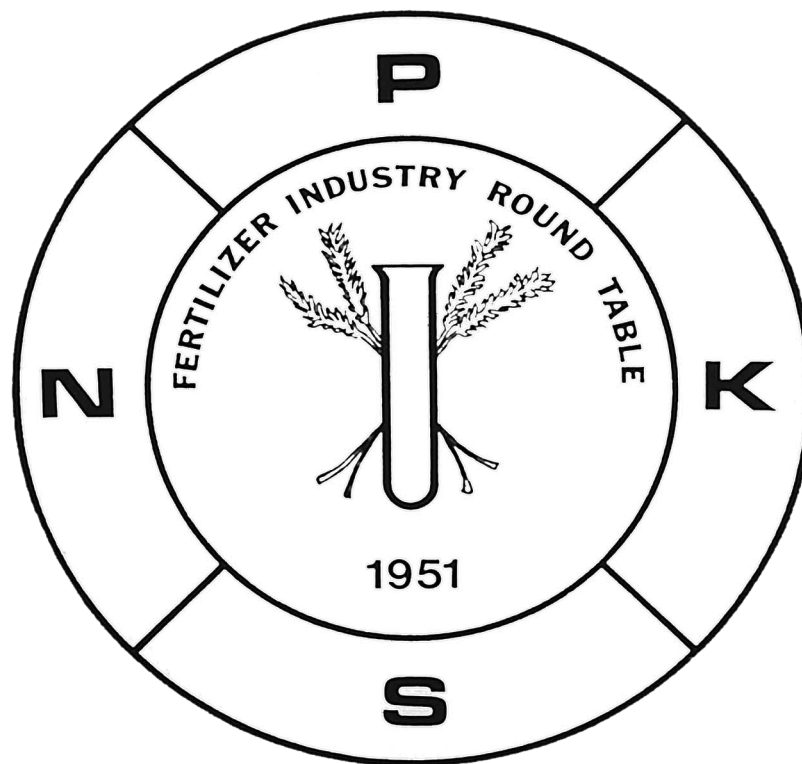


**PROCEEDINGS  
OF THE  
40th ANNUAL MEETING  
FERTILIZER INDUSTRY  
ROUND TABLE  
1990**



**November 12, 13, 14, 1990**

**Hyatt Regency Hotel  
Baltimore, Maryland**

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## **Fertilizer Industry Round Table Award Of Merit**

*Presented To Joseph E. Reynolds, Jr. by  
Harold Blenkhorn*

The Fertilizer Industry Round Table Award of Merit was initiated a few years ago for the purpose of recognizing individuals who are judged by their peers to have made an outstanding contribution to the fertilizer industry. Past recipients have been Travis P. Hignett, Frank T. Nielsson and Rodger C. Smith. This year we are pleased to add the name of Joe Reynolds.

Joe Reynolds is a native of Oklahoma. He served in the United States Air Force from 1943 to 1946, attaining the rank of captain. In 1948, following graduation from the University of Arkansas with a B.S. Chemical Engineering degree, Joe went to work for W. R. Grace and Company in Baltimore, beginning a career which was to last for the next forty years. During those forty years, Joe gained experience and expertise facets of the fertilizer industry. He started as a process engineer, advancing over the years to executive positions in NPK production and marketing.

Early in his career, Joe began to take an enthusiastic interest in fertilizer manufacturing technology. In 1951, along with Vincent Saudelli, Housden Marshall and Albert Spillman, he helped establish the annual gathering which brings us together today, namely the Fertilizer Industry Round Table, which was to become a unique international forum for the exchange of information on fertilizer manufacturing processes. His own specific contributions to manufacturing technology include the development of W. R. Grace's patented pugmill process for granulation of NPK - DAP - MAP. He has also been a frequent contributor of papers to the technical programs of the Round Table, and of such organizations as Tennessee Valley Authority, The Fertilizer Institute, The American Chemical Society and the British Sulphur Corporation.

Throughout much of his career, Joe shared his knowledge and his experience through his participation in various national and international industry and trade associations. These include The Fertilizer Institute, The International Fertilizer Association and The American Association of Plant Food Control Officials (AAPFCO). An appreciation of Joe's excellent work as a good will ambassador and technical representative for the fertilizer industry may be conveyed by a direct quote from a citation which he received from the AAPFCO at their annual meeting held in 1988.

"Joe has served as a reliable and valuable industry representative and consultant to the following AAPFCO committees:

- Guarantee and Tolerances, 1967
- Special Task Force to develop Survey Instrument for Magruder Check Sample Committee, 1967
- State Industry Relations, 1969-71
- Tonnage Reporting, 1970-88
- Uniform Fertilizer Bill, 1971-88
- Environmental Control, 1974-77
- Plant Directory, 1984-88

Joe has contributed immensely to the success of the aforementioned committees and programs. However, his most significant contribution has been as co-chairman of the Industry-Regulatory Council since its inception in 1972. Prior to this Joe served on the planning committee of the predecessor program, the Chemical control Problems conference, sponsored by the National Plant Food Institute (NPMI) and its successor, The Fertilizer Institute (TFI)."

Joe retired from W. R. Grace in 1988. He and his wife Madelyn reside in Memphis, Tennessee. Their two children, an artist daughter and sales executive son, also live in Memphis. Joe occupies his time by travelling, gardening, photography, and occasionally works as a consultant to (what else?) the fertilizer industry.

## Opening Remarks

*William F. Sheldrick, Chairman*

Good morning Ladies and Gentlemen.

First I should like to welcome you to Baltimore and to the fortieth meeting of the Fertilizer Industry Round Table. In particular I should like to offer a special welcome to those of you who have come from overseas. I believe that we have arranged an excellent program this year and I hope you all find it interesting and rewarding.

There have been many changes in the fertilizer industry since the Fertilizer Industry Round Table was formed in 1951 and during this time the Fertilizer Industry Round Table has had to adapt its program to meet the changing needs of its members. Several of our members, some of whom have been involved in the Round Table since its formation, met this year to put together for our interest and the record, the major changes that have taken place in the industry over the last forty years or so, each from a different perspective. We are grateful to Joe Reynolds, Walt Sackett and Jim Schultz for their efforts in this respect. We are also very grateful to John French, publisher of British Sulphur's Fertilizer International, for including their contribution in this month's *Fertilizer International*.

When we last met in Atlanta my opening remarks were concerned mainly about the problems that the industry was facing on environmental issues and particularly the need to respond in a more positive way to some of the ill-informed criticism that was being directed against the industry. I am happy to say that the industry is responding well to this challenge both in the USA and in Europe.

Of course, in the last few months we have had a lot of other things to think about that are having a major impact on the industry. The changes that are taking place in Eastern Europe are having a major change on both the supply and demand situation as market forces and planning methods in the region change. The situation in the Arab gulf will have a major short term impact as supplies of urea and ammonia into the world market are reduced. Most of all we have had an increase in the price of oil which makes it more difficult for developing countries with limited financial resources to import fertilizers.

I feel particularly sorry for our outlook speakers today who are faced with the formidable task of reviewing the future with so many uncertainties involved.

Fortunately for the world, we have had a world record cereal crop in 1989/90, something which according to FAO was very badly needed to improve the world food security situation.

We have as our keynote speaker today someone that has always been very much involved in studying this issue and has had a great deal of practical experience in working in this field over many years in developing countries.

Ladies and Gentlemen, I am pleased to introduce you to Mr. Luc Maene, Secretary General of the International Fertilizer Industry Association, who will talk to us about the Outlook for Fertilizer and World Food Production".

# Monday, November 12, 1990

## Session I Moderator:

Leo Bewer

### Keynote Address

#### Outlook for Fertilizer Use and World Food Production

*Luc M. Maene*

International Fertilizer Industry Association

#### INTRODUCTION

The spectre of famine has always existed and continues to haunt us at the end of the 20th century. It is a question which recurs periodically, with experts divided between the "pessimists" and the "optimists". As always, the truth lies in between.

Some populations suffer from malnutrition, others from over-weight, some populations impose quotas on agricultural production and take land out of cultivation, others still use the hoe and pray that it may rain.

We represent the fertilizer industry, and our aim is to establish the relationship between fertilizer and food, and perhaps try to determine how, in the future, the over-supply/famine paradox may be resolved.

#### LESSONS FROM THE PAST

In the early 1970's, world cereal supplies fell as a result of a series of bad harvests and cereal prices rose sharply (Figure 1). It was thought that there were only a few days stock of food in the world. The United Nations convened a World Food Conference to discuss the problem. In the event, the predictions proved to be wildly pessimistic. Improved agricultural technology, including a substantial increase in fertilizer use, ensured a more than ample supply of food for all who could afford to pay for it.

The importance of the contribution of fertilizers to food supplies is unquestionable.

In China, for example, fertilizer use with improved irrigation and high yielding varieties has been primarily responsible for the substantial increase in food grain production during recent years. Increased fertilizer use has also partially offset the effects of natural disasters and has greatly increased the output of other crops during the last decade. When fertilizers were in short supply in 1985, largely as a result of import restrictions,

harvests suffered accordingly. Their recovery coincided with increased fertilizer supplies (Figure 2). Grain output dropped from 366 million tons in 1984 to 339 million in 1985 and it was not until 1989 that the 1984 level was reached again. In the meantime, the population had grown by at least 60 million people.

#### MAN AND HIS NUTRITION

With the improvement in living standards and increasing urbanization, the relationship between man and his nutrition is changing. In the poorest countries, people eat what they produce, normally the basic staple foods. As their standard of living improves, they may prefer wheat to other cereals and, gradually, begin to eat more meat.

This is illustrated by developments in the Near East. Between 1973 and 1980, meat consumption grew at 12.7% p.a. in the oil-exporting countries of the Middle East and North Africa, compared with 8% from 1966 to 1973. Consumption of animal feed increased from 5% to 9% per annum, with a consequent large increase in coarse grains imports. The demand for animal feed continued to increase in the above-mentioned countries in the 1980's but at a somewhat lower rate than during the 1970's. In the developed countries, grain-equivalent consumption amounts to almost 1 ton per person per year. In the least developed countries, the consumption may be 1 ton per 5 or 6 people per year. Most of the difference is accounted for by the feeding of cereals to animals.

In the OECD countries cereal consumption per head is fairly stable and unlikely to increase significantly. In developing countries, on the other hand, there is a considerable pent-up demand for both wheat and coarse grains (Figure 3), but its realization requires sustained economic development. Also, in the USSR and some East European countries, there is a latent demand for a higher-quality diet. A marked improvement of the economic situation in the foreseeable future in developing countries is doubtful but it is quite likely that in five years' time the East European countries will have a high degree of economic activity and more efficient systems of producing and distributing agricultural products.

A significant increase in cereal consumption per head in developing countries would have a major impact on the world demand for agricultural products, but

unfortunately it seems unlikely to happen during the next decade.

## **1. FOOD AND FERTILIZER USE: THE BASIC ELEMENTS AND THE VARIABLE FACTORS**

### **The Basic Elements**

#### **•Man**

World food production over the past 4 decades has more than doubled and the rate of production growth has exceeded that of population growth. But this growth has slowed in recent years. However, because of the large population base in the low-income developing countries where population growth rates are still high, the absolute number of people added to global population annually is still very large—approximately 90 million.

#### **•Soil**

The world has surface area of 45 billion hectares but only 1.4 billion, or 3%, is arable land. These 1.4 billion hectares will have to provide a high proportion of the food needs. The average yield per hectare will have to increase considerably and this will mean substantially higher nutrient requirements.

#### **•Climate**

Agriculture, by its very nature of dependence on uncontrollable weather, is subject to unanticipated variations in production from year to year. The effect of weather-induced production variability is localized rather than spread evenly around the globe, and therefore its impact on the food supply of a particular population is much more dramatic than on global supply.

But are these basic elements really static?

a) It goes without saying that we have the technical means for reducing the birth rate in regions where the demographic increase is very high.

b) Soils are not inert. Their nutrient content can be improved and they can also become exhausted. The cultivated area can be increased, but within limits.

According to the FAO, by the year 2000, arable land expansion and cropping intensity increases are projected to account for only  $\frac{2}{5}$  of the growth in production in developing countries (excluding China) (Figure 4).

c) The climate cannot be changed and nothing can be done to prevent destructive hurricanes and prolonged drought. Is this a “fixed” factor?

Again, according to the FAO, between 1982/84 and 2000, a substantial proportion of the increase in arable land will be accounted for by expansion of irrigation. Irrigated agriculture is concentrated in Asia and 85% of the expansion in irrigated arable and harvested land is projected to take place there, notably in India. Irrigated areas will account for nearly 60% of the

fertilizer usage in developing countries (excluding China) in 2000, compared with just over half in 1985, but the proportion of growth in global agricultural production derived from expansion of cultivated areas and irrigation is declining.

Since the physical factors can be improved as required, is there really a problem? In fertilizers, which have proved over many decades their value for increasing yields, do we have the panacea? But fertilizers also have their limitations. On the other hand, interaction with other inputs has a synergistic effect on yields and the use of fertilizers is more variable and easier to influence than man, the land and the climate.

### **THE VARIABLE FACTORS**

#### **A) Agronomic**

##### **•Fertilizer Use**

In many developing countries fertilizer use is inefficient and unbalanced. In some places, the response to additional quantities of nitrogen is now limited. This applies particularly in developing countries which have achieved large gains in agricultural production. The problem is well recognized in major consuming countries such as China, India, Pakistan. This awareness is likely to result in a relatively greater demand for nutrients other than nitrogen in these countries in the coming years.

There are exceptions for particular crops and locations, but average rates of fertilizer use in developing countries are well below those of developed market economy and centrally planned countries. Plantation crops and irrigated crops are normally well fertilized but there is considerable potential for increased fertilizer use in rainfed areas, on which a substantial proportion of increased food production will depend.

##### **•Improved Plant Varieties**

High-yielding grain varieties have been the basis of the “Green Revolution” in the developed countries. They have produced spectacular increases in yields. In only the last 10 years, wheat yields in India have risen by 45%, and in China by 49%.

But they have still not reached the levels achieved in West Europe 10 years ago. Since then, West Europe’s wheat yields have risen by a further 28%. Similarly maize yields in the USA rose by 45% between the mid-70’s and the mid-80’s.

In the UK., for example, it is thought that new varieties may account for 50% of the increase in wheat yields over the last 40 years. In the USA, slightly less than 50% of the rise in the maize yield is attributed to this factor over a similar period.

But in many developing countries, particularly in Africa, the increase in agricultural production has not been keeping pace with increased food requirements. It is quite possible that this trend will continue. For example, heat tolerant varieties of wheat are still lack-



ing, and in many developing countries the facilities for the production of hybrid maize seed are inadequate. The requirement for imported cereals for these countries is likely to continue to increase.

#### •Other Inputs

Fertilizers, improved varieties and irrigation account for a substantial proportion of the increments in crop production. However, the higher productivity resulting from more intensive agriculture favors the propagation of weeds, pests and diseases and plant protection products constitute another indispensable and complementary input. And, of course, the use of the off-farm inputs must be accompanied by correct on-farm management practices.

