer agricultural industry; consumption plummeted to 1.5 M tpy in 1990 and 0.6 M in 1992. The region's future, like other regions affected by problems related to dissolution of the USSR and other political issues, is difficult to foresee, but is predicted to follow a similar trend described for F.S.U., although at a slightly faster recovery rate. Consumption of 1.2 M tons in 2000 is based on 5% annual increases. By 2010 the demand is forecast at 2.0 M tons, but notably lower than the 1980 peak of 3.0 M tons.

Other Reasons

Other countries not addressed above are mainly in South America, Asia, Africa, and Oceania, where the current fertilizer consumption is considerably below world average and population growth is considerably above the world average. In these countries, future consumption is predicted to increase about 3% per year.

Consumption per Capita

Table C shows P_20_5 consumption per capita increased 23% from 1970 to 1980; then declined another 4% by 1990. Our forecast is a decline of 9% by 2000 to equal a consumption of 6.8 kg per capita, where it will remain constant to 2010 at a rate 16% lower than in 1980.

Our consumption forecast is conservative, we hope, because it indicates growing food shortages.

Fertilizer Products

By 1998, IFA predicts the world's P_20_5 consumption will recover to the rate of 1991/92 that's a loss of six years' growth! To achieve that recovery, many very difficult problems must be resolved in the world, especially in the F.S.U., Central Europe, and the developing countries where inadequate food supplies are an old story. But, the phosphate industry will resume a growth rate and we predict by 2010 the demand will be at 48.9 M tons P_20_5 - 18% above 1990. This is 3 M tpy less than our estimate for 2010 that was made in 1992 before impacts from the USSR dissolution were recognized.

The world P_20_5 consumption-demand for major products shown in Table D indicates DAP/MAP will continue to be the dominant fertilizer commodity in world trade.

Table C

P_20_5 Consumption per Capita

	1980	1990	2000	2010
World Population(1) - millions	4,453	5,329	6,285	7,240
10 Years Increase - %	20	20	18	15
World P_20_5 Consumption -milliontons	36.2	41.4	42.5	48.9
10 Years Increase - %	50	14	3	15
P_20_5 per Capita- kg	8.1	7.8	6.8	6.8
10 Years Increase - %	23	4	-9	-0-

(1) Source: U.S. Department of Commerce Bureau of the Census

Table D

World Consumption of P_20_5 Products (million tons P_20_5)

	1990		2000		2010	
Products	Tons	% Total	Tons	% Total	Tons	% Total
DA	2.1	5.1	2.1	4.9	2.5	5.1
SSP	7.3	17.6	7.3	17.2	7.7	15.8
NP	2.6	6.3	2.6	6.1	3.0	6.1
TSP	4.3	1 0.4	4.3	10.1	4.5	9.2
DAP/MAP	20.8	50.2	21.5	50.6	26.1	53.4
Sub-total	**37.1**	**89.6**	**37.8**	**88.9**	**43.8**	**89.6**
Feed	1.9	4.6	2.1	4.9	2.3	4.7
Industrials	2.4	5.8	2.6	6.2	2.8	5.7
Sub-total	**4.3**	**10.4**	**4.7**	**11.1**	**5.1**	**10.4**
Total	**41.4**	**100.0**	**42.5**	**100.0**	**48.9**	**100.0**
WPPA Required	27.1	65.5	28.4	66.8	33.8	69.1
Rock P_20_5 %	31.1		31.1		31.0	
Rock P_20_5 Recovery	88.8		88.2		88.7	
Rock Consumption	46.6		48.2		55.1	

Direct application phosphates, single super phosphate, and triple super phosphate are predicted to remain at about the same tonnage to supply P_20_5 to soils in developing countries as the more affluent countries use more expensive, although more cost-effective fertilizers.

WPPA requirements are predicted to increase at a rate slightly greater than total P_20_5 consumption. This reflects the logistical economies of shipping and handling DAP/MAP that support its increasing popularity and the increasing use of purified WPPA for industrial products.

Table E shows WPPA capacity and production for 1990 and our estimate of new capacity and production in 2010. This indicates 7.8 M tons of new capacity will be required by 2010 to provide increased demand and to replace some of the1990 capacity.

The prediction that most of the Central Florida existing WPPA capacity will be maintained is based on the premise that new investments in local phosphate rock mines will be available to sustain a local rock supply. If the new investments are not economically justified and new mines are not constructed in Central Florida, then a substantial portion of the Central Florida chemical industry will not be competitive in world export markets, according to our previous studies. The comparative cost analysis for which we are currently gathering information will reveal if the rock cost and grade from new mines will be competitive with other new mines in competing countries.

Phosphate Rock Demand

Notice that Table F shows world rock demand at 156 M tons in 1990 increases only 3% by 2000, and 18% by 2010. This is a remarkably lower forecast than those we made before the current market slump occurred. Near-term production rates from existing mines will be less than previously estimated, and reserves life will be extended, but they will be depleted.

All mines require periodic new investments to maintain capacity; new pipe for slurry transport; new trucks; replacement conveyor belts; overhauls of draglines, shovels, loaders, and beneficiation facilities. When rock demand and prices are low, these investments are not justified and capacity diminishes. As demand grows, prices must increase to justify investments for restoring capacity. We see this occurring in many mining areas -

Table E

Phosphoric Acid Capacity-Production
(million ton P_20_5)

	1990		2010		
	Capacity	Production	Capacity	Increase	Production
Western Europe	3.4	2.8	1.9	(1.5)	1.7
Central Europe	2.1	.5	1.8	(.3)	1.5
F.S.U.	5.9	4.6	5.0	(.9)	4.0
U.S.A.	11.4	10.5	11.5	.1	10.6
Morocco	2.8	2.4	4.2	1.4	3.7
Tunisia	1.4	1.1	1.4	0	1.1
Jordan	.4	.3	.8	.4	.7
China	.2	.1	2.8	2.6	2.1
India	.5	.4	.7	.2	.5
Others	6.8	4.4	9.9	3.1	7.9
World	34.9	27.1	40.0	5.1	33.8
% Utilization		77.6			84.5

Table F

WORLD ROCK DEMAND
(million tons)

	1990	2000	2010
P_2O_5 in Products (1)	41.4	42.5	48.9
Rock P_2O_5 Delivered	46.6	48.2	55.1
Rock Grade	31.1%	31.1%	31.0%
RockTons Producedl (2)	156.1	161.4	185.1

(1) average recoveries 88.8%, 88.1%, 88.7%

(2) includes 4% unaccounted disappearance

Table G

1992 Central Florida Rock Demand

Market	Plant Location	MtPv Rock
U.S.A. Fertilizer	Gulf Coast	5.7
U.S.A. Fertilizer	Central Florida	2.4
Industrials and Feed	Central Florida	3.6
Fertilizer Export	Central Florida	17.0
Rock Export	Central Florida	3.5
Total		32.2

Florida, Russia (Kola), Kazakhstan (Kara Tau) - and expect to find the same situations in Morocco, Tunisia, and Jordan.

Central Florida Outlook

Central Florida mines had peak production of 38.5 M tons in 1980 that declined to 32.2 M tons in 1992. In a 1992 study to estimate rock tonnage the local industry may process and market from 1993 to 2010, we identified three scenarios - Optimistic, Probable, and Pessimistic. Production from existing mines was predicted to continue at the 1992 rate of 32 M tons rock until available reserves are depleted. Priority of markets and annual demand for Central Florida rock tonnage is shown in Table G.

Existing mines with 37.4 M tpy capacity can supply the 32.2 M tpy demand until 1995, but by 2010 the Central Florida capacity would be reduced to 8 M tpy.

The estimated mine-out dates in Table H evidence the need for new mines before 2000 in order to continue supplying the industry's current market demands.

Market Losses

In each of the three scenarios, Central Florida rock production would be sufficient through 2010 to supply all of the 1992 markets for U.S.A. fertilizers, Industrial and Animal Feeds, but not the export fertilizer and rock markets. Table J shows the market losses for the Probable Scenario would be 10% by 2000 and 40% by 2010. Market losses are greater in the Pessimistic Scenario and deferred until after 2010 in the Optimistic Scenario.

Table H

Projected Mine-out for Existing Mine
(million tons rock capacity)

Owner	Mine Name	1995	2000	2005	2010	>2010
Mobil	Big Four	2.1				
IMC/Agrico	Payne Creek	2.4				
USSAC	Rockland		1.7			
IMC/Agrico	Clear Springs		1.7			
IMC/Agrico	Noralyn-Phosphoria		4.2			
CF Industries	North Pasture		1.0			
Mobil	Nichols		1.3			
Cargill	Fort Meade			2.8		
IMC/Agrico	Kingsford			4.7		
IMC/Agrico	Fort Green				3.8	
Cargill	Hookers Prairie				3.2	
IMC/Agrico	Hopewell				.5	
Nu-Gulf	Wingate Creek					1.4
IMC/Agrico	Four Corners					4.5
IMC/Agrico	Fort Lonesome					2.1
		4.5	9.9	7.5	7.5	8.0

Table J

Central Florida Future Rock Supply
Probable Scenario
(million ton rock)

Markets	Plant Location	1992 Rock Demand	1995 Supply	2000 Supply	2010 Supply
U.S.A. Fertilizers	Gulf Coast	5.7	5.7	5.7	5.7
U.S.A. Fertilizers	Central Florida	2.4	2.4	2.4	2.4
Industrials & Feed	Central Florida	3.6	3.6	3.6	3.6
Fertilizer Exports	Central Florida	17.0	17.0	15.2	6.6
Rock Exports	Central Florida	3.5	3.5	2.0	1.0
Total		32.2	32.2	28.9	19.3
Market Loss				3.1	12.9

New Mines

The 1992 study assumed market prices and defined reserves could justify investments in prospective new mines as listed in Table K.

The indicated Central Florida market supply loss of 1 2.9 M tpy rock by 2010 in the Probable Scenario means that other world rock producers must provide this tonnages, plus new capacity of 29 M tpy to supply the forecasted world demand of 185.1 M in 2010.

It is important to note that if new mines in Central Florida are not constructed, then many of the local fertilizer plants with no local rock supplies will become worthless. In the 1992 study we assumed the Bonnie and Piney Point plants would not be restarted. Unless fertilizer prices are increased, or cost of rock from new mines is reduced, many of the other plants listed in Table L are doomed.

Table K

Projected New Mine Construction
(million tons rock capacity)

Owner	Reserve	Startup Year	Pessimistic Scenario	Probable Scenario	Optimistic Scenario
Mobil Mining & Minerals	South Ft. Meade	1995	3.2	3.2	3.2
IMC/Agrico	Ona-Carlton	1998	-0-	2.7	2.7
CF Industries	South Pasture	2003	-0-	2.7	2.7
IMC/Agrico	Ona-Carlton (expansion)	2003	-0-	2.7	2.7
IMC/Agrico	Horse Creek	2002	-0-	-0-	5.5
Farmland-Hydro	Hickory Creek	2005	-0-	-0-	1.8
CMI	Pine Level	2008	-0-	-0-	2.7

Table L

Central Florida Fertilizer Plants
(1000 tons)

Owner	Location	CAPACITY P_2O_5	ROCK DEMAND Rock
Agrico	South Pierce	435	1,869
IMCF	New Wales	1,551	5,805
IMCF	Nichols	209	753
Cargill	Tampa	680	2,612
Cargill	Bartow	689	2,621
CF Industries	Zephyrhills	853	3,265
CF Industries	* Bonnie	544	1,968
Farmland-Hydro	Greenbay	590	2,222
USA Agri-Chem	Ft. Meade	245	889
Seminole (Tosco)	Ft. Meade	245	889
Fertilizer Develop. Invest., Inc.	* Mulberry	272	989
Fertilizer Develop. Invest., Inc	* Piney Point	181	653
		6,494	24,535

** Closed January 1993*

Future World Rock Supply

There are many indications that prices of rock and DAP will increase and the work we have underway will provide information for making price predictions based on comparative cash costs and return on investment. Unfortunately for U.S.A. producers, governments in the three major competing countries find financial assistance for their phosphate industry because H provides foreign exchange and domestic employment. However, all of these countries have heavy foreign debt burdens and international financiers have declined to support phosphate investments in recent years - even before this recent slump of work P_20_5 consumption

Finally, Table M shows a summary of the world phosphate rock production, highlighting the supply countries especially influencing export markets.

Table M

World Phosphate Rock Production (million tons rock)

	FSU	Isreal	Jordan	Morocco	S.Africa Senegal Togo	Tunisia	U.S.A.	Others	Total
1970	20.4	1.0	1.2	11.4	4.2	3.0	35.1	8.6	84.9
1975	24.1	0.9	1.4	16.2	4.6	3.5	44.3	12.5	107.5
1980	25.3	2.3	3.9	18.8	7.7	4.6	54.4	20.9	137.9
1985	33.7	4.1	6.1	20.7	6.7	4.5	50.8	22.7	148.8
1986	33.9	3.7	6.2	21.2	7.1	6.0	38.7	24.2	141.0
1987	34.1	3.8	6.8	21.3	7.1	6.4	41.0	29.6	150.1
1988	34.4	3.5	6.6	25.0	8.6	6.1	45.4	31.6	161.2
1989	34.4	3.9	6.9	18.1	8.6	6.6	49.8	31.7	160.0
1990	33.5	3.5	5.9	21.4	7.6	6.3	46.3	29.9	154.4
1991	30.0	3.4	4.4	17.9	7.8	6.4	48.1	31.7	149.7
1992	21.0	3.6	4.3	19.2	7.4	6.4	47.0	34.9	143.8
2000	Pending Results								161.4
2005		From Comparative							172.7
2010			Cost Analysis						185.1

Source: BOM & IFA Phosphate Rock Statistics
Forecast by ZW

Other countries in 1990 include China (21.0), Brazil (3.0), Syria (1.7), Egypt (1.3), Algeria (1.1), Nauru (.9), Iraq (.6), and lesser tonnages from Finland, India, Korea, Mexico, Venezuela, Vietnam, Zimbabwe, and a few countries with very small outputs.

The column on the right side - Total - for the future years showing 185 M tons in 2010, is to supply the 48.9 M tons P_20_5 demand. In addition to supplying the 41 M tpy of new rock demand, existing mines to be depleted by 2010, including 29 M tons of capacity in Central Florida, must be replaced. Our forthcoming comparative cost analysis will define where those mines may be located and how much new capacity is necessary.

Outlook for Potash

Hubert Vis
SCPA, France

I should like first to thank you for this opportunity to speak to fertilizer experts and to present our assessment of the world potash situation: currently and its prospects.

Before turning to the more difficult part of this presentation - the outlook - I feel it is important to give you a review of the last five years. Profound changes have occurred which will keep affecting the potash industry.

The Recent Evolution of the Supply-Demand Situation

Historically, potash production has been concentrating in the northern hemisphere, namely in developed countries having a strong agricultural base and a high level of fertilizer inputs.

In 1988, the production split up by regions was the following:

(In '000 TK20)

USSR	NORTH AMERICA	WESTERN EUROPE (incl.GDR)	MIDDLE EAST	OTHERS	TOTAL
11300	9788	8654	2030	115	31887

GDR has been aggregated to Western Europe to keep the same basis for comparison in the following years.

Within five years, the production picture has changed dramatically and reached the following numbers:

	FSU	NORTH AMERICA	WESTERN EUROPE	MIDDLE EAST	OTHERS	TOTAL
1992	6949	8903	5811	2059	175	23897
1992/88	-38.5%	-10%	-32.9%	+1.4%	+52.2%	-25.1%

Two major events have driven down demand over the last five years and as a result production alike:

- ◆ The collapse of the communist regime with its two major consequences: on the one hand the break-up of the FSU and COMECOM, and on the other hand the German renunciation,
- ◆ The PAC reform in the EC.

As a result, we have seen the K20 consumption collapsing in the FSU (from about 7 MTK20 in 1988 down to 3.5 MTK20 in 1992) and in Eastern Europe where potash consumption today is merely a quarter of what it used to be (see figure 1).

In Western Europe where actually the bulk of the demand takes place in the E.C., the decline has reached 2 MTK20 from 7.2 MT in 1988 down to 5.28 in 1992 (see figure 2).

As we have outlined before, the FSU and Western Europe have reduced very significantly their respective potash output:

- ◆ The FSU by 38.5 %: it used to be the world largest potash producer and in 1992 became second to North America and even Canada alone.
- ◆ Western Europe has cut down its capacity, primarily through the restructuring of the former GDR industry. The latter will have seen its capacity reduced from 3.5 MTK20 to 1.1 in the near future.

To give you an idea of the extent of these far-reaching changes, just realize that the restructuring in the former GDR means the definitive shutdown of 8 mines and that the drop of more than 4 MTK20 output in the FSU is equal to putting 4 large mines idle.

As the following figure (3) shows, the three major producing areas rely for more than half of their sales on their respective domestic markets. As the recent evolution has exemplified, it is an asset which can turn into a weakness.

Features of the Present and Future Demand-Prospects For the World Potash Market

Let us first examine the demand in the major producing areas, since producers' domestic sales accounted for 56 % of world sales in 1992.

Potash producers' domestic sales are highlighting the respective trends in each area (see figure 4):

◆ The FS market definitely collapsed as the centrally planned economy ceased to dictate the demand. It is expected to bottom out in 1993 and to recover slowly up to 5 MTK20 in ten years time,

◆ After experiencing a significant drop of 20 % between 1990 and 1992, the West European market will likely keep declining at 1 % per annum in the coming years,

◆ The Middle East domestic sales are largely geared to the production of Potassium Nitrate in Israel and soon of NPKs in Jordan,

◆ Only the North-American producers are sitting on a vast and stable domestic market.

According to the above forecast, we should see the following evolution (figure 5).

However, the potential growth of demand lies with Agricultures of developing countries which will need more potash to produce more food for an ever growing population.

Let us keep in mind that out of the world population anticipated to reach 6.3 Billion people in the year 2000, 80 % will live in developing countries.

Clearly (see figure 6), Asia will pull up the demand and Latin America to a lesser extent. In Africa most of the consumption will remain restricted to populated areas like Egypt, North Africa, Nigeria and the developed agriculture of South Africa / Zimbabwe.

China followed by Brazil and India are to remain the largest import markets (see figure 7). There are still some uncertainties as to the real impact of subsidies phasing out on consumption in India and China.

If we take the Agronomists' viewpoint, we have good reasons to believe that crops in developing countries will need more potash:

◆ Intensification will be necessary because arable land is getting scarce, especially in Asia,

◆ High yielding varieties resulting from genetic improvement remove more nutrients form the soil. Irrigation has the same effect,

◆ And finally the widespread use of high nitrogen application will have to be balanced by phosphate and potash, the more since tropical soils are reputedly poor in P and K.

As shown in a simplified way on the following diagram (figure 8), Europe and North America have built up steadily soil fertility (before 1980, more P and K than N were applied) whilst Asiatic developing countries are depleting their soil fertility. In this context, it is striking that the nutrients ratios (N:P_20_5:K20) for Western Europe and North America respectively 100:39:45 and 100:38:42 whilst it is 100:34:10 in China.

Having said all that, what is the outlook for potash ?

Basically the potash industry will inevitably keep facing a significant over capacity even beyond the turn of this century: the surplus of potential supply over demand amounts currently to 4 MTK20 and will still be 2.5 MTK20 in 1999.

As a result, large producers will have to operate at a reduced rate of capacity: primarily Canada and the FSU. In the 70's, these two countries have expanded dramatically their capacities on assumptions which proved later on incorrect:

◆ Canada firmly believed in UNIDO demand estimates which bluntly extrapolated the past growth. In 1978, UNIDO forecasted that world potash consumption in 2000 would reach 67 MTK20 ! Today, experts are risking the figure of 25 MTK20 for that year,

◆ In the FSU planned economy, the offer had to dictate the demand and not the reverse. Incremental output from new potash mines was allocated to a home market which was bound to grow.

However, in the short term, Western producers will follow a different policy from the CIS. Being in a market economy, the former must secure at the end of the day an acceptable profit to remain viable.

- The West European producers will continue to adjust production to market demand (figure 9). Through restructuring and rationalization, they are cutting production, improving productivity despite a high proportion of fixed costs and high labor constraints. Those producers will want to supply the largest share of what is their home market at a fair value,

- In North America, private producers who achieve high technical performances and low costs will aim at a decent return on equity,

- In the Dead Sea region both Israelian and Jordanian producers need to run profitable potash operations to finance future expansion and downstream product development. They enjoy a dishing logistic advantage to supply South Asian markets.

By contrast potash marketing by CIS producers will in our view follow a different line at least in the short time. Potash being an important foreign exchange earner, the FSU will continue to push tonnages in the export markets and try to achieve more than their present 30% share of potash world trade. This pressure entails disturbances in the market place for the following reasons: many different channels are involved to supply the same customers, offers are made on basis of export availabilities rather than on account of real enquires as far as timing and quantities are concerned. As a result, erratic prices are observed ranging from US$ 60 to US$ 90 FOB whilst Western suppliers have established prices around the US$ 110 FOB benchmark in international contract markets.

In the medium and longer term, this two-tier price situation may change. The CIS domestic market will likely increase in terms of purchasing power and plant nutrient requirement: after all those new Independent States will have an economic interest in getting self-sufficient for good crops. Besides, the CIS mines will require huge investments to improve mining and mill processing efficiency, to expand compaction capacity and foremost to cope with waste disposal. They will also gradually pay more for transportation and handling of potash since the existing railway and port infrastructures are either saturated or in poor condition.

The growing impact of cost factors will inevitably drive CIS potash producers to seeking price improvements.

In conclusion, the Western potash industry has definitely a difficult challenge to meet in the next few years. In rougher market conditions, Western producers are bound to enhance their respective strengths: strong position in home market, cost or logistic advantage, quality of service. By capitalizing on those attributes, they will be in a position to provide more market stability and ensure viability. This market driven approach will surely also benefit potash buyers.

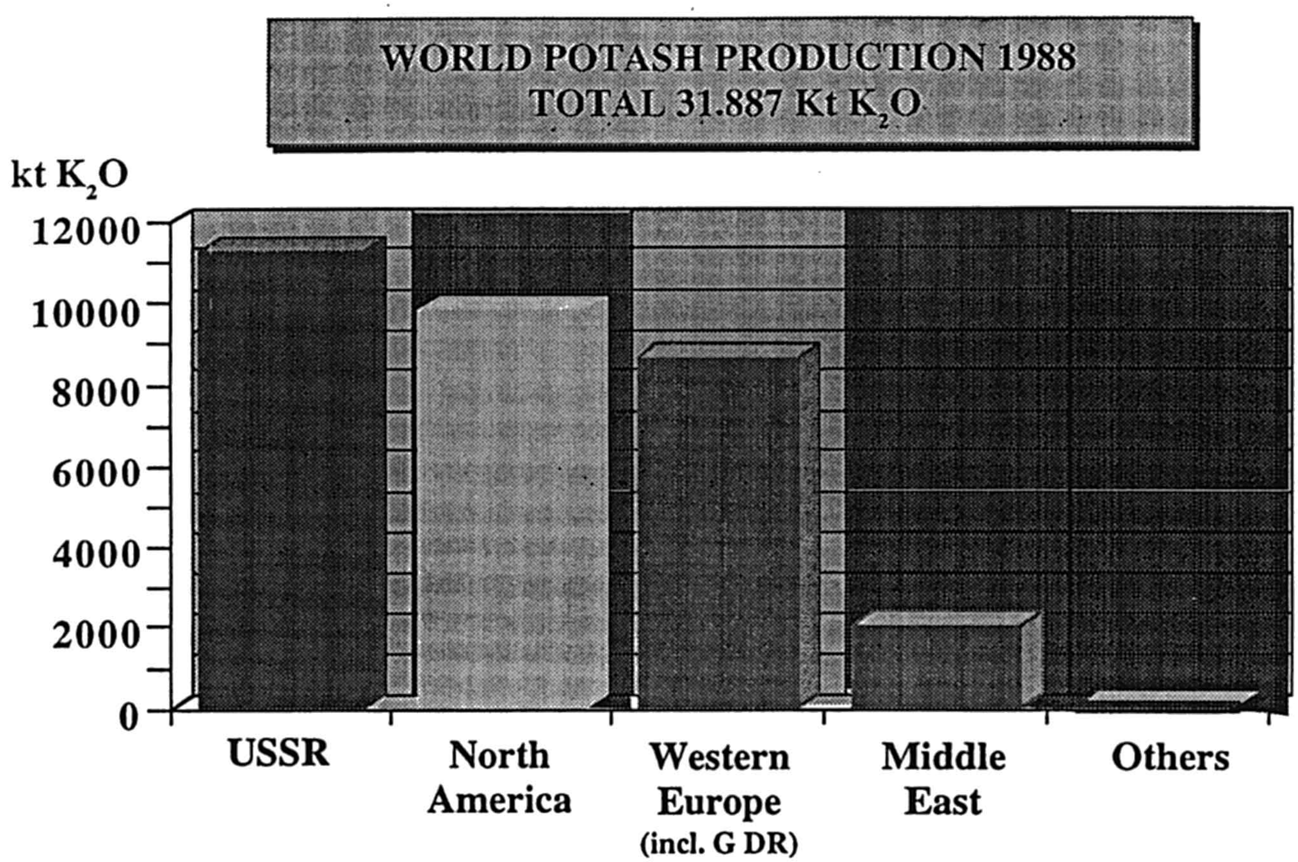


Figure 1: World Potash Production 1988

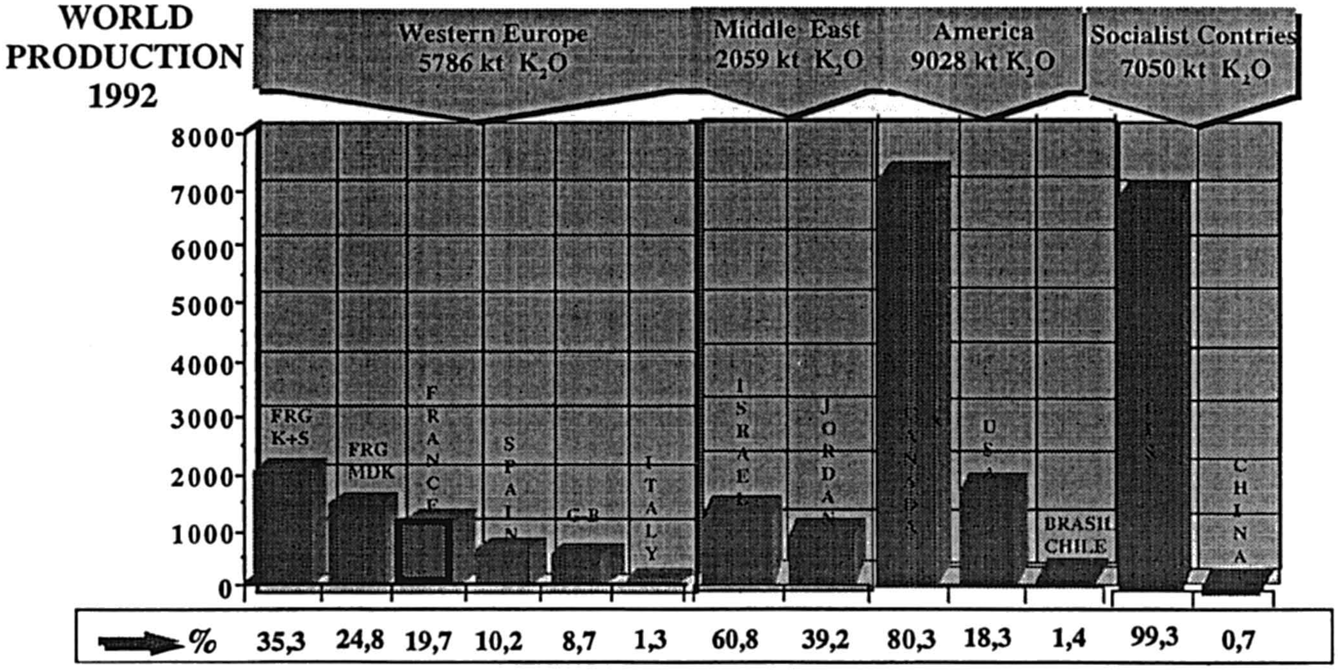


Figure 2: World Production

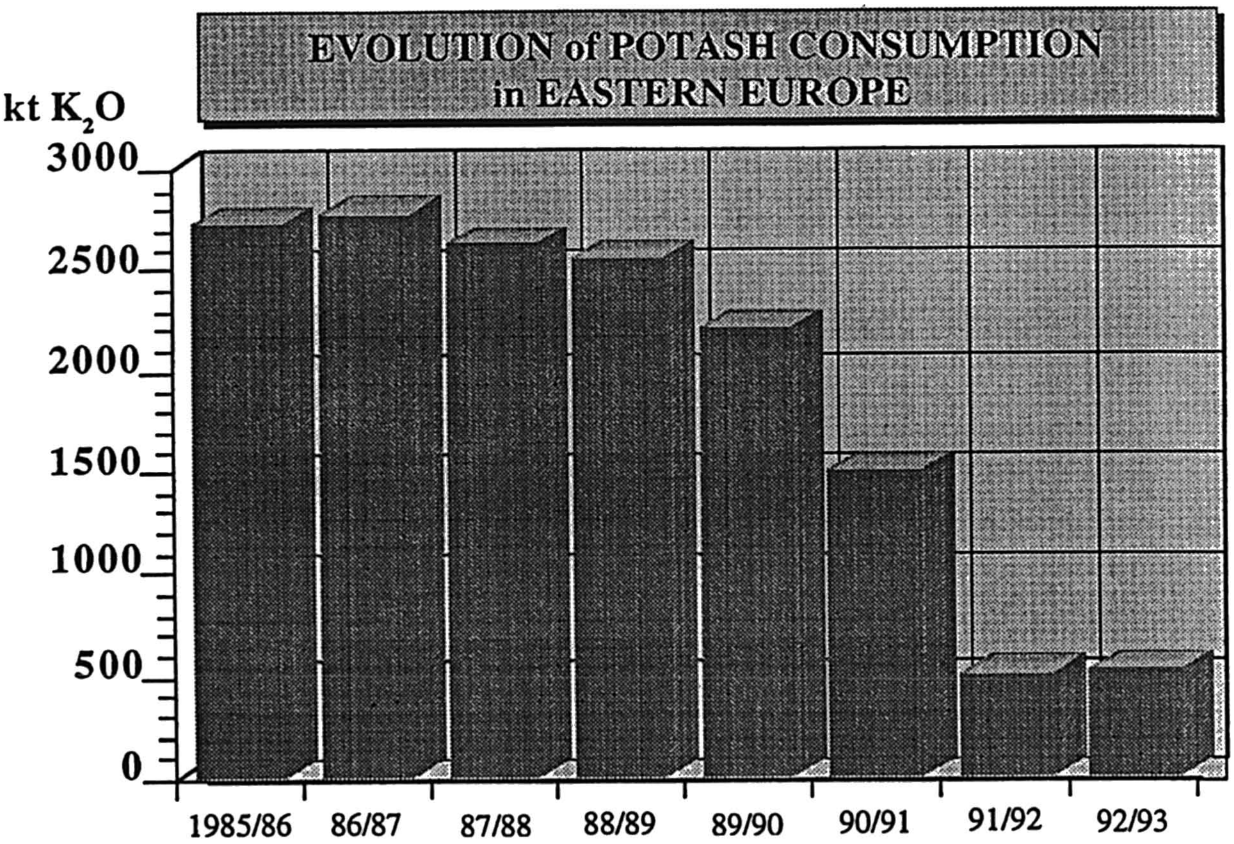
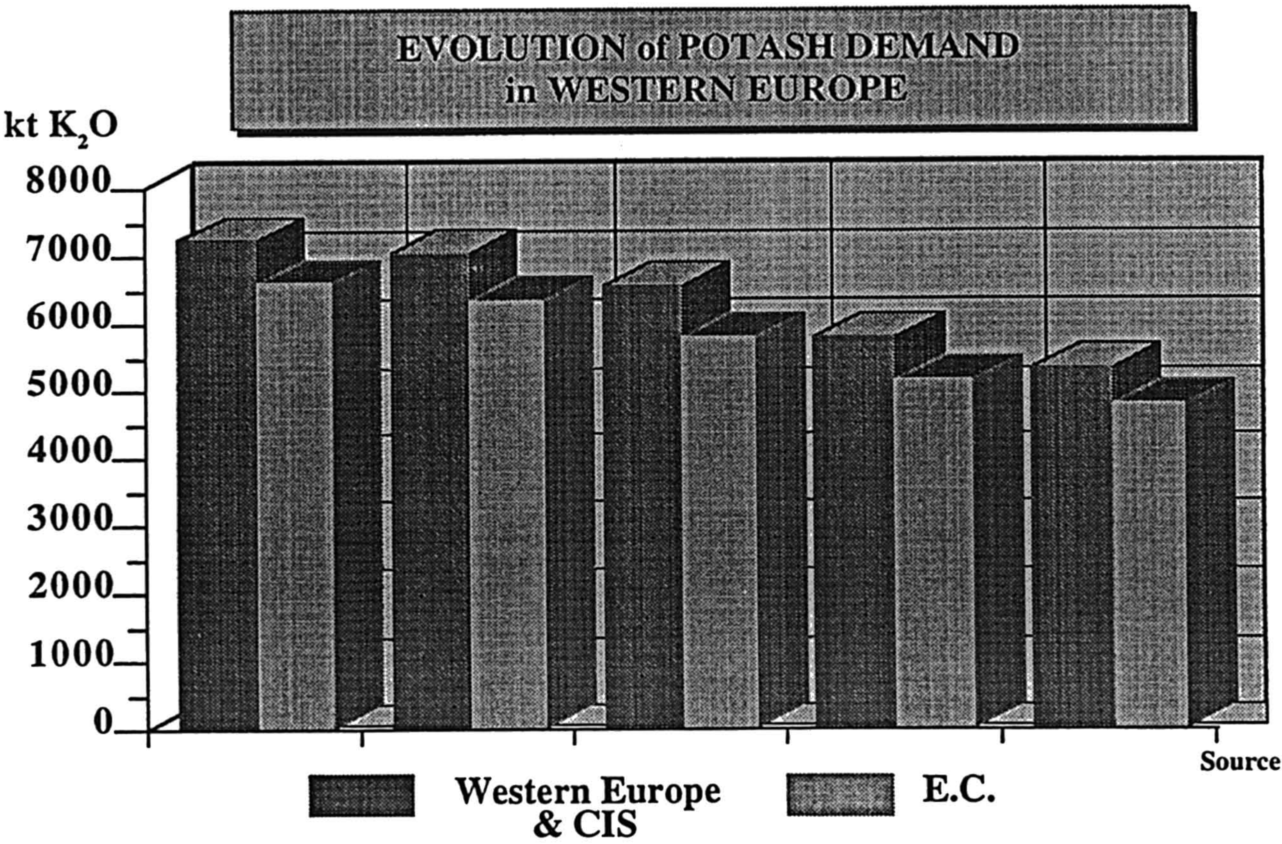


Figure 3: Evolution of Potash Consumption in Eastern Europe



Source: IFA

Figure 4: Evolution of Potash Demand in Western Europe

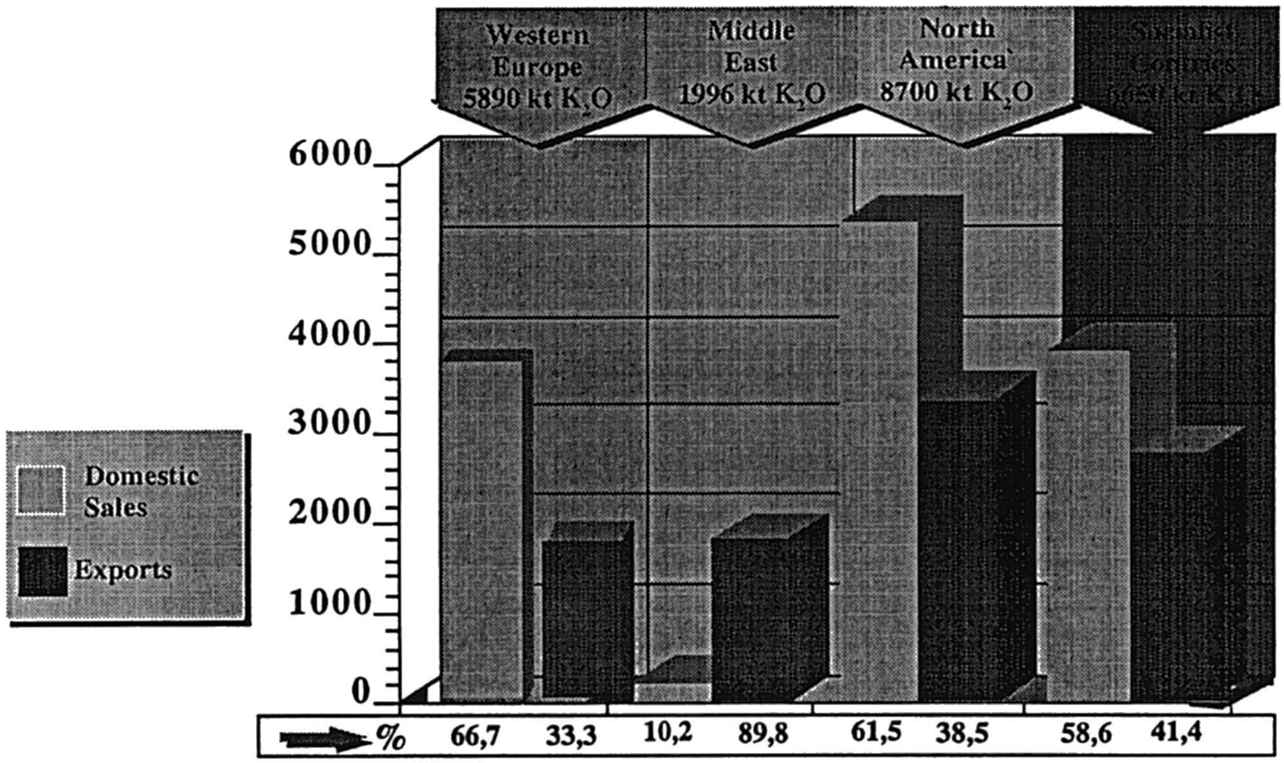


Figure 5: World Total Sales 1992

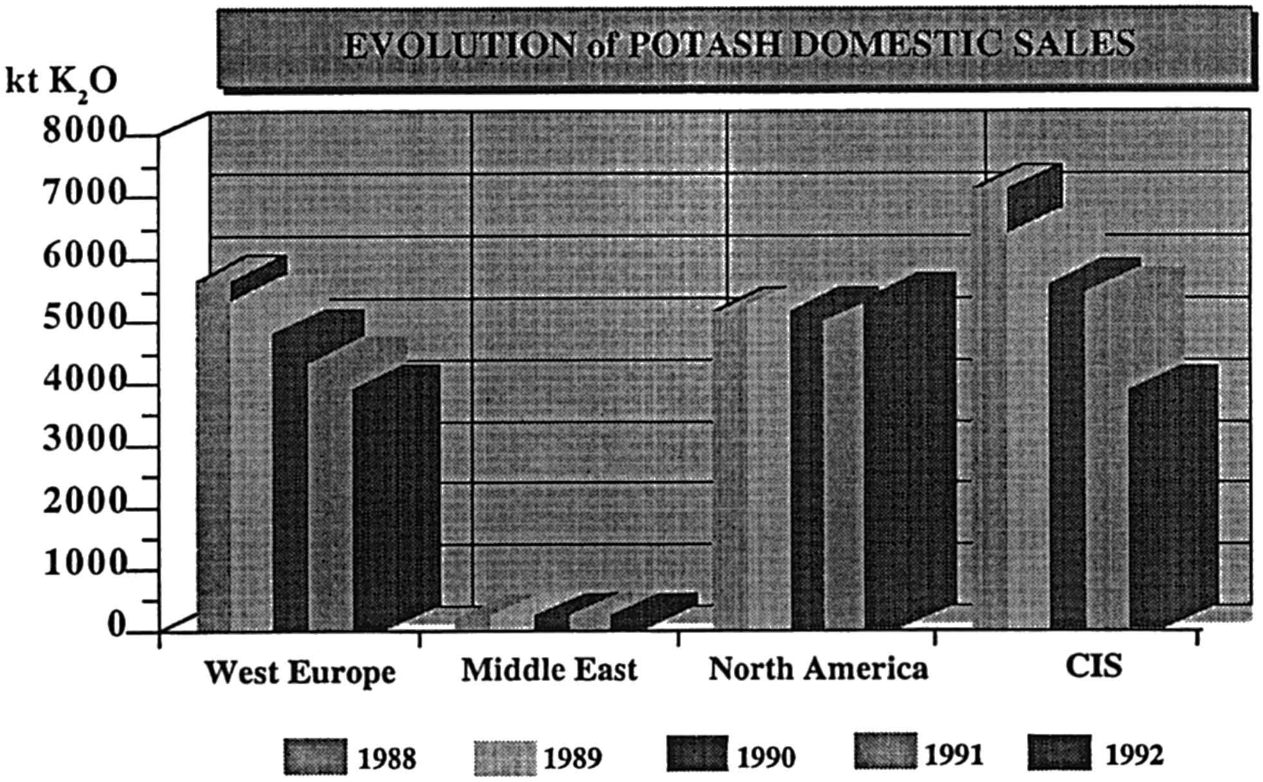
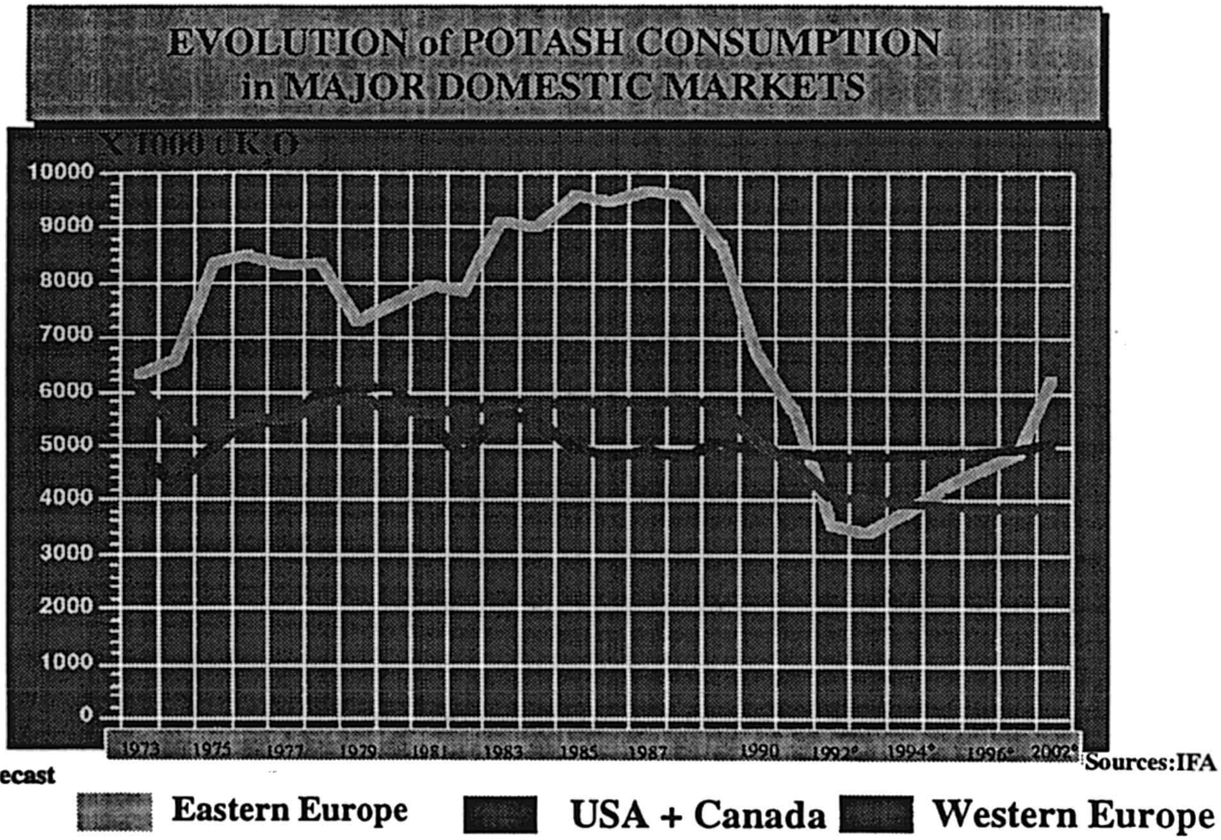


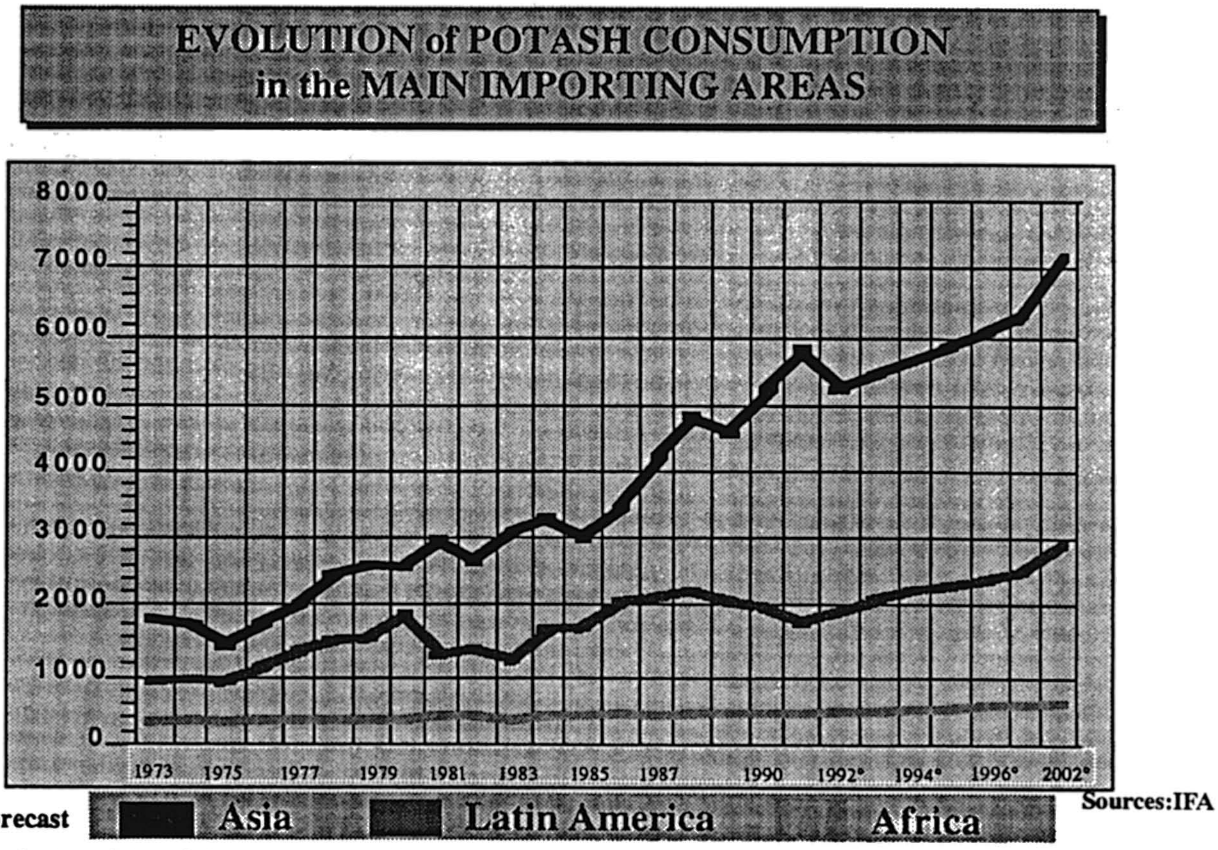
Figure 6: Evolution of Potash Domestic Sales



° Forecast

Sources:IFA

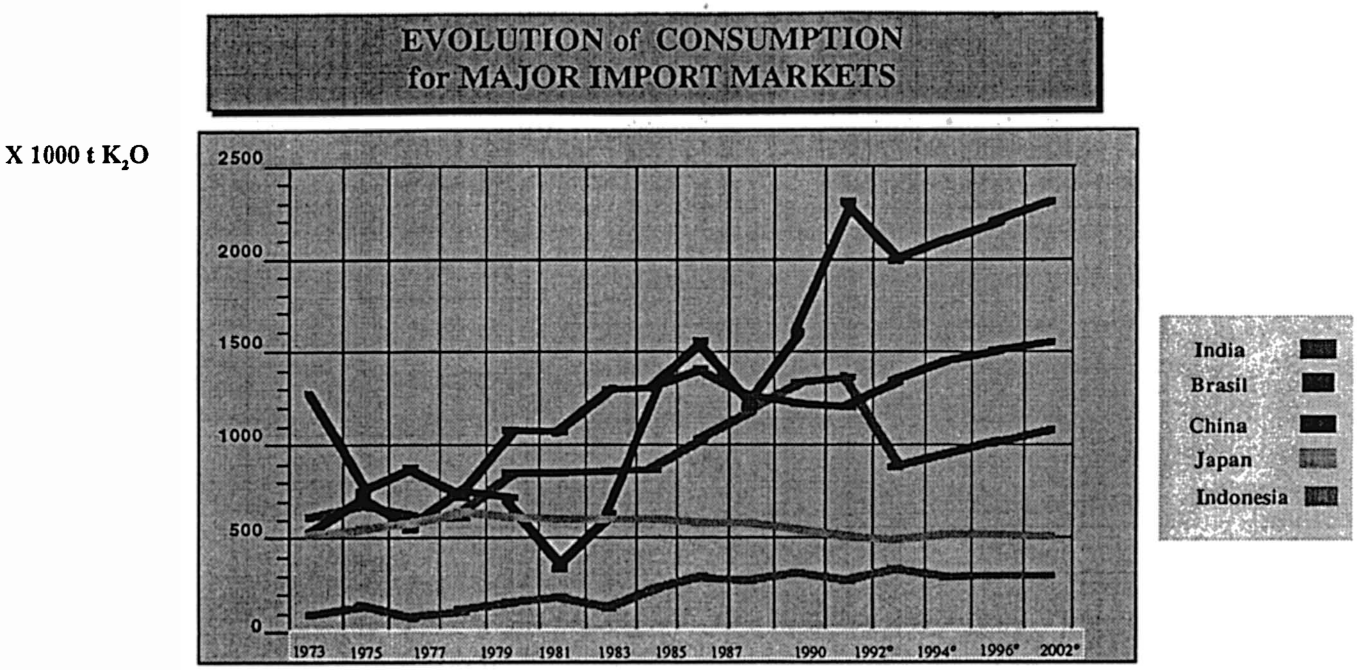
Figure 7: Evolution of Potash Consumption in Major Domestic Markets



° Forecast

Sources:IFA

Figure 8: Evolution of Potash Consumption in the Main Importing Areas

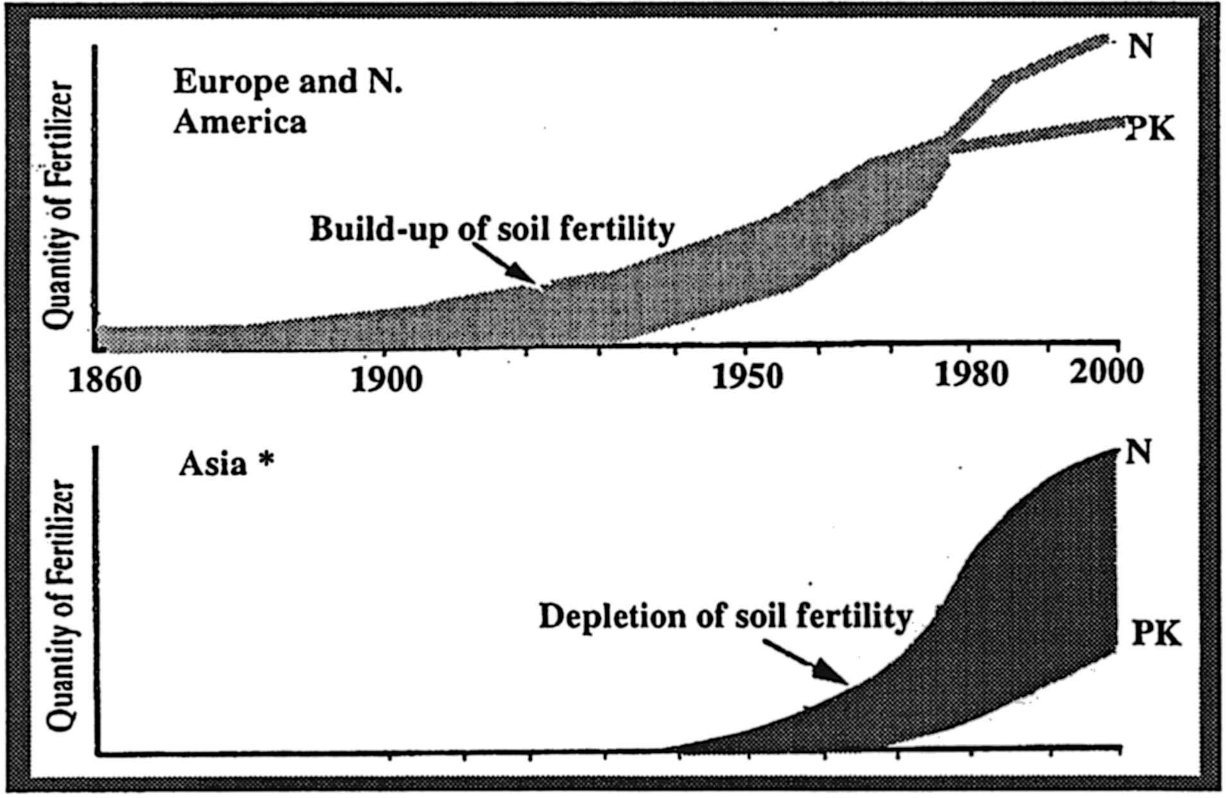


° Forecast

Source : IFA

Figure 9: Evolution of Consumption for Major Import Markets

Trends and time sequence in the use of N and PK in Europe and North America as compared to Asia (Von Uexkuell 1985)



* Asia minus Japan

Figure 10: Trends and Time Sequences

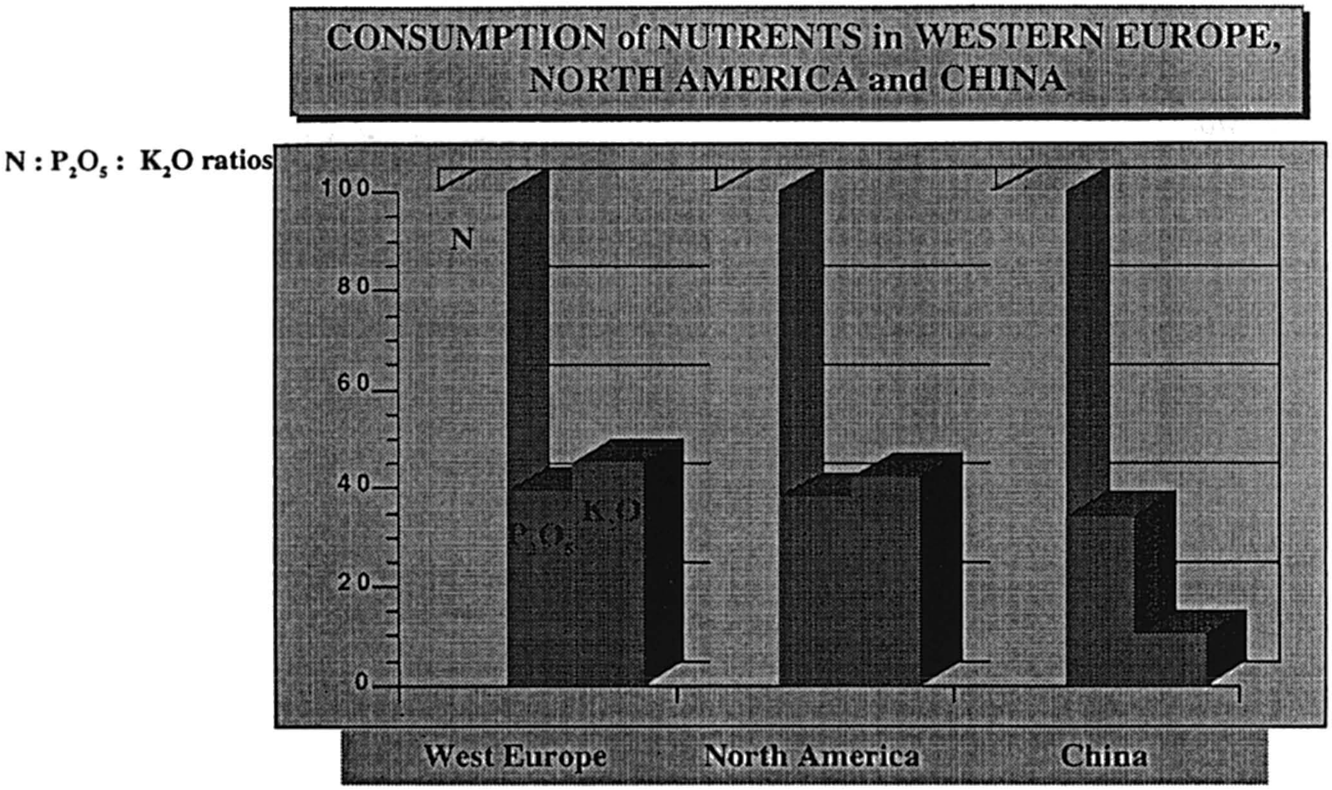


Figure 11: Consumption of Nutrients in Western Europe, North America and China

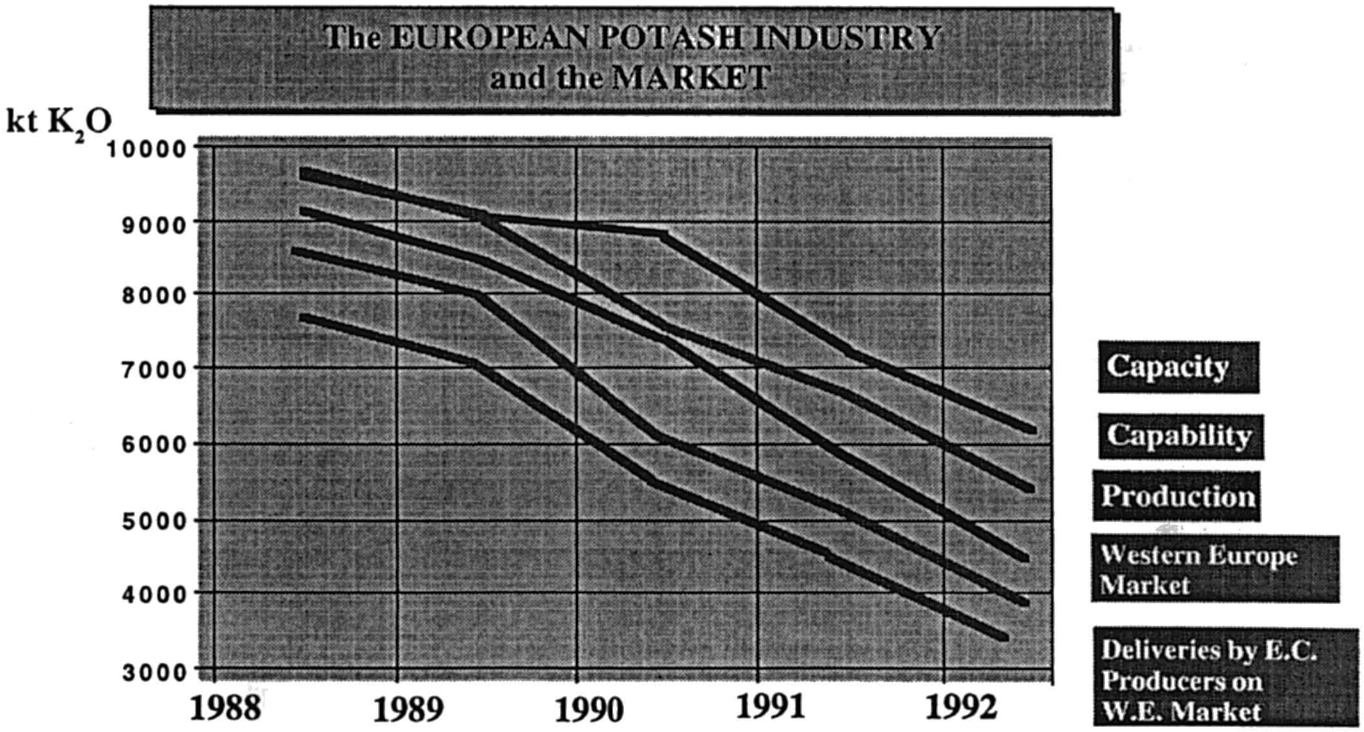


Figure 12: The European Potash Industry and the Market

The World Sulphur Situation – Trends in Production, Consumption, and Markets

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The Sulphur Institute

Introduction

The sulphur industry continues to be influenced by the effects of world political, economic, and environmental changes. Economic and political events in Eastern Europe and the Former Soviet Union (FSU), changing governmental structures and economical policies in India and China, increasing environmental legislation in North America and Western Europe, and other events, had a negative effect on the sulphur marketplace over the past year. This paper will present the world sulphur market scenario during the last year highlighting some of the major factors influencing the supply and demand of sulphur. Further, the sizable potential opportunity presented to the fertilizer industry by plant nutrient sulphur to diversify and expand current markets is discussed.