### B) Economic

#### •Subsidies

In the developing countries, fertilizers are still very much a major agent of food production growth, limited only by the growth of purchasing power. A majority of the population of many countries in this group spends 60 - 80% of their income on food. Rising food prices in the absence of rising individual incomes are politically dangerous and socially intolerable.

Subsidies are used in many developing countries both to control food prices and to stimulate the use of fertilizers and other inputs. However successfully they are in meeting these objectives, they eventually become an intolerable burden on national budgets, if government revenues do not rise proportionately. Because of the large share of agriculture in the economies of most developing countries, and the weak rural tax base, they cannot normally afford this. There is then pressure to reduce or eliminate the subsidies. If this is done, there must be commensurate investment in other factors such as credit, extension and marketing facilities. In a situation of capital scarcity, there are often richer pickings for private investors than unsubsidized agricultural input services.

#### •Infrastructure

If fertilizer use is to increase, the farmer must have access to fertilizers as and when he needs them. The development of the infrastructure is a critical causal variable for the expansion of fertilizer use. J. W. Mellor reported that in Bangladesh, villages with a good infrastructure use 65% more fertilizer per unit area than villages with poor infrastructure. Infrastructural development is essential not only to strengthen fertilizer supply, but also to support the entire process of market development and conversion of agronomic potential into effective demand for fertilizers. Apart from rural roads, there is the whole gamut of infrastructural requirements for an efficient fertilizer distribution system, including adequate port and railhead facilities, internal transport means and storage facilities.

#### •Research and Development

A large share of incremental production must come from higher yields per unit of land or labor. Yet, in all developing regions there are areas where present agricultural production cannot be sustained with prevailing farming practices. Moreover, this problem will intensify in the future as population pressure force the further development of marginal land. So expanded research is required even to maintain existing yields. In particular, extension, perhaps the most important link in the research process, is a neglected field, with excessive dependence on approaches modelled on developed-country practices, and only limited efforts at formulating approaches more appropriate to the economic and human resources, and social systems of developing countries.

Since agriculture has become increasingly technology-dependent, questions are raised about the ability of science to provide a sufficient future stream of new technology to keep pace with increasing demands for food. The prospect for continually increasing global food production is further clouded by potential constraints on the adoption of technology by concerns of environmental quality and food safety. A further concern is the adaptability of modern technology to the low-income, food-deficit developing countries of the world.

#### •Extension

Advice, demonstrations and training are essential components of policies for expanding agricultural production. The extension staff must be properly trained and motivated. Unfortunately, in the majority of countries, limitations of finance and trained manpower result in either a thin spread of the resources or concentration on areas of high potential. Extension has been neglected in many parts of the developing world, particularly in Africa. Where facilities exist they are often underfinanced or poorly maintained.

## 2 - Outlook for Food and Fertilizer Requirements

### A. Importation of Food or Fertilizers?

C. Joly (1987) analysed the advantages of importing fertilizers rather than food.

An important factor contributing to cyclical concerns over food supply is the fact that most food is consumed in the country in which it is produced. That is, a relatively small percentage of the world's food production enters into international trade. Thus, in the case of grains, the most widely traded set of commodities, only 11% of world production was traded in 1986/88. It is also true that much of the trade in food is between net exporting countries and takes place to add variety to diet and to overcome seasonal shortages of domestic production. The number of net food exporting countries is small, and they tend to be highly developed, high-income, low-population growth countries. The

vast majority of the world's population lives in chronic food-deficient countries. Many of these countries are also poor, under-developed, and have very limited capacity to utilize commercial food imports to offset domestic food shortages.

An option for these countries is to substitute imports of fertilizer and other agricultural inputs for food imports, thus permitting local production to increase and covering at least partially the food deficit.

The substitution of imports in favor of mineral fertilizers and agricultural inputs in general offers several advantages both for the farmer and the government.

#### •Advantages for Farmers

At the farm level, the rational use of fertilizers permits the maintenance or improvement of soil fertility, increases the productivity and significantly improves farmers' incomes.

Indirectly, as has often been observed, the application of fertilizers constitutes a powerful encouragement to the application of improved cultural techniques and to the use of related agricultural inputs, which are other important factors in agricultural development.

#### •Advantages for Governments

From a macro-economic point of view, it seems much more advantageous to import fertilizers than food, which could be produced locally:

- increase of the GNP by the value of the extra production,
- improvement in food self-sufficiency and greater contribution from national production to food security,
- promotion of national agriculture and in consequence rural development,
- substantial savings in foreign exchange,
- farmers are kept on the land and in consequence, the rural exodus is reduced.

Globally, except in the case of famine, the import of food has limited effects on urban centers, while fertilizer imports constitute injections of capital into the rural sector, thus contributing to its development.

The multiplying coefficient of fertilizer imports is substantially greater than that of food. The effects of fertilizer imports are felt in sectors as different as: storage, transport (of fertilizers and agricultural products), the distribution system, the banking network and the farm credit, the system for the collection, marketing and processing of agricultural products.

In addition, quantities of fertilizer which need to be transported would be about two thirds lower than the quantities of food.

### B. Outlook for Food and Fertilizer Availability

Based on the post-1974 experience, there is hope that continuing technical progress in agriculture will provide sufficient food for the increasing populations. However, there is no room for complacency. Achieving

the required level of production will not be easy. Agricultural land is being taken for other uses. Even more serious is land degradation. The "mining" of soil nutrients i.e. removal by crops without being replaced is, according to the FAO, a potential "environmental catastrophe". In some African countries, crop yields are already falling on this account.

Food supplies remain precarious. World cereal production fell in 1987 and 1988. Production increased in 1989 but consumption was also higher and cereal stocks fell to the minimum level considered necessary by the FAO for food security (Figure 12). This year, harvests are generally good and, for the first time in four years, the level of production is likely to be sufficient to meet consumption and allow a partial replenishment of global stocks.

Up to the year 2000, the world population is expected to increase at a rate of 1.7% per annum (Table 1). We estimate that fertilizer consumption will increase at an annual rate of 1.5% over the next five years, which, at first sight is insufficient, particularly in view of the deterioration of soils in many areas.

But in some countries, fertilizers are used inefficiently, in others fertilization is unbalanced (normally too much N in relation to the other nutrients). An improvement in the efficiency of fertilizer use could offset an insufficient quantitative increase. And, of course, further advances in agricultural technology and in the application of this technology can be expected.

### 3-Fertilizer Supply and Demand Balances

An industry source predicts that the fertilizer industry will have to invest some \$35 billion during the next ten years to provide the required quantities of ammonia, phosphate and potash.

#### A- 1990 to 1994

The following estimates are based on the results of our 1990 surveys, carried out during the second quarter, together with limited new information on East Europe and on the possible consequences of the Middle East crisis.

#### • Nitrogen (Figures 5 and 6)

Approximately 97% of the nitrogen fertilizers is derived from ammonia (the remainder being by-product nitrogen, whose level of availability remains approximately constant) and the ammonia supply/demand balance reflects accurately that of nitrogen fertilizers.

World ammonia capacity is expected to increase by about 7% between 1990 and 1994. Little increase is expected in the developed countries and the additional capacity will be in a number of developing countries (Bangladesh, China, Egypt, India, Indonesia, Iran, Nigeria, Pakistan, Saudi Arabia). (Table 2.)

If all the new plants come into operation as planned, the world ammonia surplus should remain at more than 1 million tons N. However, if some of the new plants are delayed, supply and demand could be close to



equilibrium by 1994.

The urea market has been relatively tight this year and the Gulf conflict has restricted supplies further. The supply/demand balance may remain tight for the next two years but, unless the Gulf conflict deteriorates, it should ease as new capacity comes on stream in 1993.

•**Phosphate** (Figures 7 and 8)

A substantial proportion of the phosphate fertilizers consists of products derived from phosphoric acid, and almost the entire increase is in the form of phosphoric acid-based products.

Between 1990 and 1994, no increase in phosphoric acid capacity is expected in the developed countries, nor in Latin America. The largest increases are in Morocco and China.

(Table 3.)

Our calculations indicate that the world capacity surplus of about 2.1 million tons  $P_2O_5$  in 1990 is may fall to 0.2 million tons in 1994. However, the situation is unlikely to become as tight in 1994 as the calculations suggest. There is sufficient time for increased production to materialize and the changes in East Europe and Gulf situations may result in reduced fertilizer demand.

• **Potash** (Figure 9 and 10.)

The world capacity of potash is expected to rise by 5% between 1989 and 1994, largely due to increases in Jordan and the USSR. It is expected that potential supply will continue to exceed demand throughout the period but the surplus should decline as consumption grows faster than capacity. (Table 4.)

• **Sulphur** (Figure 11.)

A deficit situation will persist until 1991, the extra supplies being drawn from stocks. It should ease afterwards when more Soviet, Canadian, US and possibly Middle East sulphur becomes available. A significant surplus could develop in the mid-1990's.

(Table 5.)

## **B - Events in East Europe and the Gulf**

It is too early to predict the effects on the fertilizer market of the changes occurring in East Europe and the conflict in the Gulf. Increased oil prices will tend to slow economic growth. They will also directly increase the production cost of oil-based plants. The ammonia, urea, triple superphosphate and sulphur exported previously from Iraq and Kuwait are removed at present from the market. Shipping in the Gulf has become more costly and risky. All these factors will tend to increase the cost of fertilizers and reduce demand.

Fertilizer consumption in East Europe is falling, following the removal of subsidies. East European countries will shortly have to pay for energy from the

USSR in hard currency, at the market price. Also many plants in the region are inefficient and are polluting the environment. Some are likely to close. These factors influence both supply and demand and the end result is anyone's guess.

## **C. Longer-Term Supply Prospects**

As regards the longer term, there are ample supplies in the world of the raw materials for the manufacture of fertilizers; air, natural gas, phosphate rock, potash and sulphur. Fertilizer prices during recent years have been far too low to justify investments in new grassroots facilities. The situation is somewhat easier as regards the expansion and modernization of existing plants.

The price mechanism should ensure that the necessary investment materializes. The question is whether this investment will be made in a rational and progressive manner.

## **SUMMARY AND CONCLUSION**

The problem of adequate food supplies is one which essentially concerns developing countries. They have to cope with increasing populations, often an unfavorable climate and soils which were poor to start with and which are deteriorating. In order to reach a standard of nutrition which is approximately satisfactory, these countries have to increase their agricultural production, using fertilizers and other inputs. A major problem faced by the governments of these countries is how to give farmers a sufficient economic incentive to use fertilizers. Given the problem of increasing the prices of basic foodstuffs and the high cost of subsidies, it is difficult to give farmers an attractive crop price/fertilizer price relationship. But even if this is achieved, it is not sufficient if the physical infrastructure, for example the transport system, is unsatisfactory. Inadequate research and advisory services also are partly responsible for poor overall agricultural production.

India has resolved the problem by means of policies favoring progressive agriculture, but at a high cost in subsidies. Most African countries have failed lamentably. But even there, the economic remedy works. In Tanzania, among the world's four poorest countries, food output since 1987 has almost doubled. The reason for this dramatic improvement appears to be largely to the higher prices the government is now paying to farmers. Tanzania has a maize surplus but in neighboring Mozambique tens of thousands of people are facing starvation.

The theoretical solution to this problem is evident. Technically we know how to make nature more productive. All the factors required to resolve the problem can be controlled both from agronomic and demographic point of view.

The problem is that economics dictate that production depends on true demand, not on needs. Countries which can afford to pay, will never have a food problem.

Hunger is the problem of the poorest countries, often with exhausted soils and arid climates and heavily in debt.

At present there are over 500 million malnourished people in the developing countries (excluding China and other Asian Centrally Planned Economies) largely because they lack the purchasing power to buy food, although in some cases because they lack the credit for access to fertilizer. The number of malnourished is projected to increase to some 530 million by the year 2000 with improvements in Asia being off-set by deterioration in Latin America and particularly sub-Saharan Africa where absolute numbers are projected to increase by one-third between 1983/85 and 2000.

The fertilizer industry has an important role to play in resolving the problem. And, despite the current uncertainties, it seems that the industry will continue to be able to supply the required quantities of fertilizer nutrients. But, unless the other factors are also dealt with, the industry is powerless.

#### *ACKNOWLEDGEMENTS*

The contents of this paper are to a large extent based on information provided by IFA members in response to questionnaires. The estimates of demand were made by K.F. Isherwood and the supply/demand balances by P.L. Louis, both of the IFA Secretariat, based on second quarter 1990 surveys, partially updated. The FAO's Global Information and Early Warning System on Food and Agriculture is acknowledged as source of information for the agricultural situation.

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**Table 1 - WORLD POPULATION AND FERTILIZER USE**

YEAR	POPULATION		FERTILIZER USE	
	Million	Growth % p.a.	1000 t. NPK	Growth % p.a.
1970/71	3697	-	69	-
1988/89	5114	1.8 % p.a.	146	4.3 % p.a.
99/2000	6252	1.7 % p.a.	173	1.6 % p.a.

**SOURCE : FAO, IFA and the FAO/UNIDO/WB/Industry Fertilizer Working Group.**

**Table 2 - AMMONIA, WORLD SUPPLY AND DEMAND BALANCES  
million tonnes N**

	1990	1991	1992	1993	1994
Capacity	115.6	117.4	118.5	121.9	123.3
Supply	79.2	80.6	82.7	84.9	86.7
Demand (1)	78.1	79.8	81.7	83.5	85.4
<b>BALANCE</b>	<b>1.1</b>	<b>0.8</b>	<b>1.0</b>	<b>1.4</b>	<b>1.3</b>

(1) Excluding by-product nitrogen

**Table 3 - PHOSPHORIC ACID, WORLD SUPPLY AND DEMAND  
BALANCES  
million tonnes P205**

	1990	1991	1992	1993	1994
Capacity	36.0	36.4	36.8	36.9	37.5
Supply	25.4	25.8	26.2	26.3	26.2
Demand	23.3	24.2	24.9	25.5	26.0
<b>BALANCE</b>	<b>2.1</b>	<b>1.6</b>	<b>1.3</b>	<b>0.9</b>	<b>0.2</b>

**Table 4 - POTASH, WORLD SUPPLY AND DEMAND BALANCES**  
million tonnes K<sub>2</sub>O

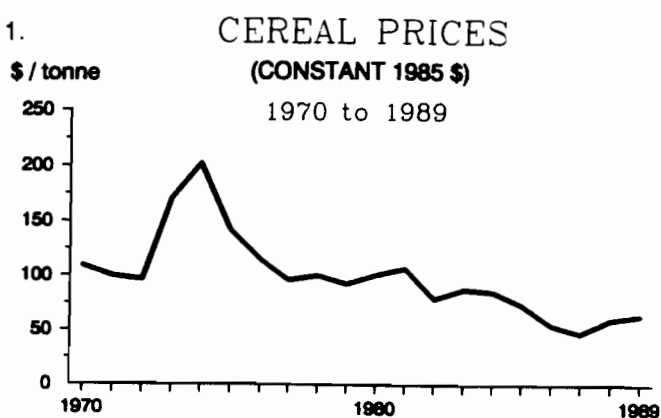
	1990	1991	1992	1993	1994
Capacity	37.7	38.1	38.7	38.6	39.5
Supply	30.2	31.0	31.2	31.3	31.4
Demand	27.3	27.9	28.4	28.9	29.4
<b>BALANCE</b>	<b>2.9</b>	<b>3.0</b>	<b>2.7</b>	<b>2.4</b>	<b>2.0</b>

**Table 5 - ELEMENTAL SULPHUR (all uses)**  
**SUPPLY AND DEMAND BALANCES**  
million tonnes S

	1990	1991	1992	1993	1994
Supply	39.6	40.5	42.8	45.6	47.1
Demand	40.7	41.6	42.0	42.9	43.6
<b>BALANCE</b>	<b>- 1.1</b>	<b>- 1.1</b>	<b>0.9</b>	<b>2.7</b>	<b>3.5</b>

*Note : Except in the case of elemental sulphur (brimstone), the supply and demand estimates relate to fertilizer use only. In the tables, the differences between "Capacity" and "Supply" are explained by the effective operating rates, non-fertilizer use, processing and other losses etc.*

Figure 1.