Sulphur Consumption

At the close of 1992, world sulphur consumption totalled 53.1 million tons, a 7% decline from 1991. The decline in 1992 marks the fourth consecutive year in which world consumption fell. The trend for sulphur consumption in the last 10 years indicated significant growth from 1982, when consumption was at its lowest 10-year level of 50.6 million tons, to 1988 when world consumption peaked at 60.4 million tons (Figure 1). Declining sulphur consumption from 1988 to 1991 was largely due to decreasing world phosphate fertilizer production and consumption. In 1992, that reduction was exacerbated by a global recession, continued political and economic restructuring in Eastern Europe and the FSU, and austerity measures taken in many developing countries such as India. These factors, in addition to increased environmental legislation affecting many sulphur industrial consumers, reduced both fertilizer and non-fertilizer sulphur consumption.

Of the sulphur market share for fertilizer, 90% is used for phosphate fertilizer manufacture. Thus, one cannot evaluate sulphur demand without addressing phosphate demand. Phosphate consumption declined for a third consecutive year to an estimated 37.3 million tons P_2O_5 in 1992. Total phosphate demand, which includes fertilizer, feed, and various other industrial uses, declined 7%, nearly 5.0 million tons since its peak in 1989, three years ago. Dramatic changes in phosphate usage in Western and Eastern Europe and in the FSU are responsible for most of this decline. While some decline in phosphate consumption was expected during the transition to a free market economy in the FSU, the magnitude of these changes was unprecedented. In 1992, sulphur consumption for the production of fertilizers declined about 1.8 million tons from the previous year to approximately 31.6 million tons (Figure 2). Substantially reduced fertilizer consumption in the FSU and Eastern Europe, combined with agricultural policy changes in India and China, and the privatization of the fertilizer sector in Brazil, Mexico, and Pakistan all contributed to reduced global fertilizer consumption. Prior to the 1992 decline, fertilizer consumption increased at an average annual rate of 1.3% since the early 1980s.

Non-fertilizer sulphur consumption declined about 2.1 million tons in the last year to 21.5 million tons. The market share for non-fertilizer sulphur consumption has been eroding slowly from 10 years ago, when its market share accounted for over 50% of all consumption. The very large reduction in non-fertilizer sulphur consumption in 1992 was a result of a multitude of factors, including a global recession and environmental restrictions. The greatest reductions in sulphur consumption occurred in the hydrofluoric acid, carbon disulphide, phosphate detergent, and titanium dioxide industries. As increasing environmental legislation restricting industrial sulphuric acid use is implemented, and sulphuric acid recycling becomes prominent, the share of non-fertilizer sulphur markets is expected to erode further.

When evaluated by region, during 1992 sulphur consumption in Eastern Europe and the FSU was 9.8 million tons, approximately 2.3 million tons lower than the previous year, accounting for 59% of the total consumption decline. This region experienced reduced sulphur consumption in all markets, with the greatest decrease in fertilizer consumption. In Western Europe, sulphur consumption decreased by over 1.6 million tons to

7.0 million tons. In this region, the change was greater for non-fertilizer sulphur consumption as a result of environmental mandates on many sulphur end-use industries, the recession, and increasing sulphuric acid regeneration and recycling. In Latin America, sulphur consumption dropped approximately 400,000 tons to total 3.2 million tons, primarily because of reduced sulphur consumption for fertilizer production in Brazil and Mexico.

In the remaining regions of the world, Asia, Africa, the Middle East, and Oceania, sulphur consumption either remained stable from the previous year, or experienced a modest increase. Issues involving government fertilizer policies in India and China had a negative impact on the region's level of sulphur consumption compared to the past; however, increased consumption in other countries in the region, resulted in overall sulphur consumption growth in Asia. The effects of the fertilizer policy changes that transpired during 1992 have continued to impact Asia's consumption during 1993. In India, several single superphosphate and diammonium phosphate producers may eventually shut down as a result of subsidy removal. The situation is still unclear and subject to changes as the government removes and reinstates subsidies trying to achieve the right balance.

The Sulphur Institute forecasts sulphur consumption will begin an upward trend during the next decade, increasing to 55.9 million tons by 1997 and 61.0 million tons by 2002 (Figure 3). During this period, phosphate fertilizer demand is expected to rise in Eastern Europe and the FSU. Sulphur consumption in Asia is expected to increase for both fertilizer and non-fertilizer consumption due to Asia's rapidly expanding industrial base and increasing agricultural demands. Sulphur consumption in North America may experience a slight decrease during the next few years, and then increase. Latin America's sulphur consumption is forecast to increase for both fertilizer and non-fertilizer use during the forecast period. Consumption in Western Europe is expected to decrease gradually for both fertilizers and non-fertilizers through the year 2002. The Middle East and Africa are forecast to increase their sulphur consumption significantly, primarily for fertilizers, while little change is expected in Oceania during the decade.

The current forecast may be influenced significantly by a number of factors, including the rate at which fertilizer demand increases in Eastern Europe and the FSU, the outcome of continued government policies relating to and affecting fertilizer growth in India and China, and the rate at which phosphate demand will grow. Even if only 25% of the potential market for plant nutrient sulphur is realized, the impact on world sulphur consumption would be dramatic.

Plant Nutrient Sulphur

Plant nutrient sulphur will be of growing worldwide importance as food production continues to increase while overall sulphur inputs tend to diminish. Increasing crop production, reduced sulphur dioxide emissions, and shifts in major fertilizer sources have led to worldwide increases of documented sulphur deficiencies. Despite the vital role of sulphur, most of the growth in fertilizer consumption has been essentially in sulphur-free nitrogen and phosphorus fertilizers, even though higher yields of crops per unit area are removing greater quantities of sulphur from the soil. Obviously, much of this sulphur must be replaced or sulphur deficiencies will severely limit agricultural production.

The need for plant nutrient sulphur and its application to soils are not new. During the fertilizer year 1990-1991, 10.1 million tons of sulphur were applied as fertilizer. This volume compares to about 20% of the total world sulphur consumption. What is new is the growing recognition that it has been given away as a"free nutrient," the increasing number of companies selling new sulphur fertilizers, and others selling traditional materials. Sulphur is the fourth largest plant nutrient consumed in the fertilizer business (Figure 4).

The bulk of the sulphur has been applied in multi-nutrient fertilizers, mostly as ammonium sulphate (24%S) and single superphosphate (12%S). During the fertilizer year 1990-1991, of the 10.1 million tons of sulphur fertilizers applied, 3 million tons were from ammonium sulphate and 4.1 million tons were from single superphosphate. Therefore, these two sources alone provided 70% of the sulphur in fertilizers applied worldwide. An additional 1.0 million tons of sulphur from ammonium sulphate is estimated to be included in compound fertilizers. Ammonium sulphate is an internationally traded commodity, with about 15 to 17 million tons (about 4 million tons sulphur equivalent) of product produced per year. The predominant source of this fertilizer is its production as a co-product of the sulphur-consuming nylon fabric business. Usually single superphosphate is consumed in the country where it is produced; however, in many areas of the world, its production is declining. Most phosphate fertilizer producers now produce ammoniated phosphates instead of single superphosphate, a switch that benefits the consumption of raw material sulphur and exacerbates sulphur deficiencies. During the past two decades, with increased popularity of high analysis materials such as urea, triple superphosphate and ammoniated phosphates, world agriculture has witnessed a dramatic reduction in sulphur additions as a percentage of the total fertilizer applied. This scenario is one of the major contributors to the increased market potential for sulphur fertilizers.

Crop production has been increasing at a rate of 3% per annum in developing countries and 0.9% per annum in developed countries according to statistics from the Food and Agriculture Organization of the United Nations. The growing production has put an increased demand on the soil to supply sulphur. In an increasing number of regions around the world, the soil's supply is no longer sufficient to support the expanding level of production; sulphur deficiencies need to be corrected with sulphur fertilizers. The Sulphur Institute has developed a model based upon historic crop production levels and growth trends to project the total sulphur requirement and total market for sulphur fertilizers through 2010. On a worldwide basis, sulphur fertilizer applications have shown little historic growth since these have been primarily a component of multi-nutrient fertilizers where the sulphur value was unrecognized. Without a change in this trend, sulphur fertilizer deficiencies and demand for sulphur fertilizers to correct the deficiencies will increase dramatically. The Sulphur Institute estimated that in 1990 the total deficit, which equates to the annual unrealized world market potential for plant nutrient sulphur, was 6.6 million tons. The annual plant nutrient sulphur deficit has been projected to reach 8.1 million tons by the turn of the century and 11.1 million tons by 2010. Asia will have an annual deficit of 5.5 million tons in 2000 and 7.3 million tons in 2010. China and India will be particularly important to the fertilizer industry because by 2010, China and India's annual plant nutrient sulphur deficit will be 2.9 and 1.8 million tons respectively. This figure could become higher if their single superphosphate production is replaced.

Worldwide increases in total crop production, changes in fertilizer preference, and rapid reductions in sulphur dioxide emissions from industry in developed economies have combined to increase attention to the sulphur fertilizer market potential. These factors combined to increase sulphur deficiencies, helping stimulate the commercialization of sulphur-containing fertilizers. In 1962, 29 countries reported sulphur deficiencies. Currently, 73 countries are reporting sulphur deficiencies. Farmers have observed that sulphur fertilizer can improve crop production effectively while the fertilizer industry has realized the potential profits to be made in sulphur fertilizers. Many manufacturers of ammonium sulphate have started marketing this product as a multi-nutrient fertilizer, rather than just a nitrogen fertilizer. This product promotion has led to increased demand for granular ammonium sulphate with prices reaching historically high levels in the United States during this spring's fertilizer season. Compared to last year's spring fertilizer season, granular ammonium sulphate FOB prices have increased by 10% in the Corn Belt, while urea prices have shown only a slight gain, and phosphate and potassium prices have declined. In Germany,retail prices of sulphur fertilizers are currently at DM0.40 per kilogram of sulphur, while in the United States, sulphur fertilizers are retailing at about US$0.45 per kilogram of sulphur. This translates into a metric ton sulphur equivalent of US$255 for Germany and US$440 for the United States.

The Opportunity for the Fertilizer Industry

As the market for sulphur fertilizers expands, sulphur producers are introducing new products to meet the diversified requirements. Many of these new technologies are elemental sulphur-based and will directly affect the total amount of sulphur consumed. Fertilizer technology experts in New Zealand have developed a process to add elemental sulphur during fertilizer manufacturing. This process avoids grinding elemental sulphur and facilitates the incorporation of elemental sulphur into fertilizers. Hi-Fert, an Australian firm, introduced a sulphur-coated triple superphosphate a few years ago that is available in two grades, Gold-Phos 10 (0-41-0-10S) and Gold-Phos 20 (0-36-0-20S). The company has expanded its product line to include sulphur-coated monoammonium phosphate and single superphosphate, sulphur-coated partially acidulated rock phosphate and single superphosphate, and sulphur-coated partially acidulated rock phosphate and triple superphosphate. Solterra Minerals Ltd. has introduced a newer elemental sulphur-based material. In the United States, Kerley Ag. Inc. developed potassium thiosulphate as a fertilizer product which is marketed under the trade name KTS. It is a clear liquid fertilizer containing 25% potassium and 17% sulphur which offers additional versatility to farmers and fertilizer retailers.

The European fertilizer industry is also responding with new products to capture a portion of this rapidly growing market. La Grande Paroisse in France and ICI in the United Kingdom have introduced new fertilizers. Sulphur-Gold, ICI's new product, contains 30% nitrogen and 19% sulphur and is particularly designed for oilseed rape and winter cereal cropping systems. Kemira and Norsk Hydro, two of the largest fertilizer companies in Europe, along with BASF and DSM have introduced and are marketing sulphur-containing fertilizers. Sulphur Ten (20-4-14-7S), developed for silage crops, has been marketed by Kemira for several years. More recently, Kemira Fertilisers in the United Kingdom, has released DoubleTop, a new granular product which contains 27% nitrogen as well as 12% sulphur and is specially formulated for oilseed rape and cereals.

Sulphur Production

In response to reduced world sulphur consumption in 1992, sulphur production also decreased significantly, dropping 4 million tons from the previous year to 53.7 million tons (Figure 5). In the last 10-year period, production had increased from 50.5 million tons during 1982 to 60.3 million tons by 1989, before entering its downward trend. Brimstone accounted for 34.9 million tons, or 65% of all sulphur produced. However, it decreased more than any other form of sulphur during 1992, declining 2.0 million tons from the previous year and 4.7 million tons from the decade's (1982 to 1992) highest brimstone production level of 39.6 million tons during 1989. The share of Frasch and native sulphur production has declined significantly during the last 10 years. In response to market conditions, Frasch and native sulphur production declined 3.4 million tons, or 31%, from the previous year, to 7.6 million tons. However, recovered brimstone continues to capture a larger portion of all sulphur production. Recovered sulphur production increased 1.3 million tons to total 27.3 million tons, representing 78% of world brimstone production, as compared to 60% during 1982.

In 1992, pyrites accounted for 8.3 million tons of sulphur, or 15% of all sulphur production. Pyrites production varied minimally from 1982 to 1991; however, in 1992, production dropped 1.6 million tons from the previous year. Production of sulphur in other forms totalled 10.5 million tons during 1992, accounting for nearly 20% of all sulphur production. Production of sulphur in other forms has increased at an average annual rate of 2.3% since 1982. This trend is expected to continue through the end of the century, as additional smelter acid production becomes available and environmental regulations areimposed upon industries.

Geographical shifts in total sulphur production are also noteworthy (Figure 6). In the last 10 years, production in North America has been on an upward trend, increasing from 16.0 million tons during 1982, to 17.3 million tons during 1987, and 18.2 million tons in 1992, as indicated primarily from increased recovery of sulphur from sour gas and crude. During the last 10 years, the largest production changes occurred in Eastern Europe and the FSU, where production increased from 15.4 million tons during 1982 to 16.8 million tons during 1987, but dropped to 11.7 million tons during 1992. This reduction in Eastern Europe and the FSU accounted for 68% of the total world decline; production declined approximately 2.7 million tons from 1991, to 11.7 million tons and has occurred primarily because of reduced Frasch and native production in Poland and the Ukraine. A further decline in production in Eastern Europe and the FSU is likely in the near term, as this region continues its economic and political reforms. Proportionally, the largest sulphur production increase has been in Asia, where it increased from 6.2 to 9.4 million tons during the 1982 to 1992 period. Most of the growth was in Chinese pyrites production, which accounted for 67% of overall growth, and in Japanese recovered sulphur and sulphur in other forms production, which accounted for 22% of Asian growth. Sulphur production in Western Europe averaged approximately 7.7 million tons throughout most of the last 10 years. However, during 1992, production declined to slightly over 6.9 million tons. In 1992, total sulphur production in the regions of Latin America, the Middle East, Africa, and Oceania was 7.5 million tons; the Middle East was the largest contributor. This level indicates increased production in the combined regions of 44% from 1982, when production totalled 5.2 million tons.

The Sulphur Institute forecasts that global sulphur production will increase to 62.3 million tons by 2002. The current forecast is based, in part, upon currently planned additional production capacity, which, if unrealized, will alter future production levels significantly. An overall increase in world sulphur production is expected as a result of increased recovered sulphur production in Canada, the Middle East, Western Europe, the FSU, and Asia, as well as increased pyrites production in China. Actual production within the forecast will be determined by a number of currently uncertain factors, including the level of future recovered production in the FSU at the Astrakhan and Tengiz fields. Continued political and economic uncertainties relating to the fields raise doubts to what extent recovered production from oil and gas will increase during the forecast period. Political instability in the Middle East could also prove to be a hinderance to the region's future production. Questions involving the feasibility of increased pyrites production in China and the FSU will be a determining factor within the production forecast as well. In fact, recent World Bank strategies reassessments indicate that all future funding for fertilizer projects in China will only be allocated for upgrading or replacing existing capacity. Since about two-thirds or more of the existing pyrites-based sulphuric acid capacity is considered to be inefficient, uneconomical, and environmentally unsound, this capacity will likely be replaced with sulphur burners. This means that of the 4.6 million tons of sulphur produced from pyrites, a significant portion could be replaced with brimstone. This does not include the increasing plant nutrient sulphur requirement for China, forecast to reach 2.1 million tons by 2000, or the future demand for sulphur-based phosphates. During the forecast period, overall Frasch and native sulphur production is expected to further decline due to reduced production in Poland, the United States, and Mexico. In fact, the Mexican Frasch industry is in liquidation, and Freeport has just announced the closing of Caminada.

Economic, political, and social factors, which have significantly affected both sulphur consumption and production during 1992, undoubtedly will continue to change future production, especially in the near future. It may be several years before the dynamic and dramatic nature of economic, political, and structural change stabilizes significantly.

Trade Patterns

International brimstone trade has remained crucial to balance global sulphur supply and demand. In 1992, over 40% of all brimstone produced was traded on the world market. However, the impact of unforeseen events affecting international sulphur trade in recent years has resulted in reduced brimstone trade since 1990. In 1992, brimstone exports declined 1.2 million tons from the previous year to approximately 14.3 million tons, primarily due to decreased imports by the FSU, Eastern Europe, and Western Europe. Western European imports were reduced primarily due to lower domestic fertilizer production and environmental pressure to reduce sulphur consumption for industrial uses in Western Europe. Historically, Poland had exported approximately 1.0 million tons to the FSU until the FSU's collapse, but by 1992 Poland's exports declined to 230,000 tons. Overall, brimstone exports from Poland declined, from a consistent level of approximately 3.8 million tons throughout the last decade, to 2.5 million tons in 1992. To help offset some of the reduced exports to the FSU, Poland increased its exports to Africa and Latin America during 1992.

Although its exports declined from the previous year, in 1992, with a 39% share of brimstone exports, Canada was the world's leading brimstone exporter. Canada's brimstone exports declined approximately 700,000 tons from 1991 to 1992, amounting to 5.6 million tons. Some of Canada's decreased exports to India, Africa, and Mexico were offset by increased exports to the United States, Latin America, and Oceania. Through the 1990s, Canada is expected to dominate the brimstone export market. Saudi Arabia, followed by Poland, are likely to remain significant exporters; whereas, North Africa and Asia are expected to be the largest brimstone importers.

Brimstone Inventories

World brimstone inventories have increased slightly for two consecutive years, thus ending a downward trend beginning in 1977 (Figure 7). From 1977 to 1990, brimstone inventories declined from 27.2 million tons to 9.9 million tons. Since 1990, brimstone inventories increased only 800,000 tons, or only one and half percent of the total market, to 10.7 million tons. World brimstone inventories have been crucial in meeting world brimstone demand. Prior to 1991, annual brimstone production alone did not meet world brimstone demand requirements, and drawing on stocks for market requirements nearly exhausted world brimstone inventories.

The world's largest brimstone inventories are in Canada, where at the end of 1992, inventories were estimated at 3.2 million tons. Although Canada's inventories have increased during the last year, they are significantly less than 10 years ago, when inventories totalled 15.6 million tons. Canada's increased brimstone inventories during 1992 reflect the Canadian producers' decision to hold back brimstone tonnage from the market. Brimstone inventories in France, the Middle East, and Poland remained stable from the previous year. Given the current sulphur demand and production forecasts, world brimstone inventories are likely to increase in the near term, especially in Canada.

Conclusions

The current consumption and production forecasts to 2002 might suggest that the supply and demand balance will be in a surplus situation through 2002. However, the individual supply and demand forecasts should be evaluated separately. Market forecasts are based largely upon current trends, which, especially today, are in a rapid state of flux. Given the examples of recent years' supply and demand balances, market forces have come to bear repeatedly, ebbing significant oversupply. In fact, within the last 10 years, only four years experienced a minor oversupply, while two were in a balance, and four were in a deficit situation with a significant reduction in world inventories.

Given the structural changes that have occurred within the decade and that are still taking place, the global trade balance has shifted causing the loss of traditional markets such as eastern Europe and the FSU. This has forced many producers to change strategies and develop new markets impacting the overall market situation. After the dramatic political and economic changes that occurred worldwide in the recent past, we are now in a new world where ongoing political and economic changes have altered traditional markets and shifted trade balances forever. The Chinese market remains critical. Environmental and economic developments in this immense market could result in the opening of a significant sulphur market which will expand substantially if local sulphur production from pyrites is reduced.

In spite of worldwide market uncertainties, the fertilizer industry must recognize the fact that plant nutrient sulphur provides one bright spot in the sulphur demand scenario, and should act accordingly to seize the opportunity presented by this new market. While the potential for plant nutrient sulphur is not included in any of the brimstone consumption forecasts contained in this paper, this potential market is growing. The future appears favorable for the consumption of sulphur-containing fertilizers. By 2010, there will be an estimated global unrealized market potential equal to 11.1 million tons of sulphur per year. Effective research advancements, product development, marketing, and promotion will determine what portion of this relatively new market will be translated into worldwide consumption.

Figure 1

World Sulphur Consumption

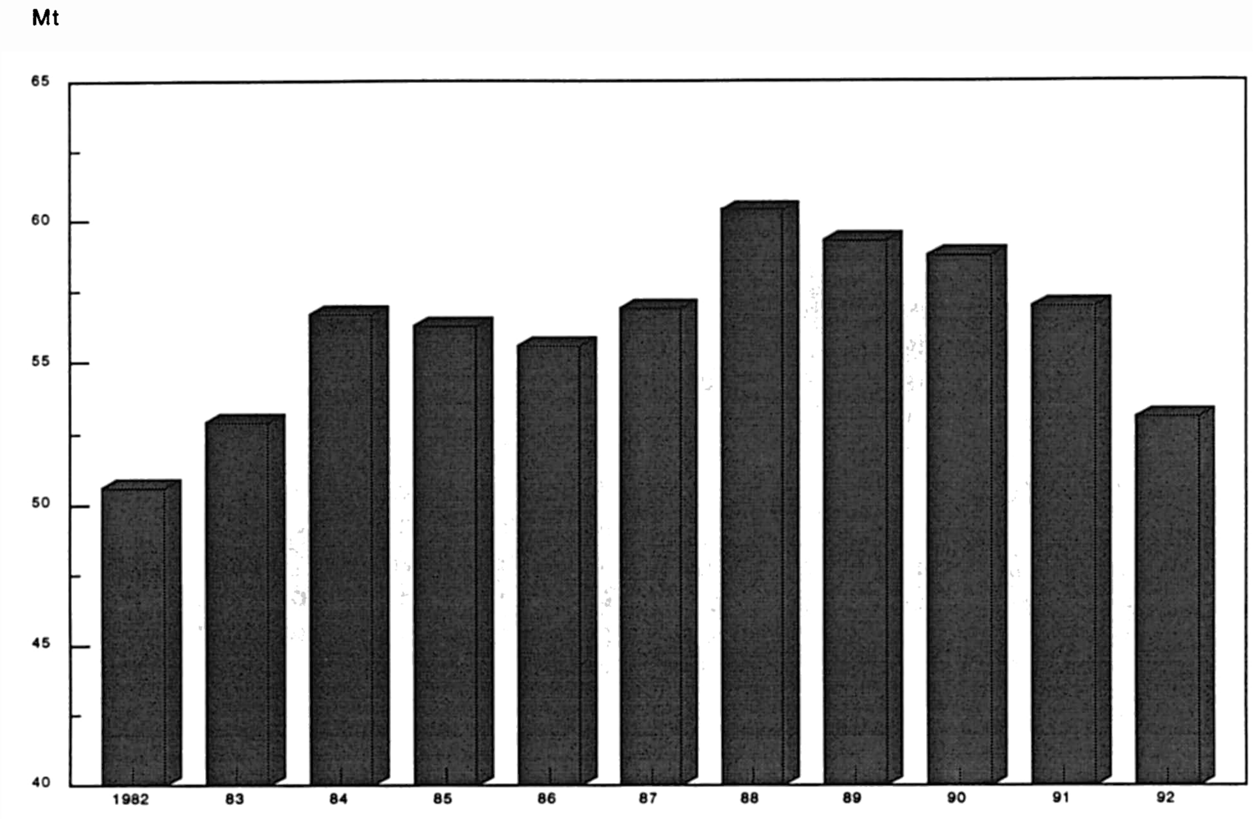


Figure 2

World Sulphur Consumption by End Use

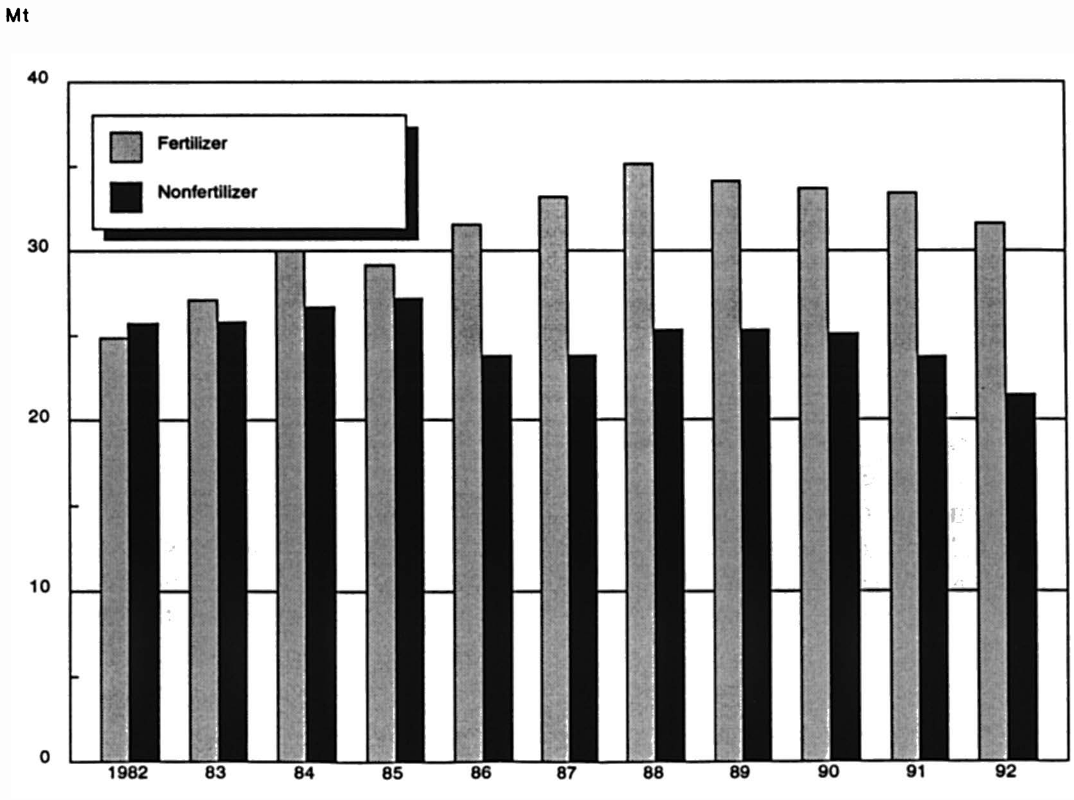


Figure 3

World Sulphur Consumption Forecast

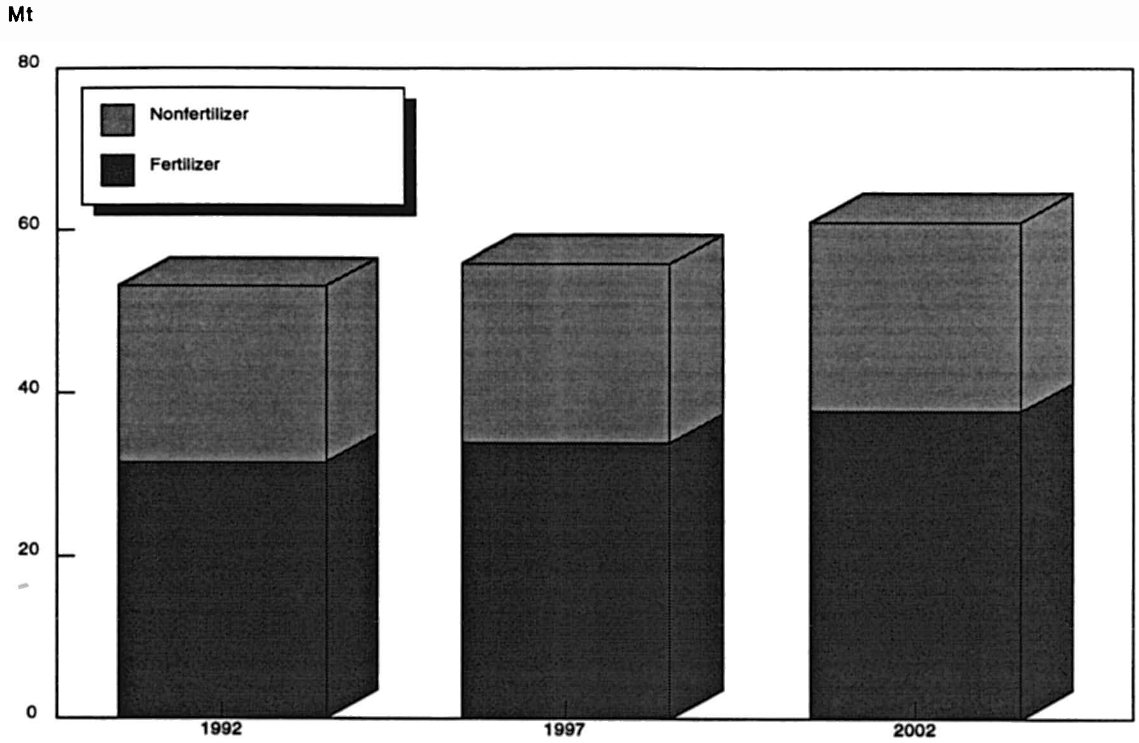
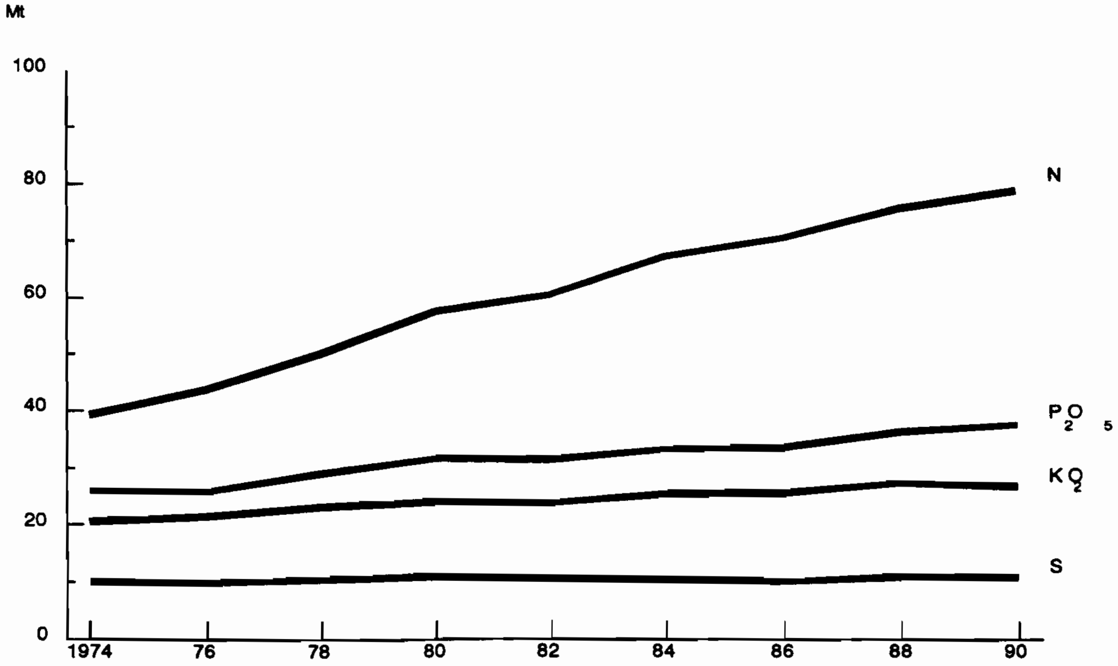


Figure 4

World Fertilizer Consumption



Source: IFA and TSI

Figure 5

World Sulphur Production

by Type

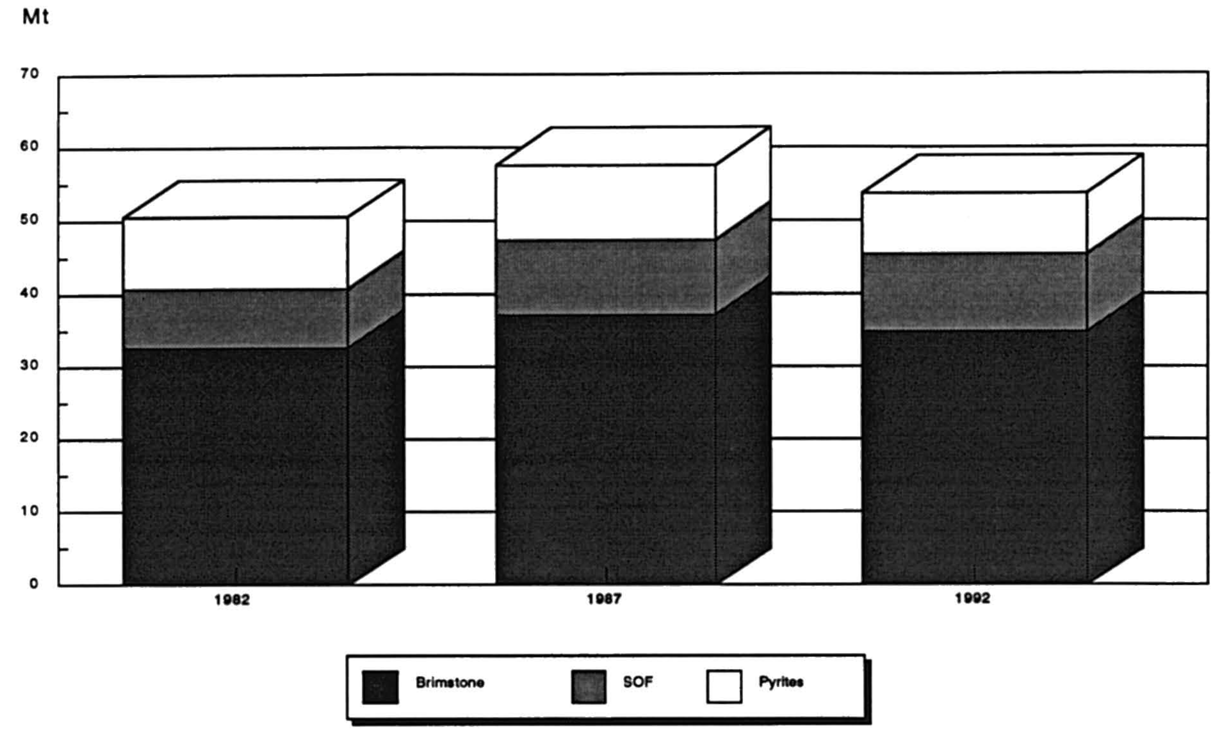


Figure 6

Sulphur Production by Region

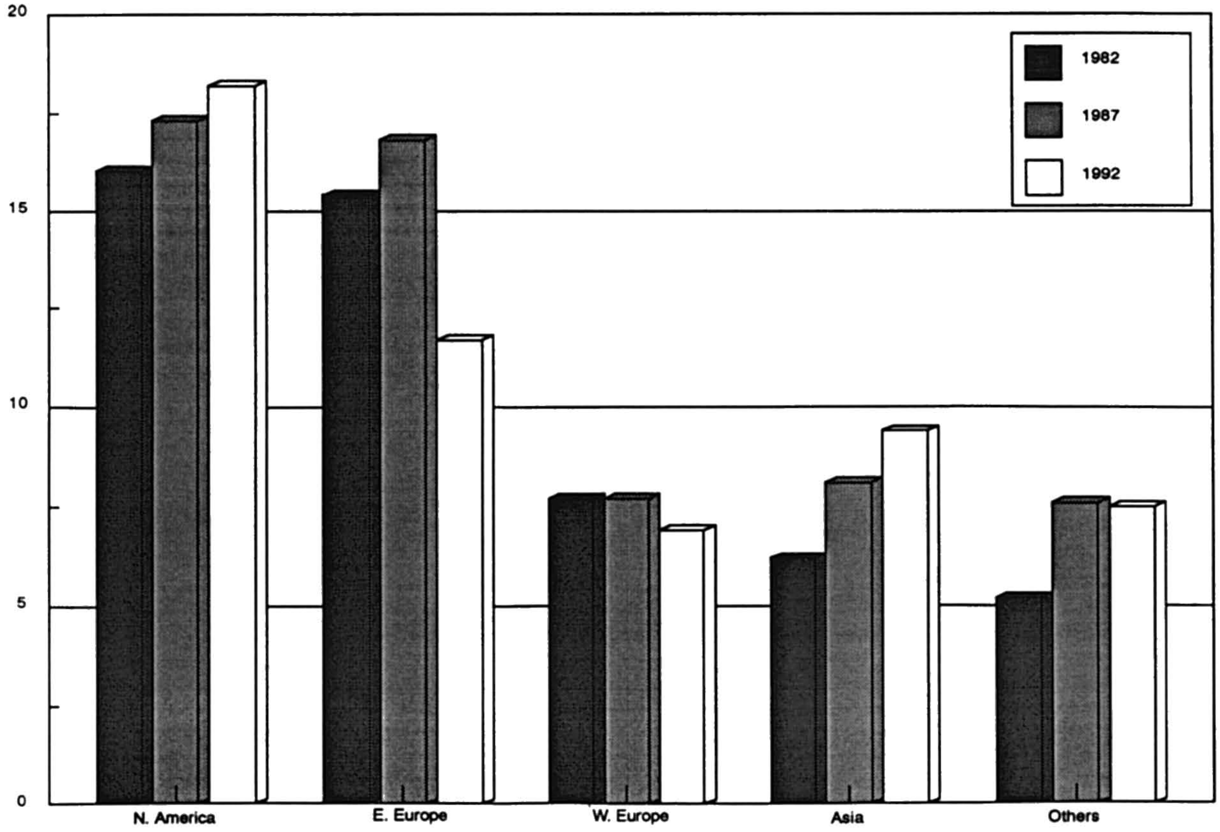
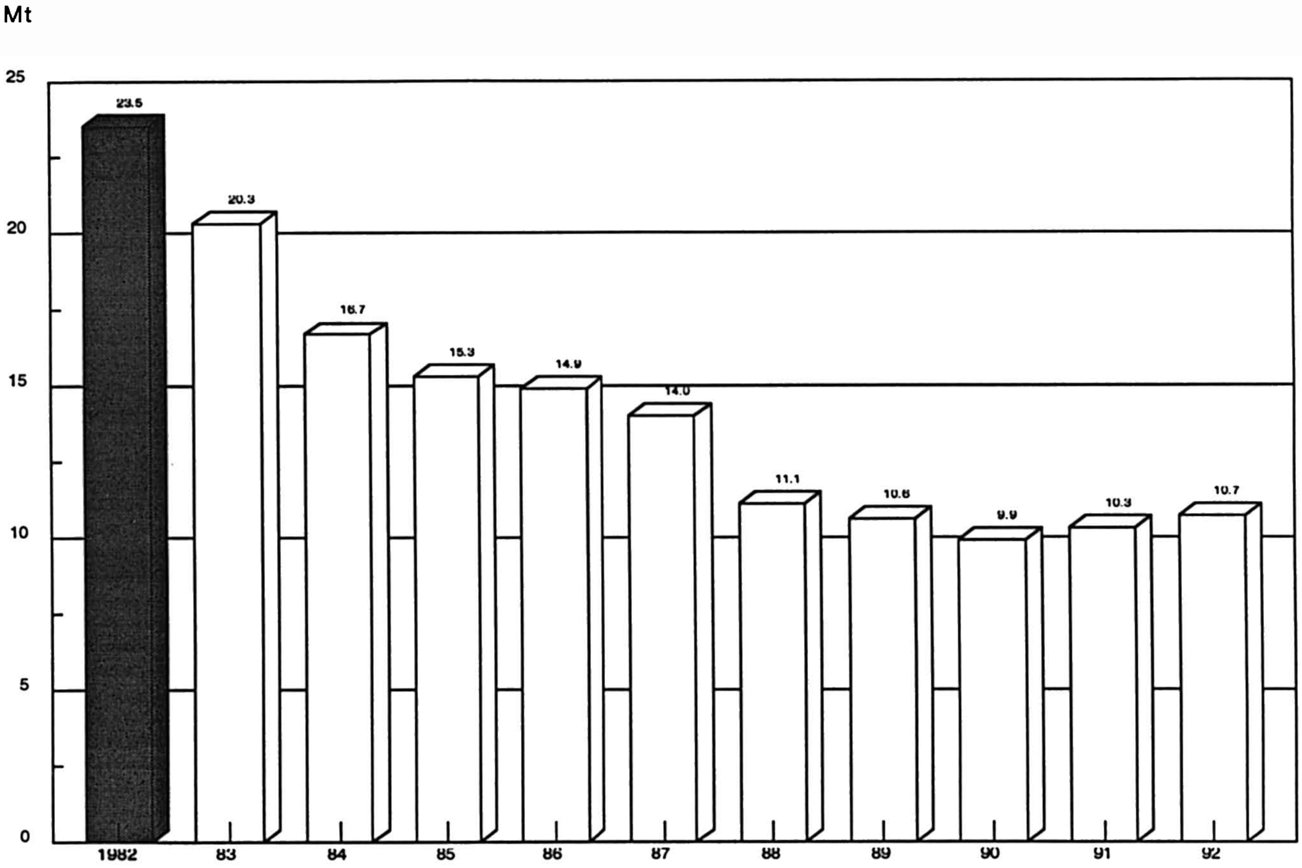


Figure 7 World Sulphur Inventories



Monday, October 25, 1993

Session II
Moderator:
Richard D. Harrell

Restructuring of the Mexican Fertilizer Industry

Fausto L. Montoya
ADIFAL
Presented by Adolfo Sisto

History and Restructuring Phase

It might be said that in Mexico, the fertilizer industry began a little over 50 years ago with the production of ammonium sulphate from the coke ovens in the Northern zone of the country, as well as superphosphates based on the acidulation of phosphate rock with sulphuric acid. Bone meal phosphate fertilizers were also produced and the guanos deposited in the Pacific Islands began to be collected so that they could be used in our domestic agriculture. This early stage of development was initiated by private enterprise in 1943 called GUANOMEX. Since then, the production infrastructure that had begun putting out low concentration products started to produce higher nutrient content fertilizer until it included in its product line 7 major products used in the last decades.

The industry was a mixed one ((private and public), it turned fully governmental in 1978 when the State finished buying all the private plants, undertaking the unified administration of the sector through an enterprise called Fertilizantes Mexicanos, S.A. (Fertimex).

With the main objective of motivating all farmers to use fertilizers, thus driving national agricultural production upward, the government subsidized the price of these important inputs during the 70's and 80's.

The results attained until 1990 under these development conditions were:

- A seven fold increase in the fertilizers production installed capacity as compared to 1965; reaching a total of 5.8 millions of tons per year.
- Fertilization levels increased greatly. There was 7 times more fertilized surface, covering 64% of the harvested soils, in comparison with only 16% in 1965.

However, although the policy of subsidized fertilizer prices (which were uniform in more than 3,000 locations in the country) actually contributed to the forementioned results, it also brought on the distortion of natural market forces and free competition as logical consequence, and led to great operational and financial problems, making it necessary for FERTIMEX to resort to costly distribution systems. This increased the need for subsidies for the Federal Government, which during 1987-1992 were for an average of 728 billion pesos per year (Annex 1).

In 1989, following the guidelines of the current National Development Plan, FERTIMEX began a structural change and resizing strategy with the objective of transforming the industry into a profitable, competitive and unsubsidized one:

- The marketing system was reorganized. Fertimex withdrew from the secondary and tertiary distribution systems, preserving only the primary network with 200 strategically located centers throughout the country.
- Subsidies were gradually withdrawn beginning with fertilizer prices applicable only to cash sales in the primary network. Products were also sold directly at the production plants at prices based on international market reference prices.
- All production units began to be sold to private industry, beginning with those not of priority importance.

Current Situation

In 1992 the government sector ended the privatization phase of the fertilizer industry with the sale of the Lazaro Cardenas facility located on the Pacific Coast in the community bearing that same name.

The final settlement and dissolution of FERTIMEX was authorized through a decree in the Official Gazette on February 26, 1993. Production facilities were all sold to Mexican businessmen so that, together with two other private plants already in operation, there are now 12 private companies in charge of producing fertilizers in Mexico (Annex 2). All of them competing in an unregulated and open market where the factors of efficiency, diversification and competitiveness are certainly decisive in determining their position within this complex market which is still undergoing a stabilization process.

Although it is true that some of the new companies inherited certain deficiencies that the State was unable to correct, it is also true that they acquired an industrial infrastructure that is modern and efficient and offers several advantages for competing in the new Mexican economic environment.

Production Infrastructure

At present, the installed capacity in Mexico is 5.89 millions of tons of fertilizers per year; of this, 28% is urea, 29% ammonium sulphate, 22% DAP/NKP, 10% triple superphosphate, 6% ammonium nitrate and 5% single superphosphate. There is no production of potash fertilizers, all those consumed in the country being imported. Almost 60% of the total installed capacity is of relatively recent creations with ages of plants ranging between 6 and 12 years. Such is the case, for example, of the Cardenas, whose plants were started up in 1986 and 1987; and the urea plants located in Pajaritos, Veracruz, that began operations in 1982 and 1984, just to mention some (Annex 3).

As for the rest of the plants, many of those built in the 60's or more recently have been subject to revampings or modifications before or after the privitization process, with the objective of restoring losses of efficiency as a result of the many years of operations but also to comply with the environmental regulations imposed by the Government.

Distributors also have certain capacity to produce bulk blendings. As to liquid fertilizers, there are also some distributors and farmers' associations that can make them, mainly in the more technified agricultural areas. However, their importance is relatively small when compared to solid fertilizers. The main liquids are aquammonia and some phosphate suspensions. In these more highly technified areas, anhydrous ammonia is applied in gaseous form in considerable amounts (around 300,000 t/y), although the country's production capacity is much greater and is mainly used to produce nitrogen bearing fertilizers and for exports purposes.

With regard to new fertilizer projects, there is a plant for the production of UAN solutions with capacity of 600,000 t/y on the Gulf of Mexico Coast which is scheduled to start production by mid 1994. In the mid 80's, two urea production plants had to discontinue construction due to financial problems, one on the Pacific Coast and another in the Northern part of the country and their status has not changed. As is well known, world markets have not been favorable for new projects and Mexico has not been the exception. Its situation was made worse by the privatization in which it was involved and whose effects are still being felt. There are also projects for new liquid fertilizer production capacity to be built in the Central part of Mexico by the end of this year as well as for putting more bulk blending units into operation.

Production

From 1985 to 1991, the production of fertilizers was more than 4 million tons per year. In 1989, a record figure of 5 million tons was reached, which meant almost 2 million tons of $N+P_2O_5+K_2O$ (Annex 4). However in 1992, the year in which the main fertilizers producing units in the country were sold, several plants shut production down temporarily, or reduced their rate of production, due to different reasons. They were:

- The logical time period required for the new management to inspect the newly purchased facilities and for their operations planning process.

- Operating problems in the plants when they were purchased and which took some time to solve.
- High inventory levels found when plants were privatized.
- Momentary demotivations of domestic production, due to low prices in the international fertilizer market, which at times made it more advisable to import.

All of the above and other factors, resulted in less than 3.3 million tons production last year, a figure 23.5% lower than that of 1991, which had already dropped 6.7% below the amount produced in 1990 (Annex 5).

Imports And Exports

As a result of the imports reduction and exports increase policy implemented at the beginning of this Administration, imports of fertilizers dropped from 597,000 tons in 1986 to practically half that figure in 1988. By 1991 only 95,000 tons were imported, almost all of them potash fertilizers. On the other hand, exports grew 116,000 tons in 1986 to 808,000 tons in 1991 (Annex 6). By 1992 both trends reverted as a result of the aforementioned effects of privatization and the lower prices in international markets. The change in the trend of imports was more marked. They found their way into Mexico through a number of trading companies who found an echo to their offerings in the country, inspite of the 10% import tariffs that fertilizers are subject to in Mexico. In 1992, 380,000 tons were imported, a 300% increase compared to the previous year (Annex 7). The shortage of financial support in Mexico for fertilizer purchases and the fact that several international suppliers offered more lenient purchases and the fact that several international suppliers offered more lenient payment terms for their imported products, also contributed to the growth in imports. Exports, comprised mainly of urea and DAP, fell 22% in 1992, principally due to less availability of DAP for that purpose. Urea exports remained almost constant.

Domestic Sales

National consumption based on sales, was about 4.6 million tons of products (1.75 million tons of $N+P_20_5+K_20$) from 1984 to 1987. After this period, there were a series of annual drops until 1990 with 4.2 million tons (Annex 8). In 1991 there was a 3.1% increase to 4.35 million tons. While in 1992, it dropped again, this time a 7.8% with an amount of slightly over 4 million tons. From the standpoint of nutrients, the decrease was not so marked (-2.5%) as there was an increase in consumption of highly concentrated products such as urea, potassium chloride and NPK's compounds. Also contributing to this increase was the fact that, although in small amounts, MAP imports began to come in, a product that had been used in negligable amounts prior to privatization (Annex 9).

Raw Materials

The raw materials that the Mexican Fertilizer Industry is dependent upon are totally local for nitrogen, 70% imported and 30% national for phosphates and 100% imported for potash (Annex 10).

It is important to remember that in Mexico, different from practically all the rest of the world, urea and ammonia plants are not part of the same industrial complex nor are they managed by the same company. This situation whose economic and logistic disadvantages were worsened when PEMEX (the state-owned ammonia producing company), reorganized its operations and divided them into four descentralized organizations that had technical, marketing and industrial functions as well as their own separate legal standing and separate financing and equity. As a result, the production of natural gas and that of ammonia was done in different subsidiaries (Annex 11) so that the raw material prices were impacted by the need to ship them from one subsidiary to another. In the end, this affected the ammonia supply to fertilizer plants, a problem worsened by the fact that since PEMEX began selling it at international prices based on those prevailing at Tampa. This had a negative effect on nitrogen fertilizer plants profitability. Currently, industry representatives are discussing with PEMEX possible agreements that may benefit both sectors.

Phosphate rock production capacity is centered mainly in the State of Baja California Sur, specifically at ROFOMEX mines. This was an enterprise bought as part of a package by the same group that bought the Lazaro Cardenas complex. Production capacity is enough to cover 30% of the national demand for rock, estimated to be around 2 million tons per year. The enterprise has currently reduced operations and is in the process of making mining operations more efficient as well as increasing phosphate fertilizer plant capacity so that this rock can be used, since in the past they had used imported rock mainly.

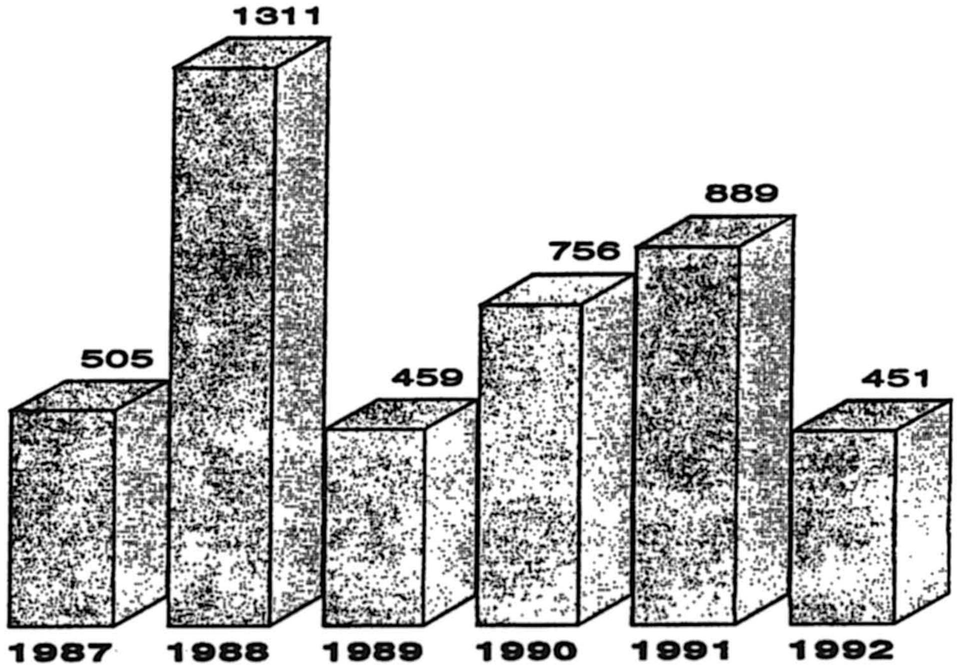
Since APSA and CEDI closed down operations, there is no sulphur production from mines, only the recovered sulphur which is in the hands of PEMEX which, since March of this year, has also the exclusive rights to market that raw material, both in the national and international markets.

Outlook

The opening of the Mexican market to International trade is fully under way and the fertilizer sector can not escape the trend. We estimate that during the first semester of 1993 higher quantities have been imported than for the whole year 1992, this was favoured by the official decision issued on the first quarter of this year to eliminate import duties on a number of products, among which are included: ammonium nitrate, NPK's compounds and potash (some of them even produced locally). As regards domestic production it is estimated that the enterprises involved in it will begin (or will continue) to implement strategies that will allow them to strengthen their competitive position in the very difficult market they now face. Some have already developed diversification plans for their activities which have thus far been only in production. They plan to explore other areas, such as importing and/or forming distribution networks that will enable them to deliver fertilizers as directly as possible to farmers. Other have, or are developing new products to offer to Mexican Agriculture based on its needs and special characteristics.

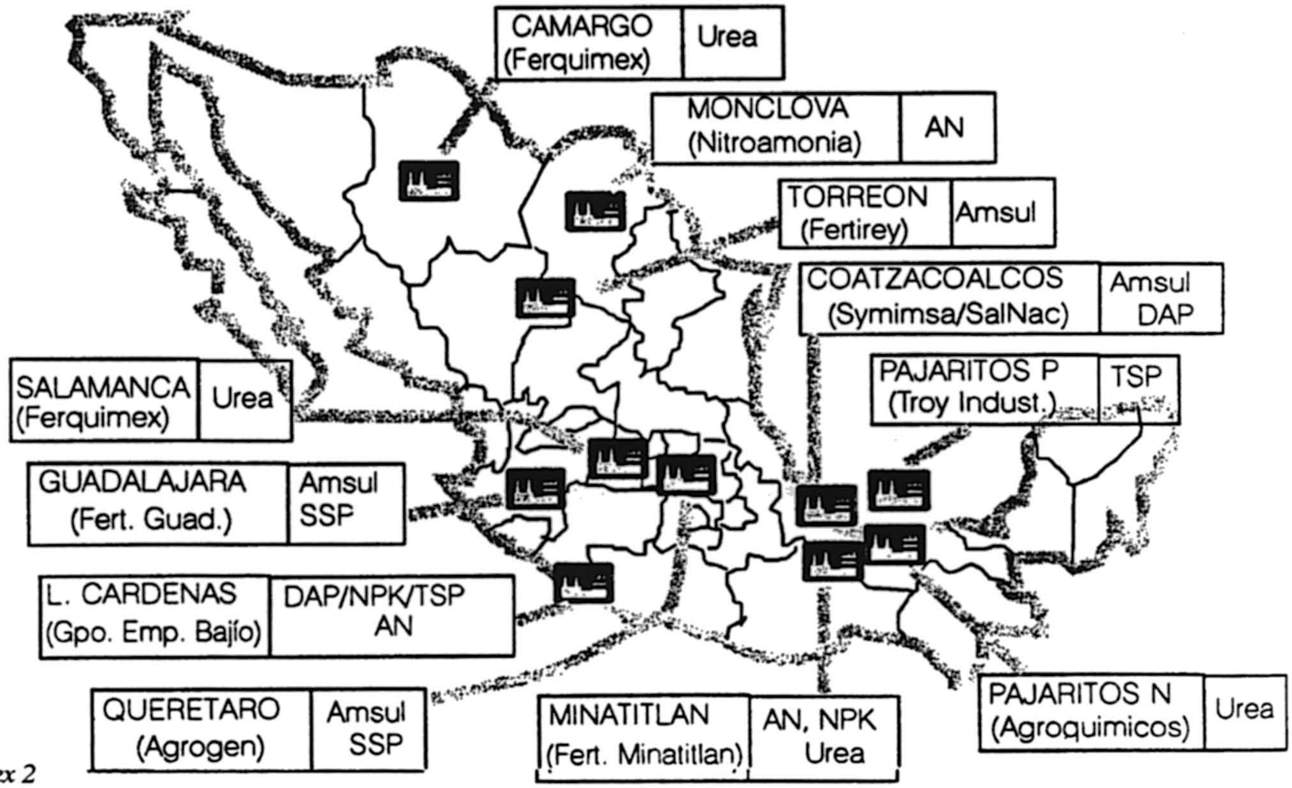
At the beginning of October a program called "PROCAMPO" was officially announced. It consists of giving, starting in 1994, 12,000 million N$ as direct support to the farmers in the form of subsidies to the growers of basic crops and in financing to solve problems of indebtedness. In light of this scheme, it is felt that in the coming two agricultural seasons the real capacity of Mexican farmers will be assessed, both for purchasing locally manufactured products and imported ones. Of course, this will be also dependent upon the competitiveness of the local industry and conditions prevailing in the always influential world markets.

SUBSIDIES TO THE MEXICAN FERTILIZER INDUSTRY
(billions peso)



Annex 1

FERTILIZER PLANTS IN MEXICO



Annex 2

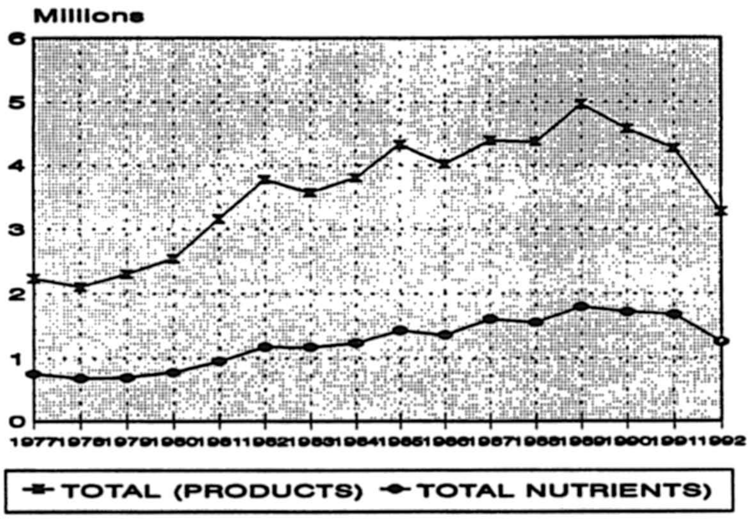
MEXICO: FERTILIZER PLANTS OF RECENT CREATION

PLANTS (NO.)	LOCATION	TOTAL CAPACITY ('000 T/Y)	START UP	PROCESS
Urea (2)	Pajaritos, Ver.	990	1982-1984	Snamprogetti
Urea (1)	Salamanca, Gto.	330	1980	Stamicarbon
Ammonium Sulphate	Queretaro, Qro.	594	1978-1981	Chemico
DAP/NPK/TSP	Lazaro Cardenas, Mich.	1320	1986-1987	Gulf Badger
Ammonium Nitrate	Lazaro Cardenas, Mich.	200	1987	Stamicarbon

Annex 3

MEXICO: FERTILIZER PRODUCTION TREND

(metric tons)



Annex 4

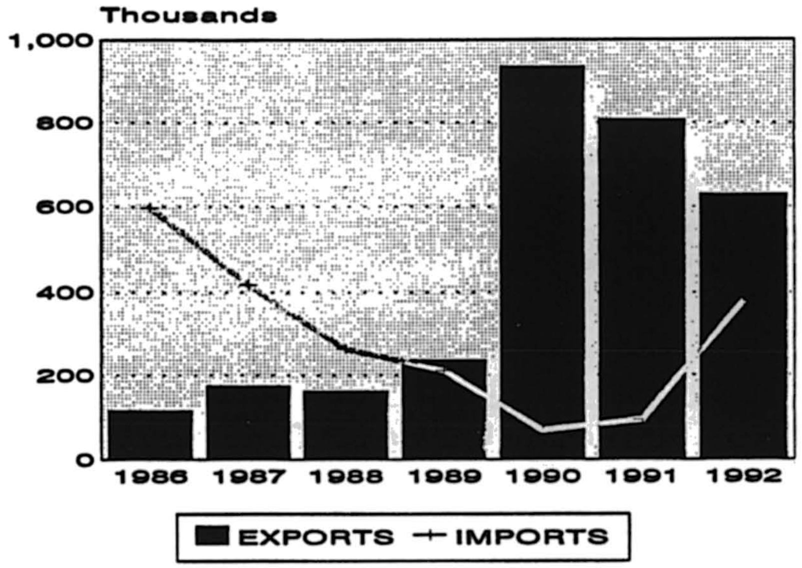
MEXICO: PRODUCTION OF FERTILIZERS

('000 METRIC TONS)

	YEARS			CHANGE (%)	CHANGE (%)
	1990	1991	1992	91/90	92/91
(PRODUCT)	4,586	4,277	3,271	-6.7	-23.5
(NUTRIENTS)	1,721	1,680	1,258	-2.35	-25.1

Annex 5

MEXICO: FERTILIZER IMPORTS/EXPORTS TREND
(METRIC TONS)



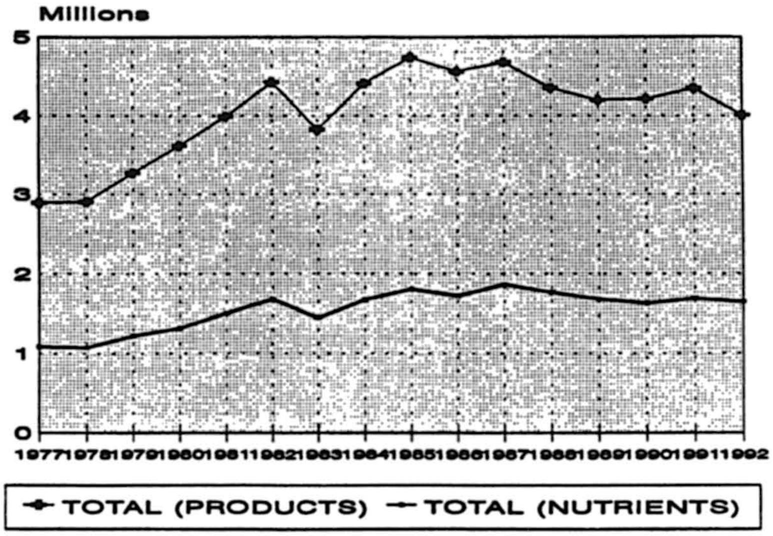
Annex 6

MEXICO: IMPORTS AND EXPORTS OF FERTILIZERS
('000 METRIC TONS)

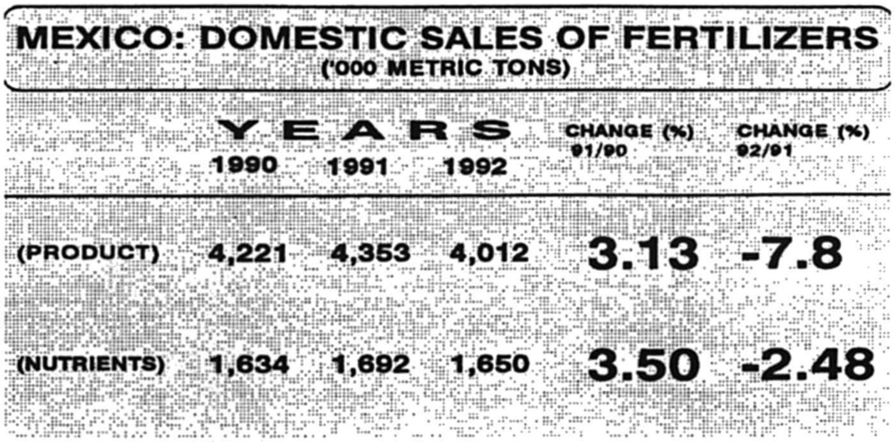
	YEARS			CHANGE (%)	CHANGE (%)
	1990	1991	1992	91/90	92/91
IMPORTS	70	95	380	35.7	300
EXPORTS	936	808	629	-13.7	-22.2

Annex 7

MEXICO: FERTILIZER SALES TREND
(metric tons)



Annex 8



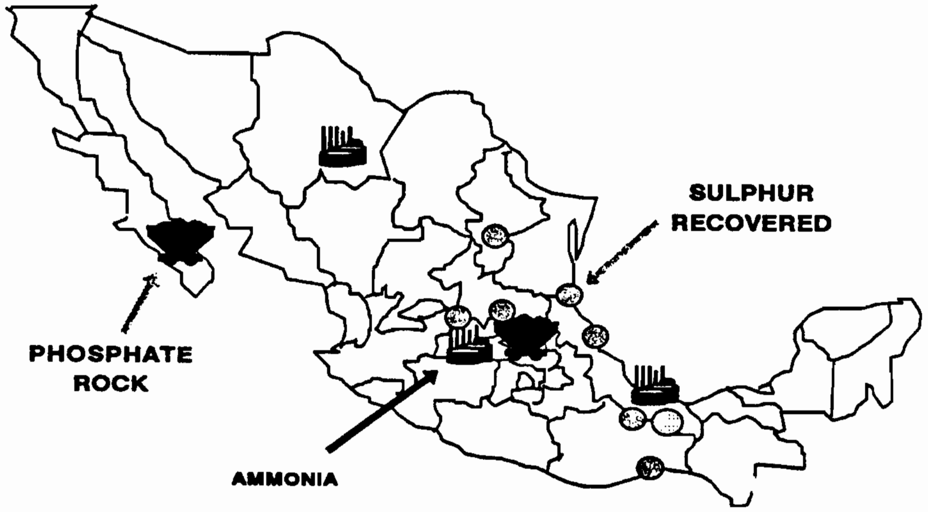
MEXICO: DOMESTIC SALES OF FERTILIZERS

('000 METRIC TONS)

	YEARS 1990	1991	1992	CHANGE (%) 91/90	CHANGE (%) 92/91
(PRODUCT)	4,221	4,353	4,012	3.13	-7.8
(NUTRIENTS)	1,634	1,692	1,650	3.50	-2.48

Annex 9

MEXICO: LOCATION OF RAW MATERIALS FOR FERTILIZERS



Annex 10

NATURAL GAS
(production, transport, warehousing and commercialization)

SULPHUR
(production)

NATURAL GAS
(processing and commercialization)

SULPHUR
(production and commercialization)

AMMONIA
(production and domestic commercialization)

AMMONIA
(exports)

Annex 11

Carnit Process For Ammonium Nitrate

J. Brandt
Kemira, Finland

Summary

The KEMIRA Camit process for production of concentrated ammonium nitrate solutions combines high thermal efficiency, low maintenance cost and optimal environment compatibility.

The reaction of ammonia and nitric acid occurs in a pressurized recycle loop which is kept slightly ammoniacal and where no process vapor is produced.

The reaction heat is distributed to the various exchangers of the recycle loop by ammoniacal solution circulation. The free ammonia in the production off-take is neutralized before pressure reduction

Efficient pH control achieves a liquid effluent with less than 50 ppm equivalent ammonium nitrate.

A specific feature of the Carnit process is the energy saving and self-regulating autothermal preconcentration step. No external heat supply is required and clean 6 bar steam is available for export.

The process can be optimized either by producing maximum export steam, or using dilute feed acid in order to decrease the investment cost of the nitric acid unit. The Tertre 2 100 t/day (100% AN) unit was put on stream in December 1990. Up till the first scheduled maintenance shutdown of July 1992, production of 97.5 wt% solution has been continuous with an on-stream time efficiency of 98.7%.

The Camit ammonium nitrate production process is available for licensing through Kemira S.A., B.P. 6, 7333 Tertre (Belgium).

Introduction

As in most industries, the evolution of the process technology for synthesis of ammonium nitrate, AN, has only recently been influenced by the need to minimize the environmental impact and avoid the risk of contamination of water supplies by release of ammonium nitrate in liquid effluents.

The main trend of technical improvements has, so far, been a gradual increase of the thermal efficiency together with the production of more concentrated solutions. The many variations about the ways in which the pressure and temperature of the various stages of the AN synthesis and concentration can be combined, have led to the emergence of an essentially conventional or typical process diagram.

The typical process diagram is based on the combination in a single unit operation, of the acid/ammonia reaction section with an evaporative heat removal and a corresponding solution concentration.

Depending on the various design approaches, either a single vessel with internal recirculation is used for the neutralization and the evaporation or both operations take place in separate vessels which are associated in a single external loop with forced or natural solution recirculation (Fig. A1).

In such a design, any free ammonia, which might be present in the solution at the evaporation stage, would be entrained by the process vapor. The process is, therefore, operated in an acidic condition.

Initially, the main concern has been the risk of corrosion. More recently, the safety risks which are associated with high temperature acidic conditions are being realized.

◆For stable acidic operation, the pH should, in practice, be maintained below pH =2, and preferably around pH = 1.5. This leaves only a narrow operating margin.

Due to the particular shape of the pH curve (fig 5), fluctuations around the baseline of pH = 2, extend easily beyond the pH inflection point, with resulting high ammonia losses.

With a baseline of pH = 1.5, poor pH electrode performance and an increased AN decomposition risk are met.

At low pH values, the response time of pH electrodes slows significantly as time constants in excess of 50 seconds appear at pH values below pH = 1.5 (3).

In order to overcome the unreliability of the pH electrode below pH = 1.5, frequent chemical analysis of the solution, in some processes up to one sample every three minutes, has been used.

◆ The risk of ammonium nitrate decomposition, at the prevailing temperatures of approx. 180° C, increases markedly below pH = 1.5. Continuous monitoring of the N20 content of the process vapor has been used to detect the onset of a potentially dangerous situation.

In addition to these risks, and the difficult corrosion problems which are associated with a hot acidic AN solution, a major drawback of such processes is the production of process condensate effluents which contain more ammonium nitrate than can be tolerated from existing or expected environmental regulations.

One way to overcome this difficulty has been to recycle as much as possible of the ammonium nitrate load of the process condensate to the nitric acid production. One obvious limitation of this approach is that the amount of process condensate which can be recycled is only part of the total process condensate production. In addition, the AN solution unit can not be kept on stream whenever the nitric acid unit is shutdown.

The CARNIT process (1) for production of concentrated ammonium nitrate solutions has been developed, at TERTRE (Belgium), in order to combine a minimal or even negligible impact on the environment with a high thermal efficiency and mild operating conditions. There are no gaseous effluents and the process condensate liquid effluent has such a low nitrogen content that it can be made to match the drinking water quality requirements.

The Carnit process uses the standard feed stocks, i.e. liquid or gaseous ammonia and aqueous nitric acid. The neutralization reaction and the concentration of the resultant AN product solution occur in two well-separated operation stages.

The neutralization occurs in a pressurized recycle reaction loop, which operates under a pressure always higher than the vapor pressure of the solution. There is, therefore, no production of process vapor in the reaction loop and no change of concentration of the reaction product.

The heat of reaction is stored as sensible heat, under form of an increase of temperature of the recycle solution. The temperature control of the loop is achieved by heat exchange in the final solution concentration exchanger and the steam export steam kettle.

The concentration of the solution occurs stepwise.

The first step is a combined flash and primary concentration stage of the hot solution off-take from the reaction loop.

The final concentration step derives its heat supply by heat exchange from the hot solution circulation of the recycle reaction loop. A solution concentration of 97.5 %wt is obtained at the outlet of the final concentrator.

No extenal heat supply is required and clean 6 bar export is produced, even when producing 98. + wt% solution with 60% wt nitric acid.

1. Process Description

1.1 Carnit Flowsheet

Fig 1 shows the basic Camit flow sheet.

The Preheated gaseous ammonia and aqueous nitric acid are fed to the main tubular reactor RI, where they are injected in a circulating flow of ammonium nitrate (AN) solution. The concentration of the resulting AN solution is directly related to the concentration of nitric acid feed.

The heat liberated by the exothermic neutralization reaction induces a temperature increase of the solution, which is related to the recycle ratio. The maximum temperature at exit of the reaction zone is set in the range of 180-190° C. The hot recirculating AN solution flows through steam kettle K and final falling film exchanger F2, where the solution of 97.5 wt% is produced.

In order to minimize corrosion problems, the circulation loop is operated with a slightly ammoniacal solution. The ratio of reactants is adjusted so as to maintain a controlled amount of free ammonia in the circulating solution.

The free ammonia in the production off-take is neutralized in the post-neutralization reactor R2 by a small nitric acid injection. Net production off-take is removed from the loop by means of the pressure reducing valve A.

The first concentration step occurs upon pressure reduction through valve A by flash vaporization in separator S1.
The first flash separator is fitted with a high-efficiency scrubber after which the vapors flow to the falling film type primary concentrator F1.

After a second pressure reduction through valve B, further concentration is achieved in the primary concentrator F1, where condensation of the flashed vapor from S1 supplies the evaporation heat.

The solution from the primary concentrator F1 is pumped from the primary concentration seal tank to the final falling film type concentrator F2, which is heated by the circulating solution of the reaction loop. In F2, the solution is concentrated to 97.5 wt%.
The vapors which are released at a pressure of approx. 0.4 bar, pass through the high-efficiency scrubber S3, after which they are used for superheating the gaseous ammonia feed and preheating the nitric acid feed to approx. 67°C.

The low pressure vapors, which are released from the primary concentrator F1, at a pressure of approx. 0.2 bar, are used for the vaporization of the liquid ammonia feed.
Any vapor in excess is condensed in the steam surplus condensers.

1.2 Neutralization section

The exothermic heat of reaction of aqueous nitric acid and gaseous ammonia, varies slightly with the concentration of nitric acid.
In the range of acid concentration from 50 wt% to 65 wt%, the enthalpy release varies, for a reference temperature of 65°C for both reactants and products, from 1.28 Gi/t AN to 1.39 GJ/t AN (curve 1 of fig 2).

Part of this heat release is used to heat the reaction product to the reactor exit temperature of 185°C.
The remainder is stored in the recirculating solution and distributed to the various heat exchangers of the loop. Curve 2 'heat supply in reaction loop' of Fig 2, shows that it increases as the concentration of nitric acid increases.

The steam production (curve 3, fig 2) in kettle K will increase as the heat duty of F2 decreases.

The temperature range of the loop circulation is defined by the inlet and outlet temperature of reactor R1. This temperature range, which reflects the heat release rate, i.e. production capacity, will depend on the recycle ratio.

The concentration of the reaction product and of the recirculating solution depends on the concentration of the nitric acid feed.

The operating pressure of the loop must be adjusted in relation to the concentration of the solution, i.e. the nitric acid concentration. With more dilute acid, the loop solution will also be more diluted and its vapor pressure will increase. Fig 3 shows the operating pressure for acid concentrations between 50 wt% and 65 wt%.

1.3 Concentration section

The first step of the concentration procedure is a specific feature of Carnit process. It occurs when the solution off-take is flashed in separation vessel S1 and concentrated in falling film exchanger F1, with the heat supplied by the flashed vapors from S1.

The combination of the adiabatic flash in S1 with a falling film evaporator F1 acts as a double-effect forward feed system.
In such a double-effect system the pressure setting on the solution side of F1 is the only operating variable.

Fig 4 shows a typical temperature vs concentration profile of the AN solution flow. The temperature of the solution, and thus of the tube wall, is determined by the pressure chosen for

point C. The amount of steam, which can be condensed on a given transfer area, will depend on the tube wall temperature. There is therefore, a constant equilibrium between the heat which is transferred in Fl and the vapor which is produced in S1.
The evaporation pressure in F1 controls the solution concentration and temperature which will be reached at point D.
This system is entirely self-regulating.

The heat recovery and concentration effect are increased as the evaporation pressure is reduced. If the operating pressure is decreased to point C^1, the temperature of the solution and of the tube wall decrease.
The lower tube wall temperature induces a decrease of pressure in S1, with point B moving to B^1, and this increases the quantity of flashed vapor. The isobaric concentration path C-D moves to C^1-D^1.
By decreasing the operating pressure in F1, i.e. the pressure at point C, the final solution composition, point D, is brought gradually closer to the crystallization curve, with the corresponding risk of freezing the solution.

A reasonable safety margin, which is mainly related to the uncertainty and inaccuracy of instrumental data, must be taken into account when selecting the operating pressure of point C.

Up to this stage of the flow-sheet no use has been made for solution concentration purposes of the heat which is stored in the recycle solution of the reaction loop.

The solution from Fl, point D, which has reached a concentration of the order of 83 wt. %, is collected in intermediate storage Vl. From there it is pumped to falling film exchanger F2, which is heated by the hot solution of the recycle loop.

On fig 4, the path D-E corresponds to the temperature rise of the solution up to its boiling temperature at the operating pressure of F2. Path E-F shows the isobaric evaporation process that leads to the desired concentration of 97.5 wt%.

As in the case of point D, the distance between point F and the crystallization curve indicates the safety margin relative to the salting-out risk.

These safety margins are important for the reliability of plant operation. They also have an effect on the thermal efficiency limit of the process.

2. Process Control

The production rate is set by the NH_3, feed stream, with an ammonia/nitric acid ratio control which adjusts the nitric acid supply.
The fine tuning of the acid feed input is attributed to a pH controller, which monitors the pH of the solution at the outlet of the reactor.

The enthadpy release and water supply into the system vary, whenever the concentration of acid or the production capacity change.
The steam kettle allows to balance the loads of heat brought into or extracted by the circulation loop. It recovers the heat produced in the reactor, which has not been used by the process itself.

A specific feature of the Carnit process is the close control of pH in the circulation loop, where a free ammonia content is maintained in the range of 400 to 800 ppm wt. In the offtake, the free ammonia is neutralized with nitric acid in a post-neutralization trim reactor R2 to an acidic pH.

Successful control of pH in a narrow range combines the problems of accurate material balance control of the reactants with the difficulties related to pH measurement.

The pH is signal is not linear. In the steep region B-A of the S shaped titration curve, fig 5, a large change of pH corresponds to such a small change of reactant concentration, that the controller gain must be set low enough in order to ensure stability around the inflection point.

In the flat range of the curve, B1-BE or A1-AE, a small change of pH corresponds to a large charge of reactant concentration, and a controller with low gain becomes inefficient. A further difficulty of a pH based control system results from the pH electrode characteristics.

The loop pH control has, therefore, to cope with the difficulties resulting from the sensitivity, rangeability, non linearity and time delay of the pH measurement. pH is a concept which has no additive properties and which by itself can not lead to a pH conservation balance. It is, therefore essential to know the titration curve of the solution under both the chosen operating and measurement conditions in order to relate a change of the measured pH to a corresponding change of solution composition.

The study (2) of the dynamic response of pH control in a Camit recycle loop has shown the importance, not only of achieving the shortest possible delay between action on the acid valve and recording of the results of the regulating action, but also of using the correct pH/concentration relation for regulation. Accurate valve responses to the pH signal are, of course, required for an efficient pH control of the recycle solution.

Adequate loop stability and efficient pH control requires accurate valve response to the temperature signals which determine the by-pass flows in the loop and trim acid supply to the reactor. Precise valve positioning is, therefore, of paramount importance.

3. Instrumentation and Safety

The instrumentation is designed so that safe plant operation will, at all times, be achieved without any supervision. If a parameter appears to move in a direction which can lead to a major deviation of the unit, a potential trip situation is indicated.

All the primary parameters which may lead to a trip situation are monitored, which means that tripping the unit does not have to be postponed until the danger situation has been reached. Any important parameter deviation starts an alarm before the actual trip occurs. If the reason for the possible trip is known immediately, the operator can react rapidly and maintain the unit on stream.

The integrated process control can be organized so that set-point adjustments which may be required, such as in case of a change in operating capacity, are done automatically by the DCS system.

In normal operation, the only parameter which must be adjusted by the operator, is the ammonia flow set-point which sets the production capacity.

The most obvious risk in any AN unit relates to the high temperature and high concentration solutions, where overheating may induce acidic conditions and lead to a run-away situation. This risk pattern increases markedly when the solution contains free nitric acid.

In the Carnit system, the highest temperature that can be reached is that of the low concentration recycle solution, in which a controlled amount of free ammonia is maintained at all times.

Heat release in the reactor is dependent on the neutralization reaction, which occurs between balanced amounts of reactants. When an instrument failure leads to an increased supply of one of the reactants, there is no increase of heat release, but rather a cooling effect.

An abnormal temperature rise could only occur in case of a continued balanced feed supply and total or partial failure of the recirculation. A trip shut-off is based on the recycle flow measurement. in such a case of reduced recycle flow, the amount of solution, which could be overheated even in case of a flow measurement failure, is limited to the small amount which has flowed through the reactor before reaching the temperature probes which control the temperature trip system.

In case of a sudden equipment failure in the hot circulation loop, which would lead to the emergence of a free jet of solution, depressurisation of the loop would activate the shut-down procedure.
As regards the depressurised solution in the jet, it can be seen from Fig 4, that adiabatic flashing (along line A-C) to atmospheric pressure, will produce cold solution with concentration of approx. 73 wt%. The risk of producing dry, low-density detonation prone AN is thus nonexistent.

4. Energy Economy

The principle of energy conservation in the Camit process is to avoid, as much as is economically justified, every unnecessary degradation of available heat of reaction.

By making the fullest possible use of latent heat in the offtake product stream, the maximum possible amount of heat is retained in the hot circulation loop, where it is available for high temperature duties.

The high temperature heat supply is used exclusively for high temperature duties such as final concentration of the solution and production of clean export steam.

The use of the low pressure process vapors, at 0.2 and 0.4 bar, for preheat of the reactants, contributes to the overall energy recovery, and reduces the amount of heat which must be removed through the cooler-condensers.

With the Camit process scheme the energy saving effect of the first concentration step increases as the acid concentration decreases. The production of 97.5 wt% solution thus remains possible, even with dilute nitric acid of 55 wt% concentration.

5. Effluent Control

There is no gaseous effluent, with the exception of the continuous purge of the very small amount of non-condensibles in the feed reactants and of the occasional small air leaks into the reduced pressure zones.
All process output streams, i.e. concentrated AN solution and condensed process water vapor, are in liquid form.

Process vapor is produced either in falling film evaporators, where entrainment of liquid in the vapor phase is minimal, or by flashing upon pressure reduction. The liquid droplet content of flashed vapor is drastically reduced by adequate scrubbing.

At every stage of the Carnit process where vapor is reused as heating medium, the controlling temperature for ammonium nitrate contamination of the vapor is maintained below 100°C.

The total nitrogen content of the process condensate does not exceed 14 ppm wt. Control of the condensate pH is achieved by adjusting the operating conditions of the high-efficiency scrubbers.

6. Process Economics in Relation With Nitric Acid Production

Typical material balance and utilities consumption data for production of a 97.5 wt% solution with 60 wt% nitric acid feed are shown in table 2.

The only AN product loss which occurs exclusively in the process condensate is so low that the overall process yield exceeds 99.99% wt. If, in addition, the process condensate is recycled to the nitric acid unit the corresponding amount of AN in the process condensate is saved, and the overall AN loss is reduced to 0.012 kg AN/ton AN.

For a process where the yield of the feed reactants is close to 100 %, the overall process economics result from a combination of different factors, such as energy and utilities consumption, maintenance and investment cost, and effluent management.

There are various options to adapt the Carnit unit to specific conditions of the plant. By considering these possibilities at an early design stage, substantial savings on total investment are possible.

When investing together in a nitric acid and an ammonium nitrate solution production units, a careful look should be given to the overall steam site balance.

In the Carnit process the amount of 6 bar steam produced is related to the nitric acid strength.

The energy efficiency of the process can be optimized in two different ways:

- It may be chosen to use standard acid concentration, in the range of 60 to 63 wt%, in order to produce a maximum amount of 6 bar export steam.
- Alternatively, if no additional 6 bar steam is required on site, the energy efficiency of the Camit may be put to use by selecting a more dilute acid with a reduced steam production.

The main interest of using a more dilute acid is related to a reduction of the investment and operating cost of the nitric acid unit.

When only dilute acid of 57 wt% or less is required the less expensive mono-pressure nitric acid units become attractive.
In addition for single pressure nitric acid units, which are usually combined with a catalytic NOx reduction, a decrease of acid concentration from 60 wt% to 57 wt% would reduce the size of the absorption column by several plates.

It is a common option, for most processes which produce predominantly heavily loaded process condensate, to recycle as much AN process condensate as possible to the nitric acid unit. This way of meeting the environmental constraints does in fact rule out the possibility of operating the AN unit when the nitric acid unit is stopped.

Table 3 shows that the net amount of condensate, which can not be recycled to nitric acid, is constant regardless of the acid concentration.

With the Carnit process AN production becomes independent of the nitric acid unit operation as the AN content of the process condensate is so low that recycle to the nitric acid unit is no longer mandatory.

It is advantageous to use the Carnit condensates for production of demin water at a very low operating cost.

In regard to the Carnit unit itself, it may happen that the site overall steam balance does not require additional low pressure steam production. Fig 6, which is based on a reactant temperature of 67°C, shows that if there is no steam production the thermal balance of the loop would require 55 wt% acid.
There appears to be a possibility in the Camit process to suppress the steam production and steam kettle. This case has so far not been tested in practice.

In regard to the demineralised water unit, the economic result of the cleanliness of the process condensate is twofold :

- reduction of the specific regeneration utilities consumption
- increase in capacity by reduction of the frequency of regeneration and reduction of the total effluent from the demin. water section.

7. Operating Experience

Since initial start-up of the Tertre (Belgium) 2 100 t/d unit in December 1990, production of 97.5 wt% solution has been maintained with a 98.7 % on stream time efficiency until the first planned maintenance shutdown of July 1992.

During the first maintenance shutdown, which lasted 5 days, inspection showed that the unit was essentially corrosion-free.
The risk of corrosion in the reaction loop which is kept ammoniacal, is obviously greatly reduced. Corrosion in the nitric acid supply section is also greatly reduced by the use of low pressure vapors for preheating nitric acid. This results in a low maintenance cost.

The Tertre CARNIT plant receives nitric acid from different nitric acid units, with acid concentrations which vary between 57 and 61 wt%. Due to layering in the main acid storage tank, fairly rapid changes of feed acid concentration are a frequent occurrence.

At initial startup, it has been chosen to maintain a constant circulation flow, which means that the temperature range between inlet and outlet of reactor varies when the acid concentration varies. It was found that loop operation was quite steady under these conditions and this operating procedure has been maintained.

The concentration of the final 97.5 wt% AN solution remains steady within a range of +/- 0. 15 wt%.

The quality of the process condensates remains quite steady. The current control parameter are the conductivity and pH of the condensates, while nitrogen contents are determined on the basis of an average 24 hour sample.
Average nitrogen contents are 6 ppm wt ammoniacal and 7 ppm nitric. Upon neutralization to pH 7 the average equivalent AN content remains below 50 ppm.
Depending on the further use of the condensates, it can be chosen to operate the unit so as to produce slightly akcaline or slightly acidic condensates. The Tertre Carnit condensates are used as feed to the demineralization water production unit and are therefore currently produced with a slight acidity.

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Acid Concentration Wt %	Condensate		
	Produced Kg/t AN	Returned Kg/t AN	Balance Kg/t AN
60	500	262	238
56.5	580	342	238

Table 3: Process Condensate Material Balance, Production of 97.5 wt% Solution

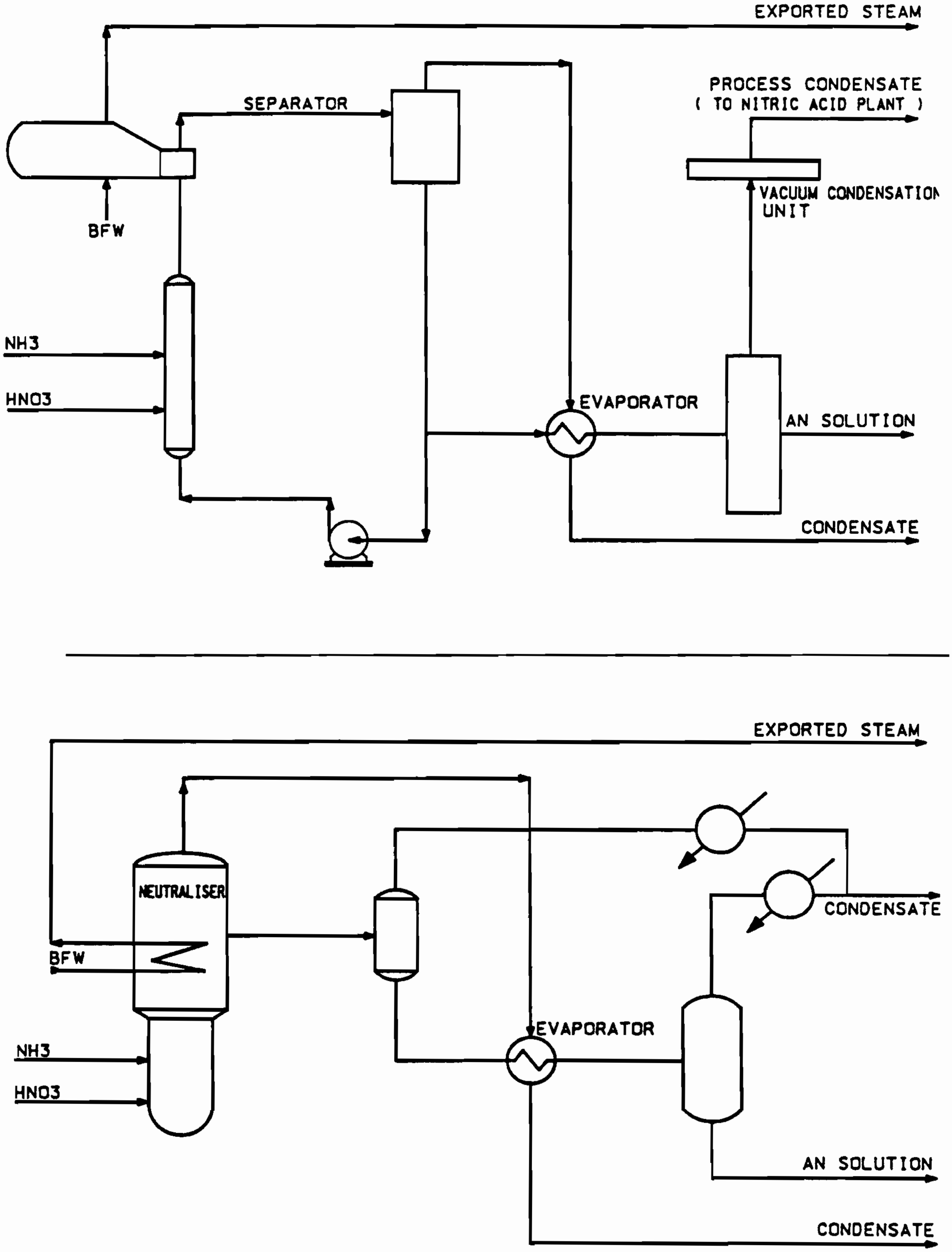

Figure A1: Conventional AN Process

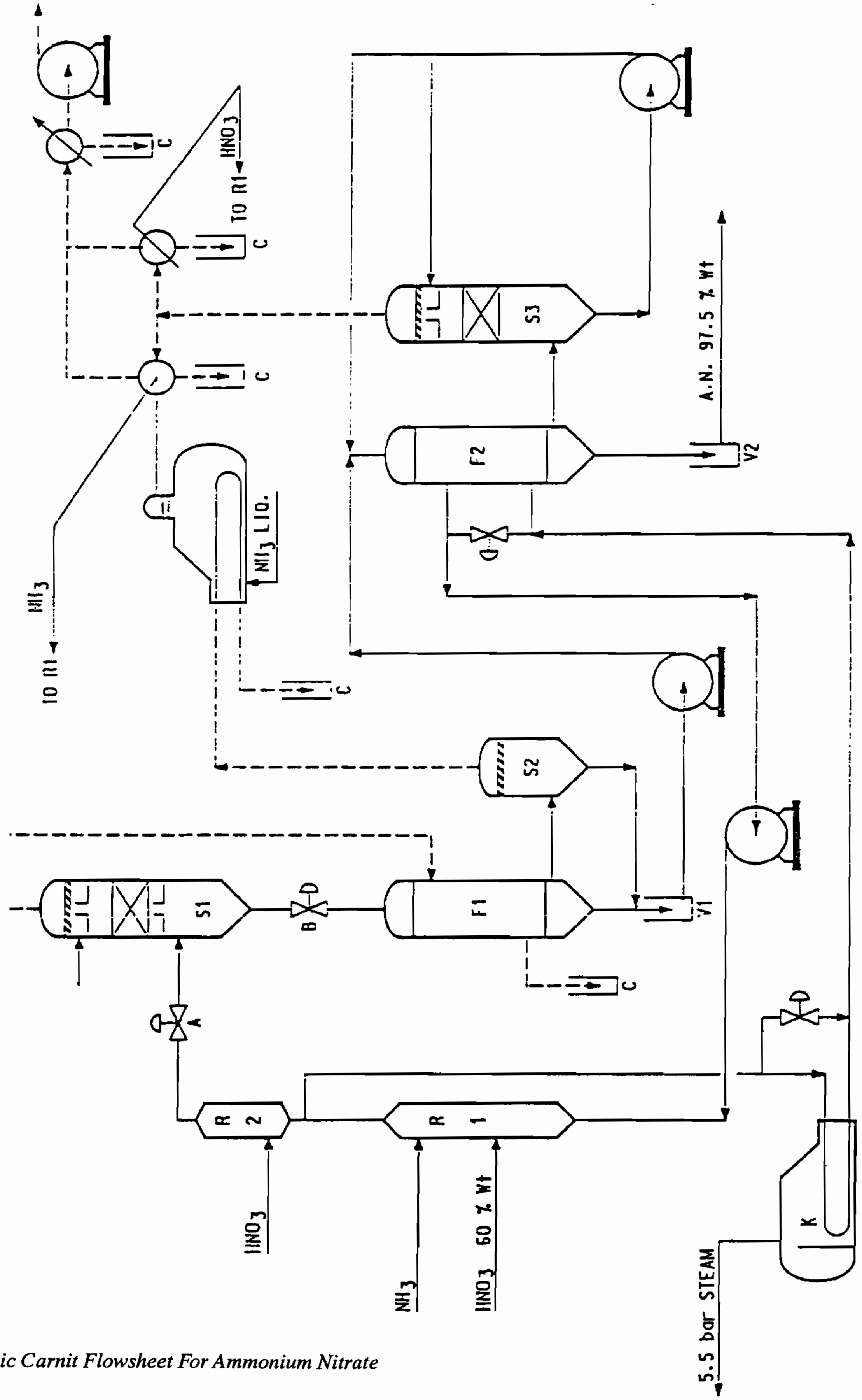

Figure 1: Basic Carnit Flowsheet For Ammonium Nitrate

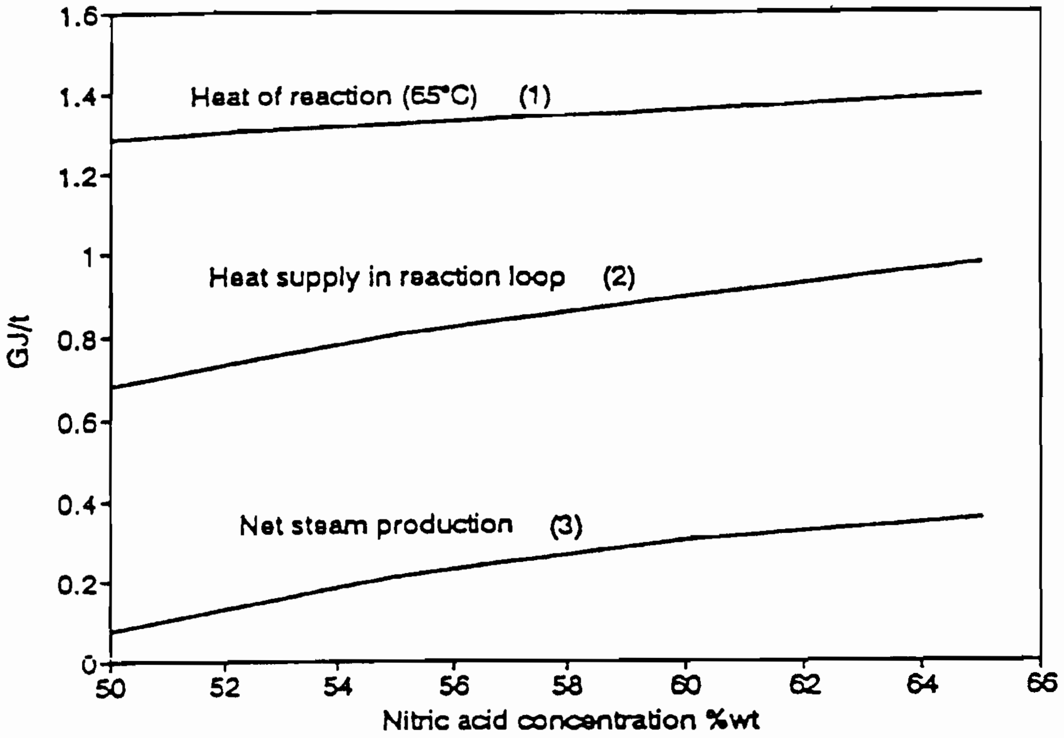

Figure 2: Neutralization Loop Enthalpy Data

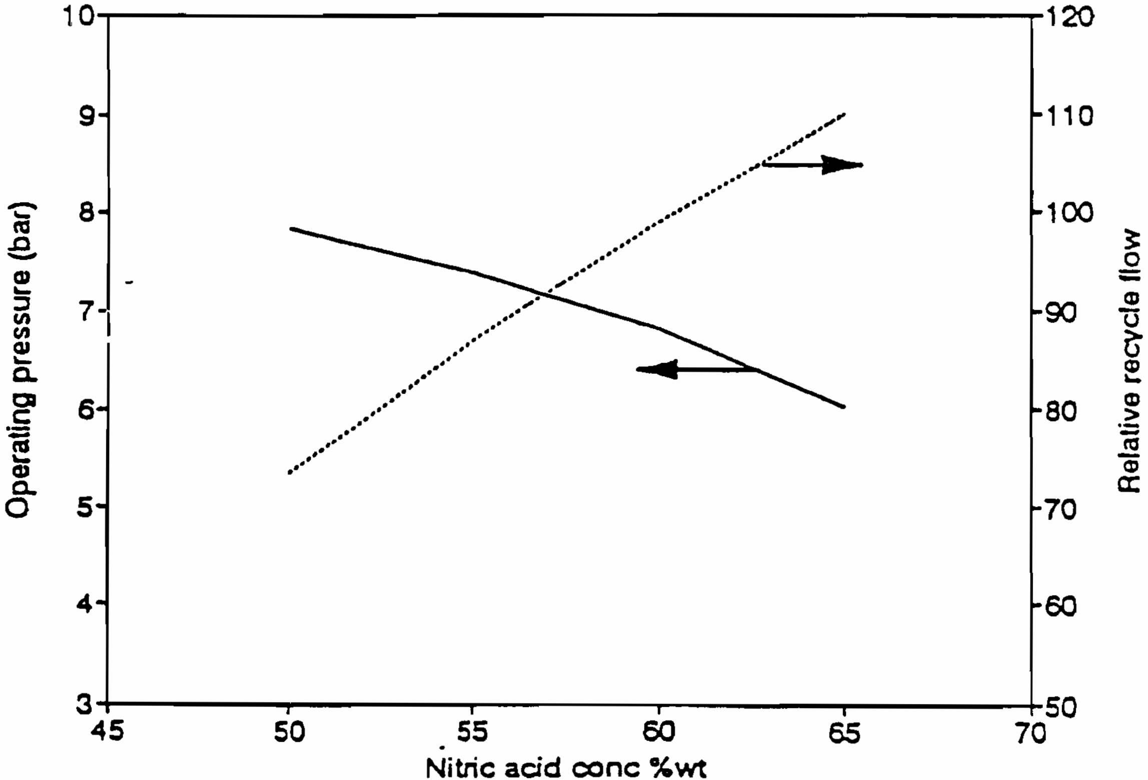

Figure 3: Neutralization Loop Control Data

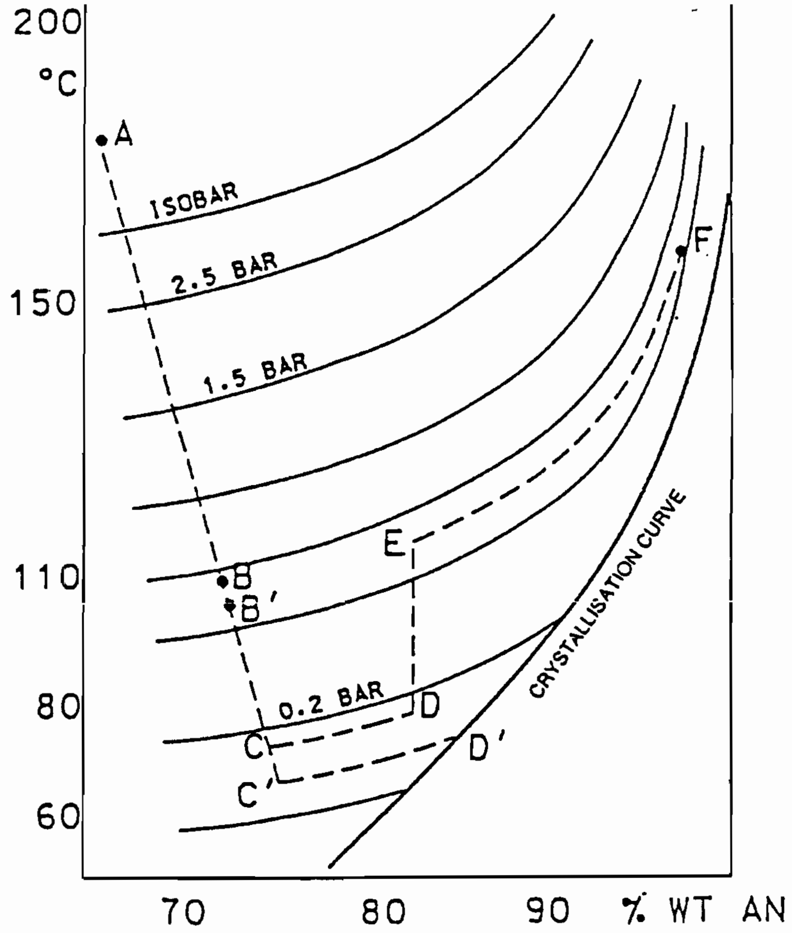

Figure 4: Temperature Profile of Carnit Process

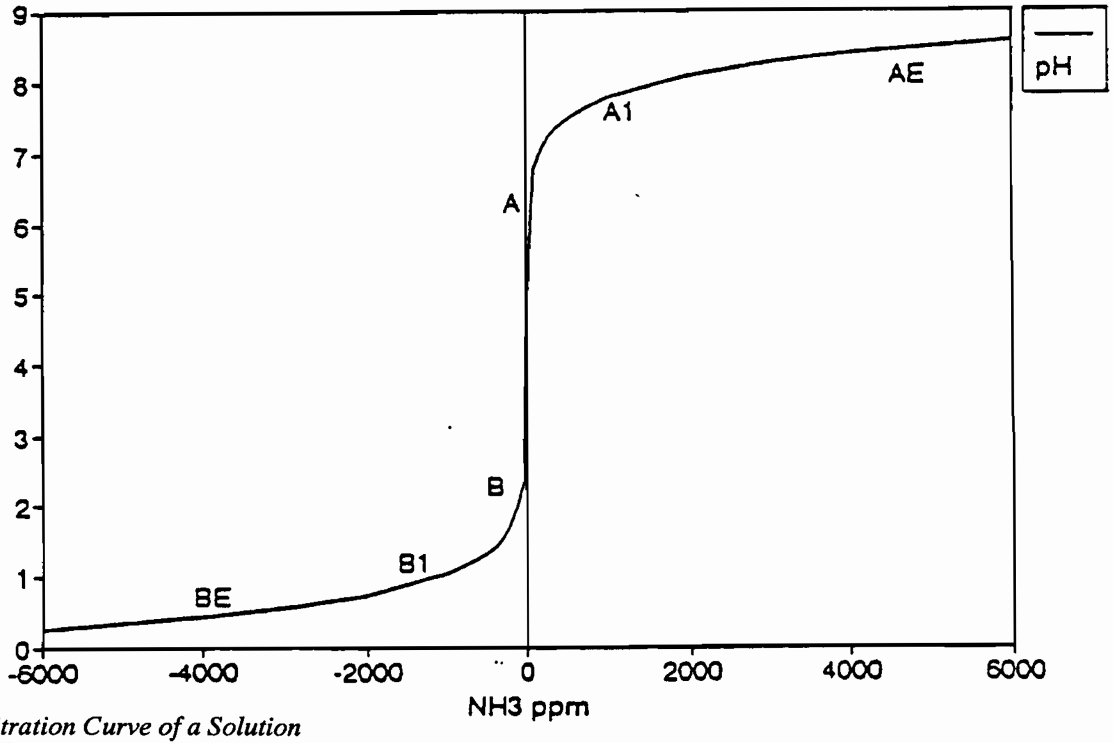

Figure 5: Titration Curve of a Solution

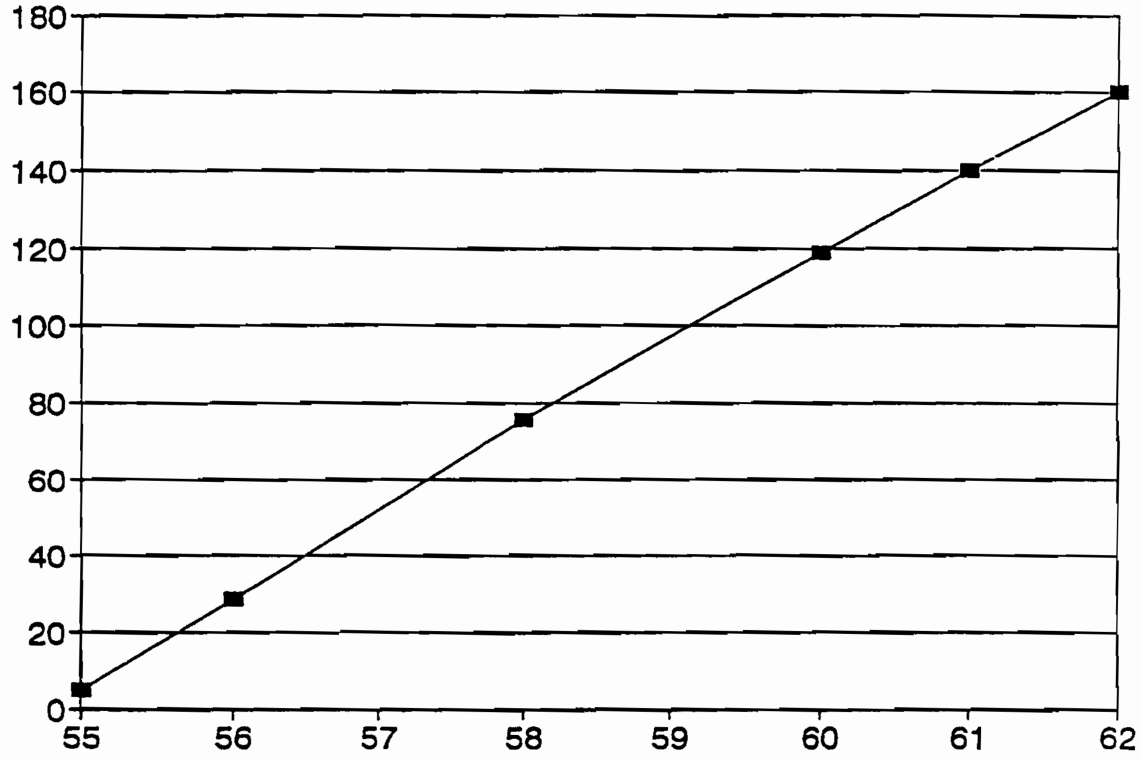

Figure 6: Steam Production vs HNO_3 conc.

	Concentration wt %	**Temperature °C**	**Pressure Bar**
Reactor Input			
- HNO3 liq.	60	65	8
- NH3 gas	100	65	8
- Recycle solution	65.6	155	6.5
Reactor Output			
- AN solution	65.6	185	6.5
Concentration section			
- AN solution F1	83 - 84	80 - 82	0.175
Product			
- AN solution F2	97.5	155	0.4

Table 1: Typical Operating Data

		BASE AN 100%
PROCESS	**INPUT**	
HNO3 60 wt%	1 312.57	kg/t
NH3 100 wt%	212.51	kg/t
	OUTPUT	
AN solution 97.5 wt%	1 025.6	kg/t
Process condensate	500.0	kg/t
AN loss in condensate	0.025	kg/t
UTILITIES	**INPUT**	
BFW	133	kg/t
Electric Power	1.85	kWh/t
Cooling water (= 10°C)	11	m3/t
	OUTPUT	
Steam production 6 bar	120	kg/t

Table 2: Material Balance And Utilities, Production of 97.5 wt% Solution

Advanced Technologies For The Ammonia Industry

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Today, ammonia technology licensors are challenged by marketplace demands for ammonia plant designs that offer reduced energy consumption at a lower capital investment, while maintaining the highest degree of safety, reliability, operability and environmental soundness. This paper highlights recent advances in technology which will have a significant impact on the ammonia industry into the next century. The M.W. Kellogg Company, with commitment to technology leadership, has recently developed two significant technological improvements to the ammonia process which meet customer demands for a reduction in both energy and up-front capital costs. The Kellogg Advanced Ammonia Process (KAAP), represents the first significant advance in catalyst technology since the ammonia process was developed in 1913. The Kellogg Reforming Exchanger System (KRES) revolutionizes the front-end of the ammonia process by replacing the conventional fired-reformer. Improved operability and stability of an ammonia plant can lower operating costs for the ammonia producer. The Kellogg Dynamic Ammonia Control (KDAC) system achieves these objectives, through more efficient on-line, real-time plant control. Driven by environmental demands, ammonia and other fertilizer producers will be anxious to find technologies which provide cost-effective solutions to environmental compliance. The Kellogg Integrated Condensate Stripper (KICS) system provides a cost-effective answer to treating of combined process condensate from both the ammonia and the urea plant.