Source : WORLD BANK.

Figure 2.

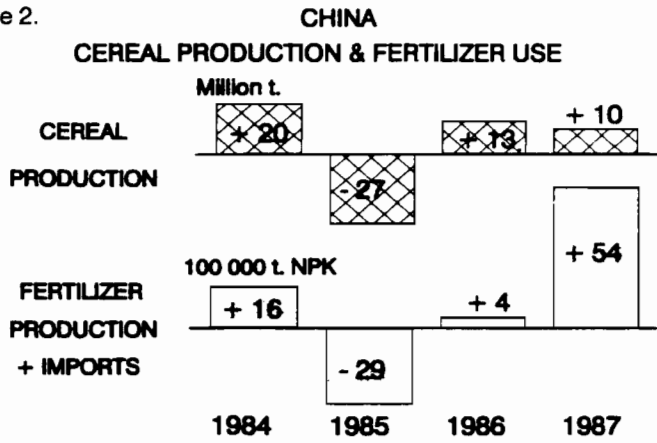


Figure 3.

### ANNUAL GRAIN CONSUMPTION PER PERSON OECD & DEVELOPING (Exc. CHINA)

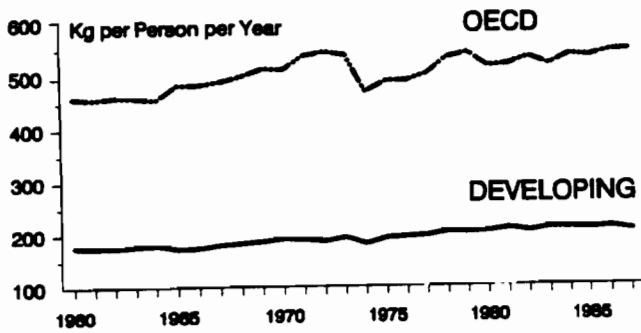
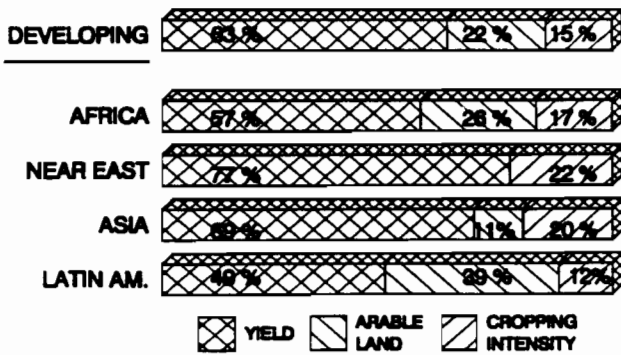


Figure 4.

### CONTRIBUTIONS TO CROP INCREASES 1982/84 - 2000



SOURCE : FAO

Figure 5.

### AMMONIA - WORLD CAPACITY Million tonnes N

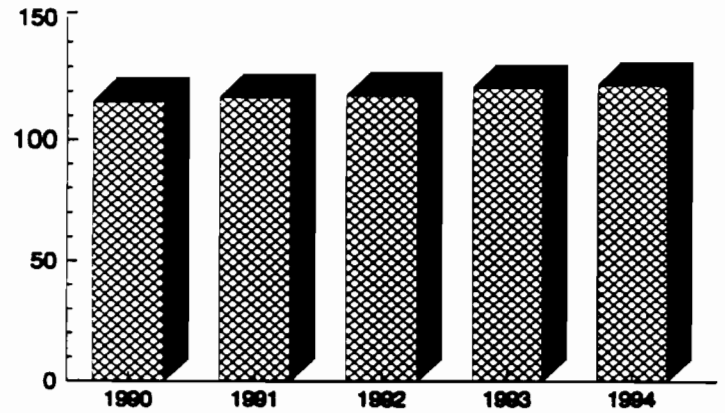


Figure 6.

### AMMONIA WORLD SUPPLY / DEMAND BALANCE Million tonnes N

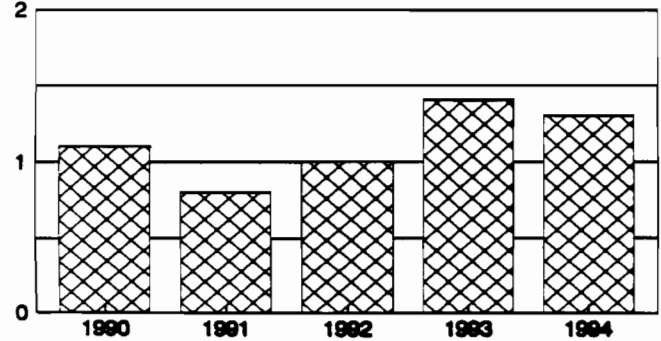


Figure 7.

### PHOSPHORIC ACID - WORLD CAPACITY Million tonnes P2O5

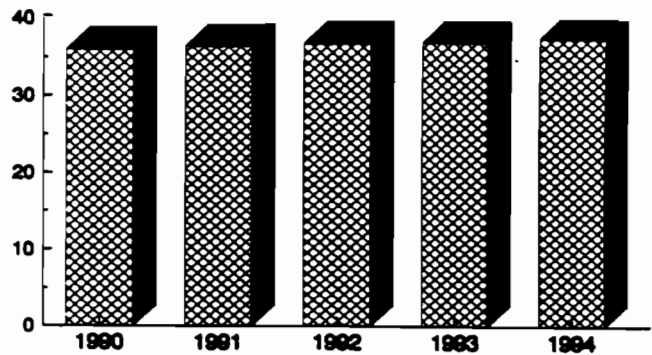


Figure 8.

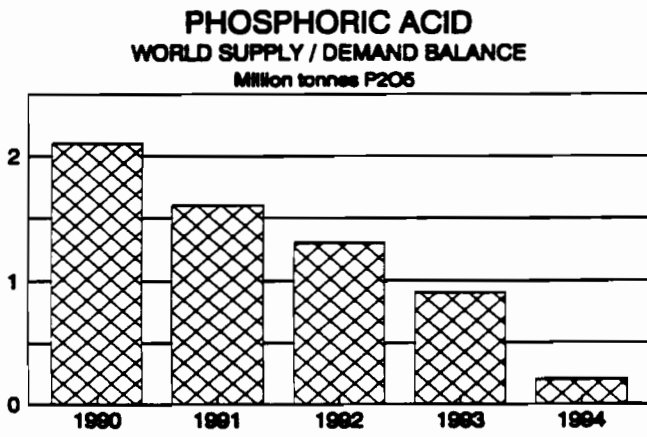


Figure 9.

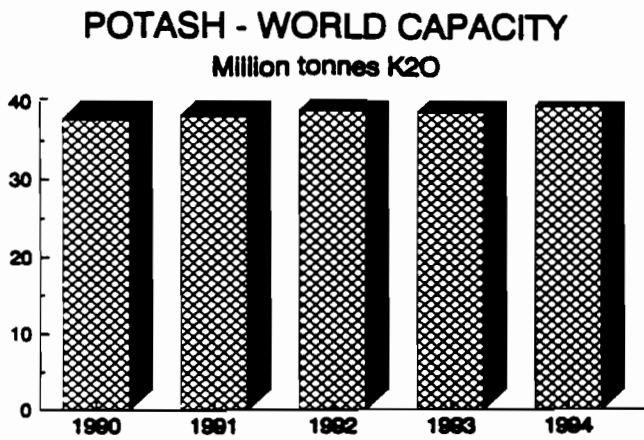


Figure 10.

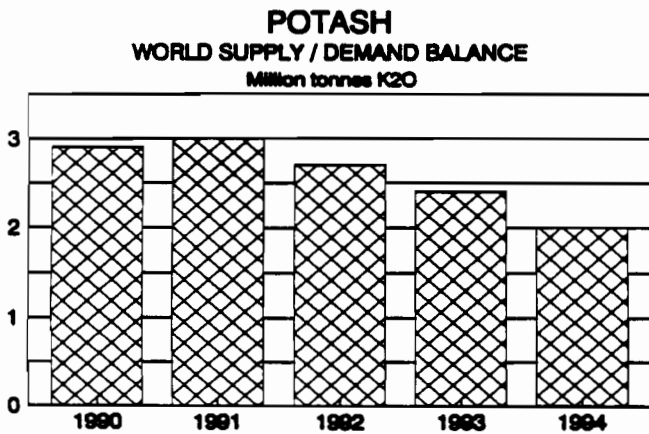


Figure 11.

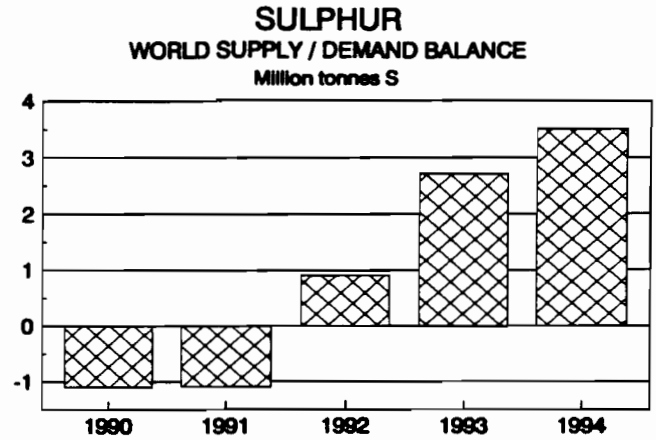
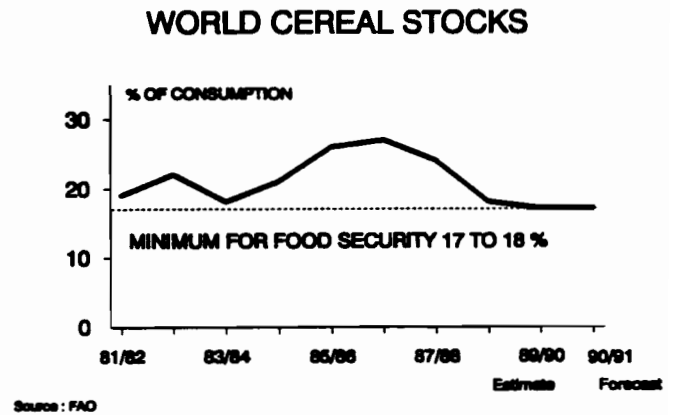


figure 12.



# The Nitrogen and Phosphate Outlook

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## Introduction - Nitrogen Industry

Over the last six months, there has been a definite change in the mood of the nitrogen industry. The change has been for good reasons. Since mid-June, nitrogen prices have increased dramatically and, for urea, are now at their highest level since the winter of 1984. The increases in price have been a welcome relief particularly when you consider that in June of this year most producers were selling ammonia at, or below, cash costs.

Most of the strength in nitrogen prices has been tied directly to the crisis in the Middle East. However, even before the crisis the nitrogen supply/demand balance was showing signs of considerable tightness. Production problems in Trinidad, Mexico, the Soviet Union, Venezuela, Malaysia, Indonesia, Abu Dhabi and in a number of plants in the U.S. were all contributing to a reduction in the available supply of nitrogen. At the same time, upward pressure on prices was being exerted from the demand side due to record DAP production and continued strength in the world urea market. After adding in the cyclical upswing in gas prices and, therefore, production costs, it is easy to see why nitrogen prices are where they are today.

The question now is, "Where do we go from here?" The gut feel of most industry observers appears to be optimistic about FY 1991. While there are good reasons to be optimistic, there are also some good reasons to be just a little bit nervous. First, U.S. nitrogen fertilizer demand this year is not expected to match last year's comparatively high level. The combination of lower crop prices, a 10 percent drop in wheat acreage, a decline in application rates on hay and pasture, and a possible, two million acre switch from corn to soybeans is expected to result in a drop in nitrogen consumption of roughly 4 percent. Second, most of the production problems that reduced supply earlier this year have been corrected. In the U.S., for example, the industry is currently running at almost 100 percent capacity. Third, domestic sales so far this quarter have been somewhat disappointing. While this probably reflects a wait-and-see attitude by retailers, it could be reflecting a higher-than-expected level of retail inventory.

In short, CF's outlook for this year can be characterized as nervously optimistic. Although we are hoping for the best, too often in the nitrogen industry history has dictated to expect the worst. (Figure 1.)

## Introduction - Phosphate Industry

The past decade has been a tumultuous ride in the

fertilizer business. Those of us left standing can attest that the ups and downs could rival any roller coaster ride in the world. Not near as fun many say, and I'd have to agree. But the question many of us have today is, "Are we getting ready to go up, down or simply around another turn?"

Everything seems to hinge on the outcome in the Middle East. Vietnam came and went and the fertilizer industry never seemed to notice any jolt from the conflict. But today is different. I think we'll see tremendous changes in the phosphate sector during the next 12 months. By mid-year 1991, I believe we'll see international selling prices higher than today, but driven more by costs than demand. Glen summarized agriculture. However, I'm not as bearish on application rates falling as Glen sees it and I expect domestic phosphate demand will be approximately equal to last year. We will see another record in U.S. phosphate chemical exports-maybe. Industry  $P_2O_5$  inventories are currently low, very low, operating rates are flat out and prices are in the upper range of what we've experienced the past 10 years. So why worry?

Costs are increasing and margins on phosphate chemicals such as DAP are not even close to what the industry enjoyed in 1988. And we see the dust on the horizon of efforts by foreign countries to construct new offshore capacity. The constant question being asked by fertilizer industry executives is, "When will it be really good again?" I don't know that anyone has the answer, but today I'll try to tell you what the near-term picture will look like.

Phosphate demand this summer and early fall has been excellent, mostly as a result of the COOP fill programs. However, with fuel prices up, commodity selling prices down, fertilizer prices rising and continued uncertainty about the new farm programs, it's no wonder that domestic business at the moment is low.

So if CF's view is one of nervous optimism for the period ahead, what does my company see? As with the roller coaster, more track and a big hill right around the corner. The question is left up to all of us as to whether the hill is up or down. (Figure 2.)

## Questions Taken From The Floor

*Are We Headed Into A Recession And, If So, What Impact Will This Have On The Agricultural Sector?*  
(Figure 3.)

If you ask three different economists this question, you'll likely get four different answers. In my opinion, the answer is we're already in one. The good news is that it will likely be a mild recession which will probably be short-lived.

The brunt of the recession is expected to occur during the first half of 1991. The economy should begin to recover during the summer months and by the end of 1991 show a modest but sustained growth.

There are two underlying assumptions in this fore-



cast. The first, is that the Federal Reserve will reduce interest rates to keep the economy from going into a deeper recession. This will likely put some upward pressure on inflation. However, this is a gamble that the Federal Reserve will likely accept.

The second assumption is that there is no escalation in the Middle East crisis. Assuming there is a flare-up, the impact on the economy will depend on whether the war is confined to Iraq and Kuwait and on the extent of the damage to existing oil production and distribution facilities. Assuming the worst, the U.S. and the world economy as a whole will likely be in for a prolonged period of negative growth, increasing unemployment, and comparatively high inflation.

With respect to the impact on the agricultural sector, recessions that are driven by either inflation or consumer spending aren't necessarily all that bad. Obviously, higher fuel prices will drive up production expenses. According to a recent USDA study, net farm income will decline by \$900 million dollars, or roughly 2 percent, for every \$5 increase in the average annual price of a barrel of oil. However, offsetting part of the increased fuel cost will be lower interest expenses. Interest expenses currently account for roughly 10 percent of total agricultural production costs. Lower interest rates will also have a dampening effect on the value of the U.S. dollar and a corresponding positive impact on U.S. exports. (Figure 4.)

And a weak dollar benefits U.S. agriculture. Approximately 25% of the annual usage of corn goes to foreign buyers. Of that portion, approximately one-fourth is shipped to Japan. If you consider for a moment what the price of corn looks like in terms of Japanese yen, it shows that prices are near 20-year lows right now. Soybeans in terms of yen are also very low and it is important to point out that we export one-third of the annual U.S. soybean crop and Asia accounts for nearly one-third of all soybean and soybean-product purchases in the world. (Figure 5.)

Another interesting twist is that U.S. grain exports have historically tracked world oil prices. Countries such as Mexico and the Soviet Union are not only major oil exporting countries but also major grain importing countries. According to another USDA study, if oil prices went up 12 percent annually for the next three years, U.S. Ag exports would likely climb by \$1 to \$3 billion.

*Now That The Congress Has Passed The New Farm Bill, What Does It Mean To The Industry?* (Figure 6.)

It will be difficult to estimate what farmers will do each year under the new rules. Try and figure it out. If a farmer can get a loan on the 15% triple base acres and also on the 10% "flex" acres, provided those acres are after 0/92 acres and after ARP's (acreage reduction programs), that oilseed crops can be planted just about anywhere, anytime, including on some of those flex

acres, and no matter what he does, his historic base never changes, what will farmer Jones plant? The USDA has come to the conclusion there will not be a significant change in production patterns because of triple base or flex acres. It's likely that we'll see fewer farmers participate in the government programs every year since by the last year of the new bill, the triple base percentage increases and government outlays decrease. Meaning, we'll be adding acreage over the period, which is good for the fertilizer industry.

(Figure 7.)

This new bill, following the budget compromise, is an example of how to slash payments to farmers without cutting target prices and make it seem like a good plan. The Secretary of Agriculture put it like this:

"Faced with difficult choices brought about by budgetary constraints, the conferees took the preferred course in selecting a "triple base" program over cuts in target prices, thus increasing production flexibility which provides an additional opportunity to earn income."

The bill is better than an across the board sequester which would have cut one-third in program payments, but it is still not as good for the industry as the 1985 farm bill.

*Will Farm Income Drop Because Of Lower Government Subsidies?*

(Figure 8.)

The "triple base" provisions of the new farm bill are expected to cut government farm payments by \$2 billion or roughly \$10 billion over the next five-year period. For every dollar cut from government payments, farm income will likely fall by roughly 90 to 95 cents. The decline is not quite one-for-one since farmers will be able to make up some of the loss in government payments by planting alternative crops on their triple base acreage.

Despite the decline in government payments and net farm income, the balance sheet for the agricultural sector is expected to remain fairly strong.

With farm income of around \$45 to \$50 billion, a \$2 billion reduction translates into a cut of around 4%.

But this only deals with the "triple base" issue, not all the aspects of the 1990 bill. (Figure 9 & 10.)

A better question is, "What will lower subsidies mean to the fertilizer industry?" Under the previous bill, Uncle Sam footed the bill for many of the inputs needed on the farm. Direct cash payments between 1986 to 1990 totaled \$63 billion, or on average, \$12.6 billion per year. Total net farm income averaged \$45.5 billion over the same span or, we can say, over one-fourth of farmers income came from the government. If we look ahead to 1995, cash payments to farmers will drop not by 4% but more like 40% when more cuts are taken to deal with the annual budget crisis that will become common. As this occurs, government payments will account for only about 18% of net farm income.

What's the knock on the fertilizer industry? Between 1986 to 1990, fertilizer expenses at the farm level totaled \$33.7 billion, or put as an average, the annual



NPK tab was \$6.7 billion per year. Ignoring for a second that government payments included such necessary programs as the wool, mohair, honey, dairy, etc. programs, non-crop programs, if you will, one could say, Uncle Sam paid nearly twice what the annual fertilizer bill totaled. So what about the next five years? Let's assume no change in total fertilizer use and that prices in real terms remain constant - meaning I'm going to escalate prices by 3-4% to account for annual inflation. In this case, government payments won't even cover the annual NPK bill. Paying the fertilizer tab is going to become more difficult and farmers will pay even closer attention when figuring their fertilizer needs.

*Did We Have A Record Corn Yield This Past Year? Are Grain Stocks Going To Be Up?*  
(Figure 11.)

The government released new figures last Thursday for this year's crop production. In the November report, the USDA estimates this year's corn harvest will total 7.9 billion bushels based on an average U.S. yield of 119 bushels per acre. The record corn yield was set in 1987 at 119.8 bushels per acre.

At one time, this year's yield had been pegged at over 121 bushels per acre. However, it appears that the late planting combined with cool weather inhibited full ear development.

The cut in production was a surprise to many commodity analysts and now the USDA estimates corn stocks at the end of the current marketing year will drop from 1.34 to 1.24 billion bushels.

In spite of the downward revision to this year's corn harvest, the crop will still be the fifth largest on record. Unfortunately, the U.S. was not the only country with a large crop. Large yields were also reported in the Soviet Union and in many of the major grain exporting nations. As a result, U.S. corn exports are expected to be down by about 15 percent from year-ago levels.  
(Figure 12.)

Despite the larger crop and reduced export demand, the corn stocks situation is expected to remain relatively tight over the next year. Total demand for corn is expected to roughly match this year's production as domestic demand for corn is very strong and, even with the fall off in exports, export demand is still expected to be fairly high.  
(Figure 13.)

The crop which is experiencing an increase in stocks is wheat, but even that build-up is not expected to be excessive. We had a record world wheat crop and the third largest U.S. crop ever this year. U.S. wheat exports are expected to be down 13 percent from last year's dismal level, and production is likely to outstrip wheat demand by nearly 400 million bushels. However, wheat stocks are rising from extremely tight levels, and for both the world and the U.S. stocks are expected to remain well below the excessive levels of the mid-1980's.

(Figure 14 & 15.)

The alarming figure is how far world wheat prices have dropped from a year ago and as shown on this chart, are now the lowest in over 16 years. It's not due solely to the slight increase in the stocks, but is a function of increasing global competition this year between major exporters such as the European Community, Canada and the United States. Extremely high subsidies to French, West German and other Common Market farmers have provided an economic incentive for European producers to more than triple the EC's wheat export capability over the past thirty years. This is the root of the problem in the current round of GATT (General Agreement on Tariffs and Trade) negotiations that U.S. free trade advocates are up in arms about. But let's face it, the Export Enhancement Program is our solution to leveling the playing field and our efforts have contributed to the tremendous drop in world wheat prices.

USDA figures on soybeans were not as friendly. Production of soybeans is estimated at 1.90 billion bushels, nearly equal to last year's level. But ending stocks have been raised by nearly 80 million bushels and the government now estimates carryout next year will be 255 million bushels. Cotton production was pegged higher, but year-end inventories were pared to 2.6 million bales versus 3.0 million last season.

There's some upside down potential to the situation if the current movement to grant Most Favored Nation Status to the Soviets comes about. Let's face it. Gorbachev is in trouble politically at home and long bread lines are fairly unpopular. The Bush administration does not want to see a revolt in the Soviet Union and a possible return to a military structure that could lead to another Cold War. We'll probably grant the Soviets MFN status fairly soon and extend them credit for wheat and corn purchases. It will take some action like this for us to reach the export projections currently being used.

*What Do You Think We'll See Acreage-wise This Next Year And Beyond?* (Figure 16.)

The upshot of the new figures is total acreage in 1991 is expected to be close to what was planted in 1990. However, there is likely to be some significant changes in the specific crops. The most significant change will be in wheat. Due to higher set-aside requirements and significantly lower prices, wheat acreage is expected to drop from 77 million acres in 1990 to 70 million acres in 1991.

Most of the decline in wheat acreage will be offset by more soybean and cotton acreage. Soybean acreage will rise as a result of the triple base provisions of the new farm bill, and cotton will be up due to strong prices and an expected lower set-aside requirement for 1991. Corn acreage for 1991 is expected to up slightly as a lower set-aside program and possible new strength in prices may mitigate the effect of some farmers planting soybeans on corn triple base acres.  
(Figure 17.)

Beyond 1991, acreage is expected to remain fairly

high, and assuming that the growth in demand will slightly outstrip the 1-2 percent growth rate in yields, acreage may move up marginally. If wheat exports rebound after this year, wheat acreage should move back toward 1990's relatively high level. Also, strong demand for corn for ethanol as a result of provisions of the new Clean Air Act and the new Farm Bill should help support corn acreage at close to current levels. Soybean and cotton acreage are also expected to remain relatively high.

*I've Been Reading A Lot About The New Proposition In California To Limit Agricultural Chemical Use. Where Do You See The Environment Movement Heading Over The Next Few Years? (Figure 18.)*

Proposition 128, also known as Big Green, was the most wide-sweeping environmental initiative ever undertaken at the state level. The portions of the bill that impacted agriculture primarily targeted the use of so-called cancer causing pesticides and did not directly impact nitrate. Although the proposition failed in the general election, many feel this is the first of a number of similar proposals that could appear in states across the country.

It was interesting to note that six months ago, the polls were showing that 70 percent of the voters in California were in favor of the proposition. Most of the early support was due directly to a very extensive campaign of scare tactics, misinformation and, of course, actor endorsements. Fortunately, the chemical industry did an effective job in presenting the facts to the California voters.

Although the proposition failed, it did underscore three important points:

\* First, is that the industry is facing an uphill battle. It is extremely difficult to fight an emotional issue with scientific fact. After all, the first motto of the environmental campaign is, "If science won't back-up the argument, Meryl Streep will."

\* Second, the environmental battle is going to be fought primarily at the state rather than the federal level. The fact is, we're outnumbered. While the industry can do an effective job in presenting the facts in Washington, it becomes an extremely difficult task fighting this battle in 50 state capitals.

\* Third, the industry is going to continue getting hit from all angles. Although most of the initial focus was on the Farm Bill and the Clean Air Act, the industry will face increasing environmental pressure in areas such as Groundwater Protection, Hazardous Materials, Superfund, OSHA and the Resource Conservation and Recovery Act.

*Along Those Same Lines, What Impact Will The Environment Movement Have On Application Rates?*

What many in the environmental movement fail to recognize is that many of the concepts they have been pushing have long been endorsed and promoted by the fertilizer industry. Crop rotation, cultural practices that reduce erosion, and more efficient use of nitrogen fertilizers are integral parts of the BMP or Best Management Practices concept.

At an organic farming conference last year, Barry Comodore, who is one of the gurus in the environmental movement, made the following statement: "We've got to quit using ever increasing amounts of nitrogen fertilizer." The fact is, nitrogen consumption in the U.S. declined during most of the 1980's and even today is below what was used ten years ago. Remember, the second motto of the environmental campaign is, "When the facts don't back up your argument, make up new facts." (Figure 19.)

In terms of application rates, per acre nitrogen use on corn has remained virtually flat over the last ten years. Over the next ten years, we expect per acre rates to move up marginally through the first half of the 1990's and then fall off slightly as the CRP acres start to come back into production.

A more relevant way of looking at application rates, however, is not in terms of rate per acre, but rather, in terms of the rate per harvested bushel. Although variations in weather result in significant fluctuations, there has been an obvious downward trend in this statistic over the last decade. We expect that a continued movement toward more efficient uses of nitrogen will result in a continuation in this trend during the 1990's. (Figure 20.)

Many things will determine phosphate demand levels in the future. One thing to keep sight of is how we have been removing nutrients from soil over the past decade. As shown here, until 1980 U.S. farmers were over-fertilizing and, you might say, building a bank of nutrients in the soil. However, since 1980, the reverse has been true and, with the exception of the droughts in 1983 and 1988, we've been drawing out of that bank. (Figure 21.)

The results from this year's Phosphate and Potash Institute soil tests confirm this fact. The red areas show how those states close to the edge in terms of soils becoming inadequate in phosphate fertility. Twelve states in the survey revealed an increase in inadequate fertility over the level found in 1986. We can't continue to keep mining the phosphate in America's farmland and reach the yield objectives we need to maintain crop production. These facts point to a continued need to increase application rates in the years ahead.

With regard to phosphates, fortunately there is no evidence linking nitrates and Blue Baby Syndrome to the phosphate business yet. Arguments favoring greater yields through adopting new biotechnology and trimming fertilizer application rates, don't wash with either phosphates or potash. There simply are no substitutes.

*How Will The Current Events In The Soviet Union And Eastern Europe Impact The Industry?*

Given the fluid situation in that part of the world, there are more questions, and certainly more opinions, than there are answers.

The importance of the events in the Soviet Union and in Eastern Europe can be put into perspective with a few key statistics.  
(Figure 22.)

\* The Soviet Union is the world's largest producer of ammonia and urea with a total capacity of almost 27 million tonnes of ammonia and 24.5 million tonnes of urea. Adding in the Eastern Europe capacity, the Eastern Bloc countries account for approximately 35 percent of total world ammonia capacity and 30 percent of total world urea capacity.

\* The Eastern Bloc countries dominate world nitrogen trade. In 1989, Eastern Europe and the Soviet Union accounted for roughly one-third of world ammonia exports and one-third of world urea exports. (Figure 23.)

The most immediate and significant changes that are expected to occur are in Eastern Europe. Over the next five years, it is expected that as much as one-fourth of the capacity in that region could close permanently. Although the demand for nitrogen fertilizers is also expected to decline, the net impact will likely be a substantial reduction in export availability.