In order to be successful, ammonia technology licensors must continually innovate and develop new technologies that meet customer demands. Today, this requires licensing ammonia technologies that offer reduced energy consumption at a lower capital cost, while maintaining the highest degree of safety, reliability, operability and environmental soundness.

Since ammonia technology was first developed in 1913 through the efforts of Fritz Haber and Carl Bosch (for which they later received the Nobel prize), significant improvements have been made resulting in today's highly efficient and streamlined process. During the 1960's, customers sought economic largescale facilities to meet the growing demand for ammonia fertilizer. The M. W. Kellogg Company responded to this challenge by pioneering the large capacity centrifugal-based 1000 MTPD ammonia plants which quickly became the Industry standard. With producers feeling the repercussions of the 1970's Oil Shocks, the emphasis shifted to energy efficiency. Technology suppliers responded with a series of energy savings features, eg, hydrogen recovery from purge, molecular sieve drying of make-up gas, low pressure drop intercooled converter designs and additional refrigeration stages. Through the 1980's, with the stabilization of natural gas prices, customer priorities have shifted toward minimizing capital investment, while improving safety and reliability. This focus on capital cost has been influenced by the fact that synthetic ammonia technology is fast approaching developmental maturity, coupled with the requirement of the plant operator to be a low cost producer.

The 1990's have seen a continued customer priority on value (low energy + low cost + high reliability), with additional emphasis on environmental issues which have been pushed to the forefront with the passage in 1990 of the Clean Air Act Amendments (CAAA) in the United States. This puts added pressure on technology designers, to develop technologies which economically attain environmental compliance. The 1990's have also heralded the Information Age. Kellogg recognized that ammonia plant operation could be improved, and thereby lowering operating costs, by implementing real-time computer control systems, which provide useful information to plant operators and managers.

Table 1 enumerates four new areas that have received concentrated commercialization efforts from ammonia technology licensors and will continue to be the primary focus of technology licensors into the next century.

TABLE 1

NEW AMMONIA TECHNOLOGY COMMERCIALIZATION AREAS

1) High Activity Ammonia Synthesis Catalyst
2) High-Level Process Heat Reforming
3) Process Simulation and Control
4) Environmental

Table 2 gives the M. W. Kellogg Company's corresponding solution or innovation to the above four key areas, (the so-called "4-K's of Kellogg Ammonia"). Each of these innovations have been or are currently in the process of large scale implementation.

TABLE 2

KELLOGG ADVANCED AMMONIA TECHNOLOGIES

1) Kellogg Advanced Ammonia Process (KAAP)
2) Kellogg Reforming Exchanger System (KRES)
3) Kellogg Dynamic Ammonia Control (KDAC)
4) Kellogg Integrated Condensate Stripper (KICS)

High Activity Ammonia Synthesis Catalyst

The search for a high activity ammonia synthesis catalyst has been on-going since the classical iron-based (magnetite) catalyst was first introduced in 1913. Industry participants agree that all of the "easy" improvements to the ammonia process have already been implemented and that the next major 'breakthrough' will require the use of a high activity ammonia synthesis catalyst. Ammonia process economics dictates that directionally, there exists a major potential for improved energy efficiency and lower installed costs if ammonia synthesis could be conducted at a lower pressure while at the same time increasing ammonia conversion. Process designers are constrained in the search for more economical designs by the conventional magnetite catalyst.

The Kellogg Advanced Ammonia Process (KAAP), which is based on the development of such a high activity catalyst, achieves these economic goals. KAAP technology represents the first use of a non-iron catalyst developed jointly between M. W. Kellogg and British Petroleum. This new synthesis catalyst features an active precious metal component on a proprietary carbon support. The catalyst exhibits an activity up to 20 times that of magnetite. Catalyst performance is maintained at high ammonia concentrations and over a wide range of hydrogen to nitrogen ratios. Equally important is the catalyst's excellent low pressure and low temperature performance. Engelhard Industries is the exclusive manufacturer of KAAP catalyst for the Kellogg Advanced Ammonia Process.

The unique characteristics of this catalyst remove traditional economic constraints imposed on operating conditions. The resulting expanded design window allows for a flexible plant design, while maintaining the high degree of integrity and experience of conventional technology. The major impact is realized in the synthesis loop, where loop operating pressures are reduced by 40% over conventional ammonia plant designs. The KAAP Grassroots synthesis loop is depicted in Figure 1. The KAAP Grassroots design achieves a 1 MMBTU (LHV)/ST energy savings over conventional technology and approximately 5% lower upfront capital cost.

KAAP which has been technically demonstrated during extensive operation of a Process Demonstration Unit (PDU) in Perth, Western Australia was successfully commercialized at the Ocelot Ammonia Co., Kitimat, B.C., Canada in 1992. Monitoring and evaluation of the initial 9 months of KAAP operation, indicates that the Ocelot KAAP Reactor System meets or exceeds all Ocelot flowsheet requirements. KAAP has demonstrated excellent stability and performance over an extended time on stream at Ocelot. The use of KAAP at Ocelot will allow for a cost-effective 40% increase in ammonia production capacity. The successful commercialization of KAAP at Ocelot is a significant milestone in the history of ammonia technology, the beneficiary of which is the Ammonia Industry.

Process Heat Reforming

While KAAP revolutionizes the ammonia synthesis loop, the Kellogg Reforming Exchanger System (KRES) is poised to revolutionize the ammonia plant front-end. Process heat utilization at the highest level is most desirable if it goes to supplying the endothermic heat of reaction necessary for reforming. The Kellogg Reforming Exchanger System utilizes secondary reformer effluent process heat to supply part of the energy requirement for the steam reforming reaction. The reforming exchanger system concept is not new. However, it has only been recently that customer requirements have driven licensors to develop and commercialize viable alternative reforming systems. The principle driving force behind the reforming exchanger system is elimination of the conventional direct-fired tubular reformer. The pressurized primary reformer, which has been the workhorse for synthesis gas generation since the early 1950's is a highly capital and maintenance intensive piece of equipment. Replacement with a reforming exchanger results in a reduction in both up-front capital cost and energy consumption.

A segment of a Kellogg reforming exchanger flowsheet, given in Figure 2, shows the synergy between the autothermal reformer and the reforming exchanger. The reforming exchanger and the autothermal reformer are arranged in parallel. Enriched air is used in the secondary reformer to balance thermodynamic and process material balance requirements.

Various reforming exchanger designs and process integration schemes have been proposed. The Kellogg Reforming Exchanger System utilizes a proprietary opentube design. This is a tubular exchanger with catalyst filled tubes. The opentube design offers mechanical simplicity and friendly operating and maintenance practices.

In addition to reducing capital cost and minimizing process waste heat, the reforming exchanger system also minimizes steam generation, improves plant safety through lower potential for tube burnout, and requires less plot space. Implementation of reforming exchanger technology is also driven by environmental concerns. The Kellogg Reforming Exchanger System contributes significantly to lowering overall carbon dioxide and NO emissions from an ammonia plant.

The Kellogg Reforming Exchanger System is currently being fabricated for Ocelot Ammonia Company, in Kitimat, B.C., Canada, as part of a new front-end installation to provide for an equivalent of 350 MTPD of ammonia. With the availability of additional synthesis gas, Ocelot will realize the full benefits of a KAAP/KRES ammonia plant design.

Process Control and Optimization

The area of plant process control shows continuous, progressive development. Improved plant operation and control can result in significant benefits to the operator from both an economic and safety point-of-view. Process control systems, spurred by recent advances in computer technology and analytical techniques, have taken on broader functions and sophistication.

Technology suppliers are making significant strides in improving ammonia plant control. The Kellogg Dynamic Ammonia Control (KDAC) system incorporates advanced steady-state and transient modeling techniques and intelligent software into a state-of-the-art supervisory computer control system. The eight main productive control strategies of the KDAC system are given in Table 3.

TABLE 3
KDAC CONTROL STRATEGIES

1) Reformer Fuel BTU
2) Reformer Feed Potential Hydrogen
3) Reformer Steam-to-Carbon Ratio
4) Reformer Methane Leakage
5) Loop Hydrogen-to-Nitrogen Ratio
6) Loop Inerts Purge
7) Converter Temperature
8) Refrigeration Purge

The Kellogg Dynamic Ammonia Control system has been successfully installed in 6 ammonia plants worldwide. The basic KDAC system is customized to individual plant requirements and provides on-line improved performance. Ammonia plant control systems will become a standard in process control.

The Kellogg Dynamic Ammonia Control system is the ammonia technology licensor's answer to the demands of the Information Age. KDAC objective is to provide enhanced profitability through the use of advanced process control and information. Increased information through ammonia plant monitoring feedback and control, allows lower cost operation through more efficient operation resulting from improved plant reliability and operability. KDAC results have indicated that ammonia plant stability with KDAC has increased up to 90% for key process variables. Figure 3 gives analysis for the loop hydrogen-to-nitrogen ratio for actual ammonia plant before and after KDAC installation.

Environmental.

The 1990's are seeing a heightened awareness and resurgence of environmental concerns and legislation. Environmental issues are expected to continue to dominate chemical process industries worldwide. The manufacture of ammonia per se is relatively clean compared to other chemical process industries and presents no unique environmental problems. However, in today's world, environmental needs of the ammonia plant are changing. The driving force behind this change is either operator's commitment to being a good neighbor or compliance to mandatory environmental regulations. In response, technology suppliers must offer cost-effective solutions to questions of environmental compliance and responsibility.

Generic choices for minimization of pollutant release are (1) stop the pollutant from being generated, (2) if generated, stop it from being emitted, and (3) if emitted, collect it and recycle, treat, concentrate or burn it. The challenge is how the pollutant can be eliminated economically.

A main area of plant discharge is the liquid effluents in the plant process condensate streams. With increasing frequency, ammonia and urea plants are being built together. The manufacture of ammonia and urea generates a significant quantity of process condensate. The development and implementation of strategies for treatment and reuse of ammonia/urea process condensate (water) are being driven by economic and environmental needs.

Historically, in older ammonia and urea plants, the process condensates were merely discharged to sewer, along with NH_3, CO_2, MeOH, urea and other contaminants, which would eventually end up in the ground water. Later on, a low pressure stripping system was developed to strip away contaminants from the ammonia plant process condensate. Low pressure stripping however was not very effective. This led Kellogg to pioneer high pressure stripping of ammonia plant condensate. This system effectively eliminates contaminates within the process, and generates water that can be reused in the process as boiler feedwater (BFW) after polishing. Additionally, urea plants developed a highly effective process for treatment of urea plant process condensate. Urea hydrolysis, which is used to decompose the urea back to ammonia and CO_2, also results in BFW quality water reuse, while also recycling ammonia and CO_2 back to the process.

Over the years, ammonia and urea plants have progressed independently in their development of process condensate treatment, to the point where a maximum amount of water is recycled as BFW and the contaminants effectively removed from the condensate and returned to the process. The ammonia plant is a large water user, while the urea plant is a large water generator. Integration of ammonia and urea process condensate treatment makes sense technically, economically and environmentally. The objective is for maximum water reuse at its highest quality (as BFW).

Figure 4 depicts analytically the Kellogg Integrated Condensate Stripper (KICS), developed and patented as a means for the combined treatment of ammonia/urea process condensate in a single tower. The KICS tower, although physically one vessel, has distinct sections, the top section for urea process condensate treatment (urea hydrolysis) while the bottom section is for ammonia process condensate treatment (high pressure stripping). The Kellogg urea hydrolysis is differentiated from conventional urea hydrolysis, in that a much higher temperature and pressure is used, which allows for a smaller diameter tower, reduced residence time for urea hydrolysis, more efficient and complete hydrolysis, and therefore a cost savings.

The advantages for KICS are a small net energy savings, but a substantial capital cost savings. The KICS approach in effect, eliminates 13 pieces of equipment associated with urea process condensate treatment, while only adding an intercooler and a slightly larger process condensate tower in the ammonia plant.

The ammonia/urea complex with KICS operates more efficiently, costs less, reduces pollution, reuses water and is more reliable and less costly to maintain than today's traditional separate ammonia and urea plant systems.

Conclusions.

The ammonia plant operator targets being the low cost producer. In the future, operators will continue to demand large-scale ammonia facilities, but at lower capital investment and at lower energy rating. The Kellogg Advanced Ammonia Process and the Kellogg Reforming Exchanger System typify the direction of future technological innovations for the ammonia industry. The KAAP/KRES plant design provides maximum synergy of the new technologies and therefore maximum benefits to the ammonia producer.

Increased attention will be given to plant safety, reliability and operability. The Kellogg Dynamic Ammonia Control system is currently making significant strides in ammonia plant control. Ammonia plant operators can accrue significant economic benefits from improved plant stability, reliability and performance.

The area of environmental impact of ammonia and fertilizer facilities will continue to be in the forefront. The extent of environmental technology development will depend on mandatory requirements and the permeance of environmental responsibility through the industry. Systems like the reforming exchanger and integrated process condensate stripper systems, which synonymously reduce generation of pollutants and offer energy and capital benefit, will become the technology of choice in the future.

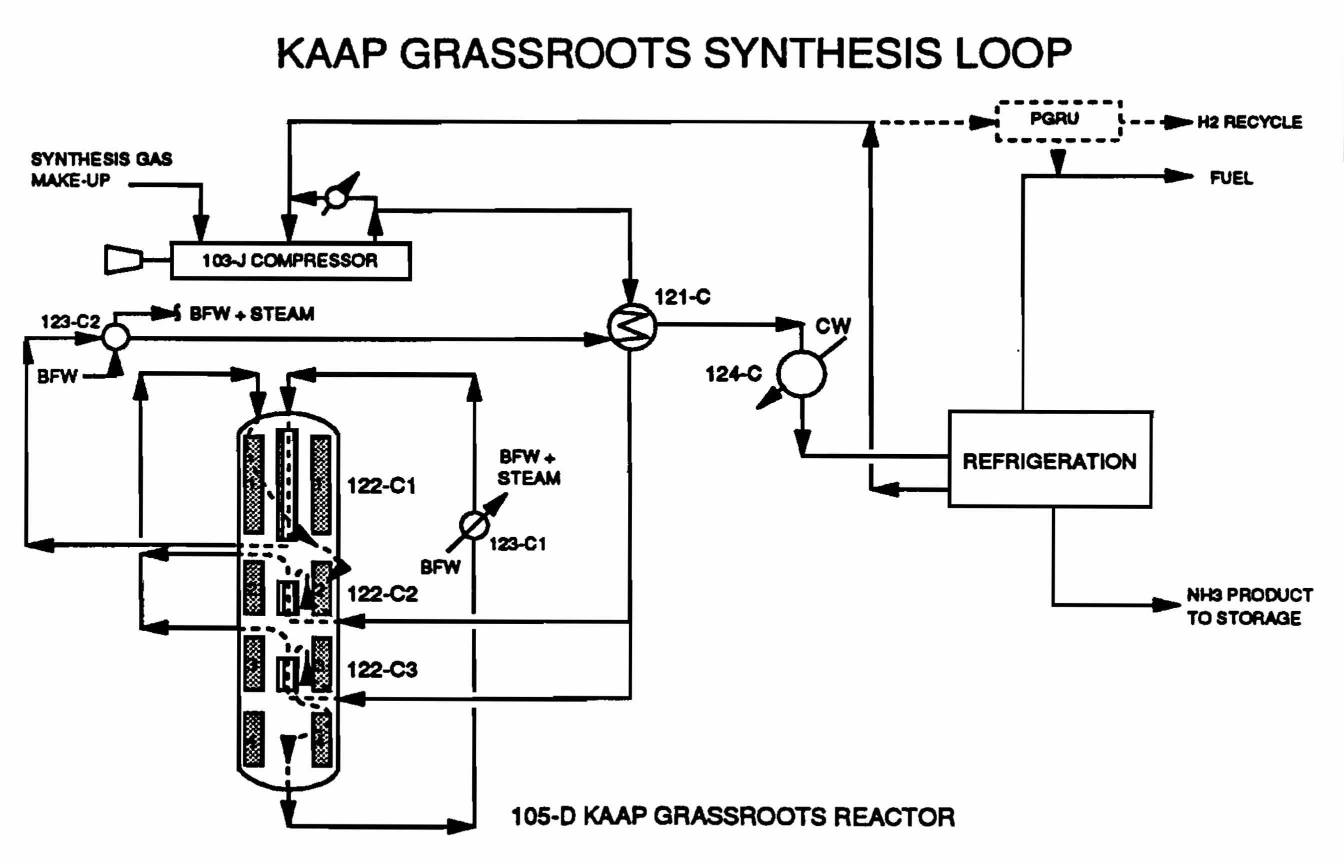

Figure 1: KAAP Grassroots Systhesis Loop

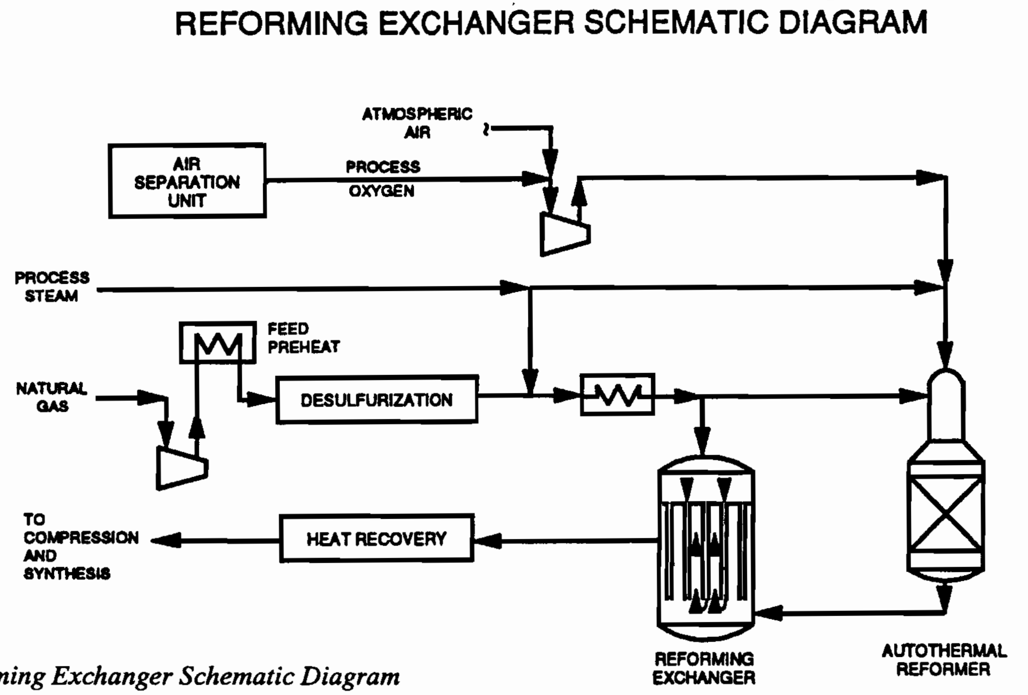
REFORMING EXCHANGER SCHEMATIC DIAGRAM

Figure 2: Reforming Exchanger Schematic Diagram

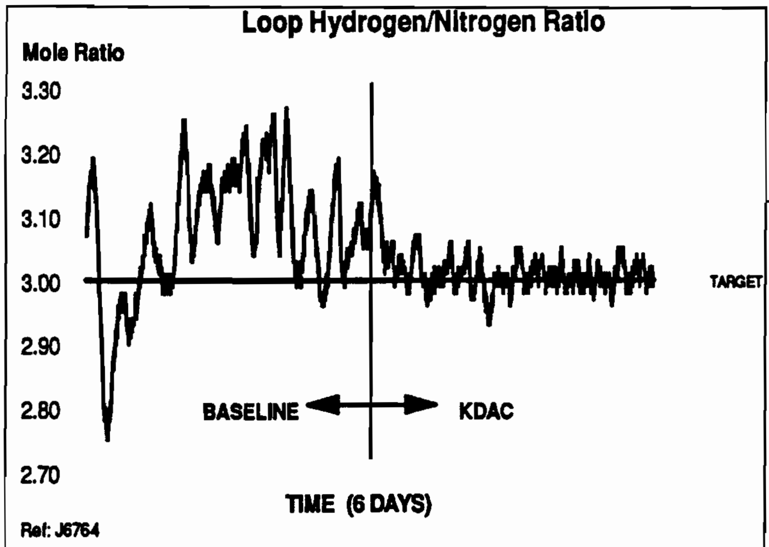
Loop Hydrogen/Nitrogen Ratio

Figure 3:Loop Hydrogen/Nitrogen Ratio

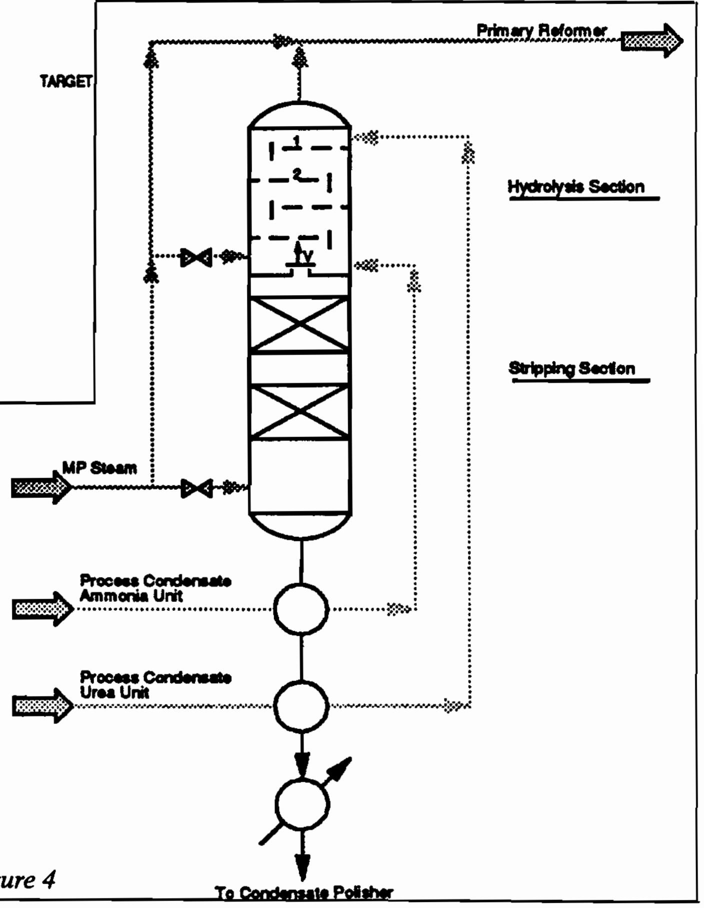

Figure 4

Lignin: It's Not Just For Breakfast Anymore

Stuart Lebo, Jr. & W.J. Detroit
LignoTech USA, Inc.

Introduction

Lignin (from the Latin lignum, wood) is a natural polymer derived from phenylpropane building blocks (see Figure 1). It is, after polysaccharides, the most abundant organic polymer in the plant world accounting for 24-33% and 19-28% of the dry wood weights of normal softwoods and temperate-zone hardwoods, respectively.

In nature lignin performs numerous functions that are essential to the life of woody plants. By decreasing the permeation of water across the cell walls in the conducting xylem tissue, it aids in the internal transport of water and other vital plant nutrients. It imparts rigidity to the cell wall and acts as natural glue between wood cells, creating a composite material which is resistant to bending, compression and impact. Lignin also impedes penetration of destructive enzymes into the cell wall and, thereby, imparts resistance to biological decay.

In terms of structure and homogeneity, lignin is the most complex natural polymer. Because of this, no definite lignin structure is possible. Vast research, however, has led to the development of working models such as the one for spruce lignin shown in Figure 2. As this figure shows, lignins contain a number of different structural linkages with the predominant type being an ether linkage. Figure 2 also shows that native lignins contain various functional groups including phenolic hydroxyl, benzylic hydroxyl, benzylic ether, methoxyl and carbonyl groups. It is these groups that account for the chemical reactivity of lignin.

Isolation

Commercially, lignin is isolated from wood by one of two main chemical pulping processes: kraft or sulfite. Depolymerization of lignin occurs in both processes. In sulfite pulping, lignin is solubilized via sulfonation, and the resulting products are known as ligninsulfonates or lignosulfonates (see Table 1). In kraft pulping, depolymerization occurs mainly via nucleophilic cleavage ether bonds within the lignin. The resulting products are known as kraft or alkali lignins and are water insoluble (see Table 2). As one might suspect, lignosulfonates and kraft lignins have distinct properties (see Table 3).

Both lignosulfonates and kraft lignins can be chemically modified in a number of different ways including ultrafiltration, sulfomethylation and oxidation including ozonation. they can also be co-condensed with phenolic compounds and graft copolymerized with vinyl compounds. The resulting products along with their unmodified raw materials find uses in many industries (see Table 4).

The production capacity of lignin in the Western world is estimated to be ca. 1.1 X 10^6 tonnes/yr. (see Table 5). This figure represents a significant reduction in lignosulfonate production over the past five years. This reduction combined with extensive product development efforts has elevated the status of lignin. It is certainly safe to say that lignin is no longer the waste material it once was considered to be. Instead, it is a valuable raw material from which numerous value added products are derived.

Uses in the Fertilizer Industry

Urea

Extensive laboratory and field evaluations by the Tennessee Valley Authority showed specific lignosulfonate systems could replace formaldehyde and/or urea-formaldehyde resins as conditioners for urea granules and prills (3,4). This could be done with improved performance in granule strength and at a considerable economic advantage.

For example, Tables 6 and 7 show a 96% fines reduction on attrition at a $1.95/ton of urea savings using lignosulfonate to replace formaldehyde or urea-formaldehyde. This equates to a plant making slightly over 500,000 tons of urea granules per year saving $1,000,000 with better product quality.

Lignosulfonate systems in urea have been in commercial use for about six years. Use is not universal due to initial quality and production problems which have now been solved or could be solved by minor modifications of the lignin systems and to the perceived resistance to color change. Commercial producers and retail users have found the following advantages:

Benefits to Urea Producers

- Lignosulfonates can be added directly to the melt at the same addition rate as formaldehyde and provide anti-caking properties equal to or better than that of formaldehyde or urea-formaldehyde resins.
- Lignosulfonates have been found to provide increased hardness and strength versus formaldehyde resulting in less dusting in-plant and during subsequent handling throughout distribution. In plant use has yielded less dust to the scrubber system, thereby lowering costs.
- Lignosulfonates provide a manufacturing cost savings of $0.75 $1.95 per ton of urea at the same addition rate as formaldehyde.
- Lignosulfonates require no capital expense. The product can be used in the same tank, lines and feed points as formaldehyde or urea-formaldehyde resins.
- Lignosulfonates are classified by the EPA/FDA as non-toxic.

Benefits to Farmers

- Stronger granules mean less dust and minimal product loss.
- Light tan urea made with lignosulfonate gives less salt and pepper effect in bulk blends.

Phosphates

The use of lignosulfonates as conditioning agents for phosphate fertilizers was first patented in 1988 (5,6). Since then field trials have been carried out in conjunction with many members of the phosphate fertilizer family. Results obtained in field trials on DAP and MAP are given in Tables 8 and 9. They show positive effects on both hardness and strength (as measured by TVA attrition) for both DAP and MAP. Particularly significant are the cycled TVA attrition test results for MAP in Table 9, simulating three shipping transfers with an overall reduction in fines of 70% when lignosulfonate is used.

Commercial continuous use on DAP and and selective use on MAP is entering its fifth year with benefits as follows:

- Lignosulfonates are classified by the EPA/FDA as non-toxic.
- Lignosulfonates can be introduced in slurry feed or acid before granulation and are safe for use and storage in standard carbon steel equipment. Capital investment is minimal.
- Where strengths are low, lignosulfonates increase granule strength resulting in improved handling/anti-caking properties during production storage and shipping.
- Lignosulfonates give significant dust reduction during production, lowering the cost of operating dust collectors and improving air quality in the plant.
- The use of lignosulfonates can reduce chute plugging and improve general transfer characteristics.
- Plant trials have shown that lignosulfonates can allow the producer to lower his recycle rate and significantly improve granulation quality and efficiency before screening.
- With the use of lignosulfonates, coating oil and the environmental concerns associated with it can often be reduced.
- Lignosulfonates offer price stability when compared to oil.
- Being a natural polymer derived from wood, it is not priced on crude oil value which is subject to fluctuation and sudden increase.

NPK

Field trials of lignosulfonates as conditioning agents for NPK granules have also been carried out. Commercial continuous use on selective NPK products is entering its third year. The benefits of using lignosulfonates in NPK fertilizers are similar to those listed for phosphate fertilizers. For example, Table 10 shows that lignosulfonates act as hardening agents in granular NPK fertilizers improving crush strength and reducing attrition. Table 10 also shows that addition of lignosulfonates can also reduce productdust especially when urea is used as a source of nitrogen. Plant trials have shown that lignosulfonate use can reduce in Plant dust and chute plugging.

Uses in Other Fertilizer Products

Lignosulfonates are currently being used or have been used in the production of many other fertilizer products. Some of these uses are summarized in Table 11.

The environmental friendliness, binding efficiency and relatively low cost of lignosulfonates make them an excellent choice in pelleted limestone and gypsum fertilizers. Lignosulfonates have also been used as a binder in the production of granular potassium magnesium sulfate, sulfur, byproduct ammonium sulfate (7) and organic fertilizers.

Use in DiCal and GTSP is also applicable. In many cases in plant dust is significantly reduced and granule strength is improved when lignosulfonates are incorporated into these products. In the case of DiCal, lignosulfonates have also been used to improve size distribution (see Figure 3).

Micronutrients

Micronutrient trace metals and trace metal chelates such as zinc, iron, copper, magnesium and manganese are widely used in the fertilizer industry. While still small in comparison to the acreage requiring nitrogen/phosphorous/potassium fertilization, areas where micronutrient application is needed are increasing.

Plant trials have shown that the use of lignosulfonates in granular micronutrients produces benefits similar to those seen in other granular fertilizers (i.e., increased strength, lower attrition and lower in plant and product dust). Chelated micronutrient trace metals prepared from specialty lignosulfonate chelants are easily applied and readily available to the plant. In addition, because lignins come from plants, chelated micronutrients based on them can be applied to leaves of plants without damaging them (e.g., lack of phytotoxicity).

Specialty Applications

Slow release urea systems have been developed through graft copolymerization modifications of lignosulfonate (8-10). Related systems utilizing kraft lignins have also been developed (11). In both cases, the material being released is either entrapped in the lignin macromolecular matrix or held by physical chemical forces of Van der Waal's, hydrogen bonding or ion association types. The resulting entrapment slows the solubility of urea in water, especially under dew precipitation conditions. This, in turn, allows for a more uniform availability of nitrogen to the plant.

Summary

Years of research and development have changed lignin from a waste material to a valuable and renewable raw material in the manufacture of specialty chemicals. Products made form lignin are used in many industries including the fertilizer industry where they act as particle hardeners, dust suppressants and/or anti-caking addi tives for numerous materials including urea, MAP, DAP, NPK, DiCal and GTSP. They are also used as a binder in the production of granular fertilizers such as limestone and gypsum, as particle hardeners/dust suppressants in granular micronutrients and as chelating agents in chelated micronutrients.

Research into new uses for lignosulfonates is ongoing. New products are being developed to meet the changing needs of producers. Its environmental friendliness and versatility make lignin a product worth looking at twice. As the title says: "It's Not Just for Breakfast Any More".

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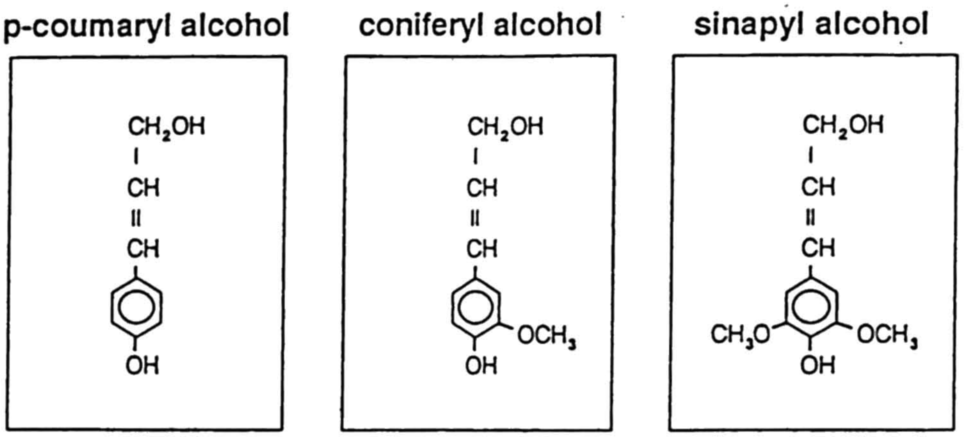


Figure 1: Basic Building Units of Lignin

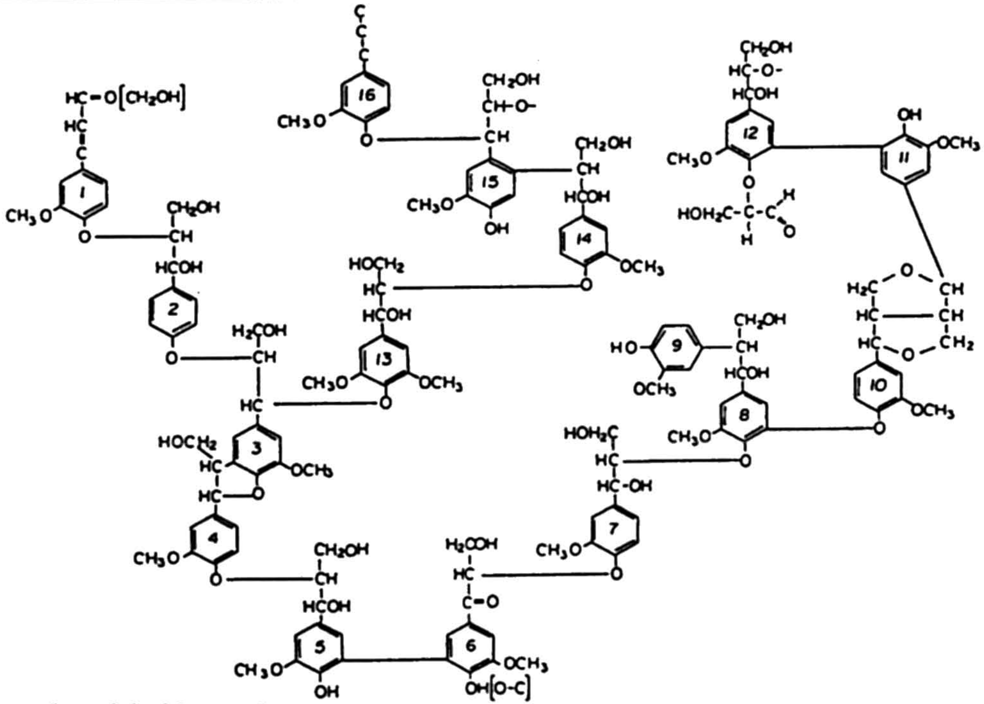


Figure 2:Structural Model of Spruce Lignin

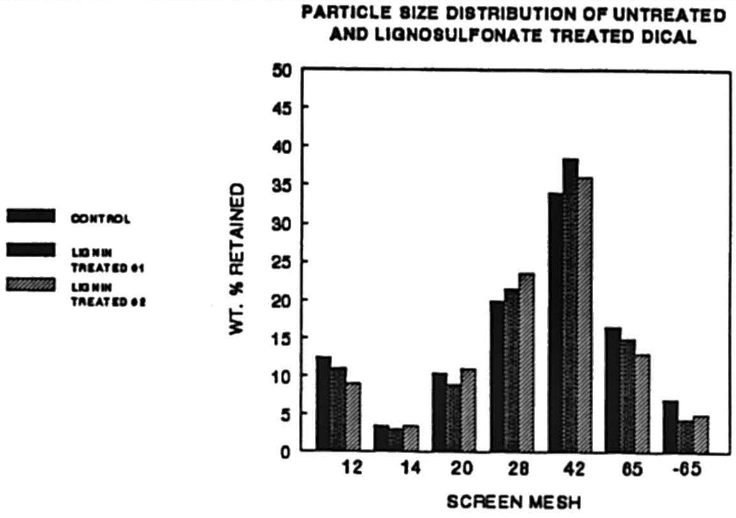


Figure 3:Particle Size Distribution of Untreated and Lignosulfonate Treated DiCal.

TABLE 1.

COMPOSITIONS OF SPENT SULFITE LIQUORS (1)

Component	Percentage of Total Solids Softwood	Hardwood
Lignosulfonate	55	42
Hexose sugars	14	5
Pentose sugars	6	20
Non-cellulosic carbohydrates	8	11
Acetic and formic acids	4	9
Resin and extractives*	2	1
Ash	10	10

* For example, polyphenolic oils and tall oils.

TABLE 2

COMPOSITIONS OF KRAFT BLACK LIQUORS (1)

Component	Percentage of Total Solids Softwood	Hardwood
Kraft Lignin	45	38
Xyloisosaccharinic acid	1	5
Glucoisosaccharinic acid	14	4
Hydroxy acids	7	15
Acetic acid	4	14
Formic acid	6	6
Resin and fatty acids	7	6
Turpentine	1	
Others	15	12

TABLE 3

PROPERTIES OF KRAFT LIGNINS AND LIGNOSULFONATES (1)

Property	Kraft Lignins	Lignosulfonates
Molecular weight	2,000-3,000	20,000-50,000
Polydispersity	2-3	6-8
Sulfonate groups	0	1.25-2.5 meq./g
Organic sulfur	1-1.5%	4-8%
Solubility	Soluble in alkali (pH>10.5), acetone, dimethyl formamide, methyl cellusolv	Soluble in water at all pH's; insoluble in organic solvents
Color	Dark brown	Light brown
Functional groups	Larger quantities of phenolic hydroxyl, carboxyl and catechol groups; some side chain saturation	Smaller quantities of phenolic hydroxyl, carboxyl and catechol groups; little side chain saturation

TABLE 4

LIGNIN APPLICATIONS

Application	Function
Batteries	Organic Expander
Ceramics/Brick & Tile	Antiscuming agent, binder, dispersant
Concrete	Water reducer and plasticizer
Dyestuffs	Dispersant and grinding agent
Oilwell drilling muds	Conditioner
Pelleted animal feeds	Binder
Pesticides	Dispersant, emulsifier, binder, wetting agent
Water treatment	Dispersant, scale remover, degreaser
Pigments, carbon black	Dispersant
Micronutrients	Complexing agent
Fertilizers	**Conditioner, dust suppressant, granulation aid**

TABLE 5

EUROPEAN AND AMERICAN LIGNIN MANUFACTURERS

Producer	Country	Annual capacity tonnes/yr
Borregaard LignoTech	Norway	160,000
LignoTech Sweden	Sweden	50,000
LignoTech Deutschland	Germany	50,000
LignoTech Iberica	Spain	30,000
Metsa-Serla	Finland	50,000
Avebene	France	80,000
Attisholz	Switzerland	100,000
Georgia Pacific	United States	190,000
LignoTech USA	United States	65,000
Westvaco	United States	45,000
Others		290,000
Total		1,110,000

TABLE 6

ABRASION RESISTANCE
LIGNOSULFONATE vs. FORMALDEHYDE - COMMERCIAL APPLICATION

Product	TVA Attrition (%)	Improvement, %
Control Urea (Formaldehyde 0.35%)	3.29	-----
Lignosulfonate Urea (0.35%)	0.13	96

TABLE 7

COST/PERFORMANCE

LIGNOSULFONATE vs. FORMALDEHYDE - UREA GRANULATION

ADDITIVE		TREATMENT PER TON OF UREA		
Product	Cost/Lb. solids	%	Lbs.	Cost
Formaldehyde	$0.300	0.4	8	$2.40
Lignosulfonate	$0.056	0.4	8	$0.45

Savings/Ton of Urea = $1.95

TABLE 8

PROPERTIES OF UNCONDITIONED AND LIGNOSULFONATE CONDITIONED DAP

Conditioning Agent	Crush Strength (psi)	TVA Attrition (%)
None	327	7.33
0.4% Norlig HP	696	0.67
% Improvement	112	91

TABLE 9

PROPERTIES OF UNCONDITIONED AND LIGNOSULFONATE CONDITIONED MAP

Conditioning Agent	Crush Strength (psi)	TVA Attrition, % 1-Cycle	2-Cycles	3-Cycles
None	551	0.90	2.44	4.63
0.4% Norlig HP	809	0.18	0.78	1.40
% Improvement	47	80	68	70

TABLE 10

PROPERTIES OF UNCONDITIONED 13-13-13 AND 13-13-13 CONDITIONED WITH LIGNOSULFONATE

Conditioning Agent	Crush Strength (lbs)	TVA Attrition (%)	Dust (g/kg)
None	8.9	3.38	5.34
0.4% Norlig HP	9.6	1.98	2.04

FIGURE 11

MISCELLANEOUS USES OF LIGNIN IN FERTILIZER SYSTEMS

Fertilizer	Function	Typical Dosage (%)
Granular limestone	Binder	3-10
Granular gypsum	Binder	3-10
Ammonium sulfate	Binder	0.1-1
K-Mag	Binder	3-5
Potash	Binder	0.5-5
Sulfur/sulfur mixes	Binder/Dust suppressant	0.5-5
GTSP	Hardener/Dust suppressant	0.2-1
DiCal	Hardener/Dust suppressant/ Granulation aid	0.2-0.5
Organic fertilizers	Binder	1-5
Liquid fertilizers	Dispersant	0.2-1

Tuesday, October 26, 1993

Session III
Moderator:
James J. Schultz

Experiences In Recycling Manures & Sludges

Sigurd Gulbrandsen
Norsk Hydro

Farmers and countries in Western Europe have increasing problems in disposing of large excesses of manure slurry. Five years ago the total amount of nitrogen excreted in animal manure in the European Community was 9.0 million tons, of which 1.5 million tons were lost as direct evaporation to the air in the form of ammonia. Of the remaining 7.5 million tons, 3.9 million were deposited by animals on grassland, and 3.6 million indoors in animal housing units. By comparison, sales of nitrogen fertilizer amounted to 9.8 million tons.

According to EFMA, the European Fertilizer Manufacturers' Association, owing to a number of technical, physical and economical constraints and to a certain lack of awareness on the part of many farmers, only 700,000 tons of the 3.6 million tons of nitrogen in collectable manure were directly used as nitrogen fertilizer in 1988.

That year the so-called "nitrate directive" was proposed and adopted by the European Community. The directive outlines measures designed to achieve improved use of animal manure. These measures, to be implemented throughout Europe, include the storage of manure during the winter, the specification of the timing of application, and of maximum application rate per hectare. This means that the use of nitrogen contained in all the collected manure in animal housing units could rise to 35%, i.e. a rise from 700,000 tons to 1.3 million tons of nitrogen. As a consequence, the use of mineral fertilizer in the EC could drop by some 600,000 tons N. However, this will take some time.

Another aspect of this situation is that a better geographical distribution of intensive animal farms in Europe is needed to ensure environmentally sound disposal of the manure. This problem has become more acute in recent years, as the intensification of modern farming has meant that livestock in Europe is housed throughout the year, while there is insufficient land on which to spread the waste adequately. The EC has been particulary interested in this, and has encouraged industry, including Hydro, to participate not only on the processing side, but also in the distribution and application of processed animal manure. So far, the economic feasibility of such processing is highly questionable.

Obviously there are alternative ways to collect and to process animal manure, and to apply it in agriculture. In spite of the large quantities available, the European farmer tends not to see manure as a source of nitrogen, but rather as a source of organic matter and stable nutrients such as phosphate. When animals are increasingly kept in larger units, so that the greater quantities of manure have become more difficult to distribute over the land, animal manure has become not only an environmental problem, but also a general waste problem. This applies particularly in the Netherlands, and in parts of Belgium, France and Germany.

The storage of manure has also changed. In the past, a solid mixture of excrement and straw was the standard. Today, the technical possibility of constructing concrete basins to hold liquid manure or slurry, and the introduction of technical equipment to pump, transport and spread liquids like slurry, have changed the whole system of slurry handling.

These, and other changes in European animal husbandry, have challenged the fertilizer industry as well as other environmentally oriented operations, to develop processes and distribution channels for an economically feasible application of the manure surplus.

In the beginning, the Hydro concept was based on a mobile unit for processing manure slurry. The unit, a truck container, was self-contained with equipment and power. The idea was to place it on the farm at regular intervals, process the manure and carry it away for composting. The key issue was to purify the water fraction to a degree that made it clean enough to be re-leased into rivers or other recipients, at an acceptable cost.

In Norway the manure problem is limited. Only a few regions need to have the manure taken care of in this way. In the most concentrated areas in Europe, there is no need for a mobile unit because the amounts of manure are so enormous that only large permanent plants can deal with it. On the outskirts of the problem areas, however, transport costs may favour mobile units. Our main object was therefore to develop a technically and economically feasible process for upgrading pig manure into compostable solid, liquid nutrient and purified water.

Our second task was to develop a scheme for the distribution and application of the stabilized product. This was a task not only for products from our own process, but also for products from other producers throughout Europe.

Pig manure is complex from a chemical point of view. It consists of organic solids, a lot of different organic and inorganic substances, bacteria and viruses, in addition to varying amounts of water. The contents depend on the type of fodder, the use of sawdust or straw, and the use of water for cleaning the pigsty.

The process was based on the fact that each component in the slurry, i.e. particles, bacteria, molecules, ions etc, is larger than the water molecules. The final product is purified, drinkable water.

The first step is a screw press with a cut size of 2 mm. The largest particles and fibres are removed and concentrated. Then liquid cyclones and a vibrating screen are installed to avoid blocking the front end of the membranes of a microfilter. These membranes separate sharply on the basis of size, at 0.1 µm. Fine particles are removed and concentrated by returning that fraction to the cyclones and the micro-filter. Water soluble organic molecules and inorganic ions are removed and concentrated from the water phase by reverse osmosis membranes. The pore size in these membranes is 3 - 4 Angstrom. We have been working in the capacity area of 8 m^3/hr because this was a size suitable for operation at the farms in the regions where this concept could be applied.

The concept is based on systems where by the manure slurry is kept in tanks or bins. Before the manure pool is emptied, the slurry must be stirred to prevent settling. This in itself may represent a problem I will deal with later.

It is difficult to present a true picture of the process economy because this will depend on circumstances that will vary considerably from place to place. Our calculations are based upon the use of a mobile unit like the one I have mentioned before.

In a certain district on the west coast of Norway there is a surplus of about 40,000 m^3 pig manure per year. This is not much in an international context, but enough to create a local problem. New legislation for the spreading of manure will be enforced from the beginning of 1994. Processing of the manure or ultimate reduction of the number of pigs is consequently the farmers' choice. Most of them have already invested in storage facilities for the slurry, and both the farmers and the local slaughterhouse are most interested in keeping meat production at full capacity. Total investment costs for the mobile processing unit (200 m^3/day) and a corresponding composting unit are estimated to be approximately $2 million. Operating costs are estimated to be about $4 million per year for the production of 5,000 m^3 composted product/year. The costs will of course vary with transport costs, energy costs and a series of other factors, but an evaporating/drying plant would be even more expensive to run.

The only way to make this economically feasible is for farmers to be willing to pay a relatively high price to get rid of their manure slurry, and for the final product to be sold at a relatively high price. Both conditions are doubtful as the fertilizer value per kilo is rather low compared to that of commercially available inorganic fertilizer.

Another possibility is to precipitate the salts in the liquid nutrient phase instead of using them on the fields as a watering product, but the value of the precipitated product, which could be $MgNH_4PO_4$, is so low that this is hardly of interest.

The farmers in the district I have been referring to are now trying to co-ordinate their interests with neighbouring communities to find the most promising solution to their situation.

However, farmers for instance in the Netherlands have a more serious problem. Long distance transport of untreated manure slurry is prohibitive, processing costs are high and no solution has been found regarding distribution and application of large amounts of a low value product.

The most interesting alternative to our separation and purification process is probably a biogas based process. Methane is produced through an anaerobic fermentation of the slurry. This gas may be used as an energy source for the rest of the process, including an evaporation step, and the gas surplus may be sold to a domestic gas distribution system. This approach has been developed in the Netherlands on a large scale, but it has faced the same economic problems as our process. A fermentation process has also been combined with the production of the amino acid lysine in an attempt to make the total process economically feasible, so far with no success. The price of lysine is too low, and the international production capacity is high.

To study other ways to lower the processing costs we have tried to determine the maximum level of liquid that could be included in the compost, without any leakage of liquid, and the heat production necessary to control the micro-flora.

With 28% dry matter there was no leakage, but the temperature reached only 45° C. With 38% dry matter, however, there was a temperature of 65° C, but the results of these experiments only had a marginal effect on the total processing costs.

Finally, to study yet other alternatives, we have briefly evaluated the energy content in the manure by mean of biogas fermentation and an incineration process.

Biogas production from manure slurry is often a two step process; first a pasteurization step at 70° C, and secondly a digestion step at 40-50° C in which the biogas is produced. As an example one can say that the amount og biogas produced from manure is about 400 l gas/kg dry organic solids. The total energy content of the biogas is about 5.6 kWh/m^3 gas. Energy is consumed in converting the gas to electrical energy, heating the fermentor and operating pumps etc. The proportion of energy available for other purposes has been estimated to be only ~55%. Our conclusion is that it is not economically feasible to produce energy from fermented manure.

One should also be aware of environmental problems related to gas production. Gas emission may be a nuisance and the water effluent from the reactor must be treated for nitrogen, phosphorus and sulphides. In addition, the sludge from the reactor must be removed, stabilized or incinerated. This sludge will contain N, P and to some extent heavy metals.

The energy content of the pig manure itself is 4.7 - 4.9 kWh/kg dry organic matter. This is about the same as the heat produced from the combustion of wood and slightly higher than the energy content of dried sewage sludge. In theory the potential energy yield is about twice as high for an incineration process as for a biogas process. But untreated slurry has a high water content and evaporation of this water will require a considerable amount of energy (0.6 kWh/kg water). The heat of combustion of dry organic matter is not high enough to evaporate all the water in the untreated pig manure. In order to obtain a surplus of energy from incineration, the manure must be dewatered mechanically, which again is costly. Data from burning of sewage sludge indicates that the water load must be low. As a rule of thumb, the dry organic matter content should be more than 50%, in order to obtain self-sustained combustion in a fluidized bed reactor.

On the other hand, incineration normally has a complete burn-out and needs only a simple effluent treatment. Investments for environmental measures, however, represent more than 30% of total investments in modern incinerators.

During our work with pig manure we could not avoid noticing the unpleasant smell that emerges from time to time, due to high concentrations of sulphide and other odour components. This is of course often considered a local environmental problem. Both laboratory and field trials have shown that addition of nitrate to manure storage tanks is an effective method suppressing development of this unpleasant odour.

However, it is not only because it is unpleasant, H_2S is a very toxic gas, and even in small amounts it can be fatal for both animals and human beings. Before the manure is spread on the fields, it has to be stirred in the bins or in the storage tanks to enable pumping into the spreading vehicle in the desired consistency and composition. During stirring, H_2S with a relatively high concentration will evolve, and this may be dangerous both for the farmer and the livestock. In fact, every year animals that are kept indoors die in stables where the manure is stored in the same building. Even people working there have become seriously ill because of such toxic gases.

Some people spend substantial amounts of money on wet composting of manure, which involves the addition of air and intensive mixing for 3 - 4 weeks prior to spreading. This will imply a high risk of H_2S evolution during start-up.

Hydro has now developed a method for adding a tailor made nitrate salt mixture to manure as an effective way of controlling emission of hydrogen sulphide and other odourous compounds. This method is now being introduced in Europe. The trade name of the product is FYMOL (Farm Yard Manure Oxidizing Liquid). The nitrate will oxidize sulphide present in the manure, and prevent further development of sulphide. Other compounds that are controlled in the same way are p-cresole, indole, skatole and etanoic acid.

Contrary to experiences of adding nitrate to municipal sewage, it was surprisingly found that in manure the nitrate would not be rapidly consumed, but react over an extended period of time, lasting several days. Adding nitrate in the form of nitric acid resulted in substantial foaming. Similar problems did not occur with the nitrates.

It has been found that the emission of methane from manure that has been treated with nitrate is lower than that emitted from untreated manure, and that the concentration of ammonium and gaseous ammonia will be approximately the same for both untreated and treated manure.

Emission of N_2O from manure during treatment with nitrate is hardly detectable and seems to be marginal, especially compared to inherent N_2O emission from manure.

No difference in pH has been found between manure treated with nitrate salt according to this invention, and untreated manure.

In conclusion, it is our opinion that manure processing so far is not economically feasible, due to the fact that the products have a very low value compared to the processing costs. However, as a result of legislation, farmers may be left with the choice between reducing production and paying to get rid of their manure surplus. The outcome of course, will depend on meat prices and competition. In some regions, governments may wish to support meat production for self-containment, trade or employment reasons, and therefore subsidize the manure treatment systems. Factors influencing the economics of manure processing are numerous, and calculations must be carried out separately for each situation. Hydro may, however, offer technology for mechanical treatment of manure slurry that produces a stable compost, a liquid nutrient product and pure water.

Waste Reduction In The Fertilizer Industry

Doug Myers
Wratt Program

Introduction

The purpose of this presentation is to discuss some of the problems of and suggest solutions to waste reduction in the fertilizer industry, among others, and the role of the Waste Reduction and Technology Transfer Foundation or simply WRATT - in providing expertise in the environmental issues involved.

The WRATT Foundation is a not-for-profit corporation consisting of a Board of Directors; and Executive Director; a headquarters staff having a Technical Project Officer (P.E.); an Administrative Project Officer, a Chief Editor, and two secretaries; and a field staff. The headquarters staff is housed at the Tennessee Valley Authority National environmental Research Center, Muscle Shoals, Alabama. The field staff consists of about 50 retired engineers or scientists, many of whom were company executives prior to retirement. About 20 member of this staff are registered professional engineers (P.E.). Almost 90 percent of the entire organization are retirees.

The Foundation is structured as a public/private partnership through which industry can participate in funding through private deductible donations, which might be solicited, but never required. The objective of this group is to provide waste reduction plant assessments at the request of plant management; the "plants" include local, state, and Federal government installations. The assessments are free of charge, totally confidential, and non-regulatory in nature; no manager is required to implement WRATT team assessment suggestions. The assessments are multi-media in nature; i.e., they cover wastes in air, water, land, and of energy.

Thus far most of the work of the group has been done in Alabama, although several other states have been assisted in starting similar programs. However, it is the firm intent of the Foundation to become nation-wide in its activities except in states with similar operations.

Background

For several years United States Environmental Protection Agency has recognized the need to *prevent* waste generation as opposed to disposal, or - "end of the pipe" treatment. Most environmental regulations are based on compliance through good process design and good management practice. Thereby, the concept of providing technical assistance in this direction to industry was born. However, it was not possible to ignore end-of-pipe disposal. As a result, grants were made by EPA to set up waste *minimization* programs in each state. In Alabama, retired engineers were recruited and trained in waste minimization techniques. The Tennessee Valley Authority (TVA) and the Alabama Department of Environmental Management (ADEM) joined forces to provide technical assistance to Alabama industry. The group was originally called the Alabama Waste Reduction and Technology Transfer Program.

The Alabama WRATT Foundation program is unique among the states in that its day-to-day operation is independent of any regulatory organization. It began operating in July 1990 and immediately enjoyed acceptance by industry. The TVA-ADEM Memorandum of understanding has only recently evolved into the previously described Waste Reduction and Technology Foundation supported by TVA, ADEM, the Business Council of Alabama, the Alabama Chemical Association, and EPA Region IV. To date, approximately 130 plant assessments have been made. Three of these were made at fertilizer production facilities. Plans are being made to make twenty waste minimization assessments per month. Where cost effective or unique methods of reducing waste are established, these success stories (technology) are transferred to other industries.

The Assessment

By invitation, WRATT teams are selected and appointments are made with plant management to make waste reduction assessments. Usually the plant manager has some specific environmental issues to be addressed. Most often the final question is "How can we reduce our waste disposal costs and our future liabilities?"

Specific waste reduction concerns of management are identified at the entry interview. In fertilizer plants the trend seems to be we toward "zero discharge" or as close to this as possible. After the entry interview, the WRATT team is usually escorted through the plant by the plant engineer or an area supervisor familiar with technical details. In fertilizer plants, the following are typical areas of assessment.

Mass nutrient (N, P_20_5, K_20) balance - from raw materials to products sold - annual basis; include amount of product sold as scrap. Up to about 4% of the raw materials may be unaccounted for. Unaccounted for materials may result from inaccurate measurements of inventory. Therefore, mass balances should be conducted over a three year period for accuracy.

- Mass water balances - from water intake to discharges to sewer or public streams. 10% to 40% of the water may often be unaccounted for.