The reasons for the sharp decline in capacity are two-fold:

\* First, a large percentage of the nitrogen plants in Eastern Europe are old and highly inefficient. Gas consumption per ton of ammonia in many of these plants is as much as 40 percent higher than what is used in the average U.S. plant.

\* Second, is the recent change in Soviet pricing policies for natural gas.  
(Figure 24.)

Beginning in 1991, Soviet gas exported to Eastern Europe will be pegged to world oil prices and sold on a hard currency basis. For some plants, this will result in a doubling or tripling in total production costs. Currently, over half of the East European plants are based on Soviet gas.

The outlook for supply and demand in the Soviet Union is considerably different from that of Eastern Europe. Similar to Eastern Europe, the elimination of fertilizer subsidies is expected to significantly reduce domestic nitrogen demand. Unlike Eastern Europe, however, only minor changes, are expected in capacity. The reasons include the following:  
(Figure 25.)

\* Most of the Soviet capacity is comparatively new having been built in the late 1970's and early 1980's.

\* The Soviet Union has shifted its emphasis from building new capacity to improving the efficiency and cost competitiveness of the existing capacity.

\* There are currently four plants in the process of being revamped and plan to revamp at least four more plants within the near future.

\* Ammonia in the USSR is produced from domestic gas which can be priced at whatever level is necessary to be competitive.

Given this demand and capacity outlook, the implication is that the Soviet Union should be able to at least maintain or possibly increase exports. The key assumption for the next couple of years is that the Soviets can solve their production and distribution problems. Due to a combination of scheduled and unscheduled plant turn-arounds and problems at the Yuzhny export terminal, Soviet exports this year are expected to be down by roughly 10 percent from year-ago levels.

From a long-term perspective, the availability of Soviet nitrogen exports will depend to a large extent on the effectiveness of the reforms in the agricultural sector and on the Soviet need for hard currency. Assuming the most optimistic case for the reforms, Soviet domestic demand would likely increase and exports fall. Given the rate of success so far, however, this doesn't appear to have a high probability.

When it comes to phosphates, it seems as though Gorbachev's reforms are stuck in reverse. Between 1975 to 1988,  $P_2O_5$  demand in the Soviet Union grew from 4.7 million tons  $P_2O_5$  to 8.6 million tons. In the last two years, it appears that demand has declined to a mark of 7.5 million tons this year.

Soviet farmers have been thrust into a position they've never been in before - that of determining how much fertilizer to use. It is doubtful that Soviet farmers will acquire the technical experience necessary for managing higher crop production through better fertilizer management practices. Or maybe these conclusions are all wet. It could possibly be that Soviet farmers have been over-fertilizing all these years because the State told them how much to use. Whatever the real answer is, long bread lines in the Soviet Union will not be solved in the short run by increased fertilizer use, but rather by a much needed dependence on grain imports from the West.

*What Does A War In The Middle East Mean To The Fertilizer Business? Is The Region A Net Fertilizer Importer Or Exporter And What Have The Sanctions Against Iraq Done To World Trade In Fertilizers?*  
(Figure 26 & 27.)

An escalation in the Mideast crisis would have major ramifications for the world nitrogen market.

The most immediate impact would be world supply. The Persian Gulf producers currently account for approximately 12 percent of total world ammonia trade and roughly 17 percent of total world urea trade. Under

a war scenario, it is likely that all of the supply from the area would be lost. Even if the conflict were confined to Iraq and Kuwait, it is doubtful that any carriers would be willing to go into the region. (Figure 28)

Probably an even more profound effect of a war would be its impact on nitrogen production costs, particularly in Western Europe. Since natural gas prices in Western Europe are tied directly to oil prices, producers in this region are already feeling the impact of the crisis. Assuming prices just hold at current levels, gas prices to ammonia producers in Western Europe could increase by as much as 40 to 50 percent during the first quarter of 1991 and raise production costs for even the most efficient producer by as much as \$50 per tonne.

Consequently, any further escalation in the crisis would definitely put the future of Western Europe producers in serious jeopardy.

For the U.S., most of the impact of a war would be indirect via its effect on world prices and world supply/demand. The U.S. currently imports only small percentage of its supply from the Gulf region. In addition, natural gas prices in the U.S., at least in the short run, typically don't track oil prices. (Figure 29.)

The most serious threat to the U.S. market is in the potential reduction in offshore imports. As production costs increase in Western Europe, so will prices and import demand. With potentially higher net backs into Western Europe, it seems likely that a significant amount of Caribbean (Trinidad, Mexico and Venezuela) tonnage will be diverted from Tampa to Western Europe. The U.S. currently imports approximately 1.2 million tons per year of ammonia from Latin America. Given the high rate of ammonia currently being used in DAP production, the loss of import tonnage would further tighten an already tight U.S. ammonia market. (Figure 30.)

From a long-term perspective, the magnitude of the impact on world nitrogen markets would depend primarily on three factors:

\* First, is whether the conflict would be limited just to Iraq and Kuwait or extended to the rest of the Gulf region. As just discussed, the Persian Gulf as a whole accounts for a significant portion of world's exportable supplies.

\* Second, is the extent of damage that is done to the existing nitrogen facilities and, even more important, to the existing oil production and distribution facilities.

\* Third, the willingness of foreign investment and foreign technology to re-enter the area.

With respect to the latter, Iraq had plans to construct four new facilities, all due to be completed between 1993 and 1994 and all based on foreign investment and foreign technology. Even without an escalation in the conflict, it's likely these plants will be delayed by a minimum of 1 to 2 years.

To make a long story short, an all out war in the Gulf

conceivably could result in a total restructuring of the world nitrogen industry. (Figure 31.)

It appears that a war is inevitable. The UN sanctions may not be hurting Iraq today, but nitrogen, phosphate and sulphur markets have felt the pinch without production from Iraq and Kuwait. Mike Kitto will certainly detail the situation regarding sulphur and the Middle East. Just to note, Iraq's imprint on the phosphate business isn't tied to the loss of triple superphosphate exports, but the loss of sulphur exports to phosphate manufacturers.

While Iraq exported roughly 500,000 metric tons of GTSP last year, and was in the midst of an expansion at it's Al Qaim phosphate complex that would boost production of  $P_2O_5$  from 400,000 to one million tons, it's the loss of nearly two million tons of sulphur from the market that will cause phosphate production costs to jump sharply in the months ahead. (Figure 32.)

If a war does occur, many defense experts debate its length. If Saudi Arabian refineries and gas plants are damaged in a war, another 1.5 million tons of sulphur could be taken off the market. Most of this sulphur has found its way to phosphate plants in Jordan, Morocco, Tunisia, India, Turkey and Egypt. Trying to replace 3.5 million tons of a product already in tight supply is impossible. Fortunately, U.S. phosphate producers don't have to worry about sulphur, just the location of the bank they need to rob in order to pay for their supplies.

When you look at the fallout from the Middle East, the phosphate sector is probably the least affected in terms of future capacity changes. As noted before, Iraq was adding capacity but all work has ceased for now. Jordan was also in the midst of expanding capacity at Aqaba. However, the funding for the project was coming from the Kuwait Fund for Arab Economic Development. Strike one for King Hussein - it seems as his early alliance with Saddam Hussein may have cost him the funding for his venture. It is likely that high oil and sulphur prices will cause all expansions in India to be shelved for the time being, due to a lack of foreign exchange. And taking that problem one step further, Morocco's plans to expand its  $P_2O_5$  capacity by three million tons may be delayed as a result of the Crisis. It's hard to sell to a customer without money and India and Morocco haven't been the best of friends recently.

*What Is The Outlook For Capacity Changes And I'd Like To Specifically Hear What Impact The Seferco Plant Will Have On The Market When It Opens In 1993.* (Figure 33.)

Saferco represents the most serious down-side risk to the nitrogen industry in the 1990's. The facility, which is scheduled to come on stream in January of 1993, will consist of a 540,000 ton per year ammonia plant and a 750,000 ton per year urea plant.

Although the Saferco project is labelled as a joint venture between Cargill and the government of Saskatchewan, it is by no means an equal partnership.

According to the information that has been released,



the Saskatchewan government will receive 49 percent of the equity and, via its initial investment and loan guarantees, assume 85 percent of the risk. Quoting a statement from a letter that was sent from a number of the U.S. Senators to the U.S. Trade Representative, the "project has the earmarks of a political pork barrel."

What will the impact of the plant be? The answer becomes obvious when you consider that there are only two ways to gain market share in a commodity business. One is to offer additional services; the second is to cut the price. There have been no statements or indications that Saferco will offer anything to the marketplace other than surplus product. That leaves only one alternative - a long and difficult pricing bloodbath.

What makes this plant even more devastating to the industry is that according to Saferco most of the product will be marketed in Saskatchewan, Manitoba and the Northern tier states of the U.S. This is an area which is expected to show little, if any growth in nitrogen consumption over the next decade. In fact, environmental pressures could actually result in a decline in nitrogen demand in this area. As a result, virtually all of the production from this plant will have to be met with a coincident decline in supply from the existing players in the market.

How deep and how long the impact will last is difficult to answer. However, it should be noted that the current players in the market not only have long-standing established affiliations in this area, but also have significant investments in both production and distribution facilities. Consequently, these players are not about to rollover and die.

As a final comment, it was interesting to read in a recent press clipping that a spokesman for the Saferco project indicated that the primary impact of the plant would be to reduce offshore imports to enhance offshore exports. This is an interesting twist considering the plant is stuck in the middle of North America, is land-locked, and will market into an area that is currently served almost exclusively by existing U.S. and Canadian producers.

No matter how you see it, if it weren't for the direct involvement of the Saskatchewan government, this plant would still be only a bad idea. (Figure 34.)

Let's look at the changes in phosphates on a regional basis. North Africa will account for over two million tons of additional capacity by the year 2000, most of which will take place in Morocco. In time, Morocco will become the leading producer of phosphate chemicals given the Kingdom possesses 75% of the world's rock resources. But it won't assume that position this decade.

Western Europe will close over one million tons of capacity during the same span due not only to age of plants, a lack of raw materials and a growing environmental problem tied to phosphates in general, but also to the problem associated with waste disposal. Eastern Europe will lose a similar amount as Western Europe for many of the same reasons.

Latin America will see minor additions to a small

base with a project in Brazil. However, this presumes the economic reforms implemented by President Collor de Mello will have taken hold to support a domestic industry.

In Asia, the largest region in terms of area and population, capacity has the potential to rise substantially with the abundant low-grade rock resources in China, there's only one problem. While rock resources are sufficient in Yunnan Province according to a recent Jacobs Engineering study, the lack of an adequate infrastructure to support these capacity plans may place the projections shown in a somewhat dim light.

I won't present the scene for Oceania, although I will say I've been there once and would like to go back. (Figure 35.)

Lastly, North America. As for Canada, I'd bet the farm that one of the two aging plants in British Columbia and Alberta will close this decade. In the U.S., new grassroots complexes appear unlikely, but we'll probably see some further debottlenecking at several plants. In the case of current idle capacity, I'm sure Glen wouldn't agree that CF's Bonnie plant probably looks like Buster Douglas down for the count - but that's my opinion, and he'd probably say the same for our Taft acid plant we aquired from the bankrupt Beker Industries. And as far as that pesky old Nu-South, soon to be Mississippi Chemical Pascagoula plant again, there are rumors out in the trade today that Mississippi Chemical is trying to source rock and sulphur for the plant. Go figure! It could be short-lived since, apparently, none of the recent bidders were serious enough to aquire the plant. And last but not least, Consolidated Minerals has left the impression they will build a new \$1 billion integrated phosphate rock, phosphate chemical, cement, and power generation complex in DeSoto county sometime this decade. I'm sure most of us in this room could figure better things to do with a \$1 billion than invest it in the fertilizer business. But, hey, let's hope they get a 20% return on investment, although I doubt this project will see the light of day before the next century.

*The Fertilizer Industry Has Been Operating At Comparatively High Operating Rates Over The Last Two Years. Do You See This Continuing And Does This Mean The Fertilizer Industry Is Now Out Of The Woods?* (Figure 36.)

The U.S. nitrogen industry operated at approximately 95 percent of capacity the last two years and is expected to operate at comparatively high levels this year. Despite the high operating rates, however, the industry is by no means on a sound footing. One fundamental problem facing the nitrogen industry is that the current balance between supply and demand has primarily been the result of supply side adjustments rather than demand side growth.

The magnitude of the adjustments can be emphasized with a few key statistics.

\* In 1978, U.S. ammonia capacity totalled 21.7 million tons; today, it stands at 17.5 million.

\* In 1978, there were 104 ammonia plants in the U.S.; today, there are 60 ammonia plants.

\* The ten largest producers in the U.S. controlled 57 percent of the capacity in 1978; today the ten largest producers control almost three-fourths of the capacity.

The restructuring of the industry certainly has had some positive effects. Most of the inefficient, high cost plants have now been closed. Consequently, the industry is now a more efficient and more cost-competitive industry than it was a decade ago.

However, the restructuring has also introduced a significant downside risk to the industry. Over the last few years the industry has experienced an unprecedented number of mergers, acquisitions and buy-outs. Since 1978, almost half of the U.S. nitrogen capacity has changed ownership at least one time. (Figure 37)

The problem is that a large number of these transactions were accomplished through debt financing. As a result, a significant portion of the industry is now highly leveraged. This shift toward higher debt has made the industry particularly vulnerable to changes in market conditions. This vulnerability could easily lead to pricing practices that are more short-term in nature and based on cash needs rather than long-term strength and stability. (Figure 38.)

The picture Glen paints in the nitrogen sector is very similar to that in phosphates. However, there are a few distinct differences. First there are significant differences between the lowest and highest cost producers in the nitrogen industry. New technology has played something of a role there, but technology has not changed the cost structure to a large degree in phosphates. The clear edge in this case goes to a company's position in basic raw materials such as rock and sulphur. Economics of scale are also critical to a producer's cost structure.

A problem that exists in the phosphate industry today is old capacity dies slowly and stubbornly. Many hopeful opportunists purchased marginal facilities under the best of economic circumstances only to find themselves undercapitalized in a market downturn. This is where the banks have learned a valuable, but expensive lesson over time. And sometimes it's the willing seller of assets that takes it on the chin. Take for example the case of Mississippi Chemical's sale of the Pascagoula P<sub>2</sub>O<sub>5</sub> complex to NU-West and the status of that "sale". More likely than not, Mississippi Chemical is stuck in no man's land. They don't want to own and operate a high cost plant that has environmental liabilities, but then they don't want to be in the hardware business or even worse, close the facility and come face-to-face with very expensive environmental shut-down costs. (Figure 39.)

Operating rates have steadily improved since 1986 as shown here. Of course as we also know, 1986 was about the darkest hour for the industry. Since then, operating rates are up to practical maximums and it would require the re-start of either Bonnie or Pascagoula

to increase output. Improbable, but not impossible. As far as being out of the woods, this industry will remain highly cyclical and largely unpredictable. Let's not forget, God and governments act in mysterious and forceful ways.

*How About Phosphate Trade? I Guess India And China Are The Major Offshore Markets For U.S. DAP Producers. What Is The Outlook For Next Year And Beyond For DAP Exports?*

If you would have asked me this question before last week's vote of confidence taken for Prime Minister Singh of India when he was ousted, I would have told you India was going to buy over two million metric tons of DAP and China would exceed this year's three million tons. I'll still stick with the Chinese figure since they have discovered what a good buy U.S. DAP is relative to urea and apparently, demand growth is far from over. But for India, sulphur prices hold the key. (Figure 40.)

In the past month, we've seen negotiations between India and Morocco break down once again on phos acid. Now that the Moroccans have lowered their price ideas, India loses it's government and foreign exchange is critically short. Taking that Mid-East war scenario into 1991 and the impact on sulphur prices I noted earlier, sometime early next year, Morocco's cost for sulphur will rise from under \$90 per metric ton today from Saudi Arabia, to close to \$120+. That will require OCP to tack on another \$30 to the phos acid price, assuming OCP can cover their sulphur needs. Later that same day, India will hold a tender and see a war still going on in the Persian Gulf. Ammonia will be in short supply and vessel owners don't want to venture a trip to Jubail. The price of ammonia will be up to \$190 on a delivered basis. Put the two together and U.S. DAP looks pretty good at even \$200 a metric ton. Bottom-line, India will buy DAP again, and a lot of it. But we'll have to wait until the new election. (Figure 41.)

When you look at U.S. phosphate exports, DAP is king accounting for two-thirds of total foreign phosphate chemical sales. Superphosphoric acid is the number two product with virtually all of this material going to the Soviet Union under OXY's 20-year barter agreement for ammonia and urea. With higher oil and ammonia prices, I would not expect exports to the Soviets to drop in the coming year. However, merchant acid exports may be tough to come by. Even though Iraq's involuntary withdrawal from world triple superphosphate trade provides an opportunity for other marketers to increase GTSP sales, U.S. GTSP exports are physically limited due to capacity constraints. (Figure 42 & 43.)

Many of you may find this chart tells the story. It illustrates how U.S. phosphate marketers have developed offshore markets in order to deal with declining domestic demand during the 1980's. It also provides a glimpse at how volume this fall has stacked up against record movement last year and how we're gaining

ground during the current quarter. While I and others anticipate India and China will continue to purchase heavily in the first half of 1991, I'd have to stop short of predicting a record third straight phosphate export year in 1991. But I'll admit, I've guessed low four years in a row now.

*I Read Somewhere That The Chicago Board Of Trade Is Looking At Trading DAP And Ammonia. Where Does That Stand And Is It Something That Will Benefit The Industry Or Not? (Figure 44.)*

The Chicago Board of Trade (CBOT) is looking at a listing DAP on the exchange. So far, a new products committee has drafted the contract and will receive a yes or no vote from the Board of the CBOT later this month. From there, the contract goes to the Commodities Futures Trading Corporation (CFTC) for study. The CFTC could study the contract and the industry for a year, but probably won't take that long. And if the CFTC approves the contract, by this time next year we might see DAP make the cover of the Wall Street Journal, or at least the commodities page.

Is DAP futures "good" for the industry? That's a subject debated in just about every fertilizer company except IMC and Cargill. Their minds are made up on the subject and I'll tell you only one of those companies definitely favors DAP futures. I personally believe DAP futures is good for producers, re-sellers, brokers and dealers. However, it's not the get-rich-quick angle that should interest us, but the ability to shift risk or minimize effective price swings that should appeal to hedgers. Furthermore, the price discovery mechanism created when buyers and sellers come together in one place makes for a more efficient transfer of expectations regarding prices in the future. Speculators love the action and only need volatility to hope for betting right. I think DAP futures will be a part of the industry in the coming months.

With respect to ammonia, the CBOT is also moving ahead on an ammonia contract and has studied urea as a possibility. If these come about, many ammonia producers will need to take a look at forward contracting ammonia and natural gas supplies as a production hedge against unwanted price volatility in either ammonia selling prices or gas costs.

*What's The Industry Outlook For Profits Next Year?*

*Nitrogen Prices  
(Figure 45.)*

Currently, there is more uncertainty about nitrogen prices than there has been anytime in the last ten years. While the normal variables that create uncertainty - operating rates, inventory, domestic demand and trade - still exist, they are far outweighed by the uncertainty surrounding the Middle East.

The key assumption on the upside is that an all-out war breaks out in the Middle East. Although all of us

want to see high prices, I'm sure none of us want to see them at the expense of a war.

The downside risk in nitrogen prices reflects some of the nervousness that I discussed in my opening remarks. The combination of continued high operating rates, possibly lower than expected demand and higher than anticipated import levels could result in a downward slide in prices throughout the spring season. It is important to note, however, that even under this scenario, nitrogen prices are expected to remain higher than year-ago levels.

*Phosphate Prices  
(Figure 46.)*

Looking back over the past ten years, and in predicting phosphate prices, or in this case, DAP prices, one only needs to know where inventories are headed. And that shouldn't be too terribly tough to estimate. (Figure 47.)

But inventory swings are difficult to forecast. However, it's pure old supply and demand that governs prices and as I've shown in this chart, the balance in 1991 is projected to be as tight as we've seen just about anytime since 1980. You don't have to be a rocket scientist to predict what impact this portends for price. But supply/demand is only one side of the equation.

Based on a war scenario, an expectation that phosphate rock prices will rise at least \$1.50 or so next year, that sulphur could hit close to \$155+ in Tampa against the current \$140 level, and ammonia prices could really pick up if the Persian Gulf lights up, cash costs for DAP will rise significantly in the first half of 1991. (Figure 48.)

Comparing prices over time is informative, but as this chart illustrates, cash is king and prices don't stay below breakeven costs for long. While I have purposely not shown a price forecast on this chart, here's where I think margins are headed during 1991. I believe the chances to see margins return to the levels experienced in 1988 are remote. However, 1991 promises to be a better year than 1989 or 1990.

Figure 1.

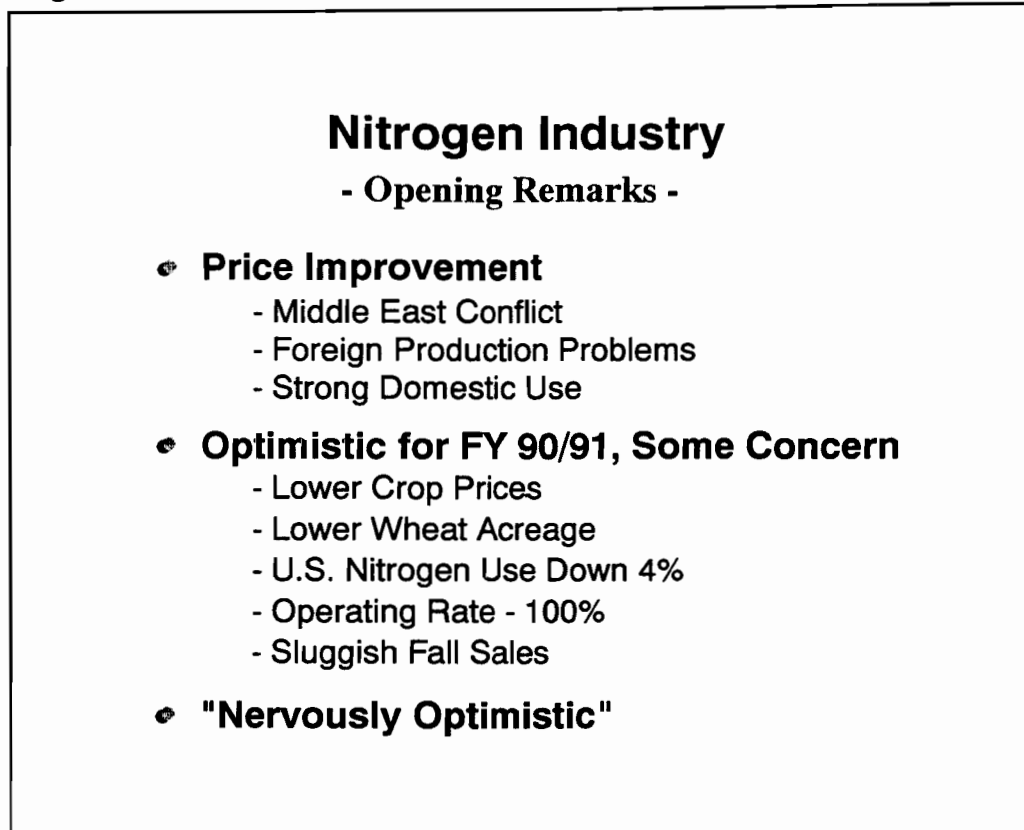


Figure 2.

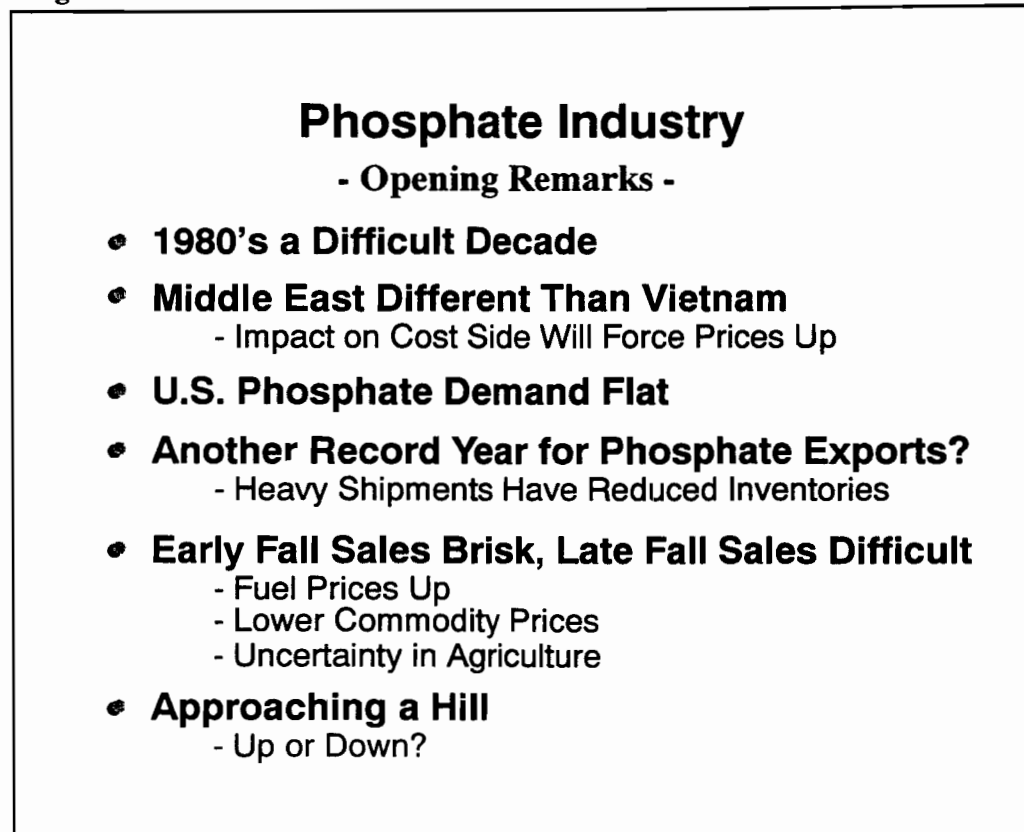




Figure 3.

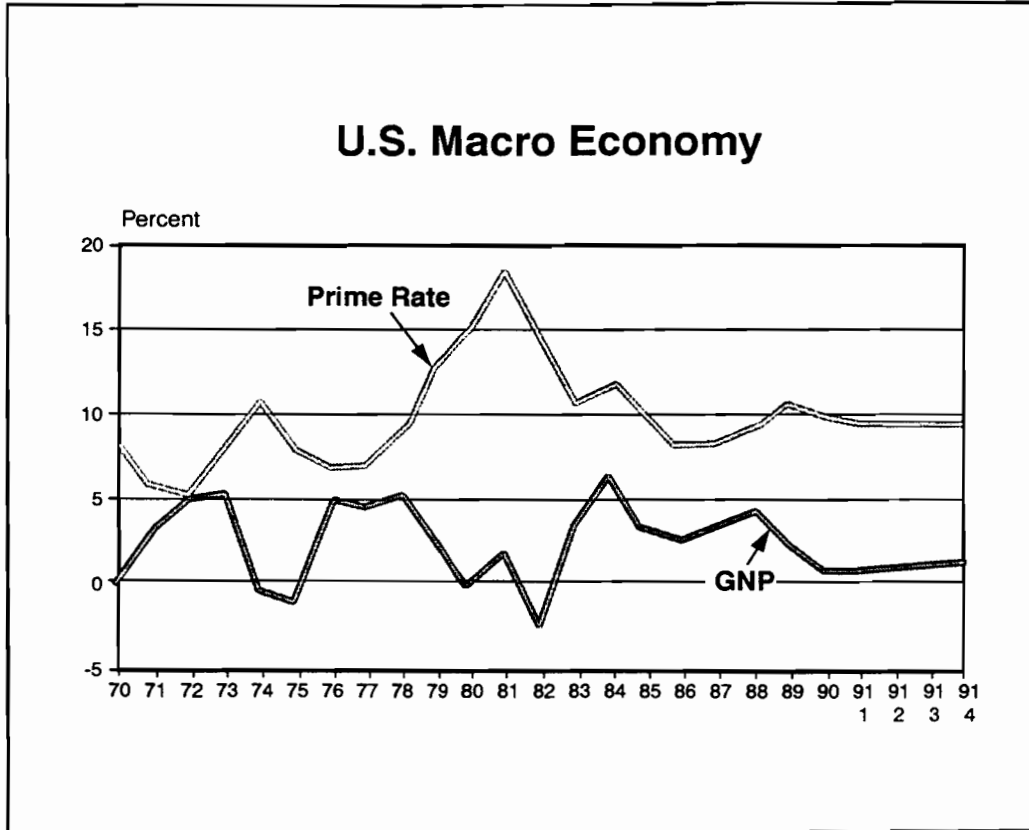


Figure 4.