- Mass steam balance - including recycling of steam condensate and boiler blowdown. Blowing steam leaks are not unusual. Also a 40% to 90% return of condensate was found. Savings can easily amount to $500,000 per year.

- Flow sheets showing quantitative distribution of process materials and wastes. Many times flow sheets are out of date, so it is difficult to follow the process.

- Metering - number of meters and records keeping required to track process materials through the plant. The ability to track materials through the plant is essential to identifying losses and amounts.

- Existence of preventive maintenance programs for steam traps, pipelines, pumps, compressed air lines, and other equipment. In most plants, fertilizer or otherwise, scheduled maintenance does not exist. Savings on the production of compressed air alone can amount to over $200,000 per year.

- Identification of storm water problems - and disposition of run-off. Uncontaminated storm water should not be added to process water adding to the volume for treatment.

- Housekeeping - notations of hoses left running, of leftover maintenance items lying around, of a general lack of neatness in appearance, and of evidence of spills to the ground. It is easy to determine if employees are helping to prevent pollution.

- Detection of the odor of ammonia or other chemicals around the plant. Anytime ammonia can be detected down wind from a plant, there is an unnecessary loss of valuable material.

- Energy conservation - results of any recent electric power utilization survey that may have been made; notation of lights left burning in the day time unnecessarily. Capacitors placed around the plant may improve the power factor and pay back the investment in three months. Savings in power can easily exceed $50,000 per year.

- Note any visible fumes from stacks or buildings (not water vapor).

- Note the workers attitude and their apparent degree of cooperation with management. This past year an assessment was made at a plant (not fertilizer) that had a Positive Employee Philosophy (PEP) in which personnel policies and practices were designed for the 95% productive employees instead of the 5% marginal employee. PEP has a major positive impact on waste minimization.

The plant-experienced assessor knows where to look for indications of loss of process materials and utilities as well as how to question the employees on plant operations. He is aware that plant operators usually know how to minimize loss of process materials and to conserve power so he obtains ideas from the employees on how to reduce waste. The following are typical employee suggestions:

- Total recycle of water - use waste heat to concentrate waste liquors; feed weak liquors as make up feed water where possible; conserve by closing valves when feasible; require this of all employees.
- Clean up spilled solids in the dry state and use water washdown very sparingly into a sump for recycle.
- Keep waste streams segregated so they can be recycled if feasible.
- Computerize certain components of plant operation.
- Establish preventive maintenance programs for utility and production systems.
- Repair all steam and compressed air leaks during plant turn-around.
- Recycle leaked oil (at source), spent oil, solvents, pallets, gloves, and rags through off-site operators.
- Assign responsibilities for water treatment.
- Recover heat from boiler blowdown.
- Insulate pipe carrying high or low temperature fluids.
- Install meters needed for quality control and mass flow balances.
- Recover railcar and truck clean-out and spills; do not landfill.
- Redesign clean out pits to recover solids and prevent contamination.
- Turn off steam heaters and if possible, boilers during summer months.
- Use photocells to turn off outside lighting and motion sensors to control lighting of offices, warehouses, etc.

Following the plant walk-through, the assessor make a list of waste reduction suggestions. Before they leave the plant, the list is reviewed with plant management to make sure that observations made and information obtained were accurate and that the suggestions are appropriate.

As indicated previously engineers with thirty to forty years of plant experience know that employees are often the best source of information. "In plant" waste reduction teams composed of both management and employees are recommended.

By-Product Utilization

By-product utilization for phosphogypsum, fluorine and ammonium sulfate is too lengthy a subject to be reviewed here. The preferred method of disposal is to turn waste into product. A literature search is made for options to dispose of waste. For example, the following may be made for phosphogypsum:

- Conversion to sulfuric acid and road-bed material.
- Conversion to cement and sulfuric acid.
- Conversion to calcium nitrate and ammonium sulfate.
- Use directly on land as a source of nutrients.
- Neutralize and return to the land.

Milorganite Update

Al Nees

Milwaukee Metropolitan Sewage

In our discussions regarding the use of recycled waste products as Natural Organic fertilizer sources, I think it is important to provide an accurate historical perspective with respect to one, if not the oldest commercially available recycled products—Milorganite. Also, I will discuss in general the manufacturing process of Milorganite; and conclude with what we feel are some of the keys to our continued success.

Approximately at the turn of the century, wastewater treatment in Milwaukee, Wisconsin, as well as in most communities was non-existent. Sewage was routinely discharged into rivers and lakes, with the belief that "dilution was the solution to pollution". For a long while it worked, too. But soon the inevitable caught up, and the public soon forced some action. The Milwaukee Sewerage District was formed by State Legislation in about 1913, and they began to research technology to adequately treat wastewater. In Great Britain, the "Activated Sludge Process" was in the developmental stage, and the process showed great promise toward water purification. The technology was further refined in Milwaukee, and construction began on the largest wastewater treatment plant at that time in the world.

The "Activated Sludge" process will be discussed later, but the end result of the process is, of course, clean water; and an organic biomass called sludge (or Biosolids as is now frequently used). The Sewerage Commission had the vision at that time to understand that this biomass would present a disposal problem sooner or later and began to work with the University of Wisconsin-Madison to develop some sort of beneficial re-use method under Dr. Emil Truog. O.J. Noer was named to carry out the work, and he recognized that the nitrogenous material closely resembled the characteristics commonly found in high quality organic fertilizers available at the time. He conducted research on field crops and vegetables, but found that other fertilizers provided better results. His attention turned to lawns and golf course turf, and the product produced far superior results to other available products. Technology was developed which is still in use today which processes the wet biomass into a granulated material suitable for uniform application and handling. In 1925 the product was named Milorganite (MILwaukee ORGAnic NITrogEn), and in 1926 the first shipments began.

The common perception is that Milorganite, and similar products, is simply dried human waste. While clearly the commode does provide one of the organic sources of solids treated at the plant, raw materials come in far larger masses from the industrial community in Milwaukee including the beer industry, leather industry, yeast manufacturing, etc. A quick tour of the plant should provide more insight as to the biochemical and physical processes involved in the manufacturing process.

Wastewater enters the plant and is screened to remove large debris. The water then flows by gravity through "grit chambers" which allow settling of sand and heavier particles. This material is removed to landfill. The water then flows to "primary clarifiers" which allows further settling of solids, and grease and scum are removed.

The water travels to "Aeration Tanks". This step represents the true "Activated Sludge" process. In this critical process, naturally occurring microorganisms are introduced to the wastewater. Using the organic compounds in the water as a food source, and in the presence of oxygen, they rapidly multiply. After sufficient retention time in the tanks to consume the solids, remaining water is centrifuged leaving clean water and a biomass of microorganisms. The clean water is chlorinated and discharged to Lake Michigan.

The biomass is conditioned with Ferric Chloride, and sent to the Vacuum Filters where water is removed and sent back to the wastewater side for treatment. The filters remove sufficient water to take the biomass from 2% solids to 15% solids leaving a wet cardboard-like material called filter cake. (The vacuum filters will be replaced by belt filter presses in the new plant to increase efficiency.)

The filter cake is removed from the outside of the drum, and transported via belt to the top side of the dryers where the amount entering each dryer is metered. The dryers are 60 feet long, and mounted on a slight angle. Thus, as they rotate, the product cascades slowly from top to bottom which takes about 45 minutes. Heat is primarily provided from waste heat produced from the generators which power the plant. This is sufficient to supply each operating dryer with temperatures at about 850 degrees Fahrenheit. Additional heat may be obtained by burning natural gas to raise the temperature to 1200 degrees.

The product is now only 5 % moisture, and free of any pathogens and/or weed seed, etc. It is sent to a screening process with over- and under-sized particles reprocessed, and desirable material sent to silos for storage. From there it is sent either bulk in railcar or truck to fertilizer blenders, or sent to a contracted facility for packaging and storage. Again, bagged Milorganite is shipped either by rail or truck from there to distributors nationwide.

After 67 years in the market, and with sales virtually consistent with production, something must be going right. We think there are 4 primary keys to the success of the Milorganite program. Specifically, they include reliability of supply, consistent product quality, exceptional customer service, and a competitive price.

In the competitive marketplace today, it becomes more important to be a reliable supplier. "Just in time" strategies are employed at several levels in the distribution chain; and, if product is not available, consumers have more choices than ever as a substitute product.

Consistent product quality is perhaps Milorganite's biggest asset. It is, in fact, virtually the same product as it was 67 years ago. Additionally, the old dryers were copied exactly for installation into the new plant to ensure product produced next year will be the same as it is this year. The analysis of the product has not seen significant changes over the years, so customers have no confusion as to how the product should be used. If anything, quality has improved by taking measures to significantly reduce dust, and improve particle size uniformity. This is perhaps as good a time as any to interject very brief comments about Milorganite and "Heavy Metals". Yes, Milorganite contains heavy metals, so does nearly every synthetic and natural fertilizer on the market today. Thanks to aggressive pretreatment programs in Milwaukee, metals levels have, in fact, been reduced far enough to favorably compare with most fertilizer products currently on the market. Cadmium levels are below 5 mg/kg on an annual average as an example. You will hear more specifics regarding metals concentrations in subsequent papers.

Finally, we feel that the product must be competitively priced particularly with direct competition in the natural organic market, but also must show value when compared to the market in general. It does have significant value, and the fact that we have survived this long, and in fact see growth in several markets is testimony.

In conclusion, Milorganite is probably the least understood product in the fertilizer marketplace, and certainly has weathered its share of criticism over the years. However, its success cannot be challenged, and the program still remains as a standard for recycling waste into a beneficial re-use product.

Marketing Bio Solid Products Under U.S. EPA-503 Regulation

Jane Forste
Bio Gro Systems

Final U.S. EPA "Standards for the Use or Disposal of Sewage Sludge" were published in the February 19, 1993 *Federal Reaister* (40 CFR Part 503). The 503 Rule establishes standards for land application, surface disposal and incineration, including pollutant limits, management practices, monitoring and recordkeeping, and reporting requirements. Compliance with Part 503 standards is required within 12 months of publication (i.e., by February 19, 1994) unless new pollution control facilities must be constructed to achieve compliance which extends the deadline by an additional 12 months. The Rule is written to be "self-implementing"— the standards are in effect and enforceable whether or not a specific permit is issued under EPA's companion 501 program for permitting facilities and projects.

The land application requirements of 503 contain the requirements for all forms of applying bulk or bagged biosolids to land for beneficial uses at agronomic rates. Such uses include: application to agricultural land used for producing food, feed and fiber crops, pasture and rangeland; non-agricultural land (e.g., forests); public contact areas (e.g., parks, golf courses); disturbed land (e.g., reclamation sites); and home lawns and gardens. Sale or give-away of biosolids products, which is the primary focus of this paper, is addressed under the land application portion of the Rule.

The 503 Rule applies to anyone who prepares biosolids for land application or applies them to the land. These parties are required to obtain and provide necessary information to show compliance with the Rule. For example, the person who prepares (treats) biosolids for sale as products must test and maintain records of the testing of these products to show compliance with (1) pollutant concentration limits (i.e., metals) and (2) pathogen and vector attraction reduction requirements.

Pollutant Concentration Requirements

Part 503 contains four tables which define pollutant limits which must be met for various land application alternatives. All biosolids applied to land must meet the "ceiling concentrations" for pollutants contained in Table 1 of §503.13 of the Rule. These maximum concentration limits regulate 10 metal pollutants: arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium and zinc. If any one of the ceiling concentrations for these pollutants is exceeded, the material cannot be applied to the land.

Table 2 in the summary above applies to bulk material which does not meet the limits set in Table 3. Under this scenario, biosolids may be applied in bulk form so long as the "cumulative loading" on specific sites is tracked and records are maintained of the amounts applied to those sites. Such materials must also be applied in accordance with specific management practices contained in 503 as they pertain to land application. These management practices include: a setback from surface waters and applications so as not to impact wetlands, water of the U.S. or endangered species, and at agronomic rates. Obviously, such requirements make it more difficult for such products to be used widely as a marketed product. By meeting the EQ requirements of Table 3, however, biosolids can be applied as freely as any other fertilizer or soil amendment to any kind of land.

Figure 1 illustrates the various options for biosolids uses under the 503 pollutant limit tables.

Pathogen and Vector Attraction Reduction

In addition to the pollutant concentration limits established in 503, the preparer must also establish that pathogens (disease-causing organisms) have been eliminated from a product which will be marketed to the general public. Similarly, vector attraction reduction requirements are imposed to insure that these materials will not attract flies, rodents or other potential vectors which can transmit pathogens. The Class A pathogen and vector attraction reduction produce an essentially pathogen-free material which is not subject to inoculation and regrowth of such pathogens before it is used.

For materials which do not meet Class A requirements, a less stringent level of pathogen reduction (Class B) ensures that public health will be protected by imposing additional site restrictions on the use of such materials. These biosolids are generally land applied under various state (and now federal) programs for specific permitted sites. This kind of traditional land application will most likely continue in much of the U.S. with distribution and marketing being reserved for the products which are treated to the more stringent Class A pathogen reduction—particularly those which meet the EQ pollutant concentration limits and can be marketed along with other agricultural, horticultural or specialty products.

Current technologies which achieve Class A pathogen reduction include: composting, alkaline treatment and heat drying. Each of these processes results in a different type of product with distinctly different markets and potential uses.

Biosolids Products

Compost results from the aerobic biological decomposition of the organic material contained in biosolids, usually with the addition of another organic material, such as wood chips or yard trimmings. The resultant material is similar to peat moss in appearance and is a valuable organic soil amendment which has found a market niche with landscapers and horticulturists in many parts of the U.S. Compost can also be used on agricultural land, particularly in arid climates with soils that are depleted in natural organic matter. The nutrient concentration (i.e., nitrogen) in compost is considerably less than that of the original biosolids, but does offer an additional organic source of nitrogen for these various applications.

Biosolids treated to Class A pathogen reduction levels using an alkaline material (e.g., quicklime) result in a source of agricultural lime (with additional nutrient value) or a material which can be used as a cover material for landfills. To date, marketing such materials has occurred mostly in relatively restricted geographic areas because of the bulk of the material and the moisture content (up to 50%).

Heat drying reduces the volume of biosolids more than any other Class A treatment and retains more of the original nutrient value, specifically organic nitrogen. Figure 2 illustrates the value of organic nitrogen from biosolids as a slow-release nutrient source. The time/temperature requirements required for Class A pathogen reduction result in a pathogen-free product which also meets vector attraction reduction requirements because of its dryness (generally greater than 90% solids). Such a product is compatible with other bulk dry fertilizer products and, as noted above, if it meets the pollutant concentration limits contained in §503.13 Table 3, can be marketed by itself or blended with other materials.

Tables 1 and 2 show typical analyses of heat-dried biosolids pellets.

TABLE 1

Typical Pellet Analysis - Metals

	mg/kg
Arsenic	2
Cadmium	8
Chromium	60
Copper	650
Lead	200
Mercury	1
Molybdenum	11
Nickel	60
Selenium	3
Zinc	700

TABLE 2

Typical Pellet Analysis - Nutrients

	%	
Calcium	2.0	
Iron	1.5	
Nitrogen	5.0	(90% Water Insoluble)
Phosphorus P_2O_5	4.0	
Potassium	0.5	
Sulfur	2.0	

There are a number of factors which may assist in developing a market for biosolids products in the next few years. The pollutant concentration limits developed for 503 are based on a rigorous risk assessment for various exposure pathways to sensitive individuals. Using worst-case scenarios, EPA established the final standards in the 503 Rule as a result of significant input from the scientific community of agricultural researchers, as well as risk assessment and environmental scientists throughout the U.S. The 503 Rule, therefore, represents the most comprehensive risk-based rule that EPA has ever undertaken. As such, it will provide a model for environmental protection programs and policies affecting agriculture in the future. Because this Rule is in the forefront of such efforts to control non-point source pollution, it will most likely become a benchmark by which other products and practices are managed.

While the total amount of biosolids generated in the U.S. would provide less than one percent of the nitrogen needed to fertilize cropland in the U.S., it can provide a unique recyclable resource in the form of an organic fertilizer product. The only other similar sources of such materials are animal wastes or crop residues (e.g., legumes) which generally tend not to be distributed as a product in the marketplace.

Table 3 in §503.13 contains the pollutant concentration limits which define a material which does not require additional regulation under 503 (provided this material meets Class A pathogen reduction requirements and is treated to reduce vector attraction). Such biosolids have been designated as Exceptional Quality, or EQ, and are not subject to any loading limits, management practices or other requirements once the preparer has established that the metal levels and treatment requirements have been met. Such a material can be sold in bulk or as a bagged product with no restrictions or controls on its use.

Materials which do not meet these Table 3 limits may also be land applied as a bulk product or in "bags or other containers", with some additional regulatory requirements. EPA defines "other containers" as open or closed receptacles, such as buckets, boxes, cartons or vehicles with a load capacity of one metric ton or less. Bulk material is not sold or given away in a bag or other container but is applied to sizable land areas (e.g., agricultural land) and generally in larger quantities. Bulk biosolids may also be distributed through a network of manufacturers of other fertilizer products who provide them to individual farmers.

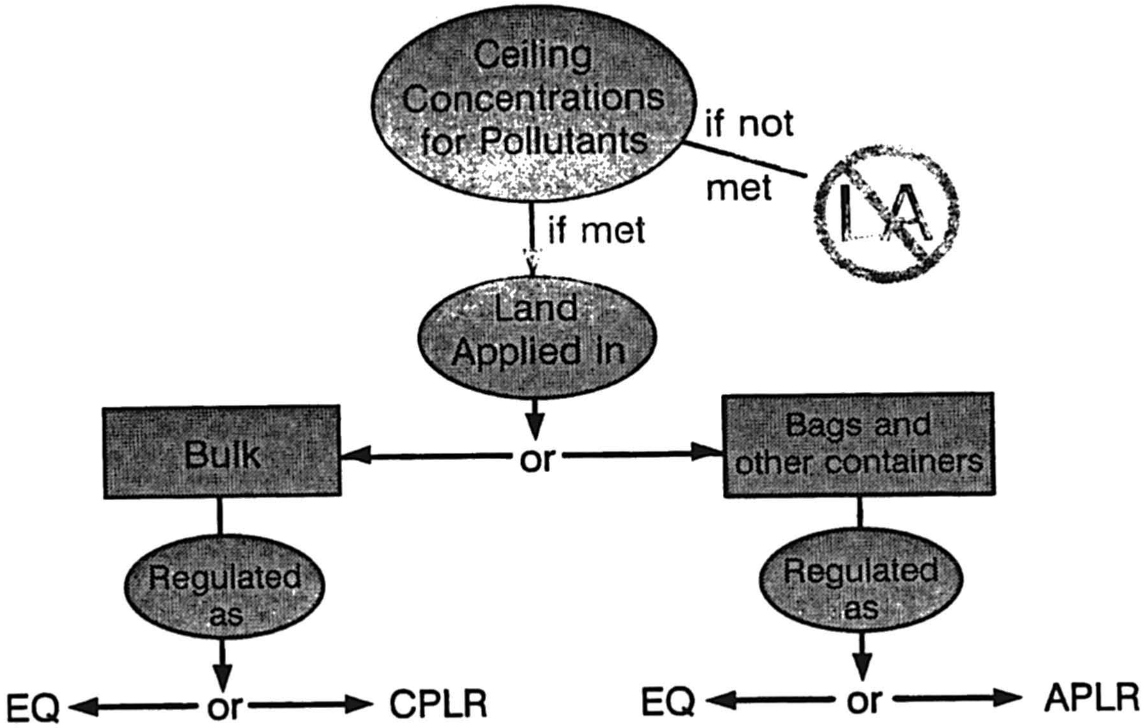
Biosolids products which do not meet the Table 3 (EQ) pollutant limits may be sold or given away *only* in bags or other containers (not as bulk material) and must be accompanied by a label which specifies the appropriate management practices and quantities which may be applied to conform to the "annual pollutant loading limits" (APLR) contained in Table 4 of §503.13. This option allows for marketing of biosolids products with the provisions that the consumer be given adequate information to meet the requirements of 503.

Numerical pollutant criteria established by the Part 503 Rule for the land application options are summarized below:

Numerical Criteria for Part 503 Rule

	Table 1 Ceiling (mg/kg)	Table 2 Cumulative Loading (kg/ha)	Table 3 EQ Limit (mg/kg)	Table 4 Annual Pollutant Loading (kg/ha/yr)
Arsenic	75	41	41	2.0
Cadmium	85	39	39	1.9
Chromium	3,000	3,000	1,200	150
Copper	4,300	1,500	1,500	75
Lead	840	300	300	15
Mercury	57	17	17	0.85
Molybdenum	75	18	18	0.90
Nickel	420	420	420	21
Selenium	100	100	36	5.0
Zinc	7,500	2,800	2,800	140

OPTIONS FOR BIOSOLIDS USES



Ceiling Concentrations for Pollutants

if not met

LA

if met

Land Applied in

Bulk

or

Bags and other containers

Regulated as

Regulated as

EQ or CPLR

EQ or APLR

Figure 1

NITROGEN RELEASE/UPTAKE

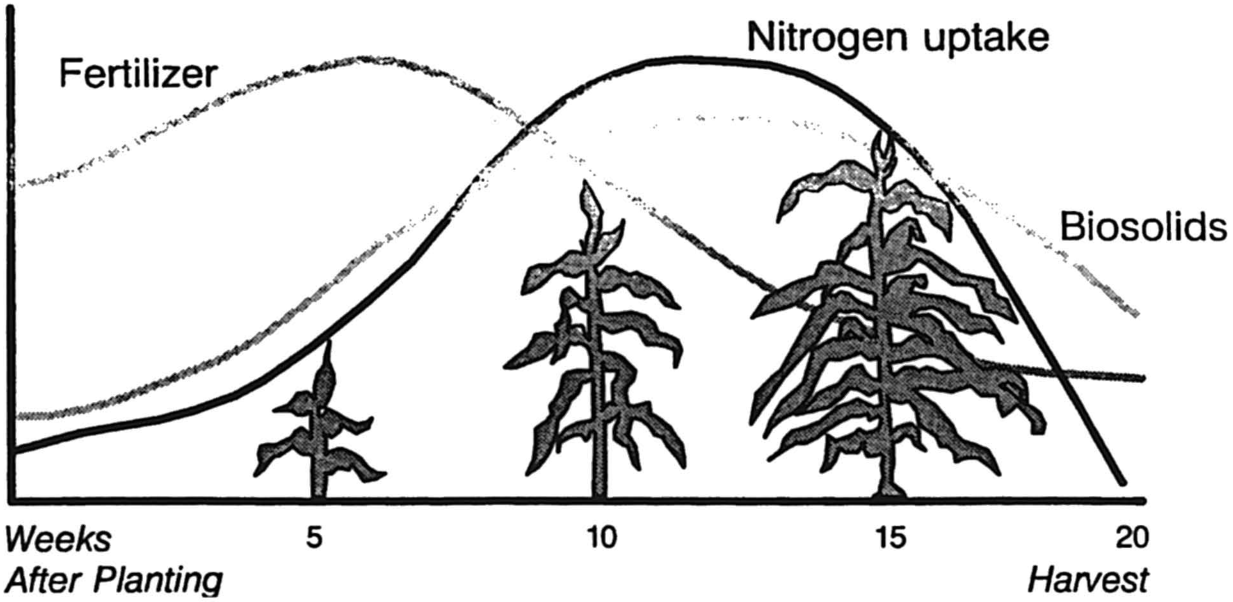


Figure 2

Tuesday, October 26, 1993

Session IV
Moderator:
James C. Brown

The Importance of Fertilizer Quality to Agronomics & Environmental Concerns

W. Shaw Reid
Cornell University

Agronomic Requirements For Quality Fertilizers

The majority of the agricultural soils in the U.S. have been fertilized annually for several years. This has increased the soil test phosphorus levels. The increase in the phosphorus level has lead some people to the false impression that the need for all fertilizer has decreased. The need for plant nutrients such as nitrogen is as large as ever. The current need is to supply the exact quantities of nutrients at the proper time and place to insure near maximum plant utilization. No longer can we apply excess quantities of nutrients to replace the need for proper nutrient management. Exacting prescriptions of plant nutrients must be supplied for economic, education, visual, and environmental reasons.

Why Do We Use Fertilizers

I had not put much thought into the question of "Why do we use fertilizer?" until recently when the New York Commissioner of Agriculture asked the question. The Commissioner is a dairy farmer and has used fertilizers for many years. He was not asking the question because he did not know, but responding to questions he had been getting from the general public about the use of fertilizers. The simple answer to the question is: "We use fertilizers to help plants to grow better."

Why Do We Want To Make Plants Grow Better?

First and most important, we use fertilizer to produce higher yields of high quality food in an economical manner. Second, we want the growers to make sufficient money to pay last year's bills and continue in business. However, these aren't the only reasons to use fertilizers. Healthy plants obtained by adding fertilizers make them more resistant to disease, drought, and other stresses. We want our plants that look their best. The lawn care and greenhouse business are based upon producing plants that are pleasing to the eye. We also want our food to look good, as well as to be nutritious. Good looking, high yielding plants require an adequate supply of plant nutrients applied at the proper time and place in the life cycle.

Objectives In Using Fertilizers

Our objectives in using fertilizers is to provide the plant with the needed nutrients at the recommended rate, at the appropriate time, in an economical manner, and with a minimum of environmental impact. These objectives require consideration of much more than obtaining higher yields and healthier plants. We must consider the farm or place in the environment where any nutrients in excess of the plant requirements will end up and the potential for environmental damage those nutrients might cause.

Nutrients Needed in Fertilizers

There are 16 elements known to be required for plant growth and reproduction. Fertilizers are commonly used to supply up to 13 of the 16 nutrients. There are others, such as silicon, that, under certain situations, may produce better growth, but are not universally required for both growth and reproduction. These other elements are also sometimes supplied in fertilizers. Fertilizers do not supply carbon (C), hydrogen (H) or oxygen (O). They are taken from the water and air.

Seldom are all 13 nutrients required in a single fertilizer for crops growing in the field. Usually, some, if not most, of the nutrients are adequately supplied by the soil. Soil testing, plant analysis and research results assist in the decision about the nutrients that must be supplied with fertilizers for optimum crop yields.

Common Nutrient Requirements For New York

The soils of New York vary from old beach ridge sands with little organic matter to clays. The most common soil texture is silt loam. The primary clay mineral is illite. The organic matter varies from below 1% to 100% for some muck soils. The average organic matter is about 3%. Our commercial farms range from dairy farms growing corn, alfalfa, small grains, and pasture, to vegetable farms growing lettuce, tomatoes, cabbage, etc., to orchards, especially apples, and to greenhouse operations such as bedding plants, roses, etc. This wide range of soils, crops, and climates require a variety of fertilizer formulations.

The most common fertilizer nutrient requirement is nitrogen. N is needed on the highest number of acres and for non-legume crops, such as corn and grasses, at the highest rate per acre. Thus, nitrogen accounts for the largest fertilizer volume in New York.

Phosphorus is the second most deficient plant nutrient world-wide. In some areas of the world where fertilizers have not been used, P is the most deficient nutrient. About 25% of the soil tests in New York are low to very low in phosphorus. However, relatively few of the intensively cultivated soils are low in phosphorus. It is very difficult to find a cultivated area on farms sufficiently low in phosphorus to obtain an economic response beyond a small amount placed in a band at planting. It is more common to find soil test phosphorus values well beyond the range where an economic response is expected.

The potassium requirements are dependent upon soil, crop, season, climate and economic yield. Potassium is required in the largest amounts by legumes such as alfalfa. Some vegetable crops need very high soil test levels because of small root systems and poor uptake efficiencies. The illite clays supply large amounts of K. It is somewhat complicated to make the most economical potassium fertilizer recommendations. Most NY soils need some K for optimum yields. The sandy and muck soils need relatively high rates.

Supplemental zinc fertilizer is required by corn, some vegetables, especially sweet corn and beans, and tree crops such as apples and pears. About one-fifth of all soil tests show a need for zinc applications for corn. One large application (about 10 lbs/A of Zn) can supply the zinc requirements for several years.

Boron responses have been obtained on alfalfa, several vegetable crops, and tree crops especially those growing on coarse-textured or muck soils. The boron needs to be supplied annually in small amounts. The other micronutrient requirements are less common and usually required in smaller amounts. Copper is recommended for onions on muck soils. Manganese is required on high pH muck soils for several crops. Iron makes the turf greener and is required for some crops growing on high pH soils. Fertilizer sulfur may be required for some vegetables, especially on coarse-textured soils very low in organic matter. If these soils are down wind from a coal burning power plant, they do not need any more sulfur.

Most of the soils of New York are acid and require lime for optimum production. Only a few of the soils would be sufficiently low in either calcium or magnesium that they would be needed as a nutrient rather than as a lime material needed for pH control.

Fertilizer Considerations In Addition To Crop Yields

We must also consider the **ENVIRONMENT, COSTS AND RETURNS, AND USE OF RESOURCES** when making fertilizer recommendations. Likewise, the composition of the fertilizer relative to the placement and timing influences the recommendations.

Most agronomists are accustomed to considering the crop yield and soils when making fertilizer recommendations, but the environment must also become a major consideration for every recommendation. The primary environmental concerns from plant nutrients are 1) nitrogen in surface waters, 2) nitrogen, especially as nitrate, in the groundwater, 3) phosphorus in the surface water, and 4) nitrogen volatilization into the atmosphere as ammonia.

N in surface waters resulting in excessive algae growth are called blooms. The water turns green when the algae are growing and brown when they die. The decaying algae removes the oxygen from the water. This may result in fish kills, odors, and unsightly appearances.

Almost all of the rural population and about 50% of the urban population depend upon groundwater for their domestic water supply. The health standard of 10 ppm N as nitrate in the ground water is very easy to exceed in some soil and cropping situations. Nitrogen must be managed very carefully in certain critical areas if excessive nitrate levels are to be avoided. It's surprising that nitrate was not found to exceed the 10 ppm standard more often in the recent EPA study. It means nitrate is being removed from the rooting zone and/or ground water in some manner, probably denitrification.

The soluble P in the water runoff results in algae blooms (lake eutrophication), but the soluble P usually does not represent a large quantity of P. Phosphorus adsorbed on the soil particles and erode into shallow surface waters promotes the growth of rooted water plants. It can also contribute to the soluble phosphorus fraction in the water. Adsorbed P is often the only measured source of P entering lakes, yet it often does not contribute very much to the problems identified as lake eutrophication for deep lakes. We need further understanding of the relationships between soluble P, adsorbed P, and plant growth in the lakes.

Volatilization of N as ammonia has not been of major concern to EPA and other agencies because no one knew how much N was volatilized from soils, fertilizers, crops, or manures. Likewise, we don't know how to determine the volatilization losses. As we learn more about the volatilization losses and become concerned about atmospheric gasses, ammonia volatilization will receive more attention and study. Currently, losses by volatilization probably help to prevent excessive nitrate leaching on many of our dairy farms by removing some of the excess inorganic nitrogen.

Why The Groundwater Nitrate Problem?

In October after harvesting a corn crop that had been adequately, but not excessively, fertilized; 25 to 50 lbs/A of N as nitrate can be found in the rooting zone of the soil profile. Some of this nitrogen was left because the corn crop is incapable of removing all the soil nitrogen. Some of the nitrate was mineralized from the soil organic matter after the corn stopped taking up nitrogen. With a ground water recharge rate of about 10 inches per year, leaching 25 lbs/A of N as nitrate is sufficient to produce about 10 ppm nitrate in the ground water. Thus, with the best nitrogen uptake efficiencies of corn, with the proper placements etc. the ground water can have the maximum nitrate concentrations permitted. This, of course, assumes all the nitrate is leached. We think that on many soils, little of the nitrate is actually leached, but is denitrified. In some cases, a major dilution of the ground water occurs from low nitrate sources such as forests. The conclusion that most of the nitrate is lost by denitrification is difficult to prove, but in many areas the ground water would contain much more than 10 ppm of N as nitrate if all the lost N were leached. The EPA study shows that most areas are not greater than 10 ppm. Nitrate leaching through an open soil profile does occur, and in some areas nitrate in the ground water is a major problem, such as Long Island. Agriculture contributes to the problem, but is not the only source. Agriculture was shown to contribute a lower quantity of N than most people perceived. Our agricultural methods must be adjusted to prevent the perception as well as the practices that result in excessive pollution.

Estimating Fertilizer Nutrients Required

The quantity of each fertilizer nutrient that should be applied depends upon the nutrient, crop, soil, yield potential, crop rotation, and the soil fertility status as determined by a soil test. Each state has some form of fertilizer recommendation or suggestions associated with the soil test system. Cornell has two principal publications that deal with field crops: (1) *Field Crops & Soils Handbook* which describes how the recommendations are made and the soils and other cultural practices which influence the recommendations. The Handbook, which is updated every 5 or 6 years, contains mostly those basic concepts that are not likely to change very rapidly and help to support the actual recommendations. *(2) Cornell Recommendations for Integrated Field Crop Management is* an annual publication. It contains the recommendations for fertilizers, chemicals and varieties more likely to change regularly. The better the information a grower has to use in making a decision, the more likely he will make the correct decision.

The Cornell Nutrient Analysis Laboratories is computerized for both data collection and recommendations. The computerized soil testing system is based upon obtaining accurate and complete information about the crops to be grown, soil, rotation, manure additions, and cover crops from the grower or fertilizer representative, as well as the results from chemical test results. Someone must fill out a background information sheet accurately and completely if a fertilizer recommendation is to be printed from the computer.

An estimated yield curve is computed for the soil, crop, and climate. The information used to produce the estimated yield curve is obtained through research on the soil or similar soils within the region. The fertilizer rate is estimated using the philosophy that the last pound of fertilizer must produce sufficient yield at the current prices to pay for itself and its cost of application. Normally the application costs are not charged because the application charge was made for the first increment of fertilizer.

There has been some suggestions to charge the fertilizer with the possible environmental damages associated with its application. There would be either a charge to the industry, or a tax on the fertilizer. This is a simple way to change fertilizer economics, thus influence its rate of use. Education on environmental effects of plant nutrients is a more desirable approach to the problem from the standpoint of the industry and producer.

Response of Corn to Sidedressed N Following an Alfafa SOD

Using the yield response curve, costs, and returns, the most profitable quantity (range) of fertilizer is computed as shown in the following graph (Figure 1). Four years of corn were grown on a Honeoye soil following alfalfa.

The most profitable fertilizer nitrogen rate is shown as the solid squares plotted on each corn yield curve (Figure 1). Notice that a relatively small quantity of about 25 pounds of N is needed to obtain maximum economic yield the first year after plowing an alfalfa sod. The quantity of N required for maximum economic yield increases each year until the rate maximizes in the 4th year. This experiment was conducted for 6 years; by the 4th year the effects of the alfalfa sod had disappeared. This illustrates that the alfalfa sod contributes nitrogen to the corn crop each year for 3 years. Similarly, the nitrogen contributions from the organic portion of a manure application lasts for 3 years. On most dairy farms, manure may be applied to the last year of the alfalfa sod in addition to each year of corn. In the 4 years of alfalfa followed by 3 years of corn rotation with manure applied annually for corn, the fertilizer N requirements are reduced to 20 to 40 lbs/A.

This data illustrates why it is so easy to overfertilize after the addition of manures and/or a legume crop. Most people do not know or believe a green manure crop or manure supplies that much nitrogen for a period of 3 years. When the grower has to pay for all of the N by the pound, he does not consistently over fertilize because the current economics in agriculture do not permit it. When the N is essentially “free” to the crop because the manure must be removed from the barn, it is easy to say “Just to make sure, I think I’ll sidedress with an additional 50 pounds/acre of N.” It also will make the corn look greener and appear to produce a higher yield. It will also leave more N in the soil to produce higher potentials for nitrate loss to the ground water. These are the types of fertilizer applications that must be avoided.

When Should The Fertilizer Be Applied?

The timing of the fertilizer application depends upon the quantity of fertilizer recommended, fertilizer source, crop, soil, climate, and management factors. For humid climates, fall fertilizer applications for spring planted crops are probably inappropriate both from an economic as well as an environmental standpoint. Fall fertilization in a more arid environment may be a management alternative. However, even in somewhat arid environments the probability of N loss is greater for applications applied months in advance of crop uptake. In New York, recovery by corn of fall applied N is only 0 to 25% as high as summer sidedress. The recover by winter wheat is 10 to 40% as high as spring topdress.

Because of the cold and often wet soils of the northeast, a band placed starter of a small amount of N and K are recommended for field crops. More than about 75 lbs/A of N and K in the starter band may result in some injury to the seedling. Nitrogen rates greater than the starter are recommended as post plant applications. It is common for growers to apply N just prior to planting, but the efficiency of the preplant applications average only two thirds as efficient as summer sidedress. The N loss from preplant applications has varied from 0 to 96% in our studies. Thus, we recommend that growers apply the N needed beyond a starter as a summer sidedress. However, only about 50% of the cash crop growers and almost none of the dairy farmers use sidedress the major time for N applications.

Organic vs Inorganic

Nitrogen Sources. Listening to the sustainable and/or organic agriculture discussions, one gets the impression that using only organic sources of plant nutrients such as green or animal manures would solve all the problems relating to nitrogen loss to the environment. However, it is much more difficult to manage organic sources of N to obtain near optimum yields without excess nitrogen remaining in the soil after harvest. Sufficient organic N must be applied for mineralization to supply the nitrogen needed by the crop during the growing season. There likely will be more mineralized inorganic nitrogen remaining in the soil in the fall after an inorganic source of N is used than under a properly managed inorganic fertilizer program. Some of the organic nitrogen will be converted to nitrate after the crop stops taking up N, thus leaving extra nitrate in the soil for possible loss prior to the next growing season. The inorganic fertilizer use by the crop can be predicted more accurately, thus leaving less N in the soil. This does not mean we should not use organic sources of N. A combination of organic N and inorganic N produces a better balance than either alone. With the combination, somewhat less organic N is added than is required to meet the crop needs. The remaining N is applied as inorganic fertilizer at the proper place and time to complete the crop requirement.

Presidedress SOD Nitrate Test (PSNT)

The Presidedress Soil Nitrate Test (PSNT) is the determination of soil nitrate within the corn rooting zone when the corn is about 6 to 12 inches in height. Its purpose is to estimate the N requirement for corn that needs to be applied sidedressed. The test appears to accurately estimate if additional nitrogen beyond the soil supply and manures is required. For New York, the Cornell recommendations based upon soil, crop history, and manures applied have been slightly more accurate in predicting the actual quantity of nitrogen required than PSNT. The PSNT does give more information to use to convince the grower not to add "insurance" N in addition to the manures.

Fertilizer Placement Relative to Composition

Fertilizer composition must be considered when we discuss placement. The fertilizers should be placed in the soil in a position that will optimize their use by the plant, minimize their loss to the environment and not be toxic to the seed, seedling, or plant roots. As an extreme example, anhydrous ammonia must be injected into the soil and sealed to prevent the ammonia from escaping and burning the growing corn plant. The ammonia placement has to be far enough away from the plant to prevent root injury. Several application methods have been adopted to prevent injury. These vary from injection between the rows of growing corn to preplant plowdown with the ammonia released under the plow sole to widely distribute the N.

The chemical characteristics of other sources of nitrogen influence their placement and corn yields. The data in Figure 2 show the corn yields averaged over 2 years at 60 and 120 lbs/A N rates for an experiment grown on the Aurora Research Farm, Aurora NY during 1975 and 1976. The yields show that all sources of N do not produce the same results unless placed in the position to produce optimum uptake. The surface placed urea and 32% N solution produced lower yields than ammonium nitrate. When the 32% N solution was injected and loss of ammonia from the urea was minimized, the yields were equal to the ammonium nitrate. Thus, for two or more sources of nitrogen to produce similar yields, the N sources must be placed in the position most advantageous for the chemical composition of each source.

Fertilizer Injury

The total fertilizer tonnage sold in NY has remained at about 600,000 tons for several years. The nutrient content in the fertilizers has steadily increased reflecting the use of higher analyses fertilizers. With the fertilizer compositions necessary to produce the higher analyses materials, it is easy to cause injury and/or reduce yields by band placing the fertilizer. Often farmers have complained that they do not get response to band placed fertilizers. The lack of response could result from soils so fertile that no response was expected, the climate did not favor a response, or the wrong fertilizer material was placed in the band. Urea and/or diammonium phosphate in the band at rates exceeding about 20 pounds per acre of N or phosphate can be toxic to the plant. Other fertilizers such as monoammonium phosphate, ammonium nitrate, or ammonium sulfate are not as harmful to the plant at similar concentrations. The fertilizers to be used in the fertilizer band should be specifically formulated for that purpose. This probably means that we should have a guarantee of chemical composition and particle size in addition to plant food. The grower should at least specify the composition of the materials to be used for blended products for band placement.

Band placed fertilizers produce large yield responses in winter grains when the soil test phosphorus is either low or medium. The phosphorus helps to reduce or prevent winter injury. Nitrogen without phosphorus on winter barley or wheat results in excessive winter injury and lower yields. Band placed phosphorus with a small amount of nitrogen results in the best winter survival and wheat yields.

Corn response to band placed phosphorus is less predictable. On a medium soil test phosphorous level, early planted corn should produce a yield response to band placed N and P 2 or 3 times in 10 years. On high soil test P soils, the band placement response is only about 1 in 10 years. This response is sufficiently large to produce an economic return over the entire 1 year period. The later the corn is planted (the warmer the soils), the less likely the placement response. Likewise, the early season growth response of plant height occurs much more often than does a grain yield response.

Potassium Requirements

Crop response to potassium is dependent on the type and quantity of clay, the rooting depth, the potassium requirement of the crop, the ability of the crop to remove K from the soil, the yield potential and other factors. The clay minerals in the soils of New York are primarily illitic types; therefore, the clay fraction has a high potassium supplying power. The sandy soils have very little clay, and have a low potassium supplying power. The most common soil texture is a silt loam which has a very high potassium supplying power. In general, legumes have higher potassium requirements than grasses and corn. Usually small seedlings have a relatively low potassium requirement; therefore, band placement of K is not as important as N and P. To make a potassium recommendation we need to know the crop, soil, yield potential, and soil test potassium level. Potassium does not appear to have adverse environmental effects; therefore, potassium is usually applied in a manner most convenient to the grower.

ZN Deficiency

Zinc deficiency in corn appears in the early season as stripping (alternating light and dark green stripes) on the leaves of the corn plant at about the 4 to 6 leaf stage. In an experiment on the Mt. Pleasant Research Farm, about a 20 bu/A corn yield response has been obtained from adding Zn. The Zn is most effective when mixed with an entire plow layer rather than placed in a fertilizer band. About 10 lbs/A was sufficient to supply zinc for several years. Applying the zinc in the fertilizer band was much less effective, but if band applied and plowed for several years, the zinc responses become similar. About 15% of the NY soil tests were low to very low in zinc for corn.

Soil pH

Most NY soils are naturally acid and soil pH remains as a soil fertility problem. The acid soil factor is not quite as serious as it was several years ago. Currently, over 50% of soils need lime prior to alfalfa establishment. Without lime on acid soils the alfalfa winterkills losing stand, hay yield, and hay quality. This problem is easy to eliminate. Establish a regular soil testing program and follow the liming recommendations. Without an adequate soil pH the recommended fertilizers do not produce the expected yield responses leaving nitrates in the soil available for loss to the ground water, as well as lower economic returns.

Summary

During this discussion a series of constraints have been placed upon the use of fertilizers in crop production. These constraints have involved the need for and dependence upon the availability of quality fertilizers. The high quality is necessary to apply the correct rate and uniformity of application necessary to match the ever increasing demand placed upon the fertilization program. No longer is it appropriate to do as one 1970's farm magazine put on the cover, *"DON'T BE A MISER - POUR ON THE FERTILIZER."* Current soil fertility programs must include soil tests, plant analysis, soil and crop knowledge to be used to make the most appropriate fertilizer recommendations for the grower, crop, and the environment. There must be minimum loss of fertilizer nutrients to the non-agricultural environment. We have the best agricultural production system in the world, but we can not stand still. It must improve. The yields must increase, but at the same time, fertilizer nutrients and other contaminants must not degrade the environment. There must be careful control over fertilizer rates and placements. The industry must improve its ability to deliver quality fertilizer products to the farm. The grower must be able to apply fertilizer uniformly within about 10 pounds of the recommended rate. The industry can supply the materials at the qualities required. It provides an opportunity for those willing to pay attention to detail and possibly produce new products or old products to new specifications.

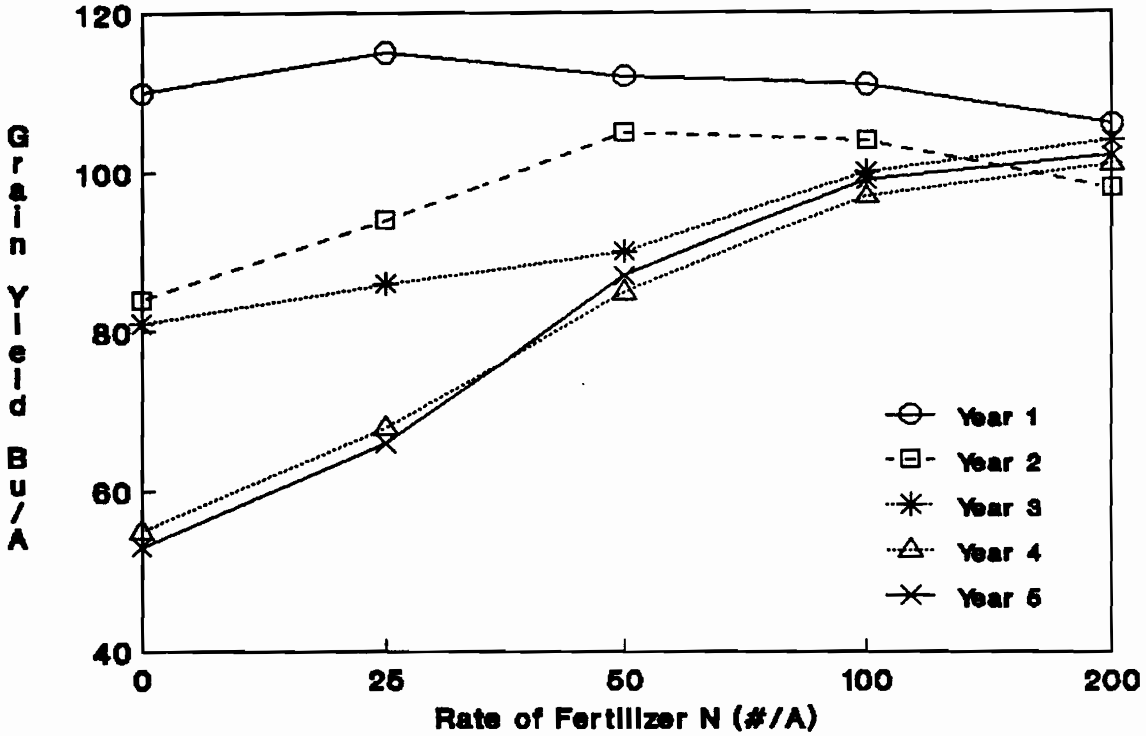
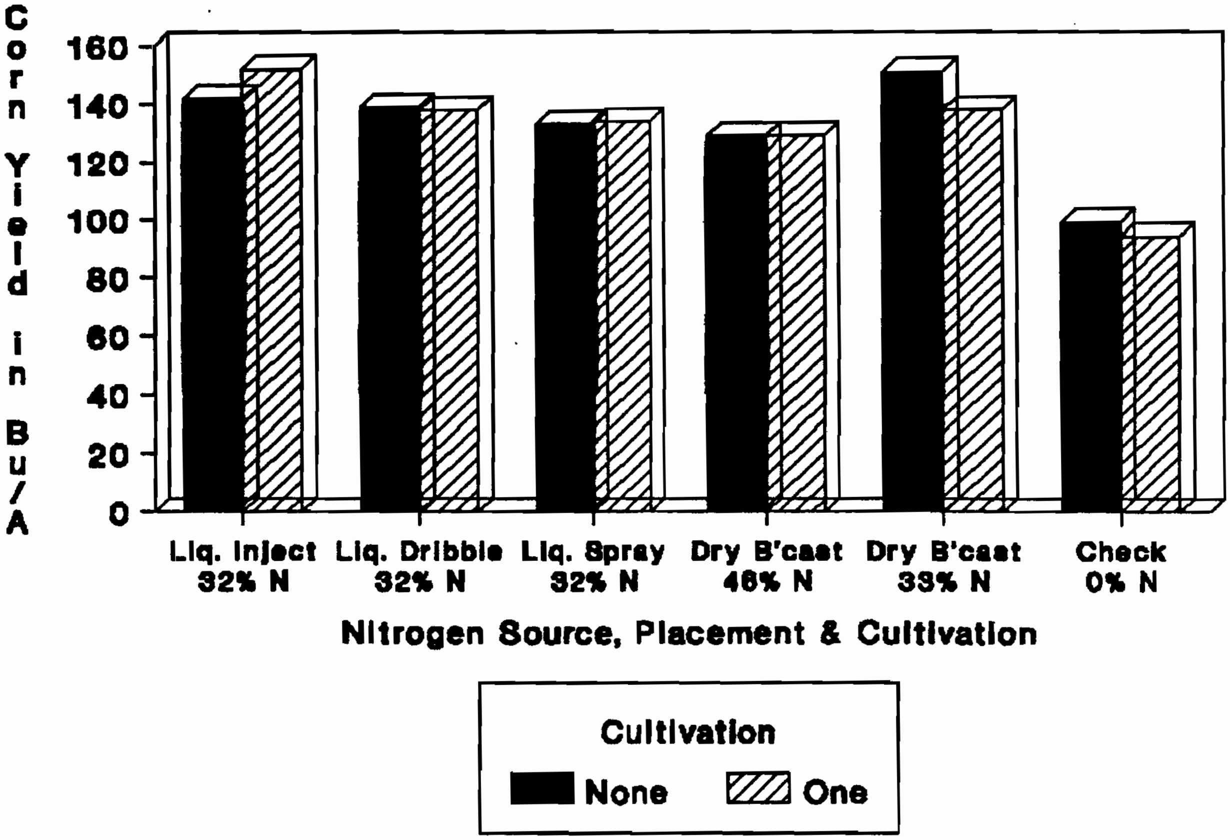


Figure 1: Response of Corn to Fertilizer N in Years Following Plowing Down an Alfalfa sod.



Unpub. Data, W. S. Reid, Cornell 1975-76

Figure 2: Influence of N Fertilizer Source and Placement on Corn Yields (bu/A). Yields Are Average For 60 & 120#/A N.

Size Guide Number and Bulk Blend Quality

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Introduction

Almost from the beginning of dry bulk blending of fertilizers, the effect of the particle sizes of the materials on blend quality was recognized (Hignett, 1965). One of the pioneers in elucidating the nature of this problem was George Hoffmeister of TVA (Hoffmeister, 1962) who in 1962 showed succinctly that the major problem with bulk blend quality was segregation when materials with unmatched particle sizes were used to make a blend. Development and implementation of techniques to solve this problem was longer in coming. One approach, suggested by Hoffmeister (1973), to minimize segregation in a blend was to use materials that matched in particle sizes. He determined that a blend would not segregate if the materials used in the blend did not vary by more than 10 percentage points in the cumulative percentage distribution on a specific sieve. The procedure to determine this physical compatibility of the materials, however, proved a little unwieldy and hard to use. A simpler yet reliable way of evaluating the particle size of materials that would also predict the stability of the resulting blends was needed. In January 1982 the Canadian Fertilizer Institute announced such a procedure now known as the SGN system that was simpler to use than the one just described and was useful in predicting the compatibility of materials for a specific fertilizer blend (Peesker, 1982). It is specifically known as the CFI Guide of Material Selection for the Production of Quality Granular Blends' (CFI,1992). It includes not only the SGN which could be described as the average particle size of a material but also the uniformity index (UI) and mixing quality index (MQI). The UI is a measure of the distribution of the particle sizes around the SGN and the MQI combines the statistical information of the SGN and UI into one single quality index. It is defined as 100 minus the coefficient of variation of the SGNs minus the coefficient of the UIs of the materials in a blend. A MQI of 100 means that each of the materials in the blend is identical in regard to SGN and UI. The CFI publication presents the details of the SGN, UI and MQI calculations and their interpretation and they have been described here at the Round Table before; therefore, I will not dwell on them here. In 1989 the Association of American Plant Food Control Officials adopted a policy statement in support of the SGN system as an important factor in improving the quality of blended fertilizer (AAPFCO, 1993). In that policy, AAPFCO urged the fertilizer industry to embrace the SGN system as a means of improving bulk dry blended fertilizer and to start including particle size as part of their specification sheets. I believe in general that has been accomplished by the industry.

I am not aware of any published data that relate actual MQIs to fertilizer quality over several years and across the fertilizer industry in a state. Cheval reported how use of the SGN concept reduced deficiencies in regulatory samples for one company (Cheval, 1984). Hester, et. al. (1990) reported that dealers in AL in 1989 with the best sample deficiency record also used materials with matched SGN values.

The objective of this presentation is to discuss the data from an ongoing study where SGNs and MQIs have been determined on samples of fertilizer materials taken throughout Kentucky over a period of six years and how they are related to certain measures of fertilizer blend quality.

Study Methods

In late 1987, we developed a program whereby our fertilizer inspectors would determine SGN's in the field on samples of a blenders fertilizer materials and then discuss with him the findings. Each inspector was outfitted with a nest of 8-inch sieves with openings of 3.35, 2.36, and 1.7 mm (USA Sieve Numbers 6, 8, and 12, respectively); a static sample riffler; and, a set of plastic volumetric cylinders. The procedure was to take a sample by official methods of all the materials that a blender was using, split them down to between 200 and 400 ml, sieve the reduced sample through the nest of sieves, determine the amount of material held on each sieve using the volumetric cylinders; and, determine the SGNs graphically. In a study in our laboratory before implementing the program in the field, I determined the SGNs on several materials using both volumetric cylinders and an analytical balance to measure the amount of material retained on each of the sieves and found no significant difference between the two methods. There were three objectives of the field program: (1) to inform the blender of the SGN system, (2) to discuss with the blender the physical compatibility of the materials in inventory, and (3) to attempt to create, at the blender level, a demand for blending materials that are SGN compatible. Our inspectors would determine the SGN's on a blender's materials and then sit down with the blender and discuss what they meant.

Results of the Program

We began the program in the spring of 1988 and have continued it ever since. The number of blenders surveyed and the number of SGN and MQI determinations are shown in Table 1. Our inspectors attempted to sample blends at each of their assigned blenders every other year. This was not always possible because of time availability and blender activity; however, as you can determine from Table 1, we worked with a total of 343 blenders during the 6-year period and made more than 1,579 SGN determinations.

Initially, we were concerned with determining the SGN only; therefore, not much attention was given the UI and MQI. Some of the inspectors would turn in only the actual SGN values but some would turn in the cumulative retained percentages in addition to the SGN values. Later we attempted to retain all the data associated with the SGN determinations. On those samples where the cumulative retained percentages were available I calculated the UI by assuming that the material caught in the pan (that is, the material passing the No. 12 sieve) would be caught on a No. 20 sieve (0.85 mm opening). This gave me four cumulative percentage numbers from which to estimate the size of the small and large particles associated with the 95% and 10% cumulative retained percentages, respectively, which are required to calculate the UI. The data were available to estimate the MQIs on 246 of the 343 blenders for which we determined the SGNs (Table 1).

The next step in relating the SGN data to blend quality was to evaluate the blends actually produced by the blenders. During the year in which the SGN's were determined, our inspectors tried to take at least 5 and preferably 10 official regulatory samples at each of the blenders to evaluate the quality of their blends. At 316 of the 343 sites we took 5 or more samples but at two sites we did not take any official samples.

Four criteria were used to evaluate the quality of the blends: (1) deficient sample rate (DEFSAMP) - which is defined as the percentage of the official samples that had one or more N, P, K, or relative value deficiencies, (2) penalty per ton (PENPT) which is defined as the penalty assessed per ton for deficiencies in any of the guaranteed nutrients, (3) total penalty per sample (TOTPEN) - which is defined as the total penalty assessed per sample and is the PENPT multiplied by the lot size in tons represented by the sample, and (4) relative value penalty (RVP) which is defined as the penalty per ton assessed just for a relative value deficiency.

The first part of the discussion of the results will be on the trends in the data specifically from the study. The second part of the discussion will be on the data from the study; but, averaged for each of the years from 1988-1993 and merged with the four blend quality indicators from the official sample record of all samples taken during these same years.

The next five figures are frequency distributions of some of the SGN's determined at each of the blenders over the 6 years. The first four show the distribution of the SGNs for DAP, urea, muriate of potash, and filler, respectively. We also determined the SGN's for ammonium nitrate, triple superphosphate and sulfate of potash but their distributions are not shown. The distributions for DAP, urea, MP, and filler are fairly typical and reflect a range of values from fairly low to high. Each vertical bar represents the percentage of all the SGN' s of the particular material that is in the range of SGN values represented by the midpoints on the horizontal axis. The materials represented by the 'filler' include not only the usual limestone aggregate but also some materials that are infrequently used such as sulfate of potash-magnesia and ammonium sulfate. The fifth figure shows the distribution of the SGN means for each blender evaluated. All the SGN' s determined for all the materials at a specific blender were averaged and termed the ' SGN Mean'. There were 343 such SGN means, one for each of the blenders evaluated during the 6 years. This also shows a fairly typical frequency distribution for SGN' s . The range is from 180 to 330. Figure 6 shows the frequency distribution for the 246 MQIs determined during the period. It shows what appears to be a normal distribution with a range from a low of 39 to a high of 99.