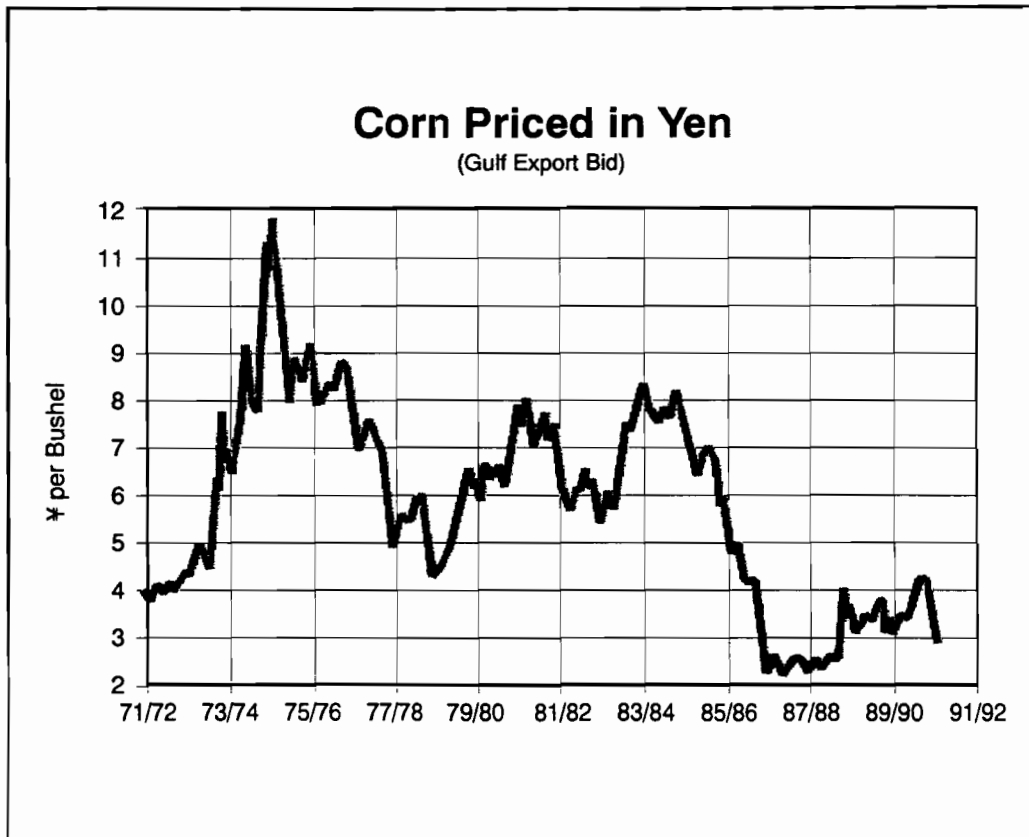


Figure 5.

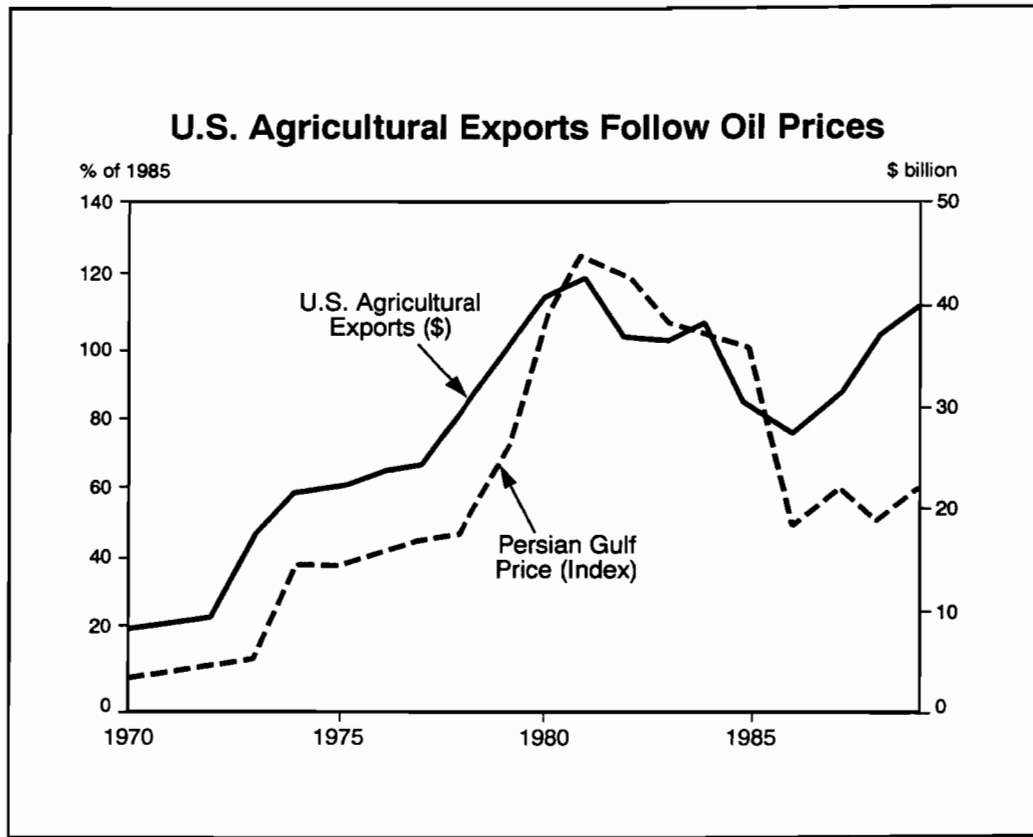


Figure 6.

## 1990 Farm Bill Features

### Flex Acres

Farmers may forego Deficiency Payments on land equal to as much as 10% of their base acres and plant any crop without losing base. (However, if USDA estimates that soybean price will average less than 105% of the \$5.02 loan rate, soybeans cannot be planted on flex.) This flex comes on top of non-payment acres below, also referred to as "flex".

### Triple Base

Participating farmers will have their permitted acres reduced by 15% for purposes of receiving Deficiency Payments. Farmers can plant any program crop, oilseeds, industrial crop, or experimental crop-but not fruit or vegetables (including dry edible beans). Winter wheat farmers have the option of getting payment on all permitted acres, but with the Deficiency Payment Rate based on a 12-month Market Price.

Figure 7.

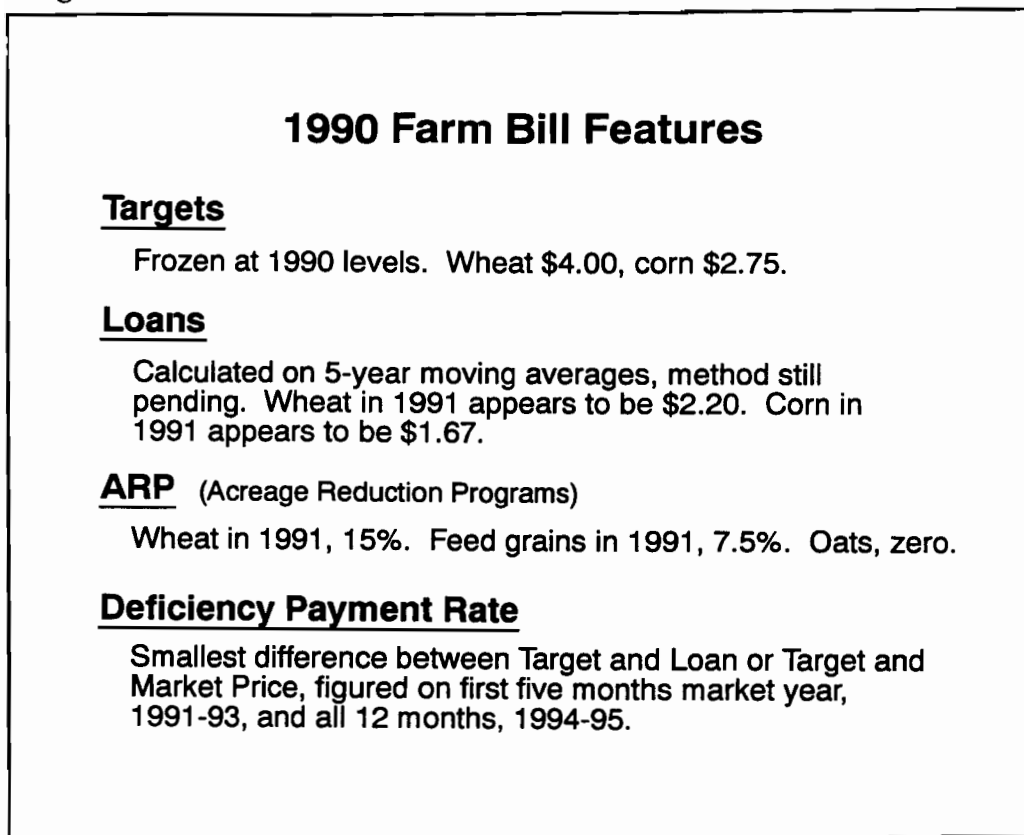
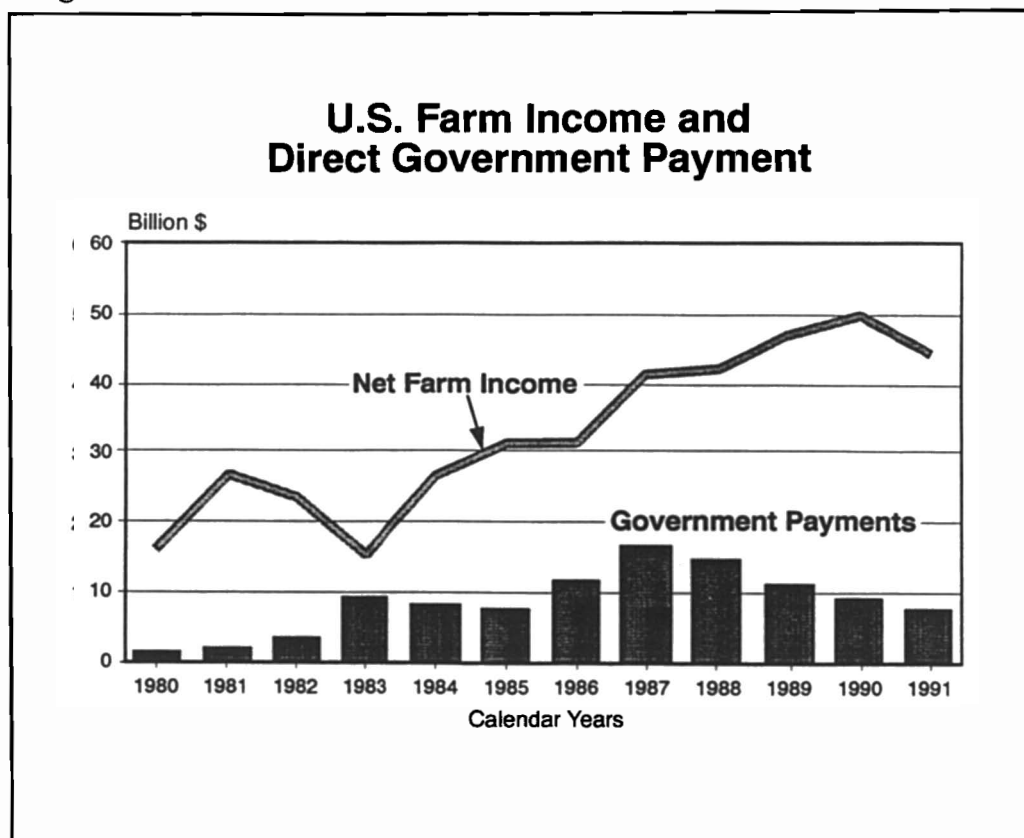
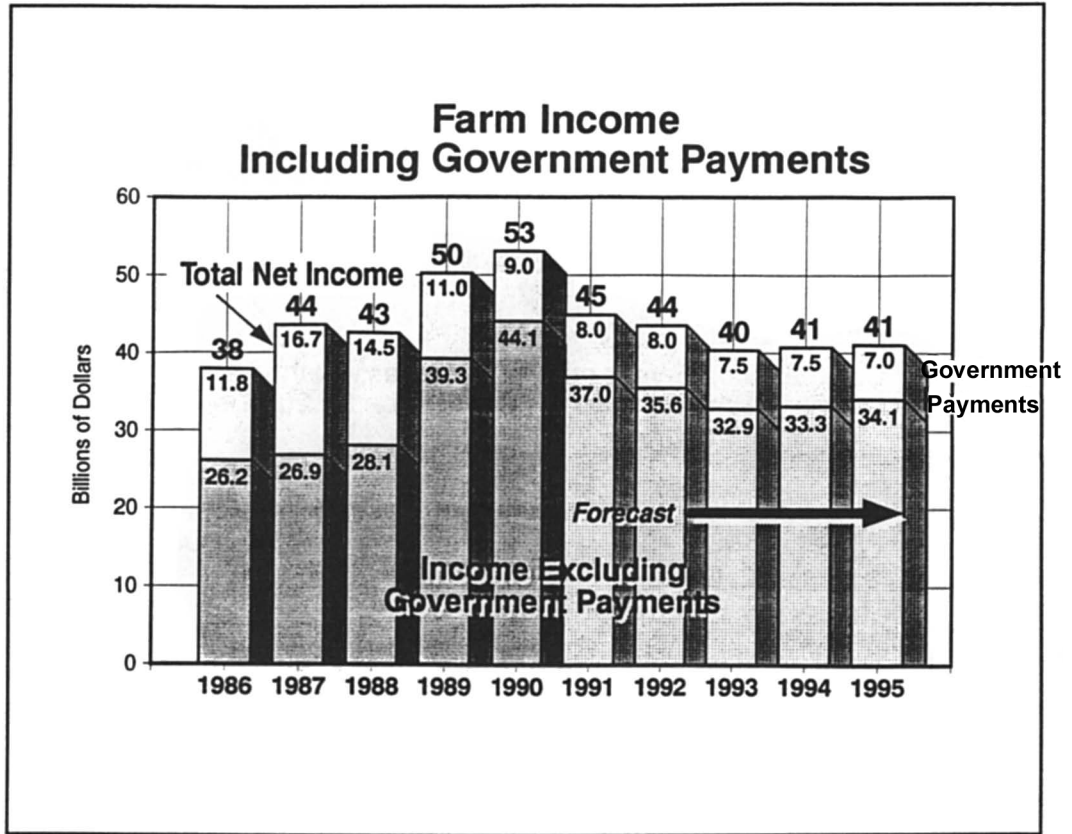


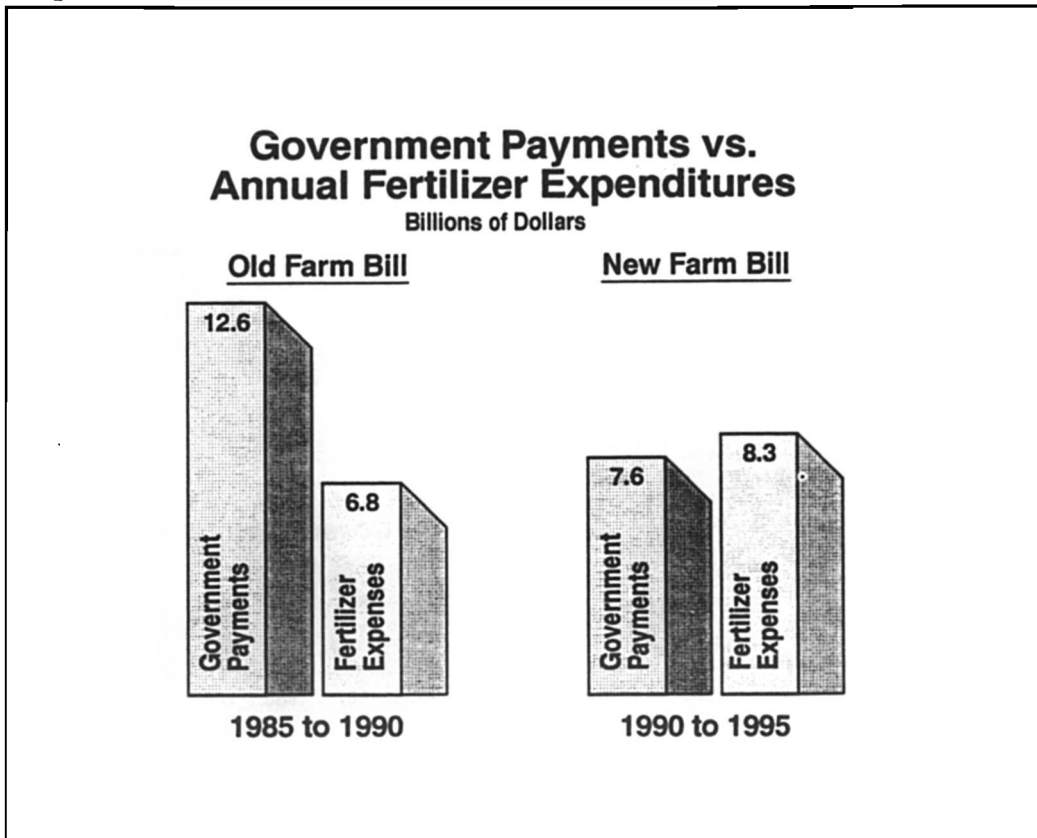
Figure 8.