The relationships of interest were the linear, quadratic, and cubic regression of each of the quality criteria on the SGN Mean's and MQIs of each of the blenders. Only the linear regression showed any significance. For example, figure 7 shows the plot of each of the blender's official sample deficiency rate vs. their MQIs. The linear regression is significant at the 0.01 probability level and the regression line is superimposed to show the trend that as the MQI increases the sample deficiency rate decreases. This is what would be predicted based on the SGN concept. You will note that there are many blenders with a zero (0) deficiency rate and two that had a 100% deficiency rate. If these were considered 'outliers" and were deleted from the analysis, there might be a clearer picture of what is going on. Figure 8 shows the relationship between sample deficiency rate and the MQIs with these outliers removed. The linear regression model improves as a descriptor of the situation. I made similar plots for the other quality criteria and they show trends similar to those in figures 7 and 8 but the regression significance was between 0.1 and 0.25 probability level.

These data suggest that the SGN system of evaluating the suitability of materials for making compatible blends has some value and should be used as a part of a blenders quality control program. They also are encouraging to control officials who continuously promote the production of quality blended fertilizers and emphasize the importance of using materials that match in particle size as measured by the SGN system.

Now I would like to switch from a discussion of just the specific data from the study to the merged data set which includes not only the specific data from the study but also the blend quality data from the official sample record. If the materials and blenders studied are typical of those throughout the state then the blend quality criteria of all the blenders in the state (including those studied directly) should show the same relationship with the SGN data from the study.

First, any change in the fertilizer quality in Kentucky during the study period should be evaluated. The next figure (No.9) shows a plot of the official sample deficiency rates (DEFSAMP) for the years of the study. These data include all the official samples taken during the respective years including those from the blenders studied. It appears that there has been a significant decrease in the percentage of deficient samples from about 21% in 1988 to 16.8% in 1993. The linear regression has a probability of 0.11, just missing the magical 0.10 level. Figures 10, 11, and 12 show the performance of the other quality criteria of PENPT, TOTPEN, and RVP, respectively, during the study period. The linear regression of each of these other quality criteria against the years of the study is significant at a probability level of less than 0.05. If we assume that a lower DEFSAMP, PENPT, TOTPEN, and RVP indicates improved fertilizer blend quality then these data establish that the quality of the blended fertilizer in Kentucky has significantly improved during the last 6 years. The critical point now is to derive a reasonable explanation for this improvement. Figure 13 shows what has happened to the average SGN over this same time. There was an increase in the average particle size of the materials we evaluated over the six years from an average 225 in 1988 up to 257 in 1993. This increase is linear over time; however, we are not sure that this increase means better quality materials until we look at the MQIs over the same period of time. Figure 14 shows that indeed the quality of the materials for blending purposes did increase in Kentucky as indicated by the significant increase from 64.7 in 1988 to 74.4 in 1993 in the MQIs determined for the materials during the years of the study.

Now, is there a significant relationship between any of the blend quality criteria of the official samples and the material quality indicators of the SGN system, namely, the SGN means and the MQIs?

Figure 15 shows the relationship between the official sample deficiency rate for the years of the study and the MQI's from the materials. The significance of the linear regression is at the probability level of 0.25. It would improve if the one outlier were removed. The official sample deficiency rate calculation includes bag, bulk, and liquid samples; therefore, I pulled out just the bagged blends and looked at their deficiency rate for the same years (Figure No. 16). The linear regression for these data has a probability of 0.11 which gives me more confidence in the relationship. Figures 17, 18, and 19 show the other quality criteria regressed against MQI. The significance of the TOTPEN and MQI linear regression is 0.07. The others are less than 0.20. Figure 20 shows the relationship between DEFSAMP AND SGN means. The linear regression of DEFSAMP on SGN means is significant at 0.08. There appears to be an improvement in the quality of the blend samples as the size of the blend materials increases. This is probably related to the concurrent improvement in the MQI's.

There are many reasons for the improvement in the quality of fertilizers in Kentucky. Some of these are: better batch scale maintenance, improved training of personnel, better management of the blend plants, improved blending equipment, and better quality of materials used by the blenders. The data presented and discussed today indicate that better quality of blending materials as measured by their MQI may be a significant factor in the improvement of blended fertilizer in Kentucky.

Conclusion

1. Fertilizer quality in Kentucky from 1988 - 1993 has improved significantly when measured by the sample deficiency rate, penalty assesed per ton, total penalty assessed per sample, or relative value penalty of the official regulatory samples.

2. The fertilizer materials use by the blenders in Kentucky has improved in physical compatibility from 1988-1993 when measured by the mixing quality index (MQI).

3. There is a significant relationship between the improvement in fertilizer quality and the improvement in the physical compatibility of the fertilizer materials normally used for blending in Kentucky.

4. While there are many factors involved in fertilizer blend quality, it appears that the improvement in the physical compatibility of the blend materials has contributed significantly to the improvement of blend quality in Kentucky.

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Table 1. SUMMARY OF SGN STUDY ACTIVITIES

Year	No. Blenders	No. SGN's[1]	NO. MQI's[2]
88	58	303	39
89	46	210	21
90	35	158	12
91	70	297	43
92	78	363	78
93	56	248	53
TOTALS:	343	1579	246

[1] SGN - Size Guide Number

[2] Mixing Quality Index

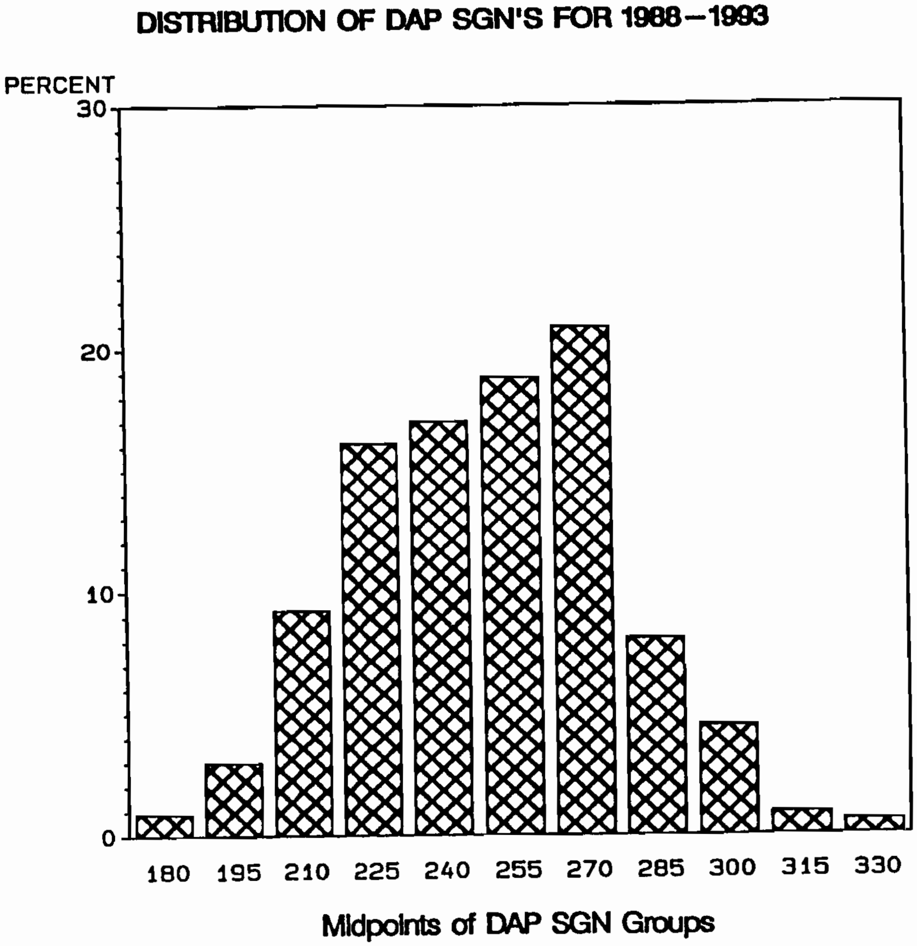


Figure 1: Distribution of DAP SGN's For 1988-1993

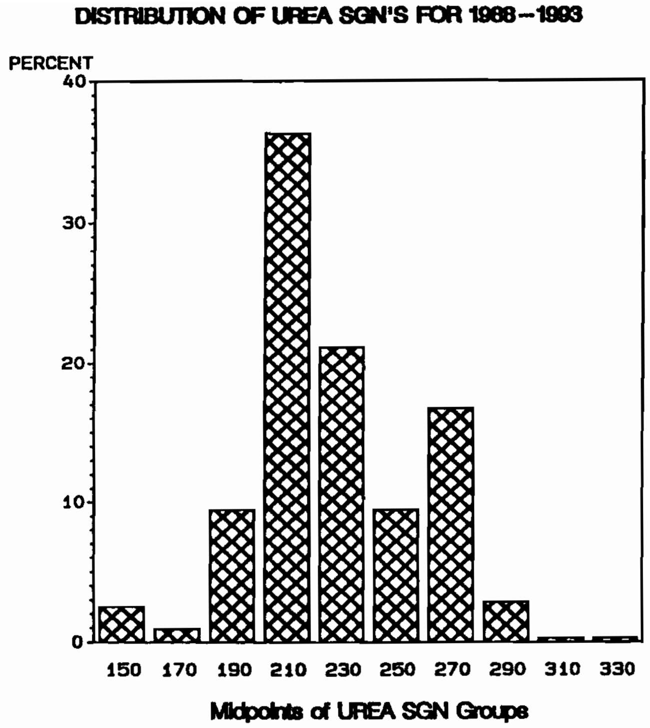


Figure 2: Midpoints of UREA SGN Groups

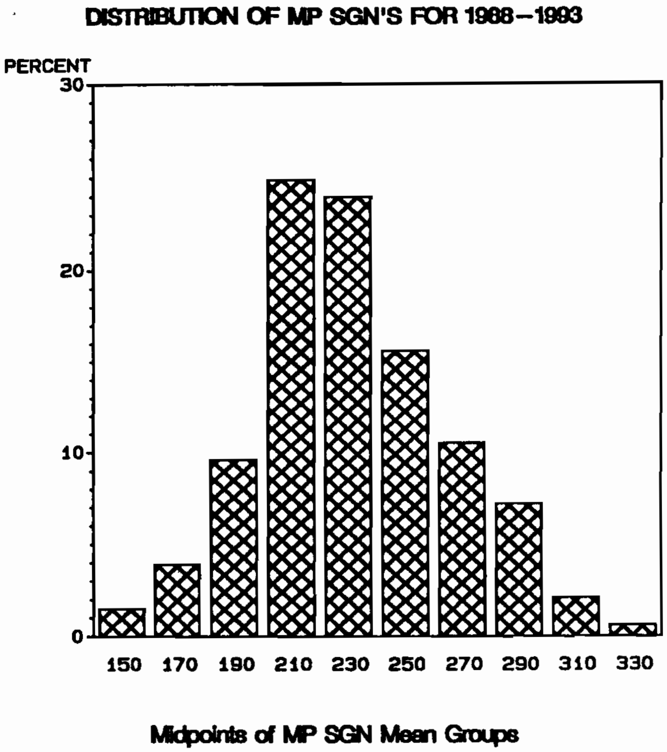


Figure 3: Distribution of MP SGN' Mean Groups

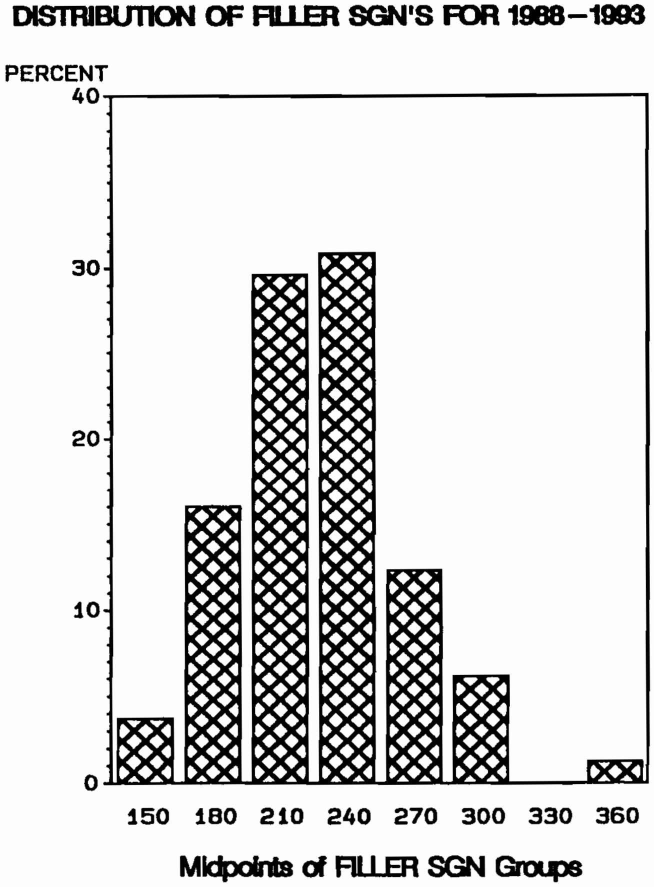


Figure 4: Midpoints of Filler SGN Groups

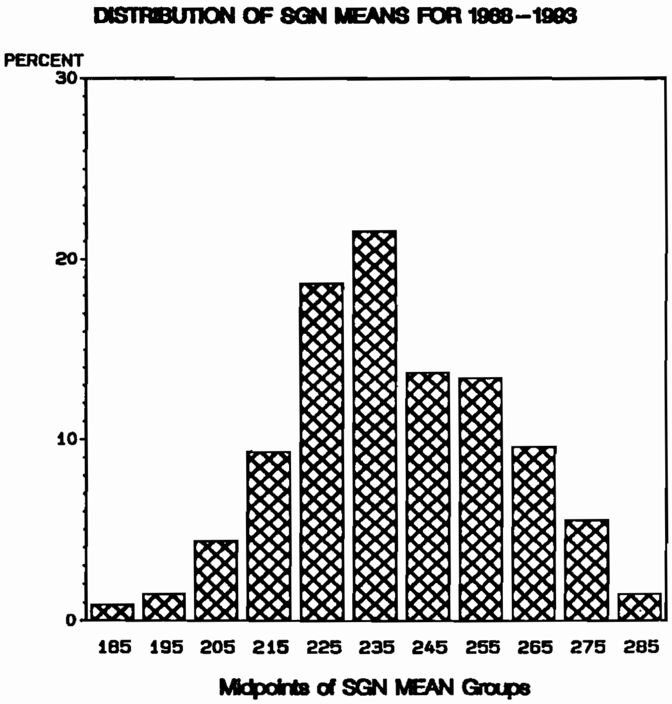


Figure 5: Midpoints of SGN Mean Groups

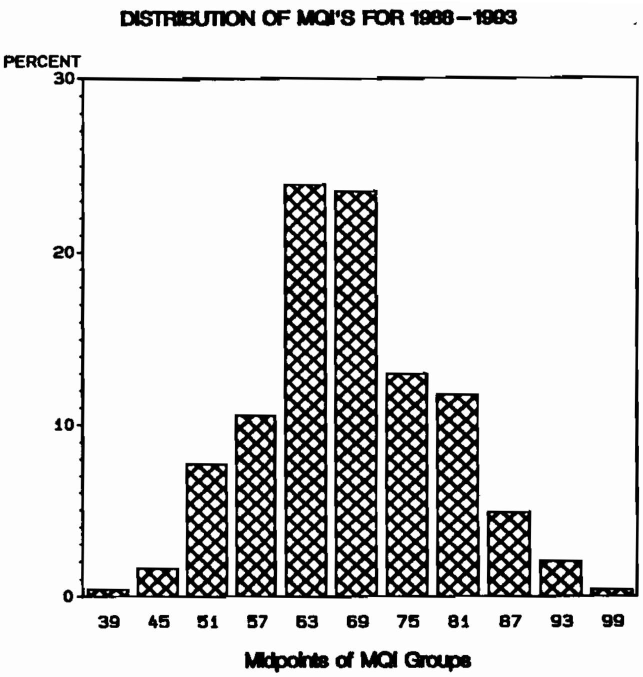


Figure 6: Midpoints of MQI Groups

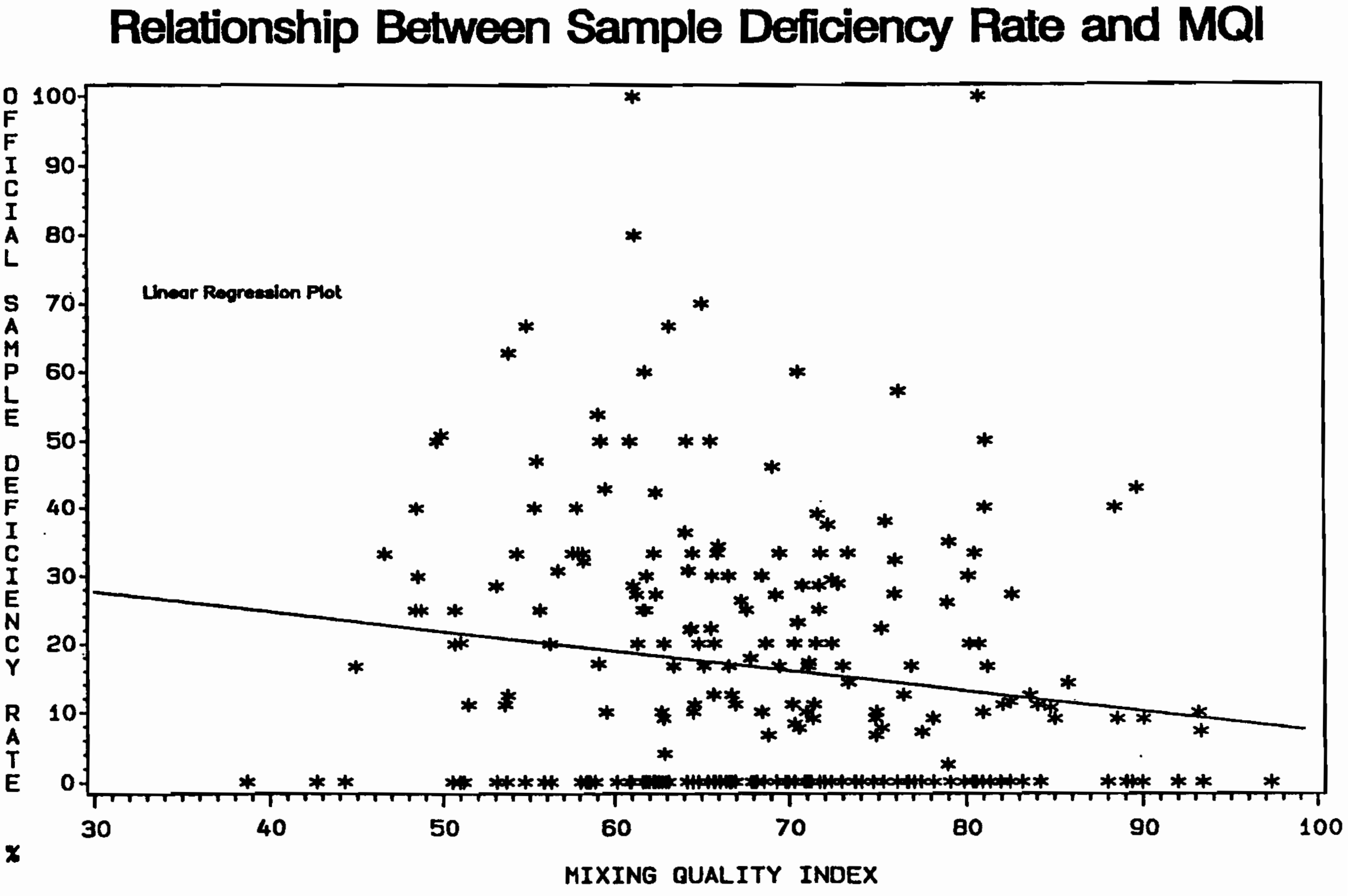


Figure 7: Relationship Between Sample Deficiency Rates and MQI

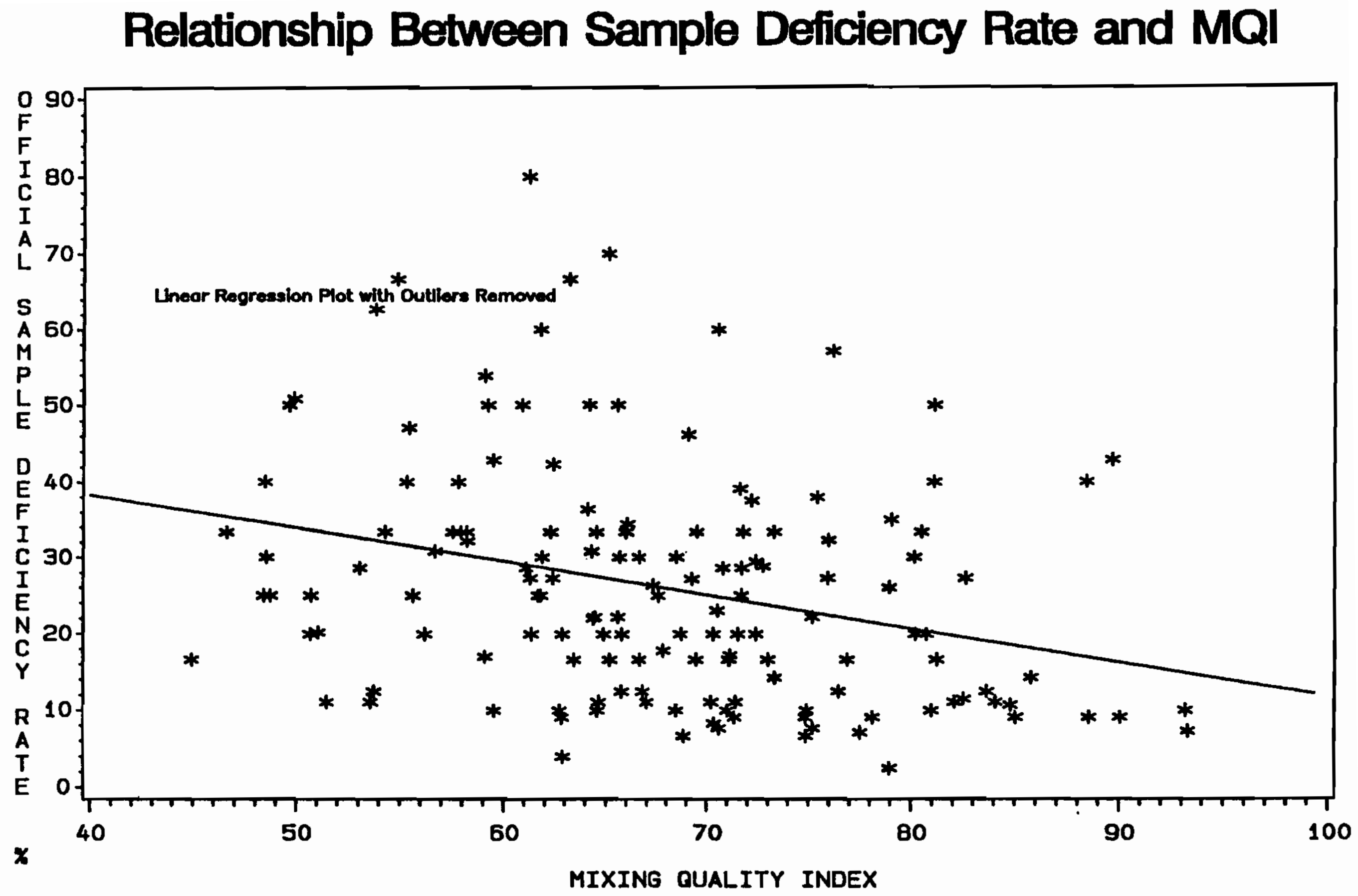


Figure 8: Relationship Between Sample Deficiency Rate and MQI

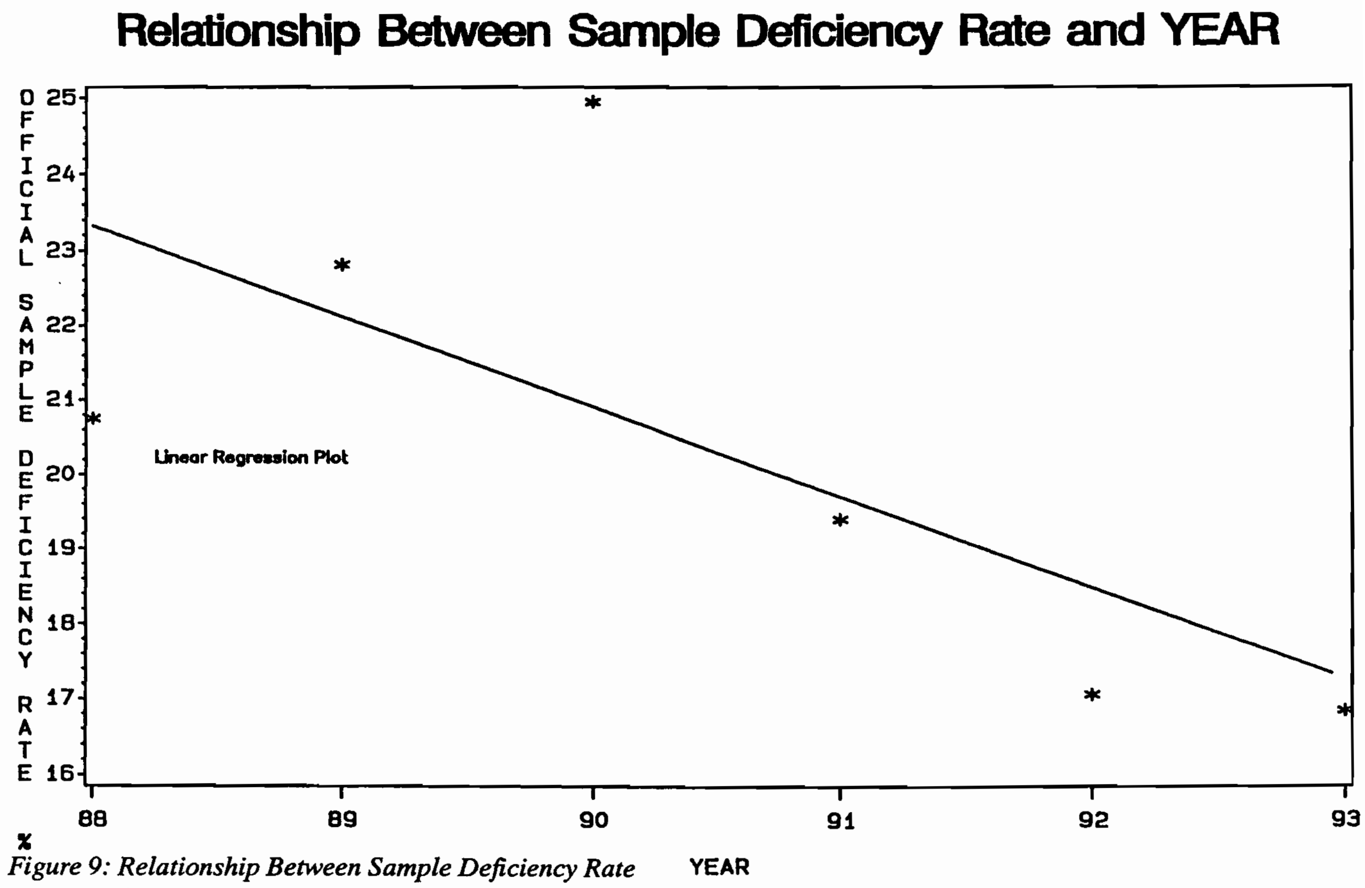


Figure 9: Relationship Between Sample Deficiency Rate & Year

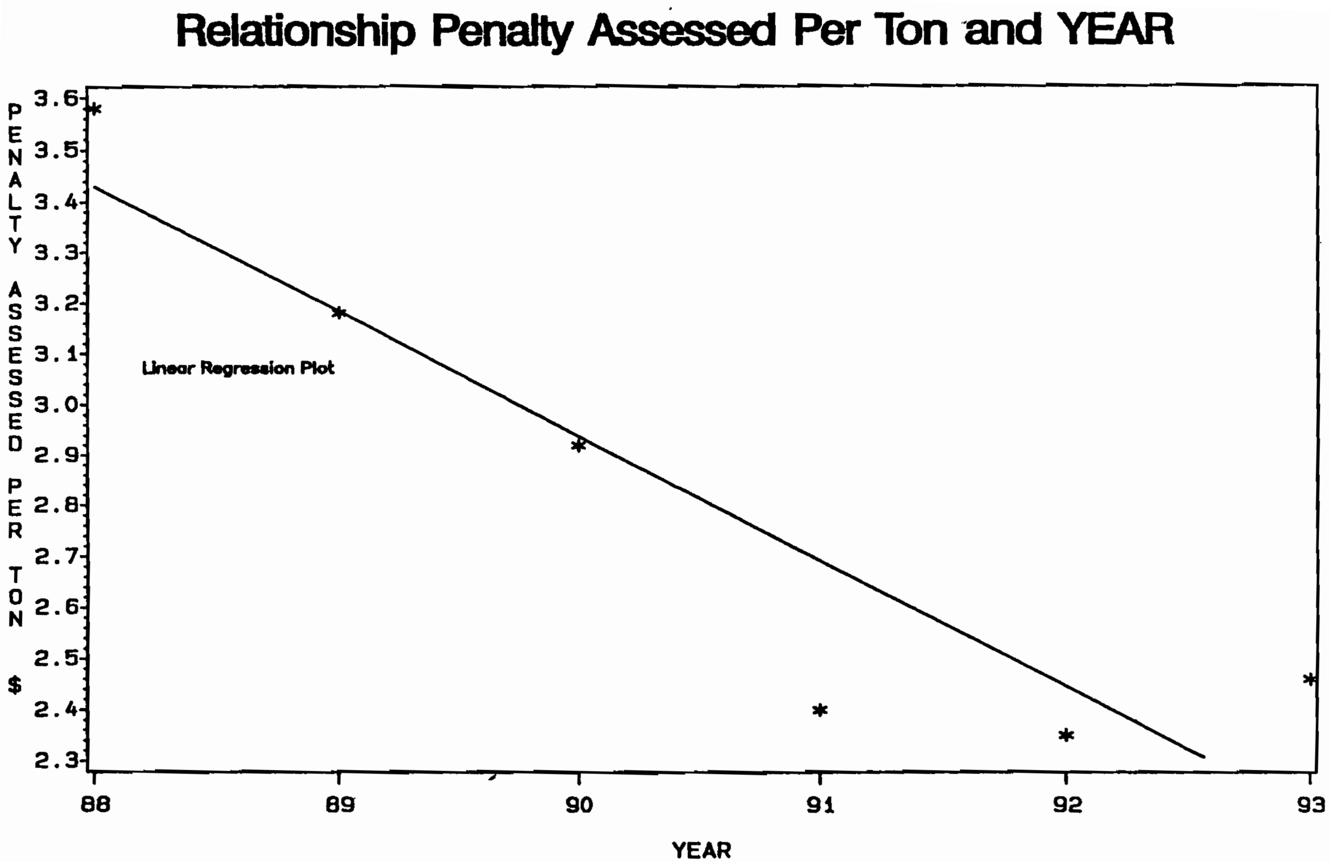


Figure 10: Relationship Penalty Assessed Per Ton and YearFigure

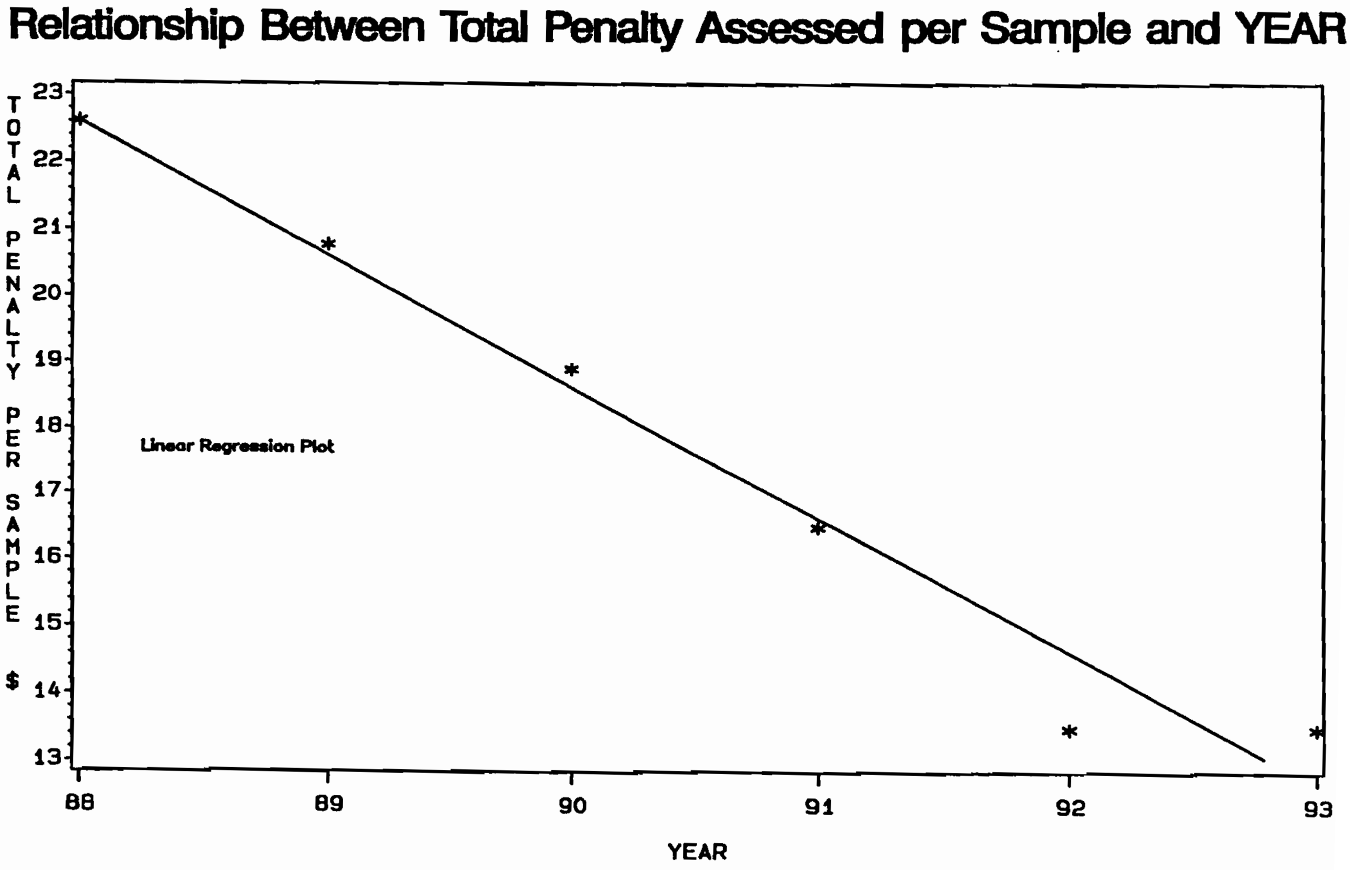


Figure 11: Relationship Between Total Penalty Assessed per Sample and Year

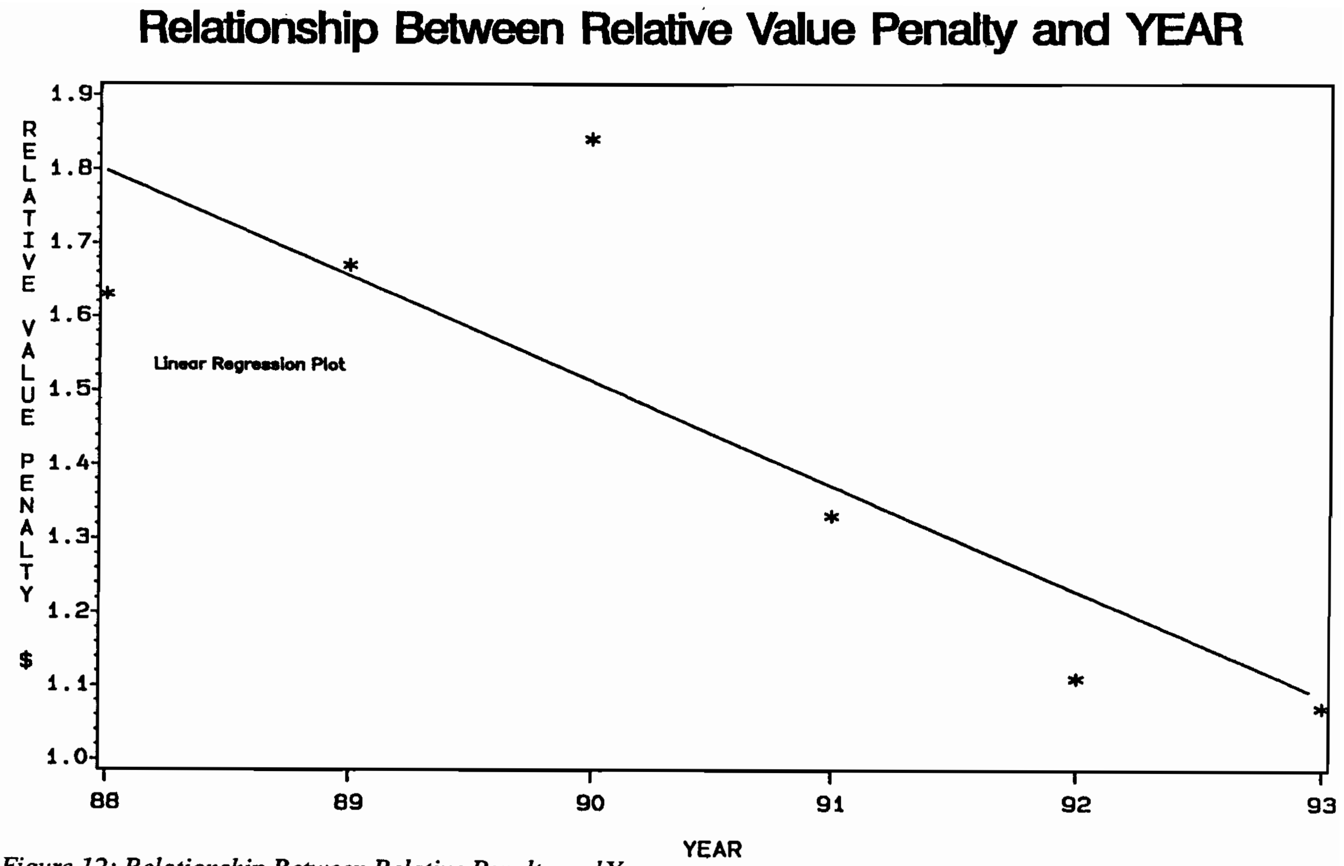


Figure 12: Relationship Between Relative Penalty and Year

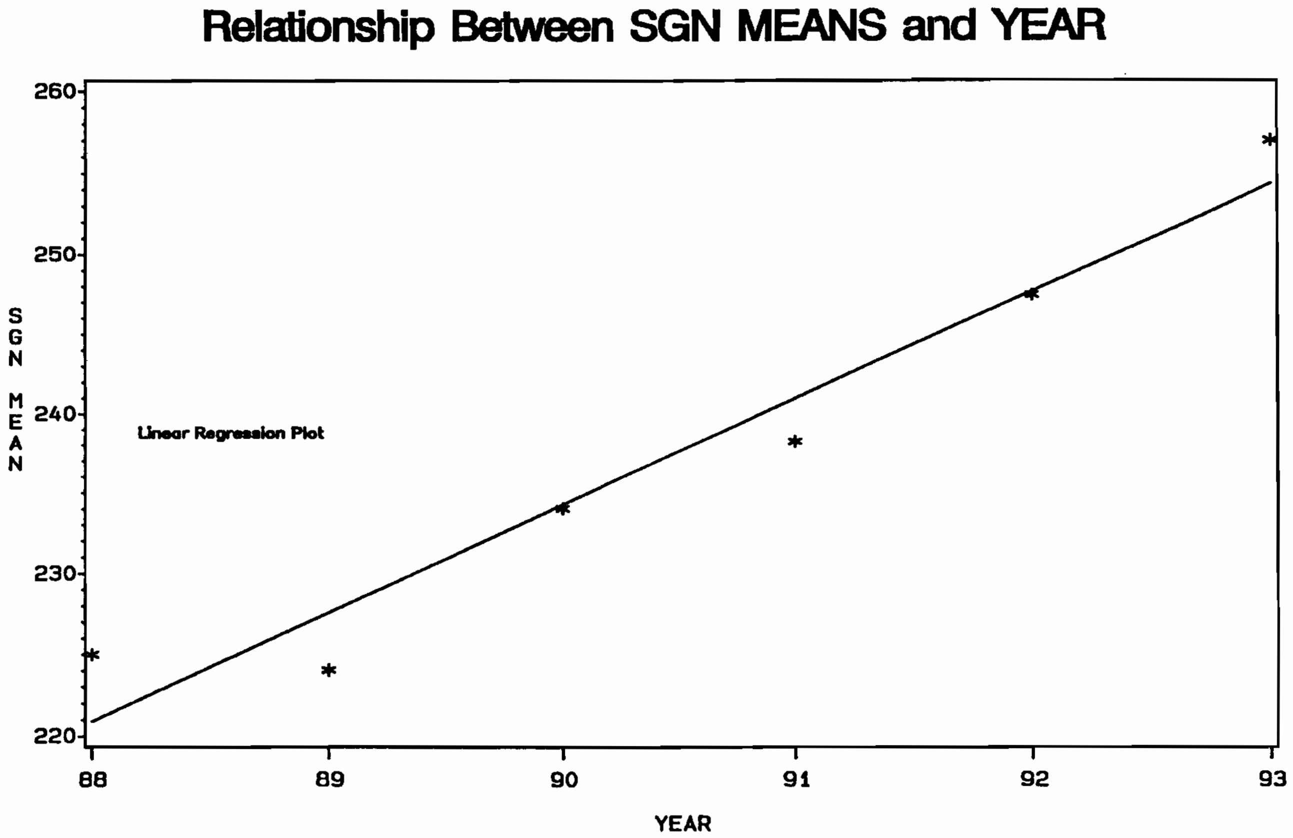


Figure 13: Relationship Between SGN Means and Year

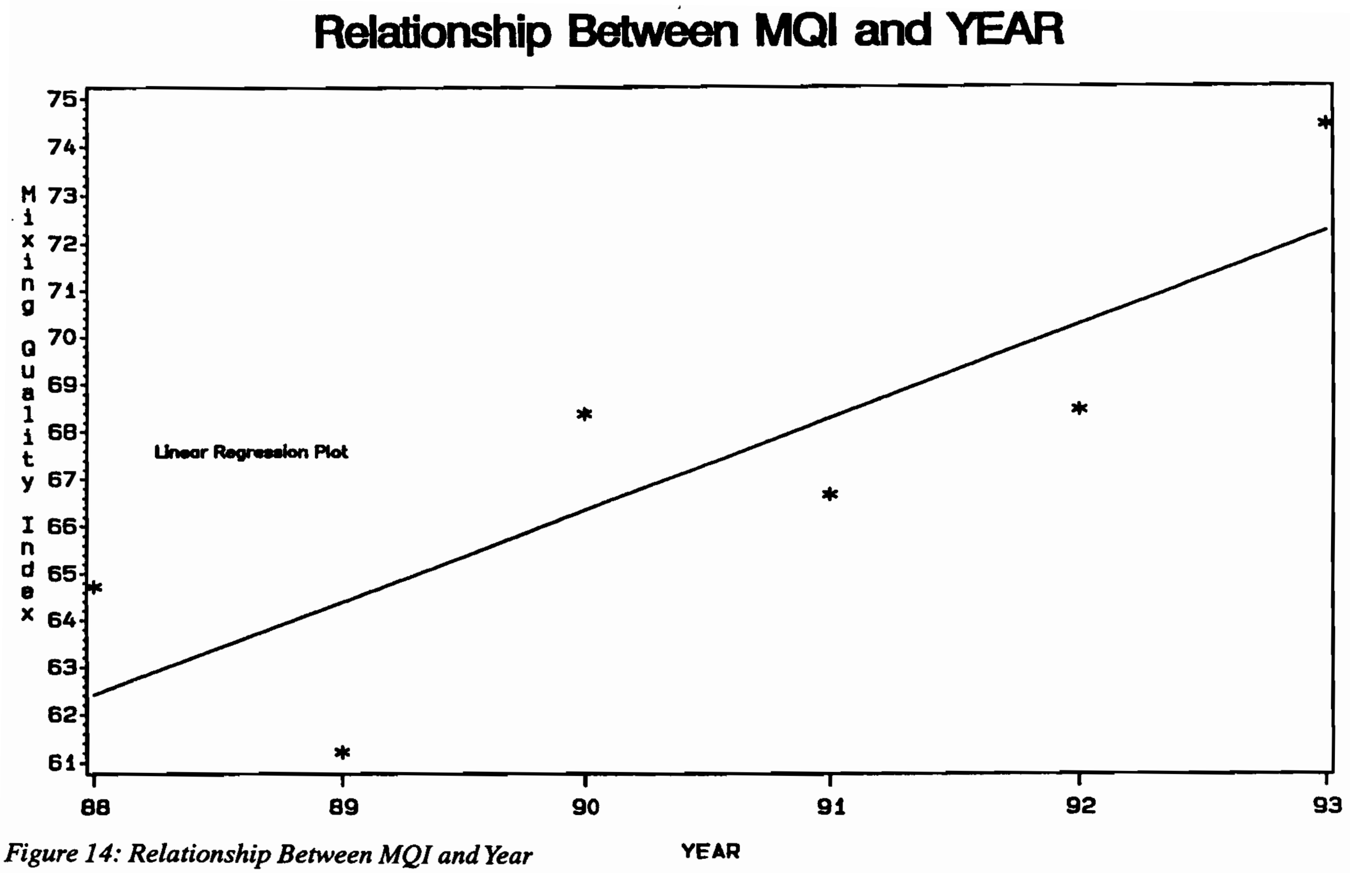


Figure 14: Relationship Between MQI and Year

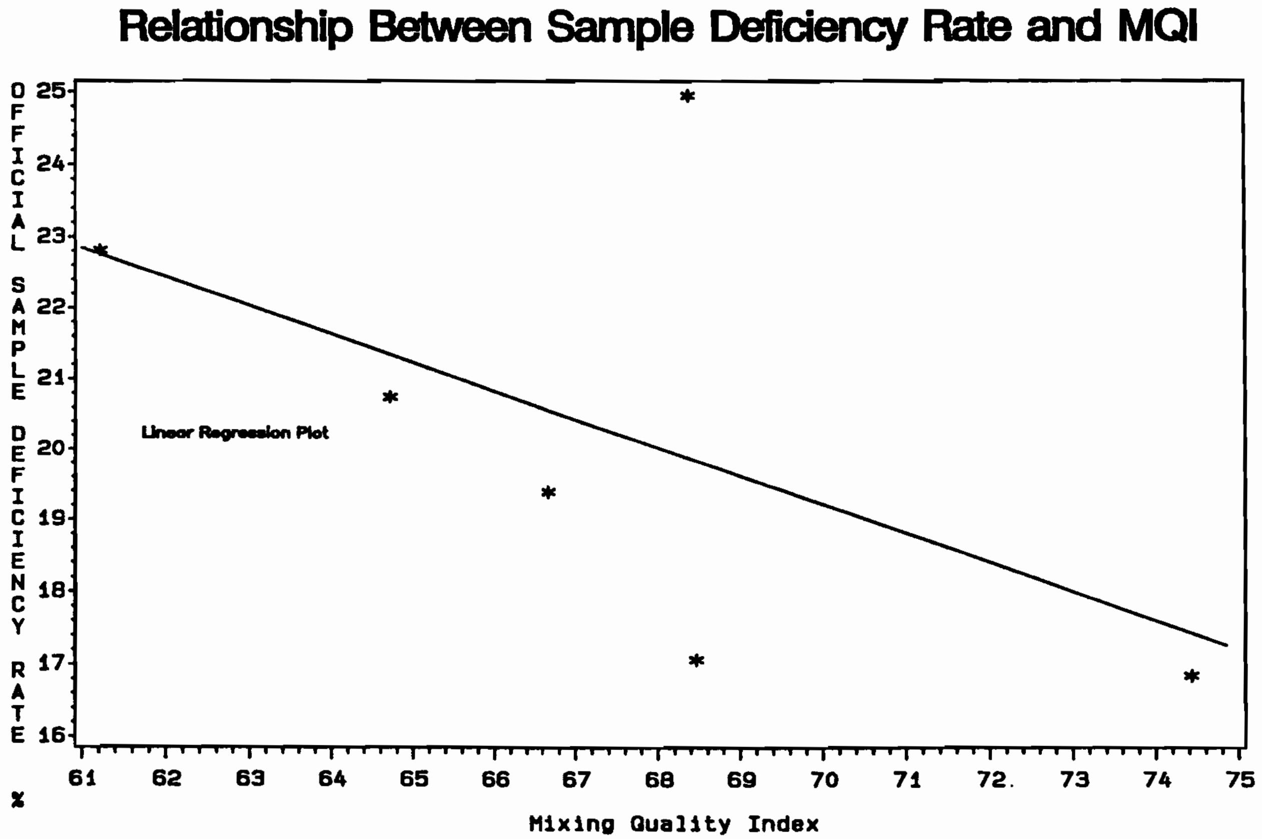


Figure 15: Relationship Between Sample Deficency Rate and MQI

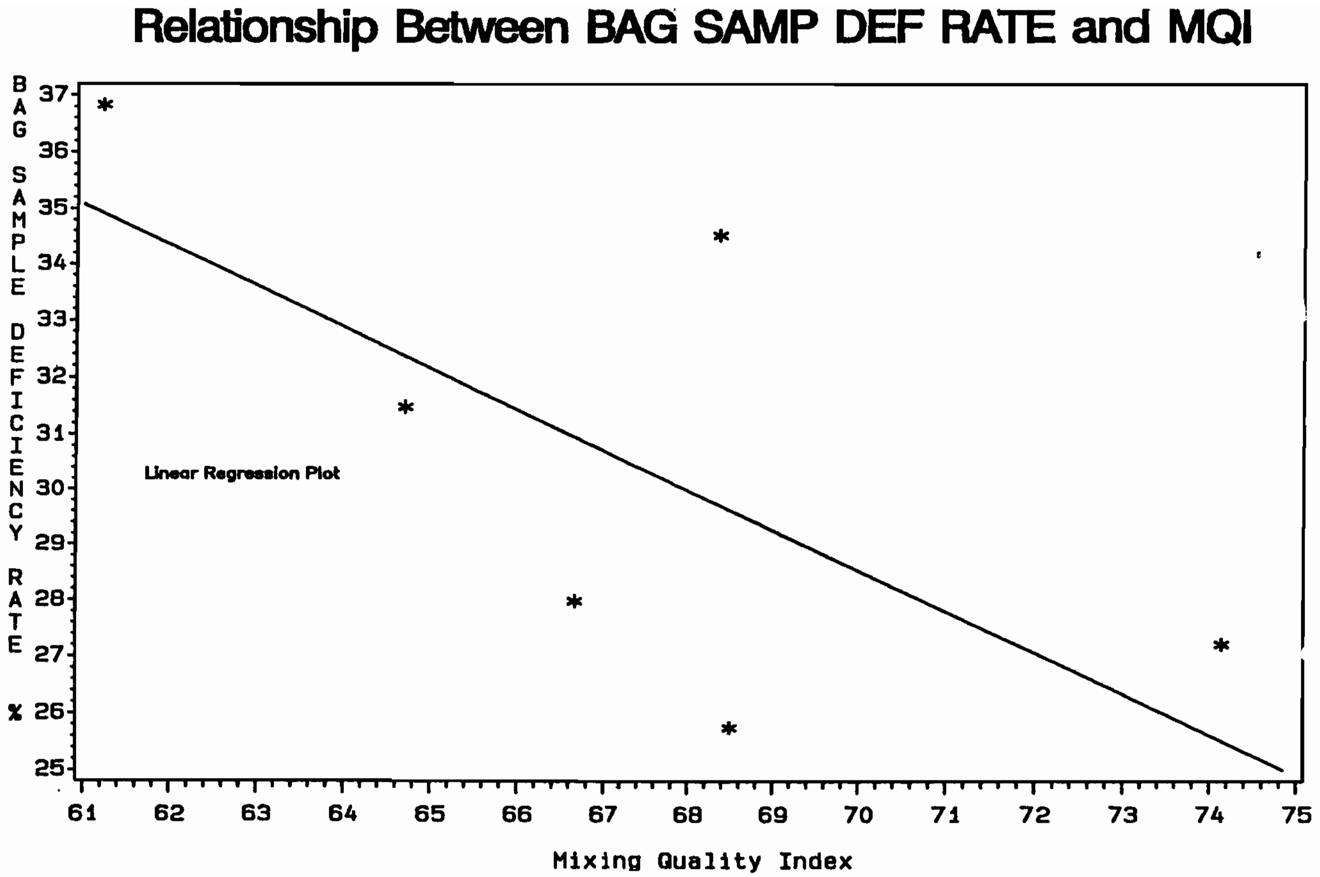


Figure 16: Relationship Between BAG SAMP DEF Rate and MQI

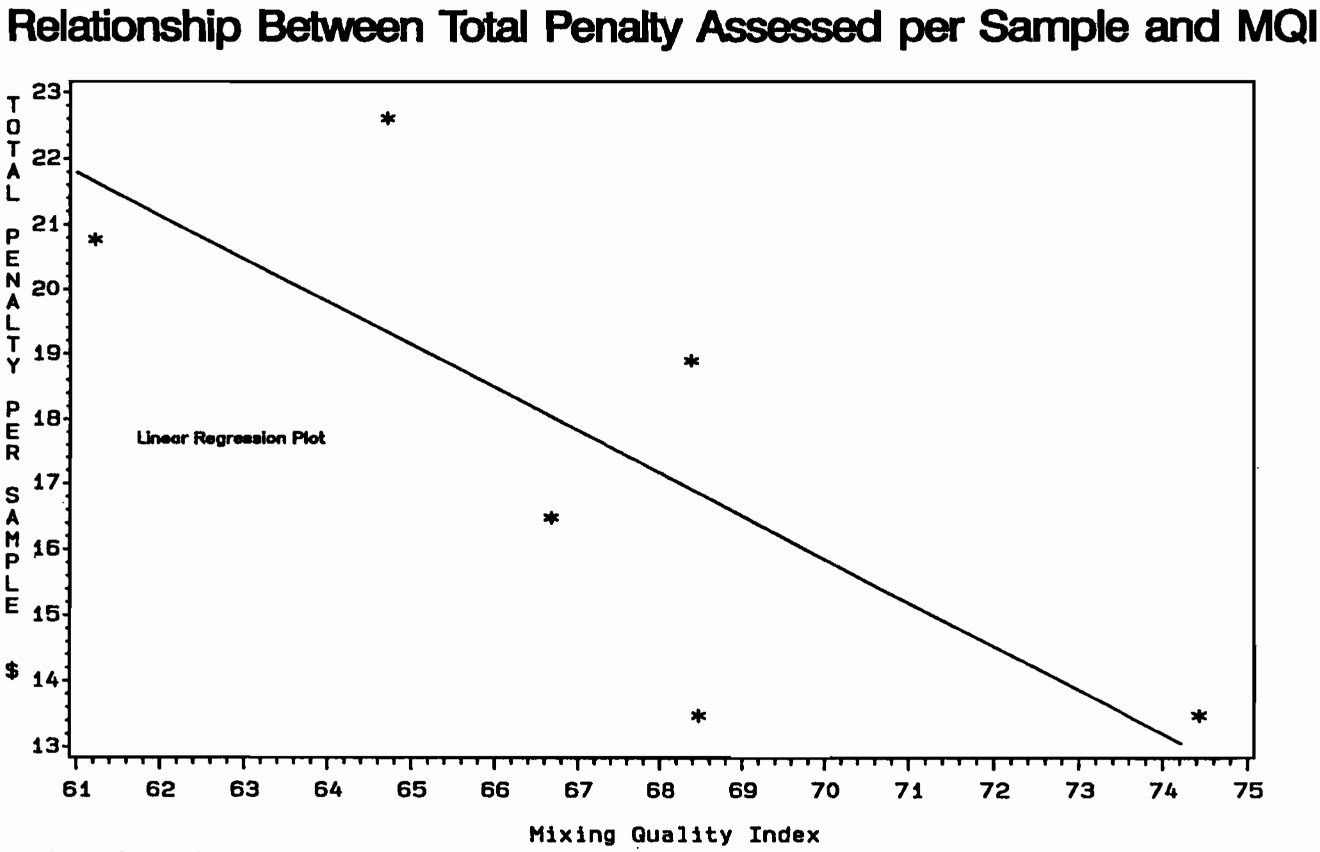


Figure 17: Relationship Between Total Penalty Assessed per Sample and MQI

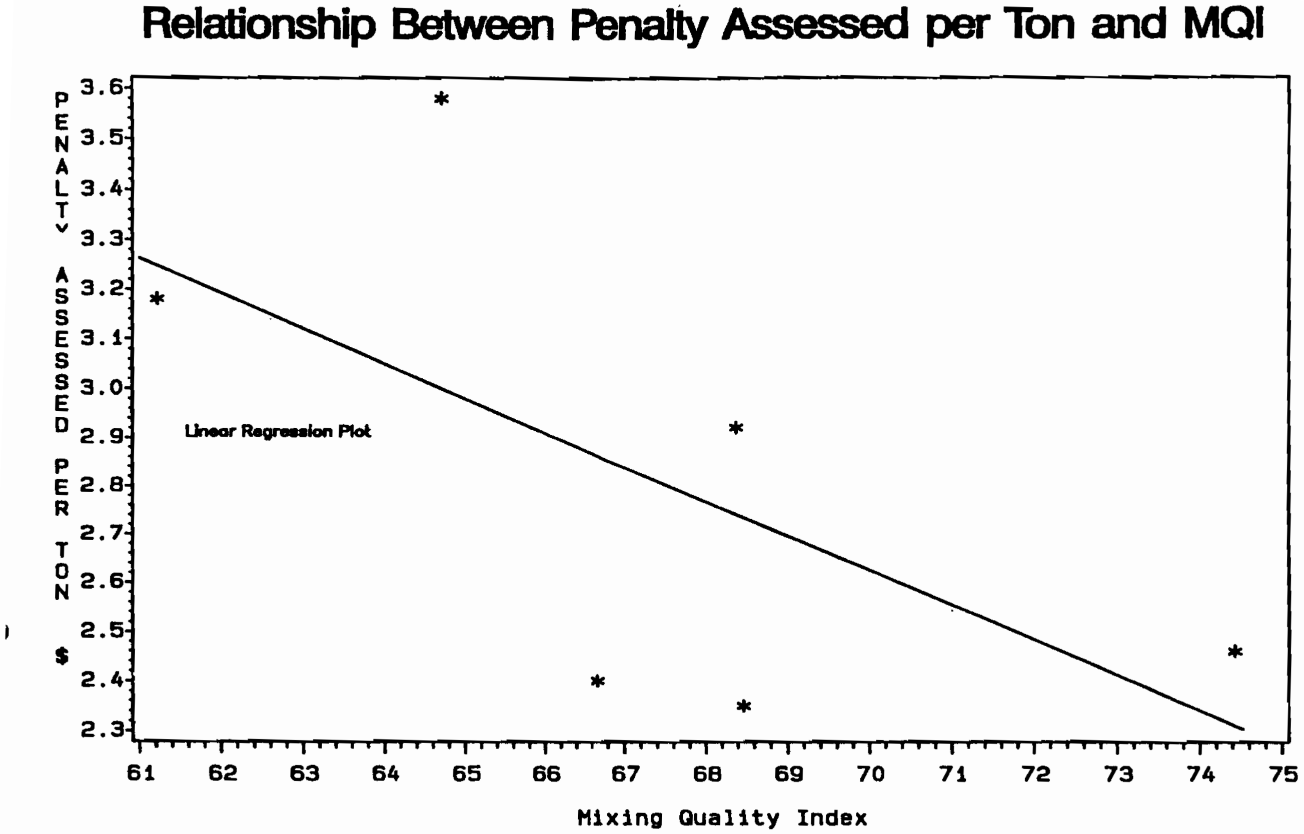


Figure 18: Relationship Between Penalty Assessed per Ton and MQI

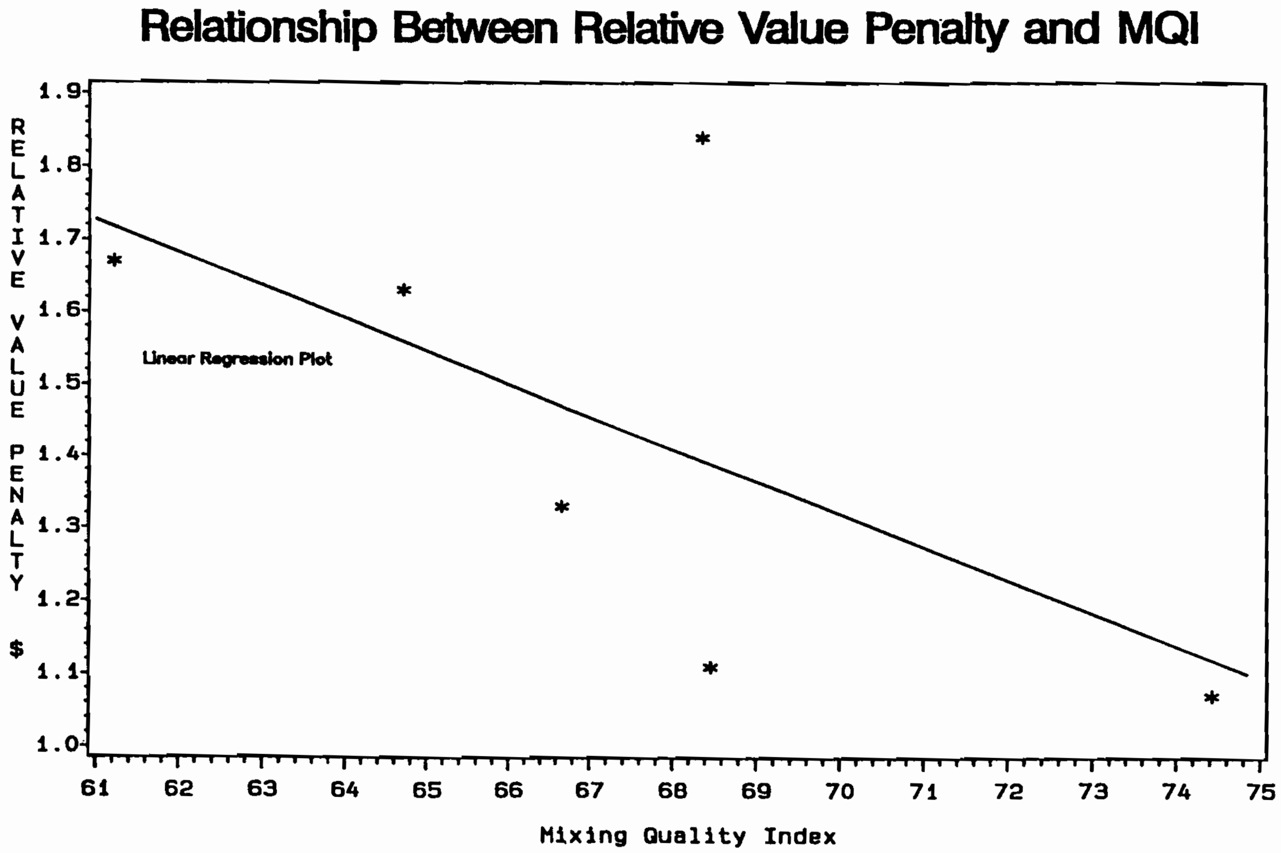


Figure19: Relationship Between Relative Value Penalty and MQI

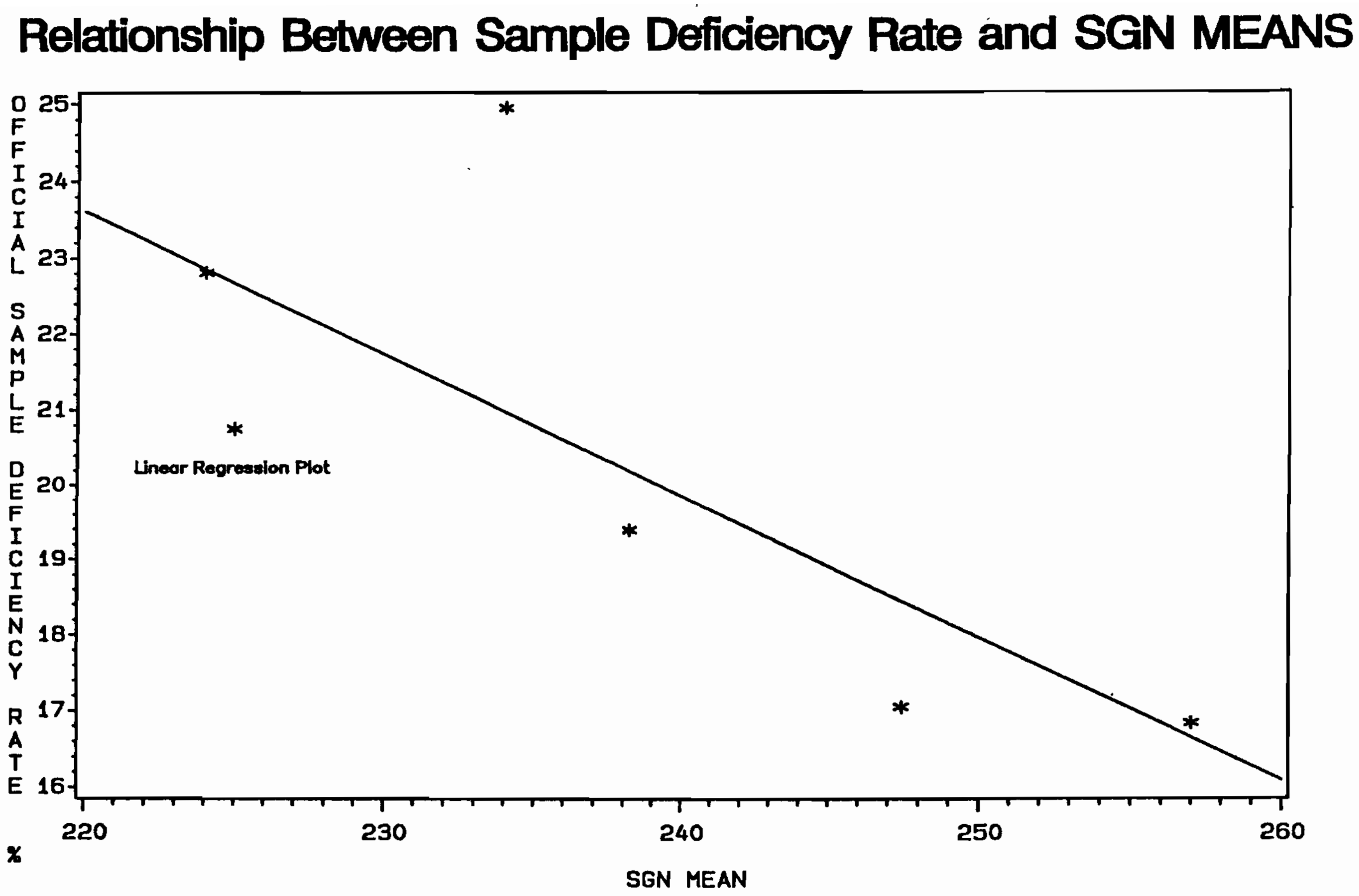


Figure 20: Relationship Between Sample Deficiency Rate and SGN Means

A Practical Quality Control System Being Utilized By An Average Size Bulk Blending Plant

Steve Godbehere
Barber Fertilizer Company

In the southeastern United States, a major portion of the fertilizer is produced in small bulk blending plants. These plants generally have six to eight 200 ton bays with a three to eight ton floor mounted mixing system. These plants will sell from five thousand to ten thousand tons per year. It is not economically feasible for this size plant to have any type of laboratory facility or quality control specialists on staff.

Barber Fertilizer operates one of these type plants in Donalsonville, Georgia. Our plant is typical of the majority of plants in Georgia, North Florida, and Alabama. Several of the large regional type blend plants, typical of south-central Florida operations have been installed, but they are generally phased out in favor of the smaller more local type of plant that serves its immediate area with spreader trucks and limited bulk hauler service.

This paper will examine the reasons for change in our operation, the impact of these changes on our business, and how we have coped with the change. We will look at how we developed a workable quality control system, what basic manufacturers can do to help the average size blender, and our plans for additional quality improvements.

Background

During the past two decades, there have been dramatic changes in the way fertilizer is manufactured and marketed in the southeastern United States. Ten years ago, there were at least thirteen granulation plants operating in Georgia alone. Today there are only four. These granulation plants were the giants of the fertilizer production scene. Fertilizer was generally marketed through a network of retail outlets, company stores, or cooperative stores. Many of these retail outlets have either closed or added blending facilities to their operations. Competition and margins have forced this change upon the industry. In the 70's and 80's corn was king. Because of government programs, and many other market forces, much of the land on which corn was grown has been lost to pine trees, super highways, cities, and other crops. Today, existing fertilizer dealers fight for a share of a decreasing market.

Cropping Pattern Changes

Over the past several years, our cropping patterns have changed from Corn, Peanuts, Soybeans, Small Grains and Livestock to Peanuts, Cotton, Corn, and diverse vegetable enterprises. Tomatoes, including the large type fresh market tomato, the Cherry, and the Plum have migrated into the Southwest Georgia and North Florida area. Two crops per year are produced. Sweet corn acreage now accounts for a sizable amount of the corn acreage.

Several types of fresh market beans are produced including both round and flat bush beans, and pole beans. Cole crops including cabbage, mustard, turnip, and kale provide a good market for fall, winter and spring fertilization. Cucurbit crops; watermelon, squash, and cucumber are produced twice a year.

Cultural Practice Changes

This increase in commercial vegetable production has been accompanied by changes in cultural practices as well. The most profound change has been in irrigation technology. Our area has been a leader in the southeast in center pivot irrigation acreage because of our vast high quality underground water supply. We have seen the high pressure impact sprinkler center pivot irrigation give way to low pressure systems that are more energy efficient.

The biggest change in irrigation has been the move to drip irrigation combined with plastic mulch. This change first occurred with tomatoes grown in the Quincy Florida area. This technology has now been applied to other crops such as pepper, watermelon, squash, strawberries, and even pole beans.

We have seen changes in cultural practices in virtually every crop grown in our area. Cotton and corn growers are now utilizing multiple applications of fertilizers, rather than one fertilization followed by one or two sidedress nitrogen applications. Many of these growers are now using fertigation. We have seen several growers switch from broadcast application to row applied sidedressing at layby on cotton.

Transportation Changes

Transportation has changed from single car rail service at blend plants to truck delivery from terminal warehouses. In many instances, truck freight is now less than rail rates and trucking companies are more willing to work with the blender than the rail roads. We have even seen several blend plants installed in areas with no rail service. Fifteen years ago, that would have been unheard of.

Farmer Profile Changes

Change has also occurred in the profile of this area's farmers. Small, diversified farms have given way to larger more specialized operations. The owners and/or managers of these operations are more educated (both formally and informally) than their predecessors. Their level of management is higher. Their utilization of consultants, pest management services, scouts, and public resources such as Extension and the Soil Conservation Service continues to grow. There is increasing demand for soil and tissue testing. Many of these growers also look to their fertilizer and chemical suppliers to provide professional services.

Coping With Change

These changes have impacted our business in various ways. Several years ago we purchased an existing bulk blend plant that was located between our other two locations. Our original locations produced suspension fertilizers and resold granular homogenized fertilizers. As bulk blends became more popular, it was necessary to expand our operation to include this type of facility. By adding this additional facility and location, we were able to increase the scale of our operation which allowed an increase in volume. This was necessary because of lower margins and higher costs.

Integration of the locations allows for better utilization of equipment, personnel, and resources. For instance, we supply customers of all three locations with bulk blends from our Donalsonville, Georgia facility. Our Bainbridge, Georgia operation supplies low chlorine clear liquids for all locations.

In order to cope with the changes that were occurring within our industry, we recognized that "new" farmers existed in our area. They have different needs from our traditional customers. In order to gain their business, we had to commit financial resources ahead of time and then work to earn the business.

These "new" farmers are different in a very important way - they physically see and handle the fertilizer. The traditional farmer generally did not see the finished product. On corn, soybeans, peanuts and generally cotton, the fertilizer was blended and spread by the manufacturer. This "new" farmer sees and handles the fertilizer either out of a side dump, tender, or bag. Any segregation is readily evident as he puts it in his equipment. Poor quality, lumps, fines, etc. are readily noticeable. This customer also demands a higher level of service because of the small window he must operate in. They will have many people in the field and are not willing to wait for fertilizer to be delivered to the site. This "new" farmer puts great emphasis on the physical and chemical quality of the fertilizers he uses. In many cases, when we begin serving a new customer, he will have the fertilizer sampled by the state inspector. When the analysis comes back and reflects the analysis tag, we very seldom see sample request from that grower again.

Development of Our Quality Control System

When we began manufacturing tomato fertilizers in particular, we knew we would be subject to the scrutiny of the grower and also the state inspector, because of our higher profile. If we were to work our way into this market, generally controlled by the large central Florida companies, we had to produce a higher quality product than they produced. Realizing this fact, we took a close look at our bulk blend plant for weak links in the system.

In this plant, raw materials are received by rail or dump truck. They fall into a drag chain conveyor and are then transferred into a bucket elevator. The bucket elevator discharges into a 12" auger which moves the materials to its respective bin. We have twelve bins that are approximately 12 feet wide, 36 feet long, and 20 feet high at the apex. Materials are moved out of the bin by skid steer loader to a 3 ton Burton horizontal mixer. It is weighed, mixed, and discharged into a bucket elevator, The elevator either discharges directly into the transport equipment or into a two bin holding hopper. Normally, fertilizer is held in the hopper for later discharge into a bulk hauler for transport to the field. After receiving the finished product in the field, the farmer dumps one of the buckets of fertilizer into a bulk tender and augers it into his application equipment.

This type of handling can induce segregation at each step in the handling process, if materials are not physically compatible. Several Roundtable speakers in past years and this year have addressed this topic of physical segregation or coning. Segregation can occur at several places between mixing and application of the product. The first location is in the overhead bin or holding hopper. The next place is in the Killebrew® bucket. Coning can also occur when the fertilizer is dumped from the bulk hauler bucket into the tender. The final place segregation can occur is in the hopper of the application equipment. Since there are four locations where segregation can occur, we concluded that the most feasible way to prevent deficient finished product was to utilize raw materials that are highly compatible from a physical quality standpoint.

Prior to assuming my present duties with Barber Fertilizer, I worked in the granulation industry as Director of Product Development. In that capacity, I developed an homogenized blend base to utilize as a carrier of secondary and micronutrients. While working with the sales force, in the marketing of that product, I was involved in performing the calculations for Size Guide Number (SGN), Uniformity Index (UI), and Mixing Quality Index (MQI). With eight or ten materials in a mix, the calculations become very tedious and time consuming. A blend plant manager just does not have the time to perform the calculations. Most of our blender customers had a computer running under MS-DOS®, so a spreadsheet was developed in Lotus that would calculate SGN,UI, and MQI for twelve materials, if one had the screenings for each material. This template worked well, but we later found most blend plant managers had no experience in using spreadsheets. Later the spreadsheet was compiled with Baler and developed into a standalone program. This program was somewhat successful in gaining awareness of physical material quality.

Granulated blend bases, no matter how good they are, are not "least cost products". The standard formulation programs in the field all ran least cost. There were a few managers, that were computer literate, who could utilize blend bases with these programs, however most managers would not take the time, nor did they have the inclination to use blend bases because they couldn't get their least cost programs to pull them out. Realizing this fact, I developed a formulation program that gave the operator, rather than the computer, control of the materials used in the formulation.

As time progressed, the two programs were combined into one standalone program and the formulation program calculates the MQI for each formulation run. Later, average SGN, average UI, and the coefficients of variations of each were added. This gives the operator a good picture of each blend he formulates.

Barber Fertilizer utilizes this program to calculate bulk blends at our Donalsonville, Georgia facility. For our quality control efforts, we utilize the Florida Department of Agriculture samples of our product. After the Florida Fertilizer Analysis Report on a particular sample is received, we go back to the formulation sheet and review that particular formulation. We compare the actual analysis as formulated to the actual analysis found in the sample. We then compare what we find to the Mixing Quality Index, and the coefficient of variations of SGN and UI.

We have noticed a correlation with our samples over the past year. When MQI is above 75, the actual analysis as reported by the state will be very close to our formulated analysis. As MQI drops to around 70, we will be within the state's tolerance, but their report will significantly deviate from our formulated analysis. If MQI drops below 65, a deficiency will probably be reported.

Three particular samples will illustrate this trend. The first sample is an 8-17-11 Tomato Bed Mix. Fourteen different guarantees were made. This particular mix is representative of the vegetable fertilizers we manufacture.

Material	Lbs/Ton		Tag	Analysis	Found
Amm/Nit	252	Total Nitrogen	8.00%	8.18%	8.13%
Pot/Nit	168	Amm Nitrogen	3.50%	3.62%	3.62%
TSP	608	Nitrate Nitrogen	4.50%	4.55%	4.51%
6-6-18	842	P_2O_5	17.00%	17.42%	18.10%
4-18-6	105	K_2O	11.00%	11.70%	12.11%
Zinc/Sul	4	Cl	Less than 2.00%	1.41%	1.46%
Boron 10-G	21	Total Mg	1.80%	1.84%	2.11%
		W.S. Mg	1.80%	1.84%	2.11%
		Total Mn	.12%	.12%	.23%
		Total Zn	.14%	.14%	.27%
		Boron	.12%	.12%	.12%
		Total Fe	.06%	.06%	.61%
		Sulfur (combined)	4.80%	4.80%	6.19%
		Total Ca	2.00%	2.00%	7.44%

	Average	CV
SGN	220	.05
UI	38	.15
Mixing Quality Index		80

This particular formulation utilized seven different materials; three of which were included in very small amounts. The tag, analysis, and state laboratory results are consistent with what has been found in similar mixes manufactured from similar material

The next fertilizer, a 4-19-19, was manufactured for corn and 5 materials were utilized.

This particular mix had a lower Mixing Quality Index. The lower CV, especially that of SGN, is very significant.

The third sample, an 0-14-27, has a lower Mixing Quality Index. The MQI on this particular product was calculated at 62.

It is fairly evident what happened in this instance. Segregation occurred because of poor compatibility of raw materials. When the inspector took his official sample, he missed some of the Muriate of Potash and Granular Triple Super Phosphate that had migrated to the outside of the pile.

Material	Lbs/Ton		Tag	Analysis	Found
DAP	552	Total Nitrogen	4.00%	4.97%	5.43%
0-0-60	422	Amm Nitrogen	4.00%	4.97%	5.43%
TSP	310	Nitrate Nitrogen			
SPM	658	P_2O_5	19.00%	19.83%	20.34%
Zinc Oxy/Sul	58	K_2O	19.00%	19.90%	18.76%
		Cl	Less than 12.00%	10.95%	9.85%
		Total Mg	3.60%	3.62%	3.12%
		W.S. Mg	3.60%	3.62%	3.12%
		Sulfur (combined)	7.00%	8.93%	7.87%
		Zinc		1.04%	

	Average	CV
SGN	211	.14
UI	34	.18
Mixing Quality Index		68

Material	Lbs/Ton		Tag	Analysis	Found
SPM	750	P_2O_5	14.00%	14.03%	13.03
0-0-60	640	K_2O	27.00%	27.45%	27.57%
TSP	610	Cl	Less than 26.00%	16.30%	15.22%
		Total Mg		4.13%	
		W.S. Mg		4.13%	
		Sulfur (combined)	7.00%	8.56%	

	Average	CV
SGN	205	.17
UI	34	.21
Mixing Quality Index		62

These index factors, when viewed together, provide us with qualitative information we cannot get in any other way. After a year of practical experience with SGN, UI, and MQI, we now have confidence in our bulk blends when MQI is high. We feel safe in guaranteeing the analysis on the tag close to the formulated analysis of the product. If MQI is low, we leave plenty of margin for error.

Changes Due to Quality Control Efforts

Our quality control efforts, utilizing SGN, UI, and MQI have changed our business. It has aided us in the purchasing of raw materials for the operation. We now place our number one priority of the physical specifications of the raw materials. Raw material suppliers are knowledgeable of their market and their competitions pricing. Generally, pricing is close and salespeople are eager for any business they get. Prior to beginning our quality control efforts, we sold bulk blends utilizing price competitiveness, service, and customer loyalty. Today we have another tool, quality indexes, to utilize in our marketing efforts. This marketing tool has carried over into our row crop fertilizers. Several of our customers now ask about the Mixing Quality Index. We have been rewarded with additional business because of our efforts to produce the best quality fertilizer available from a bulk blend plant in our area. You might notice that the Mixing Quality Index we use is a whole number and not a decimal. We found that our customers had trouble relating to a decimal number so we just moved the decimal two places to the right and round off.

There have also been cost associated with these efforts. We had to double the size of our production facility to accommodate the additional raw materials and increase the inventory needed to meet the increased demand. We now have to do a much better job of coordinating the ordering and delivery of raw materials. We are currently replacing our raw material elevator and modifying our under-track unloader for greater versatility, capacity, and reliability because now we cannot afford a breakdown. We had to add to our fleet of tenders and bulk haulers to keep up with the increased tonnage. A preventative maintenance schedule is now essential because we can't afford a breakdown during shipping season. Our overtime pay has gone up.

Plans For Additional Quality Improvements

We feel that we can improve our quality even more. There are several areas we plan to address in the future that will affect the quality of our finished product.

- Level filling of raw material bins
- TVA designed sepatators in holding hopper
- Deconing of Bulk Haulers
- Purchase of Missouri D Probe, Set of Tyler screens, riffle, and scale
- Close inspection of incoming raw materials prior to unloading

Help From Material Suppliers

Raw material suppliers can have a great impact on the quality of bulk blends. If they would get together and standardize SGN and UI specifications on their products, bulk blend industry and the end user of their products, the farmers, would benefit. Material suppliers need to better train their sales representatives in quality issues, especially screenings, SGN, UI, and MQI and their relationship to blend quality. They need to provide the bulk blender with either the SGN and UI or the cumulative screenings on each shipment of raw materials.

Terminal warehouses can also influence the quality of the fertilizer produced by the bulk blender. They need to work on the prevention of coning in piles. Loader operators need to be trained in proper reclaiming of the piles to prevent shipping off speck material that may have coned.

Conclusions

Since beginning this program of quality control, our blend plant has had only one incident of a fertilizer deficiency. There have been no real cost associated with this program. Sourcing of raw materials has been more orderly. Our market share has increased and margins have improved. We now have more to sell to the farmer than price. Our reputation among the farmers and state fertilizer inspectors is excellent. Our employees now take more pride in their work and their work environment.

ISO 9000 Registration - A Global Quality Standard

Rita Grenville
DuPont Company

Background

The ISO is the International Organization for Standardization, and its purpose is to promote international standards worldwide. The ISO has authored thousands of international standards which are then voluntarily adopted by different countries all over the world. The ISO works in technical committees; one technical committee in particular, TC176, authored the ISO 9000 series. ISO 9000 is a series of standards for quality systems. They are very generic - there are no prescriptive methods described in the standards, and they are meant to apply to any industry anywhere in the world. They specify the elements of a quality system that need to be in place in order for that system to be effective. They do not address any of the implementation aspects; the standards do not tell you how to run your business.

ISO 9000 Series

There are really five standards in the ISO 9000 series. The first standard, ISO 9000, is basically the road map to the rest of the series. It is a general overview that lists some key quality definitions and also helps you decide which of the contractual standards would be most applicable to your business - ISO 9000 is purely for guidance. Similarly, the last standard in the series, ISO 9004, is also there just for your guidance. ISO 9004 provides some additional details around the quality system elements, helping you to understand better how they might apply to your business. It includes more detail than the contractual standards. That leaves ISO 9001, 9002, and 9003, and these are referred to as contractual standards, which are used in quality system registrations. Each of these three standards specifies the elements for a quality system for a particular type of business.

ISO 9003 is the most limited of these three standards. It applies to businesses that only do final inspection and testing - no processing, no delivering of services - just the final inspection and testing of a product or service. ISO 9003 is so limited that it is only used for about 5% of the quality system registrations. ISO 9002 contains all of the elements of ISO 9003 but builds on those and adds additional elements so that it is applicable for any kind of organization that either manufactures a product, delivers a service, or both. ISO 9001, the most extensive of the three documents, contains all 18 elements of ISO 9002 but adds two additional elements - one on design and one on after-sales servicing. So you simply choose the standard that applies to what your organization does. If you do manufacturing but don't do design, then ISO 9002 is applicable. If design is an integral part of your offering to the customer, then ISO 9001 is the applicable standard.

Registration

This is something that has gone hand-in-hand with ISO 9000 almost from the beginning. Consider the entire realm of supplier certification. There are really two sides to supplier certification. One is actual product certification, either along the lines of product quality or possibly safety. That side of the certification issue may use things like lab accreditation, test methods, or actual product testing to certify that a product meets certain standards. ISO 9000 is on the other side of supplier certification. It is *system* certification, and ISO 9000 is the generic standard around quality system certification. So certification or registration to ISO 9000 does not certify your product; rather, it certifies that your system meets certain requirements. In almost every industry, there are industry-specific requirements that go beyond the requirements of ISO 9000.

Basically, quality system registration occurs when a neutral, accredited third-party audits your organization and certifies that you've met the requirements of ISO 9000. This gives you an objective, third-party registration of your quality system. First-party registration would be when you certify yourselves. Second-party registration is something most of us are familiar with - when your customers come and audit your system and maybe have some sort of certification program. But the third-party gives you some objective evidence to give to your customers - confidence that you meet this basic level of quality.

Although third-party registration was not the original intent of these standards, that is the way that they have been used and that use has grown rapidly. Many of the nations that have adopted ISO 9000 have developed an accreditation system for the third party auditors, or registrars. The accrediting body in each nation certifies that the registrars meet certain standards for auditing, are qualified to audit your processes, and are a neutral party with no conflict of interest. This kind of an accreditation system gives you some confidence in choosing your registrar so that you can ensure that you do indeed have a neutral third-party.

In the United States, the accreditation program is operated by the Registrar Accreditation Board (RAB) - a subsidiary of the American Society for Quality Control (ASQC). The RAB, in conjunction with the American National Standards Institute (ANSI), has developed an accreditation program for the U.S. This program accredits bodies that register companies to ISO 9000. In this partnership, RAB administers the actual program, and ANSI coordinates the program's processes to ensure that the United States program is in line with what is going on in the rest of the world. Talks are now underway to try to get recognition and some link with the government.

ISO 9000 & The EEC

How does this fit in with the European Economic Community? The purpose of the economic community is to reduce the trade barriers between the different European countries so that they can trade more freely with each other. The focus of that reduction of trade barriers has been very strongly on product safety, on environmental aspects, and on public health - the type of aspects that would most directly impact these different countries trading with each other. International standardization has been a very strong force in the EC in order to ensure free trade. ISO 9000 can be part of the process to obtain certification of a regulated product.

Besides the certification that a product meets certain safety requirements, many customers are asking that their supplier companies get registered to ISO 9000 to show that they meet some minimum level of quality, as well. For the most part, ISO 9000 has been customer driven - this is one of the main misconceptions right now. There is no country or government that requires ISO 9000 in order for you to trade with Europe, but there are many customers who are beginning to require it- not only in Europe but also domestically. In DuPont, we have many customers who have already either requested or required us to get ISO 9000 registered by a certain time in order to continue supplying them.

A Global Standard

Another common misconception is that ISO 9000 is a European standard - it is actually a global standard. The technical committee that wrote ISO 9000 included delegates from the United States. In total, over 55 countries worldwide have adopted ISO 9000 as their national quality system standard. So what's the impact on the United States? There is a worldwide trend toward quality system registration. The United Kingdom is the furthest ahead in number of registrations. The U.K. had their own quality system registration process in place long before ISO 9000 was approved, so the U.K. now has close to 18,000 companies registered to the standard. Most European countries have about 1,000 registrations, the U.S. has approximately 1,600 (October 1993).

In the United States, the FDA and the Department of Defense have been talking about adopting ISO 9000. In both cases, there will likely be some additional requirements. Also, the three major automotive manufacturers have announced that ISO 9000 will form the basis of their quality system requirements. The application of ISO 9000 is also broadening beyond just quality systems to the way that we manage safety, health and environmental affairs.

Near term, registration to the ISO 9000 standards may be a competitive advantage for you. The companies that get registered early to ISO 9000 may have an advantage on their competition - the differentiation that you meet this quality standard and your competition may not. Longer-term, quality system registration is moving so quickly that you can expect ISO 9000 registration to be a basic requirement of doing business - not only in the European community but world-wide and domestically as well.

ISO 9000 and Quality Awards

In the United States, a frequent question asked is, "How does ISO 9000 compare with the Malcolm Baldrige National Quality Award?" Many people are under the impression that these are two different quality systems that they need to choose between. Actually ISO 9000 is a very basic level quality system. It is not complex; it is somewhat of a foundational level quality system. If you look at the Malcolm Baldrige Award requirements, there are seven categories. One of those categories is Management of Process Quality. Most of the ISO 9000 requirements fit into that category. If you are registered to ISO 9000 or meeting those standards, you are meeting most or all of the Management of Process Quality category of the Malcolm Baldrige Award. In addition, you have begun, to a small extent, to build a system in each of the other areas. The Malcolm Baldrige Award certainly goes far beyond ISO 9000, but ISO 9000 is a good starting point. Many companies in the past have failed in some of the quality efforts or quality programs they have tried to implement simply because they have tried to run before they could walk. ISO 9000 is a very basic level system. If you implement that first, it gives you the system and the foundation to build on so that you can go further into things like Malcolm Baldrige.

Costs and Benefits

What are the benefits and costs of implementing an ISO 9000 system? The purpose of ISO 9000 is to improve your quality system, so certainly that's a benefit. There is a misconception that the only reason to look at ISO 9000 is if there's competitive pressure to do so. What is often overlooked are the extensive internal benefits that a company can realize from implementing a quality system like this. If you are improving your quality systems, you are going to see improvements in your products.

Hopefully, with the third-party registration there will be some reduced redundancy in second-party auditing. It is not a guarantee that your customers will stop auditing you. What is beginning to happen already is that some customers are auditing their suppliers using ISO 9000 as a base. If you are registered to ISO 9000 that covers a large part of the audit and then the customer can focus on those industry-specific aspects that go beyond ISO 9000. If you are spending less time with your customers going through the same audit over and over, you will have more time for value-adding activities, like developing partnerships and working on continuous improvement activities in conjunction with your customers.

Internal Improvements

Many quality systems in many companies are not yet even at the basic level that ISO 9000 covers. So, though it is just the basics, a lot of us need to improve on the basics. The following benefits are actual benefits from the DuPont businesses that have been registered to the standards - benefits that they attributed directly to their ISO 9000 implementation efforts. Currently in DuPont we have over 200 registrations worldwide, with 80 of those in the United States. So we have tried to draw from that experience and quantify the benefits.

One benefit seen consistently is cost reduction. Most of the registrars estimate that implementing an ISO 9000 quality system will reduce your cost by at least 10-15%. We have seen at least that amount in our businesses. One site reported a cost reduction of $3,000,000 which they attribute to their implementation. Others reported scrap down 40%, process improvements worth $440,000, and similar cost reductions while actually increasing production output. Many sites report internal improvements like on-time delivery increased from 70 to 90%, product cycle time reduced from 15 days to one and a half days, and in-depth problem investigations down 22%. Others have experienced great improvements in product quality - final assembly yield improved from 92% to 96%, first-pass yield up to 92% from 72%, and out-going nonconformances reduced from 500 ppm to 150 ppm. The benefits go on and on. These are just a few of the quantifiable benefits that the DuPont facilities have seen from implementing ISO 9000.

The major costs of registration are for internal resources. In most cases, systems and documentation need to be upgraded or improved somewhat to meet ISO 9000. Internal resources are needed to implement or improve the quality system, including a half- to full-time Management Representative, area coordinators, and internal auditors. There is seldom a need to hire additional personnel to implement a quality system. It is most effective when accomplished by a broad spectrum of your business; employee involvement is critical to achieving the kinds of internal improvements mentioned above.

Other costs include training and consulting. Some training is necessary to fully understand how ISO 9000 applies to your business. One requirement of ISO 9000 is to carry out a system of internal quality audits; many businesses find they need training in this area as well. In addition, some organizations choose to provide additional training on implementation or documentation. Using an experienced consultant for advice and guidance is another option.

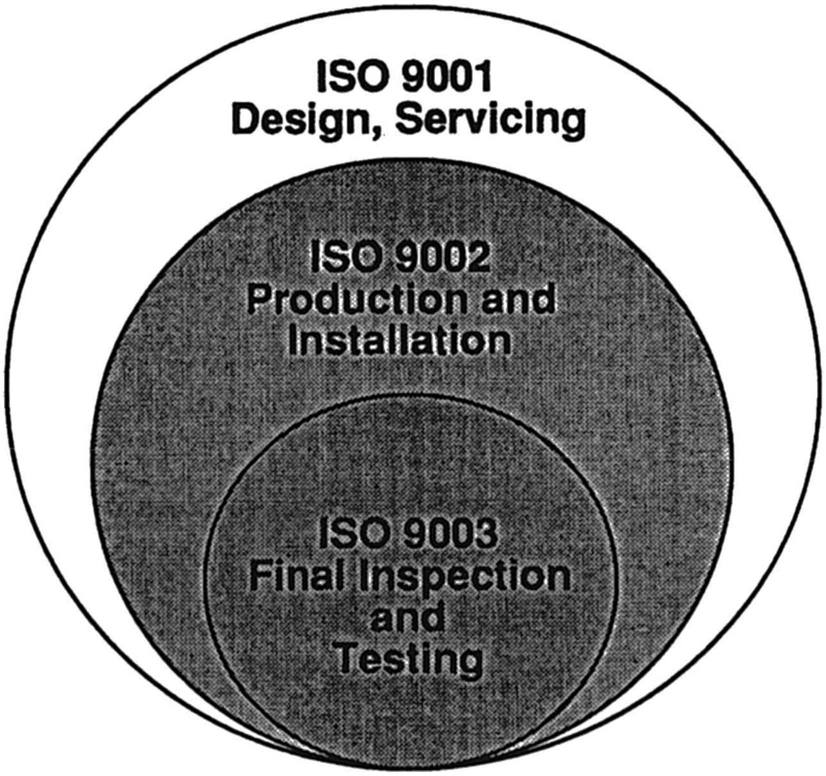
There is the cost of the registration itself, which varies from registrar to registrar. Quality system registration is becoming a big business, so there are differences in the price structure between registrars. The average range is $1,000 - $1,500 per auditor per day. The number of auditors needed and the length of the audit depend on the size and complexity of the businesses being registered. Additional registrar fees could include pre-assessments, on-going surveillance audits, and application fees. The good news is that most companies surveyed recently in the United Kingdom had recovered the costs spent in preparing for ISO 9000 within three years of being registered.

Roadmap to ISO 9000 Registration

We have developed a "Roadmap to ISO 9000 Registration", based on our experience in DuPont' s own registrations, as well as our experience with external clients. It shows the milestones that you need to go through in order to implement an effective quality system to meet ISO 9000. Basically, you have to start with management commitment and involvement. From there you build some kind of an internal structure to do the work and handle some of the implementation effort. Internal quality audits are required by the standard. We recommend starting these early. The audits are a great help in the implementation they provide a measuring stick. You can find out where you are starting from and then measure your progress as you go. Most organizations put together a quality manual to meet ISO 9000. Although it is almost impossible to write a complete quality manual at the beginning, a rough draft at the early stages is helpful. Next, you work on analyzing your processes, improving them, and documenting them across the entire organization. At some point, you feel that your practices are pretty much in place and well documented. This is a good time to have an initial visit with the registrar you have chosen.

Many companies choose to have a pre-assessment, which is basically a dress rehearsal for the final assessment. It can give you valuable feedback in how well you are meeting the standards and how well you are following your own documentation. The basic requirement for ISO 9000 can be stated in one phrase, "Say what you do and do what you say." If you have documented your practices and you're following them, and you meet the very basic requirements of the standard, then you can get registered. Finally, you have your final assessment by the registrar. If you meet the requirements of the standard and do what you've documented, you'll get a certificate. From then on, the focus is on continuous improvement. You must continue your internal audits and corrective action system, the external auditors will come back periodically for surveillance audits. Then is the time to move onto some of those higher level quality activities to continue to gain competitive advantage.

What Is The ISO 9000 Series of Standards?



ISO 9001
Design, Servicing

ISO 9002
Production and
Installation

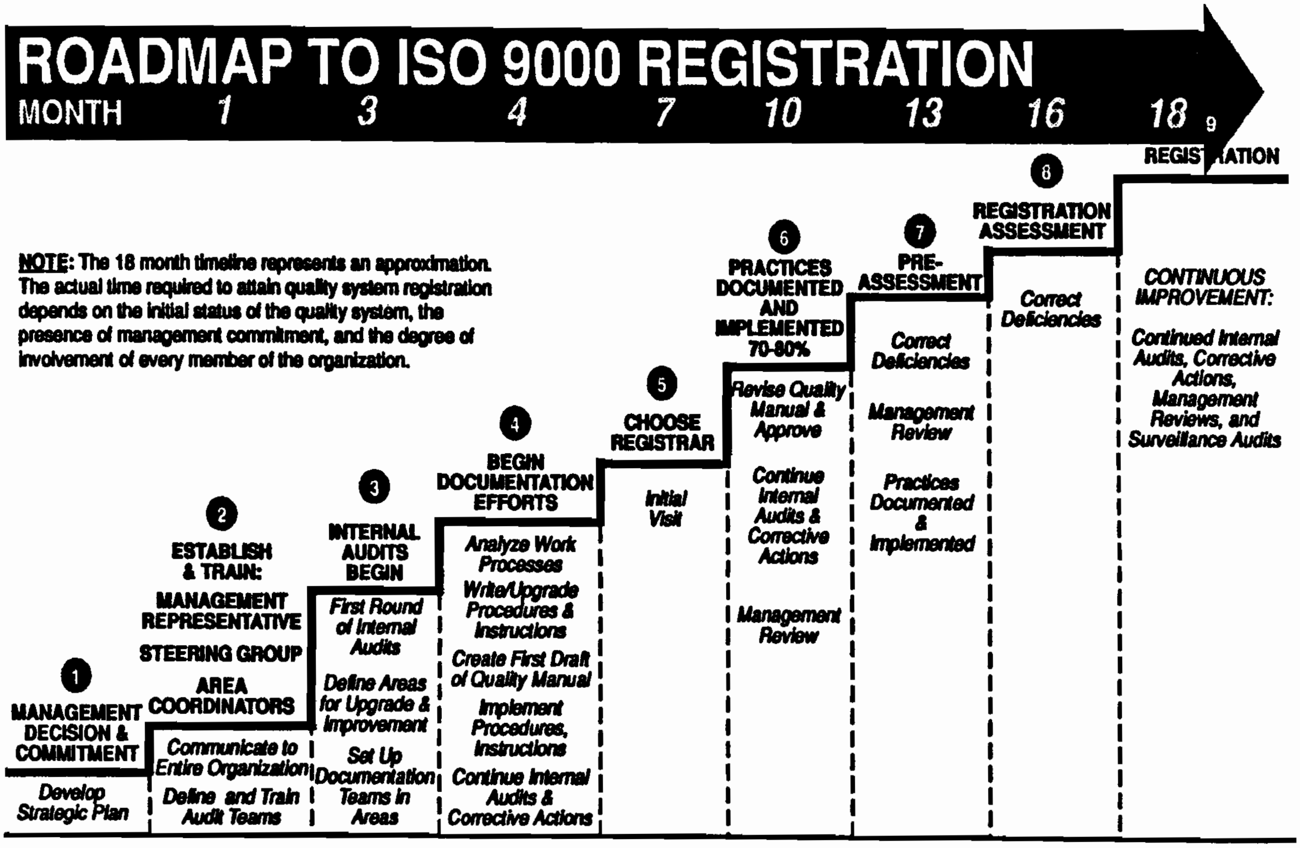
ISO 9003
Final Inspection
and
Testing

A Global Standard

Algeria
Argentina
Australia
Austria
Barbados
Belgium
Brazil
Canada
Chile
China
Colombia
Cuba
Cyprus
Czechoslovakia
Denmark
Finland
France
Germany
Greece
Hungary
Iceland
India
Ireland
Israel
Italy
Jamaica
Japan
Malaysia
Mexico
Netherlands
New Zealand
Norway
Pakistan
Philippines
Poland
Portugal
Romania
Russian Federation
Singapore
South Africa
South Korea
Spain
Sweden
Switzerland
Taiwan
Tanzania
Thailand
Trinidad/Tobago
Tunisia
Turkey
United Kingdom
USA
Venezuela
Yugoslavia
Zimbabwe

20 Sections of ISO 9001

1. Management Responsibility
2. Quality System
3. Contract Review
4. **Design Control**
5. Document Control
6. Purchasing
7. Purchaser Supplied Product
8. Product Identification and Traceability
9. Process Control
10. Inspection & Testing
11. Inspection, Measuring, and Test Equipment
12. Inspection & Test Status
13. Control of Nonconforming Product
14. Corrective Action
15. Handling, Storage, Packaging, and Delivery
16. Quality Records
17. Internal Quality Audits
18. Training
19. **Servicing**
20. Statistical Techniques



ROADMAP TO ISO 9000 REGISTRATION

MONTH 1 3 4 7 10 13 16 18 9

NOTE: The 18 month timeline represents an approximation. The actual time required to attain quality system registration depends on the initial status of the quality system, the presence of management commitment, and the degree of involvement of every member of the organization.

① **MANAGEMENT DECISION & COMMITMENT**

Develop Strategic Plan

② **ESTABLISH & TRAIN:**
MANAGEMENT REPRESENTATIVE
STEERING GROUP
AREA COORDINATORS

Communicate to Entire Organization

Define and Train Audit Teams

③ **INTERNAL AUDITS BEGIN**

First Round of Internal Audits

Define Areas for Upgrade & Improvement

Set Up Documentation Teams in Areas

④ **BEGIN DOCUMENTATION EFFORTS**

Analyze Work Processes

Write/Upgrade Procedures & Instructions

Create First Draft of Quality Manual

Implement Procedures, Instructions

Continue Internal Audits & Corrective Actions

⑤ **CHOOSE REGISTRAR**

Initial Visit

⑥ **PRACTICES DOCUMENTED AND IMPLEMENTED 70-80%**

Revise Quality Manual & Approve

Continue Internal Audits & Corrective Actions

Management Review

⑦ **PRE-ASSESSMENT**

Correct Deficiencies

Management Review

Practices Documented & Implemented

⑧ **REGISTRATION ASSESSMENT**

Correct Deficiencies

REGIS RATION

CONTINUOUS IMPROVEMENT:

Continued Internal Audits, Corrective Actions, Management Reviews, and Surveillance Audits

Pollution Control From DAP, MAP, & N:P:K Granulation Plants

Frank Achorn
SE-ME, Inc.
Charles Hodge
Tennessee Valley Authority

There are different processes for granulation of these products; however, each process usually has the following pollutants which are common to all of them.

Dust: Solid particles that are generated by handling, crushing, grinding, and decrepitation. Dust does not tend to flocculate except under electrostatic forces. Dust does not diffuse in air, but settles by gravity. Most fertilizer dust varies widely in particle size.

Fume: Solid particles generated by condensation from gaseous states. Typical fertilizer fumes are: ammonium chloride, ammonium fluoride, etc.

Mist: Suspended liquid drops by condensation from gaseous to liquid state or by breaking up a liquid into a dispersed state, i.e., as in splashing and foaming.

Gas: Normally formless fluid which occupies the space of an enclosure and which can be changed to liquid or solid only by the combination of increased pressure and decreased temperature.

Vapor: Gaseous states of a solid or liquid that can be returned to its original state either by increasing pressure or decreasing temperature. Typical vapors in the fertilizer industry are ammonia and fluoride compounds.

In all processes for the production of MAP, DAP, and NPK, there are larger dust particles that can easily be removed by dry cyclonic dust collectors such as shown in Figure 1. In this low pressure drop, cyclone centrifugal forces push particles in the gas stream toward the outside walls of the collector where they descend under the influence of gravity and the descending vortex of the said gas stream.

Experience has shown collection efficiency is best in these types of collectors when the particle sizes are greater than 40 microns. These are types of dry collectors usually used for the largest particles of dust normally encountered in fertilizer plants. The pressure drop across these types of collectors is usually 1 to 3 inches of water

A few companies do use higher efficiency centrifugal collectors which have pressure drops in the range of 3 to 5 inches and can efficiently remove particles as low as 10 microns. One design of a high efficiency centrifugal collector has several smaller collectors in a single unit and is sometimes referred to as a multicyclone unit.

Most companies prefer to use the low cost, low pressure type collector which is shown in Figure 1. The exit gases from these cyclone collectors are either filtered in fabric type collectors (bag filter) or scrubbed in a wet scrubber.

One problem with dust collectors is the devices used to seal their discharge end. Usually the exhaust blower is located downstream from the collector so that its blades will not be coated with excessive amounts of dust, which in turn will cause excessive vibrations of the blower. With this equipment arrangement, the cyclone collectors are operated under a negative pressure. If the discharge is not well sealed, air will be sucked into the discharge and will hinder the flow of materials from the collector and interrupt the cyclonic action of the collector. In turn, this will cause an overload of the downstream scrubbing equipment. Several devices have worked well to seal these collectors. One uses a motor driven star feeder; other companies use molded rubber discharge tubes, such as shown in Figure 2. And still other companies use a simpler type of sealing device such as the one shown in Figure 3.

To insure that the dust load into the collectors are kept at reasonable levels, the air velocity through the dryers and coolers should not be excessive. Figure 4 shows a typical ammoniation granulation plant for a NPK mixture. It shows the plant having a rotary ammoniator granulator, a rotary dryer, and a rotary cooler. These drums are usually common to the MAP and DAP plants also. Tests have shown if the gas velocity through the dryer and cooler exceeds 400 feet per minute then the dust loading to the cyclone collectors will be too high for economical design of these collectors. Some companies over-design the exhaust system so that they can realize higher velocities and increase efficiencies through the cyclones. When this is done, an extra fresh air inlet duct is installed such as shown in Figure 5. The fresh air inlet is usually used to suck dust from screening and crushing operations. With this arrangement it is possible to have optimum velocities in the dryer cooler and cyclone collectors.

Final cleaning of the exit fumes is usually done either by wet scrubbers or by passing the fumes through closely woven filter cloth (bag filters). These collection devices are efficient, reliable units that can remove particulate from the exit fumes which have particle sizes from two and larger to less than 0.5 microns.

They may be divided into the three ways they are cleaned: intermittent, periodic, and continual. A typical *intermittent type* is shown in Figure 6. It normally has fabric bags or envelopes and the unit must be shut down regularly to remove the dust cake. It's use is good for plants that can readily be shut down, such as bulk blending and other dry mix type plants. It can also be used for bagging operations.

The *periodically cleaned* collector, such as the one shown in Figure 7, is a series of intermittent compartments connected by inlet and outlet manifolds. On a predetermined basis, one section of the collector is removed from service by closing the air dampers, which isolates it from the dirty air stream. Then a reverse air flow is passed through the bags to clean them and the section is then returned to service. Five timers are usually set so that each section is cleaned at 90 minute intervals. The timers are adjustable if the cleaning interval needs to be changed. In the sketch of Figure 7, compartments 1, 2, and 3 are in service while compartment 4 is being cleaned. This type of exit gas filter is the one most frequently used by the fertilizer industry.

A few companies use bag filters which are *continuously cleaned* during operations. Cleaning is usually done with a reverse jet of air from traveling blow rings that move continuously up and down the bags. Figure 8 shows a sketch of this type of collector. The blow ring directs air at about one to two pounds per square inch back through the fabric and dust falls into the hopper at the bottom of the collector. Fabricators of these type of filters report with this type of cleaning systems a much higher air to cloth ratio can be used.

Advantages of Fabric Collector

1. They produce a dry product which can be recycled without adversely effecting the water balance and thus the production rate.
2. Their efficiencies are excellent and usually their plumes are less than from wet scrubbers.
3. There are very few problems with entrainment losses.

Precautions and Disadvantages of Fabric Collectors

1. They will not capture gases such as ammonia fluoride type, etc.
2. The inlet gases humidity in the collector must remain above the critical humidity of the particulate in the gas stream.
3. There must be a negative pressure throughout the entire system.
4. The melting point of the filament in the bag should not be reached.

Figure 4 shows a sketch of an ammoniation granulation plant that employs a completely dry dust collecting system. In this system the ammoniator granulator and cooler discharge their gases into the drier at the feed end. Within the dryer, the gases are heated so that the relative humidity of the gases exiting the dryer are well above the critical relative humidity (CRH) of the particulate in the gas stream. Critical relative humidity is defined as the relative humidity at which the particulate starts to absorb moisture from the air stream. If the gas cools too much in the bag filter, the particulate becomes wet. This in turn will cause wet mud to collect on the walls of the bags which in turn causes the fabric's pores to become plugged and will result in insufficient air flow for plant operation.

Safety devices should be installed that will cause the burner of the dryer to be shut down when the temperature exiting the dryer approaches the melting point temperature of the fabric in the bags. The choice of fabric must be one that does not react with the chemicals stream.

One major problem with this type of dust collector is outside air leaks into part of the system after the dryer. When leaks occur, the cool air cools the main exit gas stream so that its relative humidity is higher than the CRH in the gas stream which causes mud formation in the collector. Another problem has been insufficient negative air pressure in the rotary vessels and the dust collector. This problem can be avoided by installing an exhaust blower of sufficient size at the gas discharge end of the collector. When this is done, there is an even flow of exit gases from the drums and the collector. The dry material is usually emptied by a screw conveyor which is designed to remain full. This keeps the discharges of the hoppers in the collector sealed from the entry of outside cool air.

Wet Scrubber

In the DAP and MAP processes, gases exit from the dryer, cooler, granulator, and preneutralizer. All contain ammonia and in some instances, fluorine compounds which cannot be removed by dry collectors. Figure 9 shows a sketch of a typical DAP plant. This plant uses two stage scrubbing and a pipe reactor. However, the common practice is to use a tank type re-reactor instead of the pipe reactor. The exit gases from the pre-reactor and ammoniator granulator are first scrubbed in the first stage scrubber and the exit gases from the first stage are scrubbed in the second stage scrubber. The scrubbing medium is usually filter grade phosphoric acid (28 to 30% P_20_5) which supplies part of the product's P_20_5 (usually about 50% of total P_20_5). The acid flows in a direction counter to the exit gas flow. Therefore, fresh acid is added to the second stage and partially neutralized acid from this stage is added to the first stage scrubber. Slurry from this scrubber is pumped to the pre-reactor where higher strength phosphoric acid is added along with additional ammonia and sometimes a small amount of sulfuric acid. Slurry from the pre-reactor is sprayed into the granulator where it is further ammoniated to DAP. Some of the operating conditions are as follows:

Equipment	NP Mole Ratio	Slurry Specific Gravity	Temperature °F	NH_3 Loss, % of Total
Granulator	1.95	N/A	200	15-20
1st Stage	1.30	1.4	230	10
2nd Stage	0.35	1.3	225	0-01

Under these conditions there is essentially no fluorine lost and very little ammonia lost in the plant's stack gases. Some companies have installed tail gas scrubbers to remove traces of ammonia. They usually use gypsum pond water as a scrubbing medium. This pond water contains acids that capture the traces of ammonia. Dutch State Mines Co. conducted tests to show that if sufficient ammonia is added either from the process (DAP) or externally (MAP) so that a NP mole ratio of 0.35 is maintained there will be essentially no loss of fluorine from the scrubber's (plant) stack.

Usually the same plant used to make DAP is also used to manufacture MAP. Single stage scrubbing is all that is needed for MAP. There is little or no problem with ammonia loss. However, there is a tendency toward higher fluorine losses when manufacturing MAP. The scrubber should be operated with mostly water in it. The pH of the water needs to be kept between 4 and 5 by the addition of either phosphoric or sulfuric acid and in some cases, the addition of ammonia.

When the tank type reactor is used it is recommended that the NP mole ratio of the slurry in the reactor be at least 0.9 to avoid high fluorine losses. Also, to insure that there is a favorable water balance in the plant, it is recommended that the tank reactor be operated at an NP mole ratio of 1.45 and a slurry temperature of 245°F. With these operating conditions there are low fluorine losses and there is only a slight ammonia loss from the tank reactor. This is because the tank reactor is operated at conditions of high solubility. Slurries of relatively low water content (15 to 20%) are produced that can be effectively sprayed within the granulator. Phosphoric acid is also sprayed into the granulator to lower the NP mole ratio of the product from the granulator to 1.0. This is a ratio of relatively low solubility that is conductive to low recycle and high production rates.

Some companies have found it to be highly desirable to use a TVA pipe cross reactor (PCR) to manufacture MAP instead of a tank reactor [5]. When this is done, 90 percent or more of the ammonia used in the process is added to the PCR. With these conditions the loss of fluorine from the PCR is low because the PCR is operated at a relatively high pressure and temperature (285°F). Also, at these conditions the melt (>5.0% water) can be effectively sprayed into the granulator. There is essentially no loss of ammonia from the PCR during the manufacture of MAP.

The scrubber is operated using the same conditions as described above for the use of the tank type reactor to manufacture MAP. Since the PCR can operate and spray well at high temperatures and low slurry water content, it is possible to have higher production rates when it is used in preference to a tank type reactor.

Types and Design of Wet Scrubbers

There are generally two categories of wet scrubbers:

1. Low energy
2. High energy

The low energy type makes use of restricted passages through a liquid. They have a plate or packing on which liquid is sprayed. The gas flow is usually in a direction counter to the flow of liquids. Figure 10 shows several types of these scrubbers. They include:

A. A wet centrifugal or cyclonic type, which uses centrifugal forces and scrubbing fluid contact to effect collection.
B. An open spray tower which uses sprays in an open tower.
C. A packed tower, in which gases and liquids pass counter current through the packing.
D. A flooded bed tower, which uses one or more beds made of marbles or ping pong balls. This packing is placed loosely in the tower so they can float and rotate in the gas stream.

These scrubbers require a minimum of energy. However, in some instances there is insufficient contact between the particulate in the exit gas stream and scrubbing fluid. When the particulate is too small or concentration of gas to be absorbed is higher in the scrubbing medium than usual, a more efficient high energy scrubber is used.

High Energy Scrubbers

The scrubber most commonly used by the fertilizer industry is the Venturi scrubber. The Venturi scrubbers are used for intermittent mixing of dust and scrubbing liquid. They have a high impact velocity by the gas on the injected liquid streams. Some of the typical Venturi type scrubbers are shown in Figure 11. A brief description of each type is as follows:

A. This is the Dry Approach Venturi in which the scrubbing liquid is injected transversely at the converging section and leaves this section to discharge into the disengaging chamber where the liquid is separated from the clean air.
B. This is the Wet Approach Venturi in which a presaturator is used to wet and quench the gas prior to passing it through the Venturi section. Either this or the Dry Approach Venturi may be equipped with an adjustable throat mechanism which enables the Venturi to handle a wide range of gas flows without sacrificing efficiency.
C. This sketch is an Ejector Venturi and is used by some companies in the fertilizer industry.

Figure 12 shows a three phase injector Venturi which is used in a superphosphate plant [4]. Tests show this scrubber recovered 99.6 per cent of fluorine added to it. It produces a 23 to 26% hydrofluosilicic acid (H2SiF6) which is used by municipalities to treat their drinking water with fluorine. In this type, Venturi scrubber liquid is added under pressure through a spray nozzle. The passage of fluid through the spray nozzle sucks the contaminated air into the Venturi.

The dust collection efficiency of Venturi scrubbers varies with power input. The higher the power input the higher the efficiency. Tests show higher power input is required for the smaller particulates.

This has been a very general discussion of different types of pollution control systems now in use. We would be remiss if we did not mention that control of the process has much to do with the efficiency of these scrubbers. Much could be done to control pollution at its source rather than after the pollutant has been formed. Some operating factors which cause pollution are: NP mole ratio in scrubbers, particle size in recirculating circuit, velocity of gas through dryers and coolers, granulation and dryer temperatures, condition of granulation equipment, design of equipment, etc. In the future complanies will select processes and equipment which will cause a minimum of pollution control problems.

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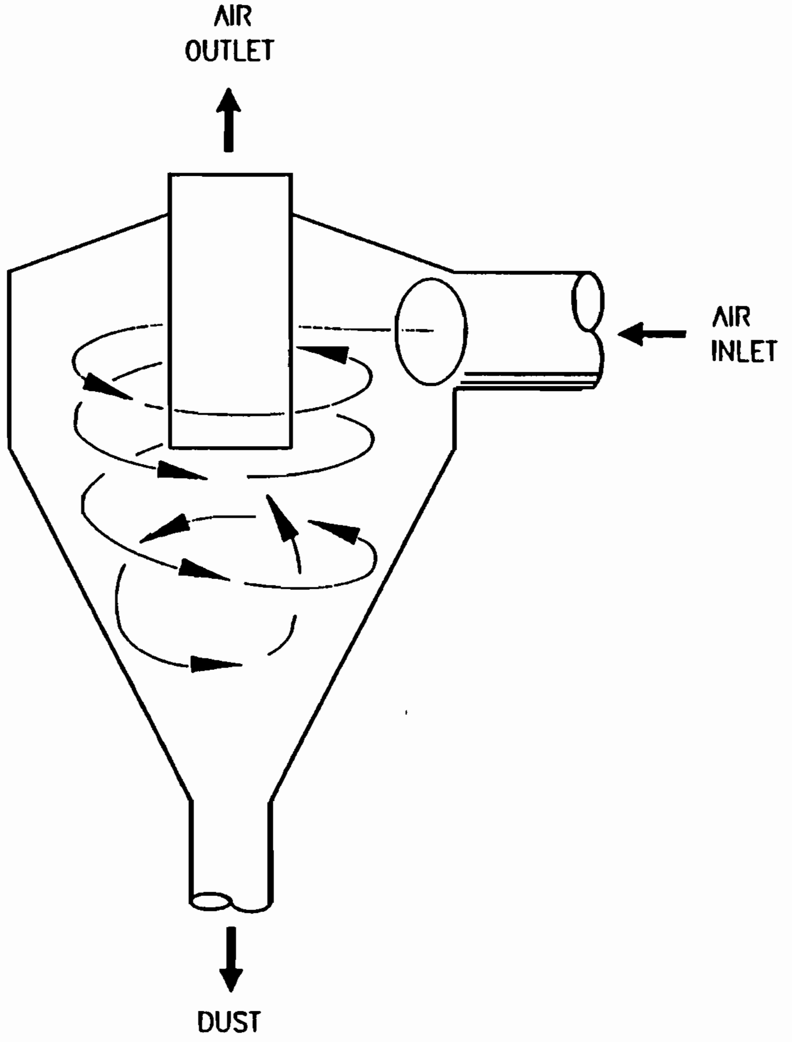


Figure 1: Cyclonic Dust Collector For Solids-Gas Separation

Figure 2: Dust Tight Cyclone With Closure Molded Rubber Seal

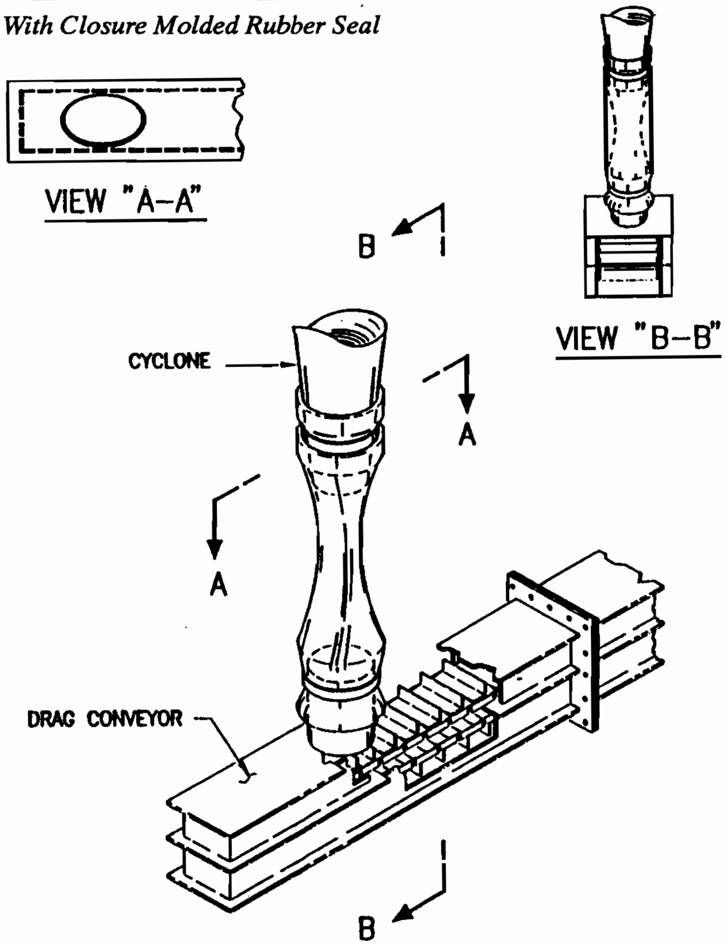


Figure 3: Dust Collector Seal

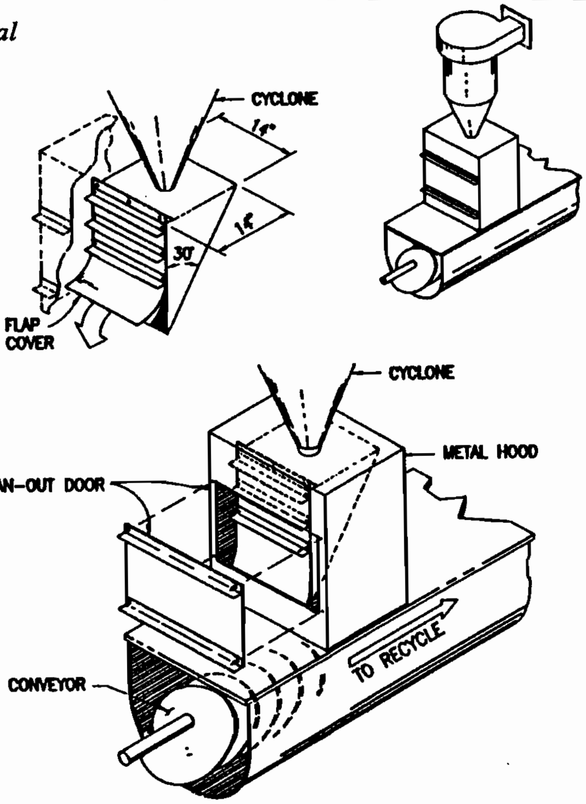


Figure 4: Typical State-Of-The-Art Ammoniation-Granulation Plant

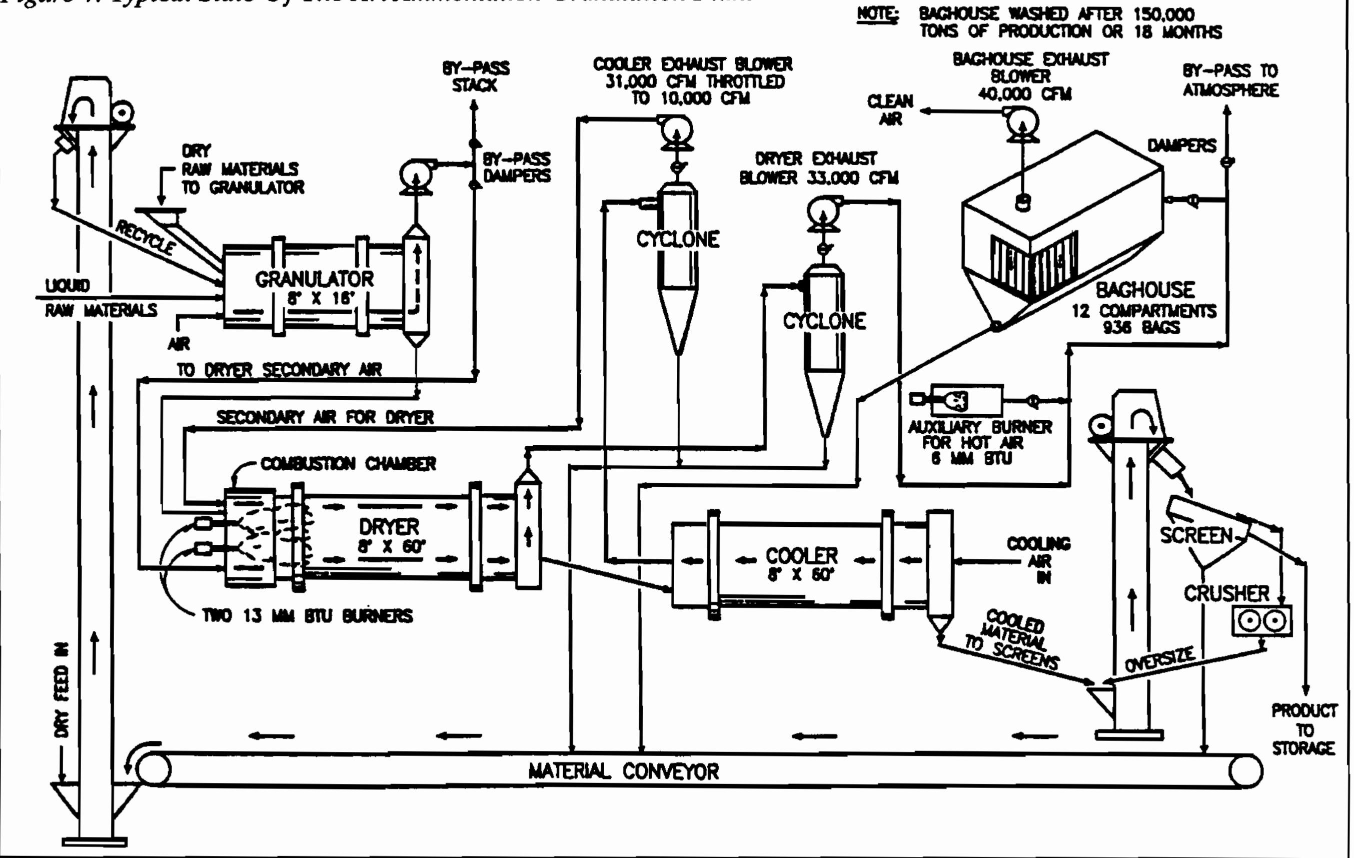


Figure 5: Cyclone Gas Velocity Control

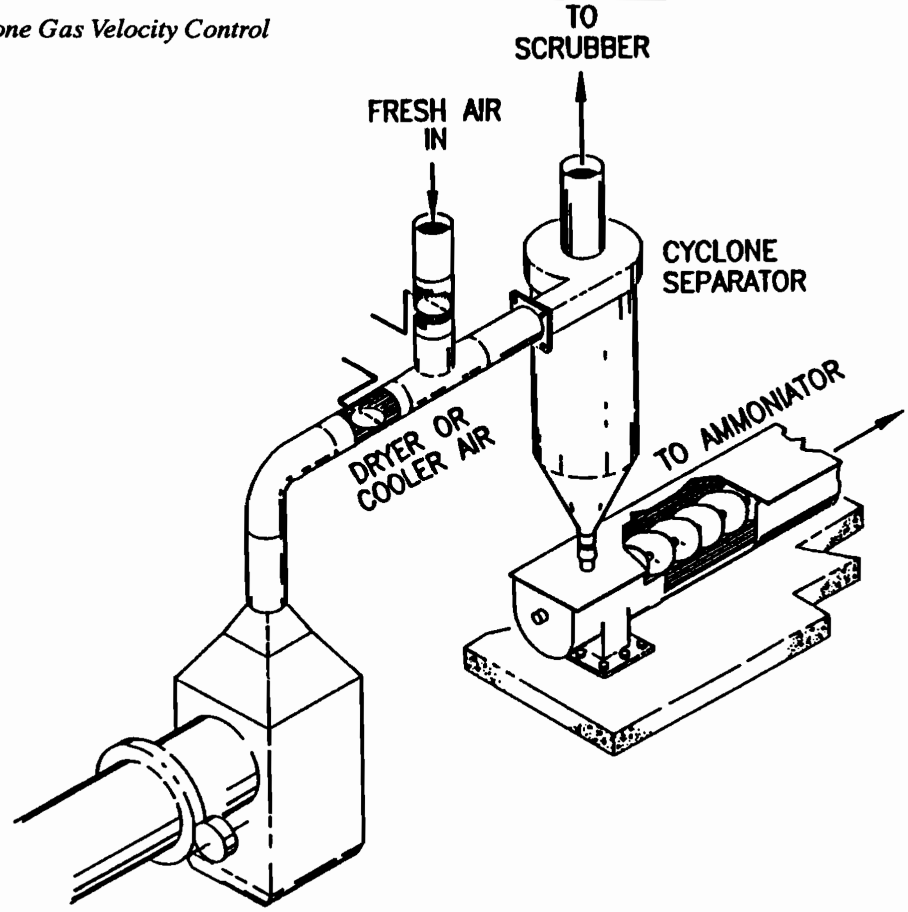


Figure 6: Fabric-Type Dust Collector, Cleaned by Vibrator

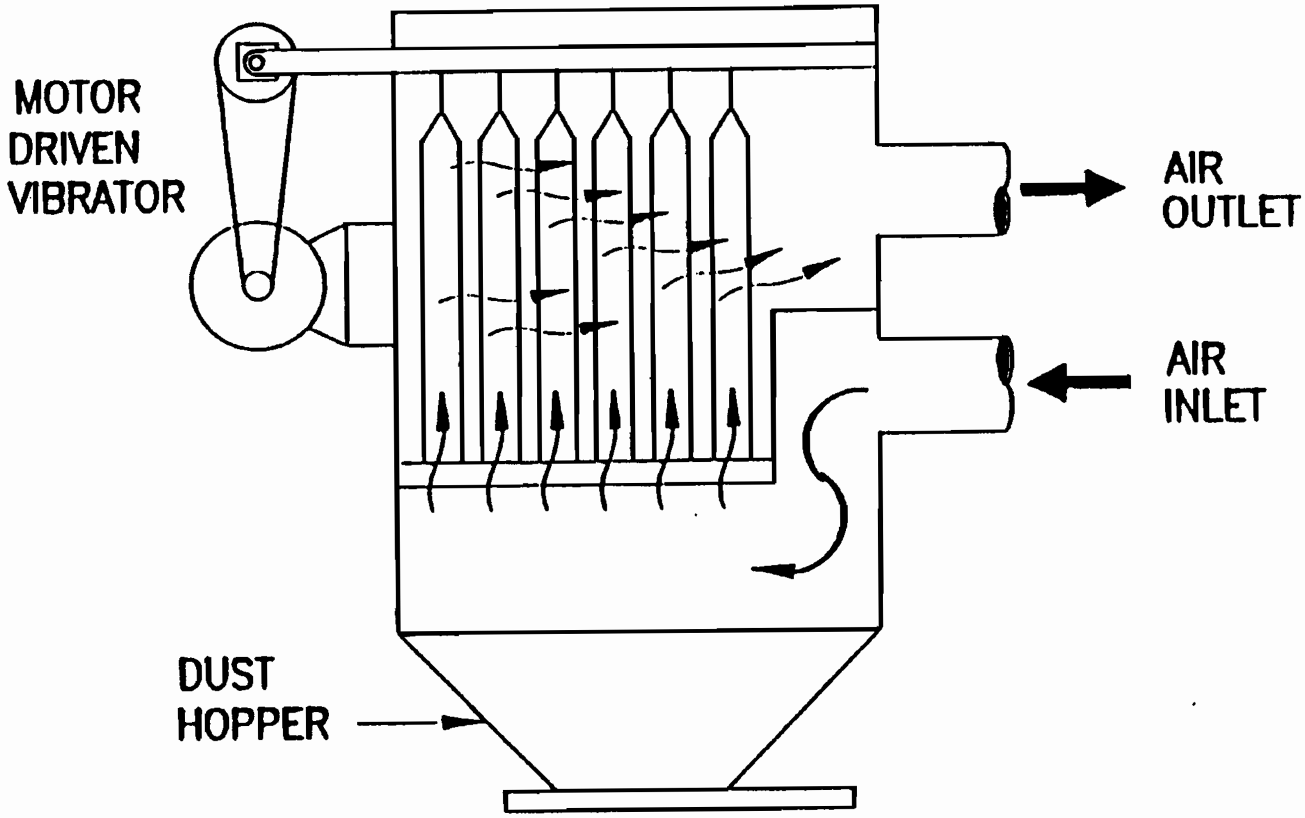


Figure 7: Fabric-Type Dust Collector With Multiple Sections

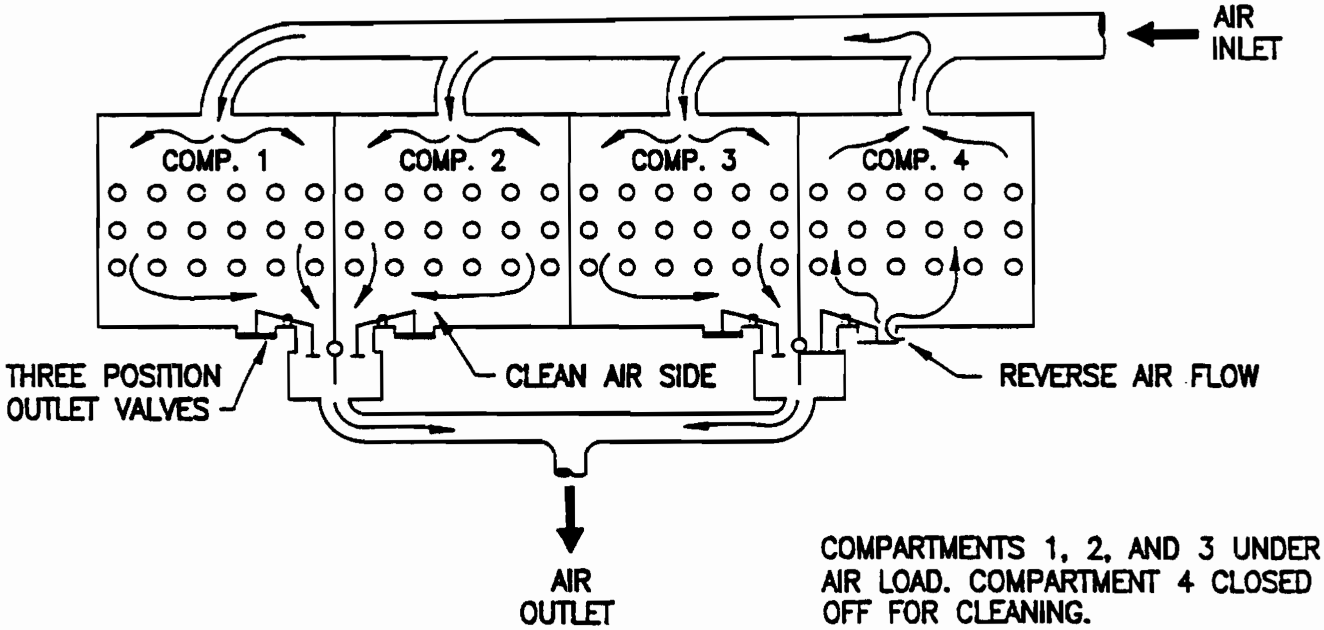
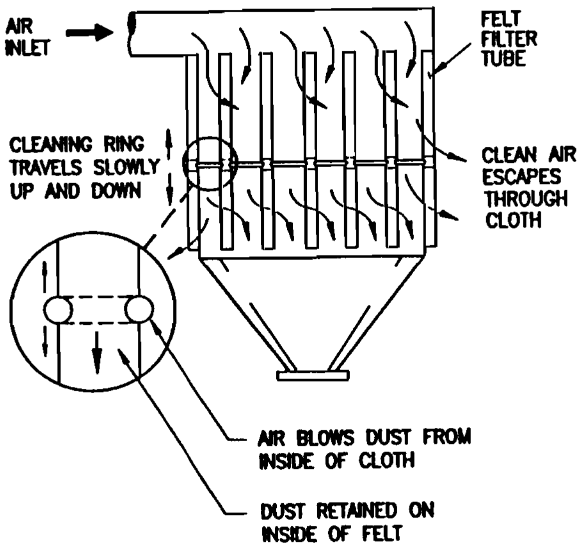
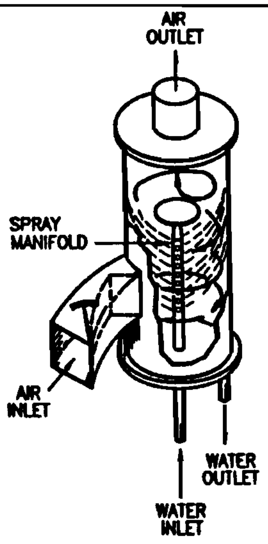
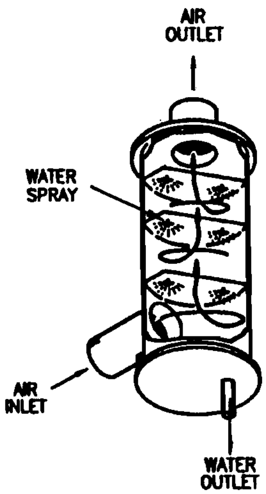


Figure 8: Fabric-Type Dust Collector With Continuous Air Cleaner

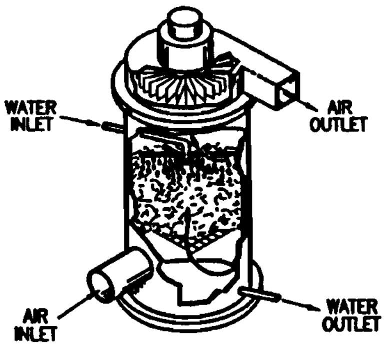




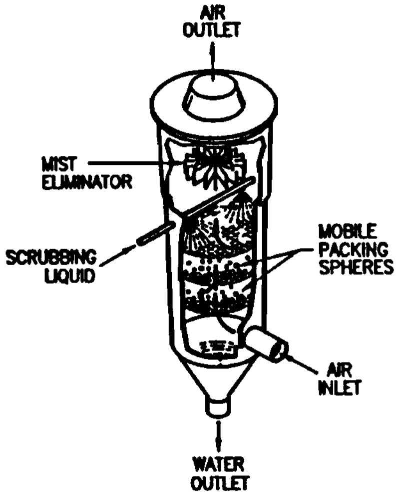
WET CENTRIFUGAL



SPRAY TOWER



PACKED TOWER



FLOODED BED

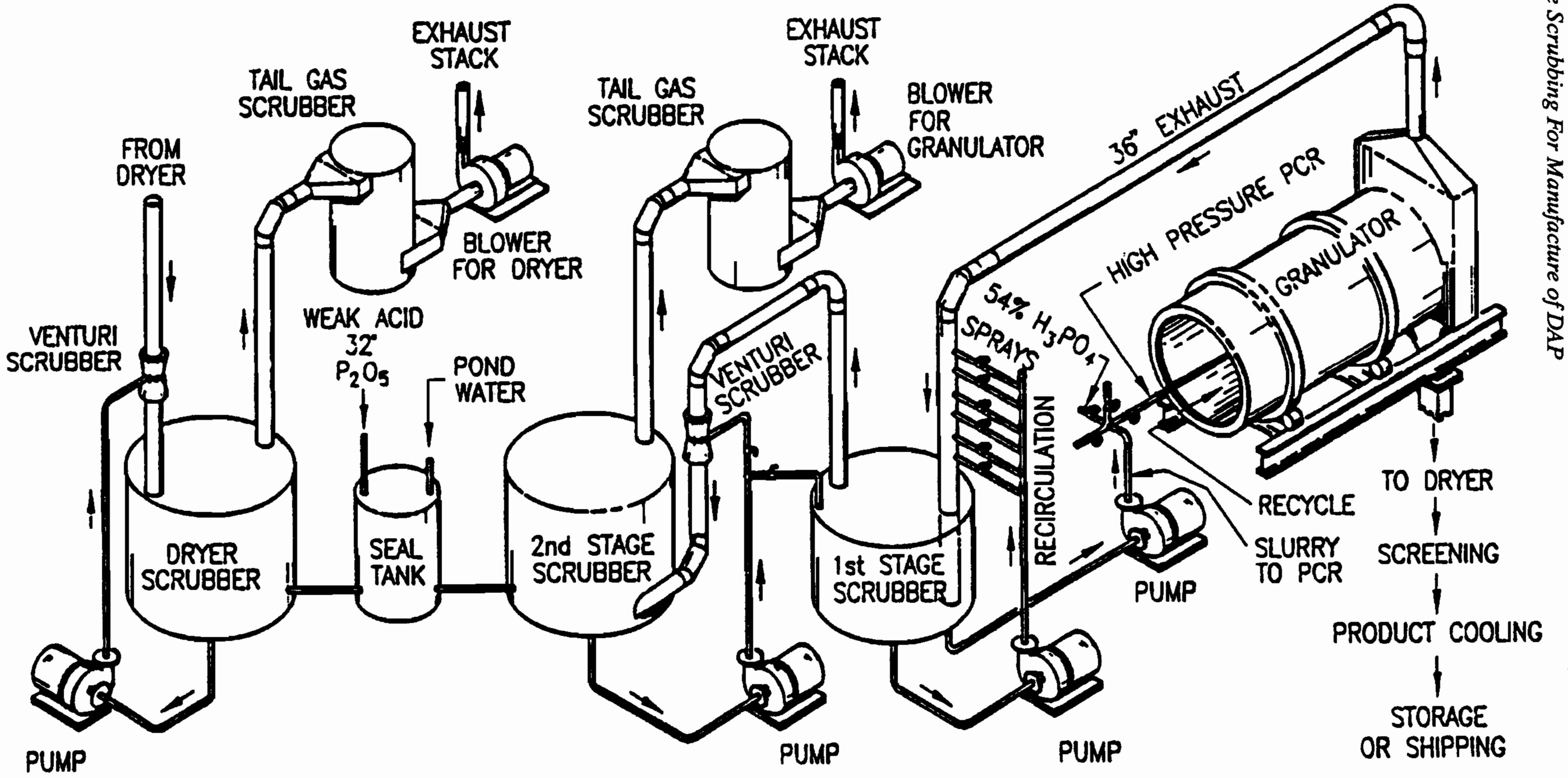


Figure 9: Two-Stage Scrubbing For Manufacture of DAP

Figure 11: High Energy Ventury Scrubber

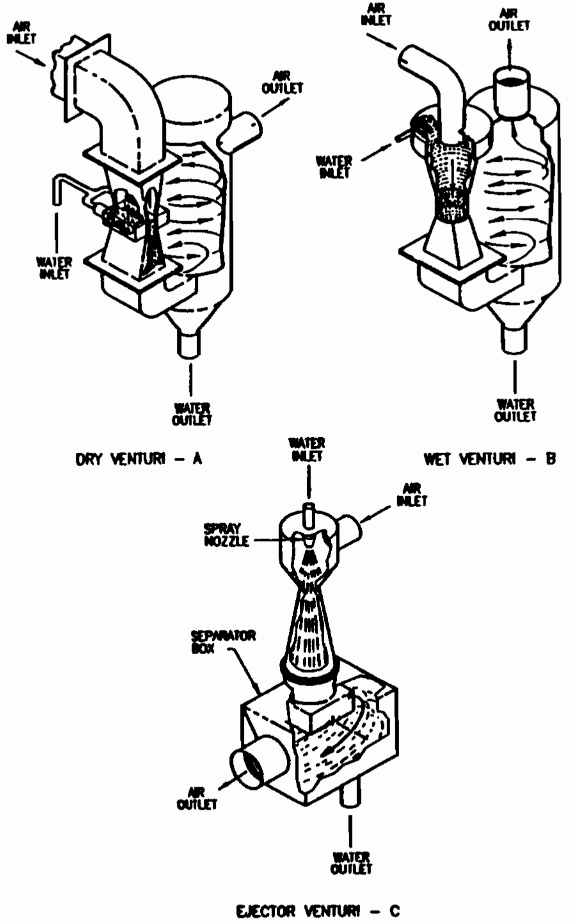
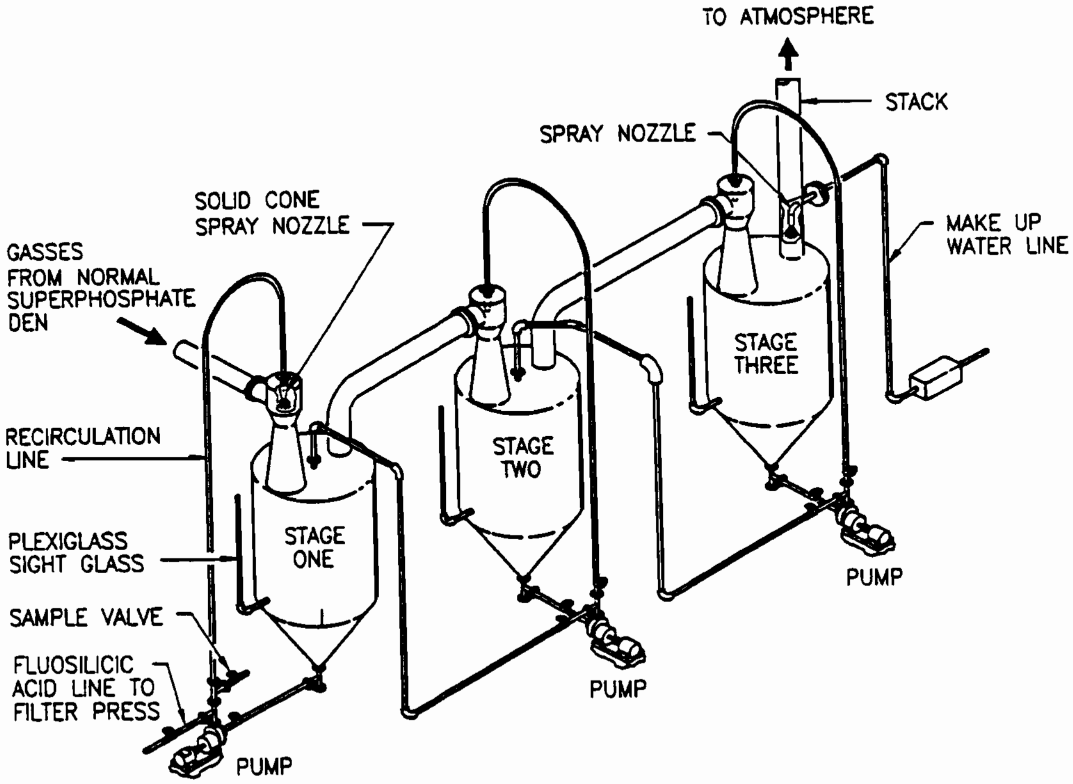


Figure 12:Three-Stage Venturi-Type Scrubber For Normal Superphosphate Plant



Nitrogen Fertilizer and the Environment: The Role of Crop Modelling in Management and Impact Assessment

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Despite the fact that we are often described as living in the "information age", a critical bottleneck in development and technology transfer is the provision of useful information that can help decision-makers make better decisions. When it comes to a consideration of the environment, facts are often clouded by emotions and perceptions. The onus is clearly on technical specialists and researchers to provide sound, objective information to those who need it to make informed decisions. One of the ways in which this can be done is through the use of appropriate modelling techniques, where "what if ..." questions concerning complex and risky processes can be answered rapidly. This paper discusses some of the models currently available and outlines applications of crop modelling techniques that start to answer questions relating to the use of fertilizers and their impact at the farm and regional levels. Much work is required before the full potential of modelling techniques is realized, but they represent a tool of considerable power for decision-makers in the agricultural sector. In the final analysis, there are few other ways in which the complexities of environmental issues can be integrated in the search for solutions to the important agricultural and resource problems that affect all segments of society.

Introduction[1]

The provision of pertinent information to decision makers in the agricultural sector on issues related to the environment and sustainability is, in many ways, one of the defining problems of the age. "The information age" is something of a misnomer; the pessimist would argue that there is little evidence, except at the trivial level, that we are a great deal more objectively informed than our ancestors, nor is there much to suggest that the current glut of information is actually used to make decisions that are any better, either for society at large or for the environment. The challenge is to provide knowledge and information that will be used to make more informed decisions concerning issues that affect society. Recent concerns about food security and mankind's impact on the environment, and public perception of farming practices and the real or imagined effects on human welfare, have cast this issue in an entirely new light, and has long- and short-term consequences on our ability to maintain food production, conserve natural resources, and protect the environment.

Description and prescription, the fundamental tasks associated with any scientific endeavor, are carried out using models of many different types, because we all necessarily have to deal in representations of reality (which is all that a model is). Models may be simple or complex; empirical or process based; verbal or mathematical. We use models all the time, built up from our own experience, and most people's models for many everyday occurrences are likely to be very similar. For complex biophysical processes, which often involve considerable interactions, mental or verbal models are not sufficient. Instead, we generally frame these processes in mathematical terms, because a great deal of information can be neatly summarized in algebraic form. The standard statistical analyses of a field trial using analysis of variance is nothing but a particular type of model. The analysis is designed to allow conclusions to be drawn concerning the precision of the experiment as well as the significance of the response obtained. Of course, more complex models can be used, such as fitting a response surface to the results of a N by P experiment, whereby we can use the fitted surface to predict outcomes (yield as a function of N and P levels) that were not necessarily obtained in the original design of the experiment.

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[1] This is a modified version of a paper originally presented at the International Workshop "Nitric Acid-Based Fertilizers and the Environment" in Brussels, Belgium, June 14-18, 1993, organized by the International Fertilizer Development Center (IFDC) in cooperation with the European Fertilizer Manufacturers' Association (EFMA) and the International Fertilizer Industry Association (IFA).

Such statistical models, while being the bread and butter of data analysis for research, have their drawbacks, however, chief among which is that it is difficult to extrapolate through space and time the results of the experiment. Simply because at location X in year 1 we obtained a particular response to N, there is no guarantee that in year 2 we will get the same response (although we might); nor may the response to N at location Y be the same as at location X. Without an understanding of the processes involved that make up the response, it is difficult, if not impossible, to say much about response in general. Now of course researchers have built up many such response surfaces over time, through replication across years and across sites, and we do know much about the particular processes involved. Indeed, from a detailed study of the abundant literature, agronomists can build up good verbal models of what will happen on soil type A with climate of type B when urea is added to maize, for example.

The key point is that for many processes, a great deal of information already exists. Increasingly, technical specialists are being asked to face issues such as sustainability and the environment where knowledge is limited, either because of the complexity of the processes involved and their interactions, or because we know little about some of the key component processes themselves. What is to be done in such a situation? We need better models.

The Ideal Crop Simulation Model

The models discussed in the remainder of this paper are of a particular type: they are mathematical computer simulation models. Such a model can be thought of as a black box; we feed it inputs (information on conditions), press the button, and it simulates what would occur in the real world with the same inputs, a feature solely of the structure of the model and its input conditions. Outputs (prediction of outcomes) are produced, and these can be compared with real-world observations; once this has been done a few times, and the comparisons are favorable, the model is pronounced valid for these general conditions, and we can, with care, use it for extrapolation through time and space.

We can imagine an ideal model that is used to study management and environmental effects over the short as well as the long term. What are some of the features of this ideal model? Assume we are interested in a simulation model of the growth, development, and yield of maize. First, we can say that it is based on processes, rather than on empirical relationships. Thus instead of saying that crop yield is a function of N and P applied, for example, we will say that yield is a function of crop growth and development, based on the interception of sunlight by the plant; the dry matter produced on any day is partitioned to the plant parts growing at the time, and N and P stresses are incorporated at the process level. The object of the simulation model is to isolate the processes that are applicable to the plant in general, in whatever environment, with whatever variety of maize, and then to describe these in as simple a mathematical form as possible. In this way, it is hoped, growth and development processes can be universally described and will function correctly in any environment. It then becomes possible to simulate the growth of the plant in any environment that we care to specify; the same basic processes occur, and provided that the processes are properly described in the model, we will be able to simulate maize growth on a highly weathered, acidic, low fertility soil in the Latin American tropics as well as on a younger soil of high organic matter content in the temperate regions of central Europe. Besides universal applicability, the other advantage of a process-based model is that the model will produce outputs that can be directly checked against field data. If the model does not simulate grain yields or other measurable outputs very accurately for a particular location, then this gives us the opportunity to find the reasons for the disparity: perhaps biomass accretion occurs too rapidly in the model, or leaf area index is simulated to reach higher levels than are actually observed in the field. In these cases adjustments to the relevant components of the model can be made without having to respecify the entire model.

Second, the model should have reasonable data requirements, in the sense that input data should be readily measurable and not burdensome to collect. The level of detail at which modelling is carried out is determined largely by this consideration. A highly detailed model at the biochemical level may be a very good model for yield prediction, but it may be very difficult to collect the data necessary to run it. A less detailed model, built around relationships at a higher level of aggregation than the biochemical level, may produce yield predictions that are nearly as good but make use of input data that are much easier to collect, such as could be gathered from almost any agronomic field trial. The trade-off between the level of detail and input data requirements is a critical one.

Third, the model should be capable of simulating what happens over long periods of time. This is another facet of the level-of-detail question described above. Many biochemical processes occur with a time frame of a few seconds; for many crops, growth occurs over one or two hundred days; soil erosion may be studied over a period of 10 years; while classic rotation experiments may be studied for scores of years. For a management-orientated model, we may dispense with time periods as short as a few seconds, because there are no management interventions that we can reasonably make on the basis of such short time periods; but we would certainly want to evaluate what happens over tens of years.

Fourth, the model estimates external effects on the environment, such as nitrate leaching below the root zone, organic matter depletion, and N remaining the soil for the next crop, for example. The model is sensitive not only to the environment but also to N, P, K, and organic matter management. Growth and yield in the model is also sensitive to the effects of pests, weeds, and diseases. It successfully simulates crop growth and yield in all the environments where the crop is grown, as a function of environment (soil and weather, and pest, weed, and disease burden), varietal differences, and management.

We can say with certainty that the ideal model described above does not exist, and it may be a long time before even a reasonably close approximation to it does exist. However, models with some of these ideal characteristics have been built, and are becoming better year by year. It is clear that such a model would be of immense value. An endless stream of "what if ..." questions could be asked and answered, such as, what are the optimal fertilizer amounts and timings for this crop in this region if I want to obtain a particular level of output in this particular season type (wet, dry, or average rainfall, for instance)? What are the minimum inputs of fertilizer required if I want to maintain yields of maize and soybeans in rotation over 20 years? If I borrow money at a particular rate of interest to purchase fertilizer, what is the risk that monetary returns to fertilizer use are negative in my highly variable environment?

Models For Management & Environmental Assessment

A number of models have been developed that are capable of providing quantitative estimates of crop performance under a wide range of soil, weather, and management conditions, including various aspects of nutrient cycling, nutrient losses, and soil erosion (some of these are briefly described in Bowen et al., 1993). IFDC has been intimately involved with the development, testing, and application of a set of crop models under the auspices of the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) project, a multi-national collaborative initiative based at the University of Hawaii. The project has fostered the development of the CERES and GRO models, which allow the quantitative determination of growth and yield of a number of important food crops (Table 1). All these models share much in common, notably the same input and output

Crop	Model	Reference
CERES Models		
Maize	CERES-Maize V2.1	Ritchie et al., 1989
Wheat	CERES-Wheat V2.1	Godwin et al., 1989
Sorghum	CERES-Sorghum V2.1	Singh et al., 1988
Pearl Millet	CERES-Millet V2.1	Singh et al., 1988
Barley	CERES-Barley V2.1	Singh et al., 1988
Rice	CERES-Rice V2.1	Singh et al., 1993
GRO Models		
Soybean	SOYGRO V5.42	Jones et al., 1989
Peanut	PNUTGRO V1.02	Boote et al., 1989
Phaseolus Bean	BEANGRO V1.01	Hoogenboom et al., 1990
Other Models		
Taro and Tanier	SUBSTOR-Aroid V1.0	Singh et al., 1992
Potato	SUBSTOR-Potato V2.00	Griffin et al., 1993
Cassava	DSSAT-Cassava V1.00	R B Matthews, L A Hunt, P W Wilkins, W T Bowen (in preparation)

Table 1 IBSNAT Crop Growth and Development Simulation Models

files, and comparable levels of detail. The growth of the crop is simulated with a daily time step from sowing to maturity on the basis of physiological processes as determined by the crop's response to soil and aerial environmental conditions.

Phasic development in the CERES models, for example, quantifies the physiological age of the plant and describes the duration of nine growth stages. The crop growth submodel deals with leaf area development, dry matter production, assimilate partitioning, and tiller growth and development. Potential growth is dependent on photosynthetically active radiation and its interception as influenced by leaf area index, row spacing, plant population, and photosynthetic conversion efficiency of the crop. Actual biomass production is constrained by factors such as suboptimal temperatures, soil water deficits, and nitrogen and phosphorus deficiencies. The crop's development phase dictates assimilate partitioning on a per-plant basis for the growth of roots, leaves, stems, panicles (ears), and grain.

The soil water balance, the nitrogen balance, and the phosphorus balance submodels operate on the basis of soil layers. The soil water balance component simulates surface runoff, evaporation, drainage, irrigation, and water extraction by the plant. The nitrogen submodel simulates the processes of turnover of organic matter with the associated mineralization and/or immobilization of N, nitrification, denitrification, hydrolysis of urea, and ammonia volatilization. Fluxes of nitrate and urea associated with water movement are also simulated. The N submodel of CERES-Rice simulates floodwater and paddy soil transformations affecting the supply of N to the plant. The effects of nitrogen deficiency on plant processes are also simulated. Nitrogen transformations from different N sources can be handled, including chemical fertilizers, green manure, and other organic N sources. The phosphorus component, under development at IFDC, simulates the processes of adsorption and desorption of P, organic P turnover, and the dissolution of rock and fertilizer phosphate. The model also simulates P uptake and the effects of P deficiency on plant growth processes.

The models produce estimates of water balance, soil and plant N balance, soil and plant P, and crop growth and development. Typical field observations can be used to test the model, such as crop phenological observations and growth and nutrient uptake data. The wheat and maize models have been extensively tested in diverse environments in many parts of the world, while the sorghum, millet, rice, and barley models have been subjected to more limited testing.

Some Example Applications of Crop Models

The models described above, as well as others not mentioned, represent the state of the art for simulating management effects on long-term soil and crop productivity. Each has its advantages and disadvantages, and none has all the components that were described for the ideal model. However, with such models, we can already begin to explore the consequences of certain crop management practices, and, in time, we will improve our knowledge so that more comprehensive and accurate descriptions of the soil-plant-atmosphere continuum can be incorporated into the models. Some examples of their application follow.

(i) Nitrogen Use Efficiency in Cropping Systems

Nutrient losses associated with the application of fertilizer to cropping systems vary enormously, depending on a host of factors, but in developing countries the nutrient use efficiency of typical field crops is often of the order of only 30 to 40 percent. Simulated nitrogen losses obtained using CERES-Maize due to leaching on loamy sand soils in upland rice systems in South-East Asia may amount to 140 kg N ha^{-1} in very wet years. Similarly, simulations with CERES-Rice in wetland systems in the Philippines suggest that up to 40 percent of the nitrogen applied as urea may be lost due to ammonia volatilization within 10 days of application, if the urea is simply broadcast in the floodwater. By contrast, volatilization losses declined with increasing degree of incorporation of the urea in the soil, and were negligible when urea was deep-point placed. Details on both these studies may be found in Singh and Thornton (1990).

Crop simulation models have a role to play not only at the field level but also at the regional level. Work carried out at IFDC in collaboration with researchers in Central Malawi has involved the integration of a crop simulation model with a Geographic Information System (GIS). The GIS provides spatial databases that describe a region's soils, climate, and topography. The simulation model can then be run for various locations using data from the GIS database. Simulated results from the crop models can be stored and presented in map form. In the example from Malawi, there was considerable simulated regional variability of maize yields, a combination of soil and climatic effects. Certain soil types were also more prone to N loss, while other soil types exhibited substantial N use efficiency, in terms of comparatively large increases in maize grain yield for small additions of fertilizer N. The maps produced can provide a graphic visualization of the areas that would benefit most from fertilizer use in terms of kilograms of grain produced per kilogram of fertilizer applied. In situations where only limited supplies of fertilizer are available, such information could help to indicate where scarce resources should be allocated. By taking account of the price of maize grain and the cost of fertilizer and other production costs, estimates of the relative profitability of fertilizer use can be obtained. Such information is an important input to any analysis that attempts to determine the most economically optimum rate of farm-level fertilizer application rates, for example.

(ii) Simulation of Long-Term Field Experiments

Current preoccupations with sustainability issues highlight the importance of taking account of the longer-term effects of management practices on the viability and performance of agricultural systems. The crop models outlined above have been linked together to allow crop rotations to be simulated; in effect, the outputs from one crop model run form the inputs for the next model run, allowing the carry-over of soil, water and nutrient balances across long periods of simulated time. In one example, the feasibility of growing shortduration leguminous green manures in a continuous maize system in the acid savannas of central Brazil was examined, together with the effects on crop yield and N leaching (Bowen et al., 1993). The primary purpose of the legume was to provide an N source for the subsequent maize crop. The lack of either upward or downward trends in simulated biomass and N in the short-duration legume over periods of 10 years indicated that the wet season at the site was probably of sufficient length for planting both the green manure and the maize in the same season. Such a system would be expected to provide a sustainable source of N for maize. The use of the short-duration legume also resulted in less N leaching than the system dependent on annual fertilizer N applications of 100 kg ha^{-1}.

(iii) Nutrient Balances

Nutrient balances, on a continental and regional scale, are becoming increasingly important as broad-brush indicators of long-term viability of farming practices. For example, Stoorvogel et al. (1993) estimated nutrient inputs (mineral fertilizers, animal manure, wet and dry deposition from the atmosphere, biological nitrogen fixation, and input from sedimentation) and outputs (export of nutrients in the harvested product and in crop residues, leaching losses, gaseous losses, and erosion losses) from dominant cropping systems in Africa. The results of this comparatively simple model are alarming for the 38 countries in sub-Saharan Africa: on average, each country has a negative nutrient balance in the amounts of 22 kg N, 2.5 kg P, and 15 kg K ha^{-1} yr^{-1} for the period 1982-1984, and these negative balances are projected to decrease by some 20 percent by the year 2000. A model such as CERES could be used for estimating some of these inputs and outputs at a local level and as a function of yearly weather, for example, thus helping to identify those areas that are being mined to the greatest extent. Adding soil erosion routines to crop management models such as CERES has high priority for future work.

(iv) Fertilizer Recommendation Systems

Crop management models offer a convenient framework for helping to formulate nitrogen fertilizer recommendation systems that can be used by extension personnel. In some parts of the world, particularly the semiarid regions where rainfall is highly variable, the response of the crop to fertilizer additions is itself highly variable, depending largely on available soil water. In such locations, fertilizer additions may increase year-to-year variability in gross margins, to the extent that fertilizer additions will be wasted in some years. For some environments, there are good possibilities for constructing simple forecasting models, for example by correlating the start of the rains to total season rainfall; season types could then be defined so that fertilizer recommendations were not only site-specific but also season specific (e.g., in a year in which the rains start late, and where historical records show that late rains mean low total rainfall, much lower N fertilizer rates will be economically optimal). Work is also being done on constructing expert or rule-based systems so that recommendations at the farm level can be produced, based on answers to simple questions concerning cropping history for the field in question to establish residual fertility levels, coupled with simulations with the crop model.

(v) Water Quality Decision Support Systems

A GIS-based decision support system for helping to address problems created by phosphorus runoff is described by Negahban et al. (1993). This system allows regional planners to alter land uses and management practices in the Lake Okeechobee basin in Florida and view the environmental and economic effects resulting from these changes. This body of water has seen marked increases in phosphorus concentrations over the last 15 years, and the system allows planners to assess various phosphorus control practices, using crop simulation models and economic analysis modules embedded in the GIS. Similar systems for investigating ways to ameliorate nitrate runoff in areas that are particularly prone to this problem have been developed (Shaffer et al., 1991).

(vi) Simulation of Greenhouse Gas Emissions by Crops

The contribution of agriculture to the global emission of greenhouse gasses such as nitrous oxide and methane is not large relative to carbon dioxide (Bouwman, 1990). However, flooded rice soils are a major source of methane, contributing some 25% of total atmospheric emissions; the atmospheric concentration of methane increases by about 1% per year. The demand for rice is projected to increase by 65% by the year 2020 (Braatz and Hogan, 1992), so the contribution of methane from rice paddies is likely to increase substantially. Nitrous oxide is important primarily because it has a long residence time. For both gases, there are many basic research questions that need answering before options for minimizing their production from agricultural activity can be identified, such as the plant parts responsible for gas emission, the mechanisms of gas transport in plants, and varietal differences in emission potential. Despite a great deal of field measurement of actual emissions, process-based models of emissions from crop and soil are urgently required to make sense of the empirical data, identify knowledge gaps, and direct research activity, in addition to helping to identify options for mitigation.

(vii) Crop Models in a National Agricultural Statistics and Information System

An example of the use of crop simulation models, and one that perhaps best integrates many of the applications outlined above, is the role they are playing in a national agricultural statistics and information system being built in Albania. The agricultural sector in that country is characterised by (i) users, dealers, and the infrastructure for the storage and distribution of inputs, including fertilizer; (ii) newly enfranchised farmers who have to operate in the new market economy and must be served by revitalized research and extension activities; and (iii) the government, which has to ensure food security and equity for Albania's population and will have to rely on existing and expanded politico-economic institutions for input to the policy making process.

IFDC has been involved in the country for the last 18 months, primarily to provide technical assistance to set up and support a free competitive fertilizer marketing system utilizing private resources. An area sampling frame has been constructed to provide estimates of crop area and yield. IFDC Albania is monitoring fertilizer utilization by crop, region, and farm type, and a major activity is the establishment of reliable systems for proper and continuous utilization of the information being generated for monitoring, planning, forecasting, and evaluation. A management information system that integrates the area sampling frame, the survey development activities, and crop modelling and database systems, is being constructed to support agribusiness and highly applied research and development activities. A pilot system has been constructed for three of the most intensive agricultural areas of the country, and this will be expanded to a national coverage over the next year.

The information system will perform a number of functions for four major groups of end-user:

(i) The agribusiness sector, to help derive estimates of input use on a regional basis, the timing of input use, and the setting up of input distribution networks, and database management systems for agricultural marketing and credit support.

(ii) Regional and national government, by providing a dynamic and flexible agricultural statistics system capable of producing yield and crop area forecasts and estimates of agricultural input use on a regional basis.

(iii) Researchers, by providing a framework for collating the results of field experiments, to identify knowledge gaps that can subsequently be filled, and to pre-screen on the computer the multitude of management options that exist to identify those that are most promising.

(iv) Extension workers, by helping to derive regional and temporal management recommendations that can be assembled into simple extension information packages for delivery to the farmer through demonstration plots, radio and TV campaigns, and literature.

Information provision and the minimization of dealer, banker, and producer risk, are tightly intertwined with the economic policy reforms promoted by the US Agency for International Development and other international organizations in fostering the growth of the Albanian economy and reversing the adverse effects of forty years of collectivization. There is still much to do, but Albania is offering the opportunity of doing something radically new in terms of information provision to a wide range of players in the agricultural sector of this newly-opened country.

Prospects

The use of crop simulation models for addressing environmental problems is in its infancy. Model building and application is a resource-intensive activity, and such activities almost always have to make use of as much collaboration between a variety of players as possible. Modelling is likely to become an increasingly important tool for the study of environmental problems simply because there are few (if any) other viable approaches to quantify the effects of highly interactive processes. Such work compliments more traditional research approaches by providing a framework for assembling existing knowledge about particular processes, helping to identify knowledge gaps, and for assessing particular scenarios.

This is not to say that modelling is a panacea, or even that all scientists believe modelling to be a useful activity; Philip (1991), for example, provides a pungent critique of modelling. However, as long as the limitations of each model are clearly understood, and provided that the modelling activity is intimately linked with physical experimentation, then a model can be a tool of considerable utility, both for research purposes and for information delivery to technical specialists and, potentially, to those responsible for policy formulation and implementation.

Potentially, perhaps one of the most effective areas of information delivery where models could play a role would be in the public awareness campaigns called for by Borlaug and Dowswell (1993). As these authors note, the great strides that have been made in crop production over the last 50 years have been a result of hybrid seed-fertilizer-weed control technologies. There is no doubt that the use of chemical fertilizers, judiciously applied, has to be expanded dramatically over the next 30 years if the projected global population of nearly 10 billion in 2025 is to be fed. Development, especially in Latin America and Sub-Saharan Africa, is not a zero-sum game but a moral and economic imperative. Getting this message across to the international agencies responsible and to the public that can drive such agencies is one of the most difficult yet most important challenges that we face.

References

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Wednesday, October 27, 1993

Session IV

Tour of Arcadian Plant
Organized by Byron McCarver

At approximately 8:30 a.m., the group left the hotel by buses and proceeded to the ARCADIAN CORPORATION at Geismar, Louisiana. The group was received by Round Table Director Byron McCarver and Plant Manager Gerry Davis of the Arcadian Corporation. The group was escorted by several of the Arcadian technical personnel and Round Table Director David Crerar of Norsk Hydro through the N-H single stage, hemihydrate phosphoric acid plant and the cogeneration unit of the ammonia plant. The Fertilizer Industry Round Table is very grateful for the hospitality extended by the Arcadian Corporation during the plant tour and for the authentic Jambalaya Lunch served afterward.

FINANCIAL STATEMENT

OCTOBER 22, 1992 TO OCTOBER 21, 1993

Cash Balance October 21, 1993		$20,314.61
Income October 22, 1992 to October 21, 1993		
Registration Fees - 1992 Meeting & Cocktail Party & Coffee Break Receipts	6,975.33	
Sale of Proceedings	1,512.27	
Registration Fees - 1993 Meeting & Cocktail Party & Coffee Break Receipts	16,076.73	
Total Receipts October 22, 1992 to October 21, 1993		24,564.33
Total Funds Available October 22, 1992 to October 21, 1993		$44,878.94
Disbursements October 22, 1992 to October 21, 1993		
1992 Meeting Expenses (Incl. Cocktail Party)	4,346.84	
Misc. Expenses Incl. Postage, Stationery, etc.	710.22	
1992 Proceedings	13,121.55	
1994 Meeting Preliminary Expense	2,897.53	
Directors' Meeting	1,218.74	
Advertising	160.24	
Total Disbursements October 22, 1992 to October 21, 1993		22,455.12
Cash Balance October 21, 1993		$22,423.82

Respectfully submitted,

Paul J. Prosser, Jr.
Secretary\Treasurer

Meeting Attendance: 111