**Figure 9.**



**Figure 10.**



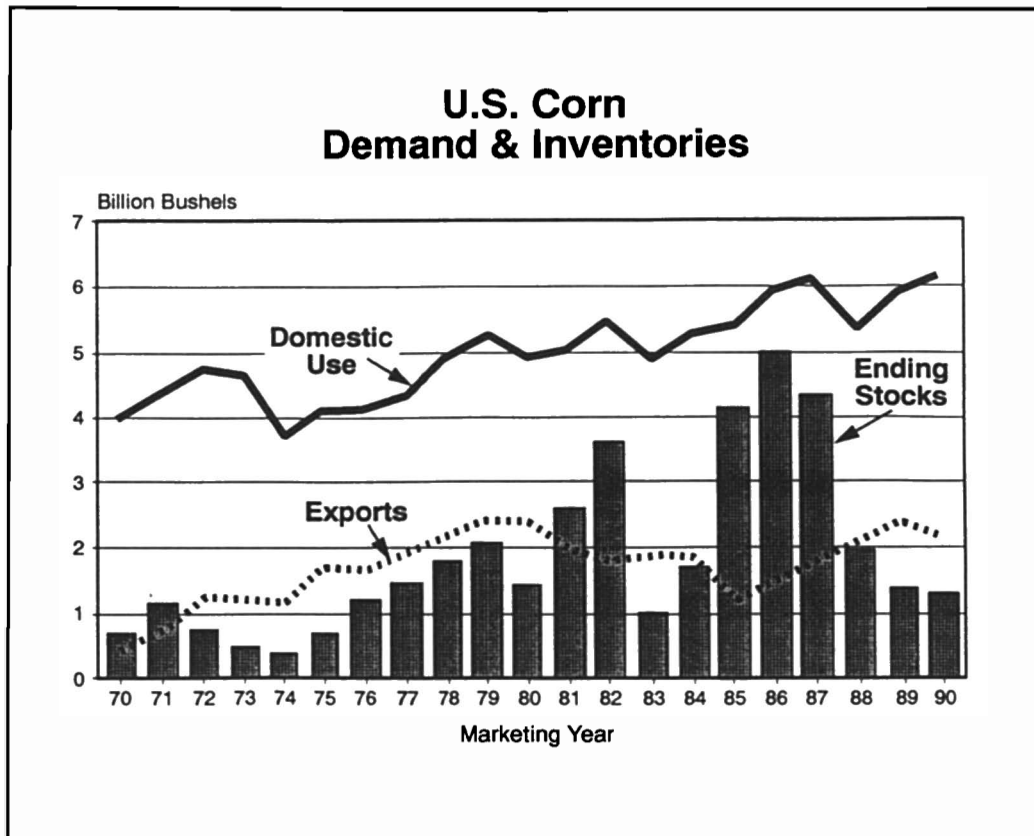
**Figure 11.**

### Yield Comparison

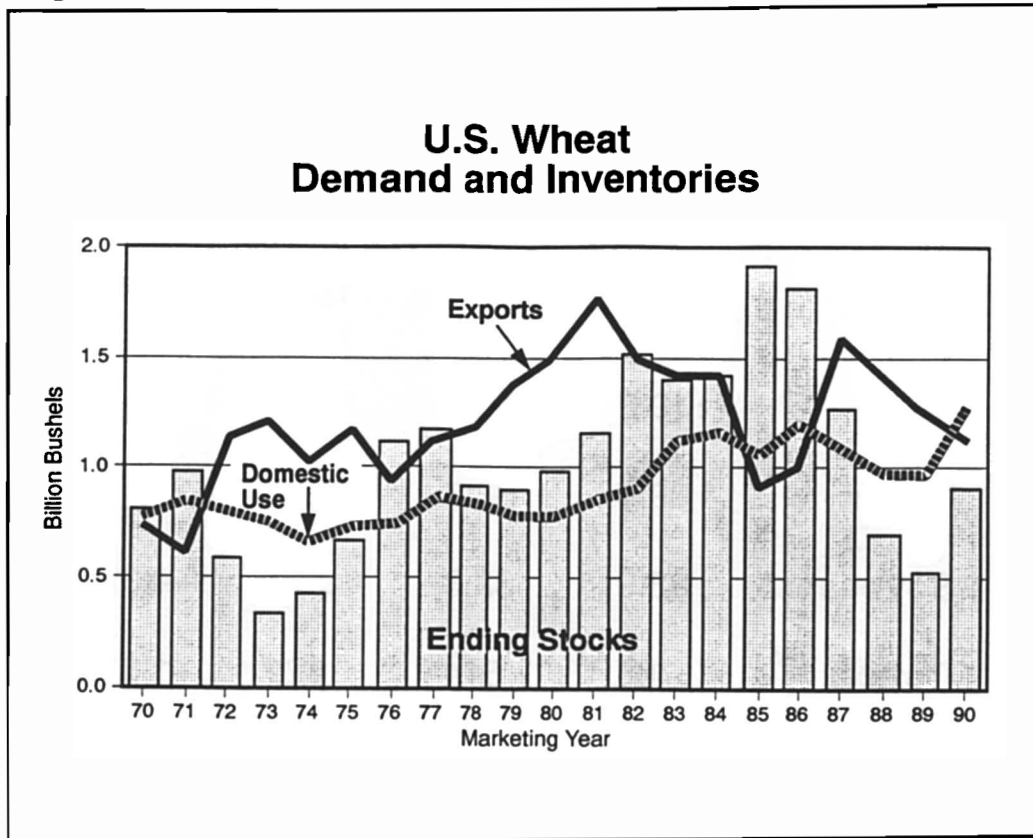
(Bushels or Pounds Per Acre)

	<u>Past Record</u>	<u>1989 Yield</u>	<u>1990 Yield</u>	<u>% Chg 89-90</u>
<b>Corn</b>	119.8	116.2	119.0	+2.4%
<b>Wheat</b>	39.4	32.7	39.6	+21.1%
<b>Soybeans</b>	33.9	32.3	33.7	+4.3%
<b>Cotton</b>	706	614	622	+1.3%

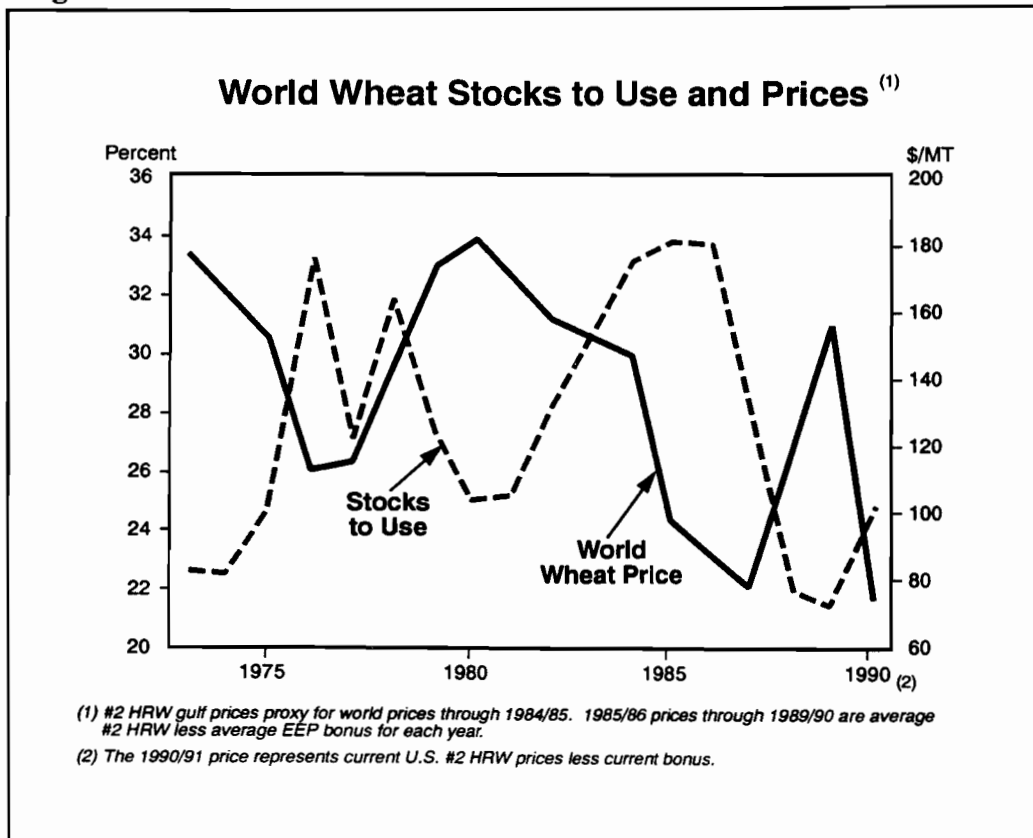
**Figure 12.**



**Figure 13.**

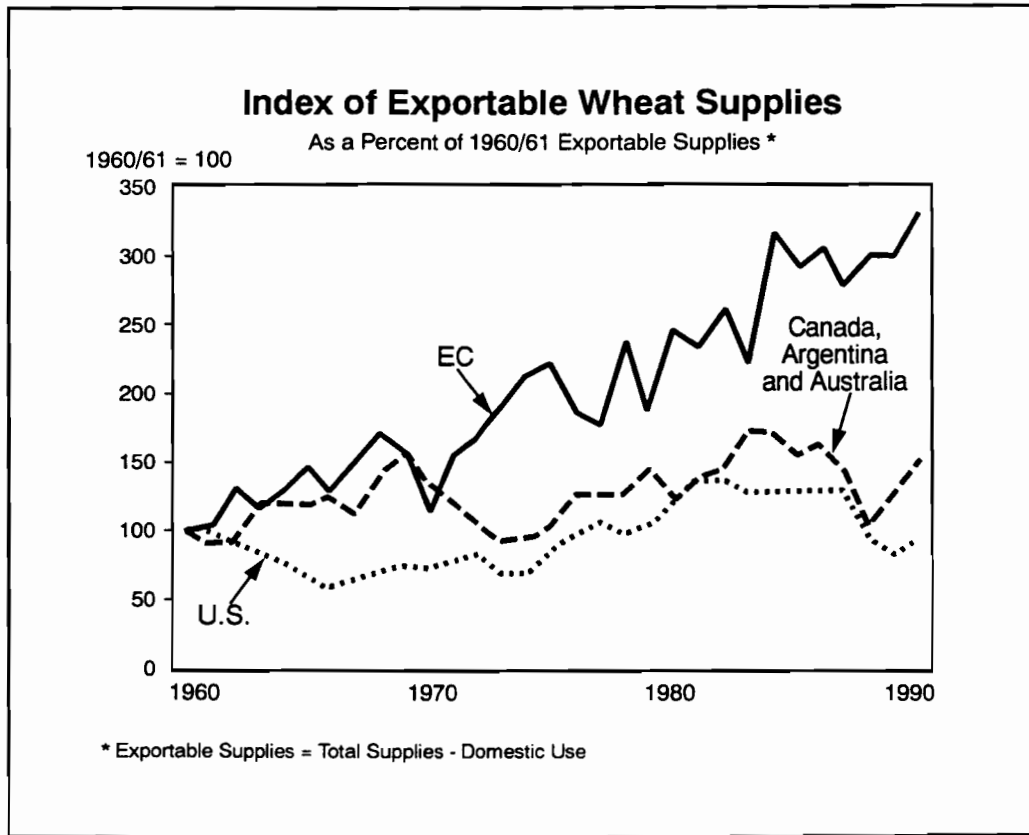


**Figure 14.**

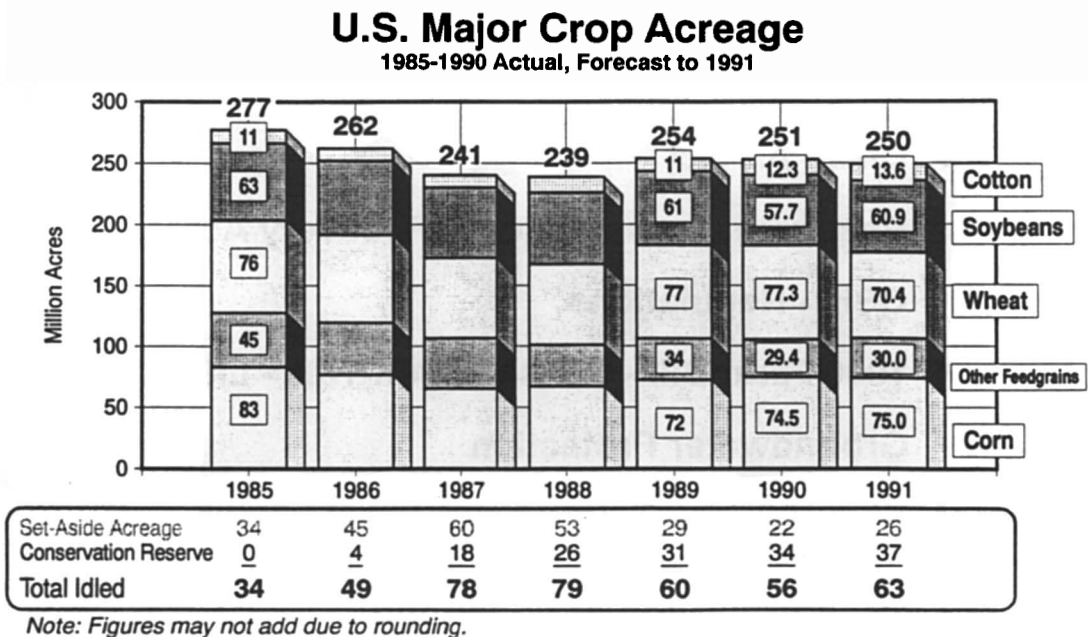




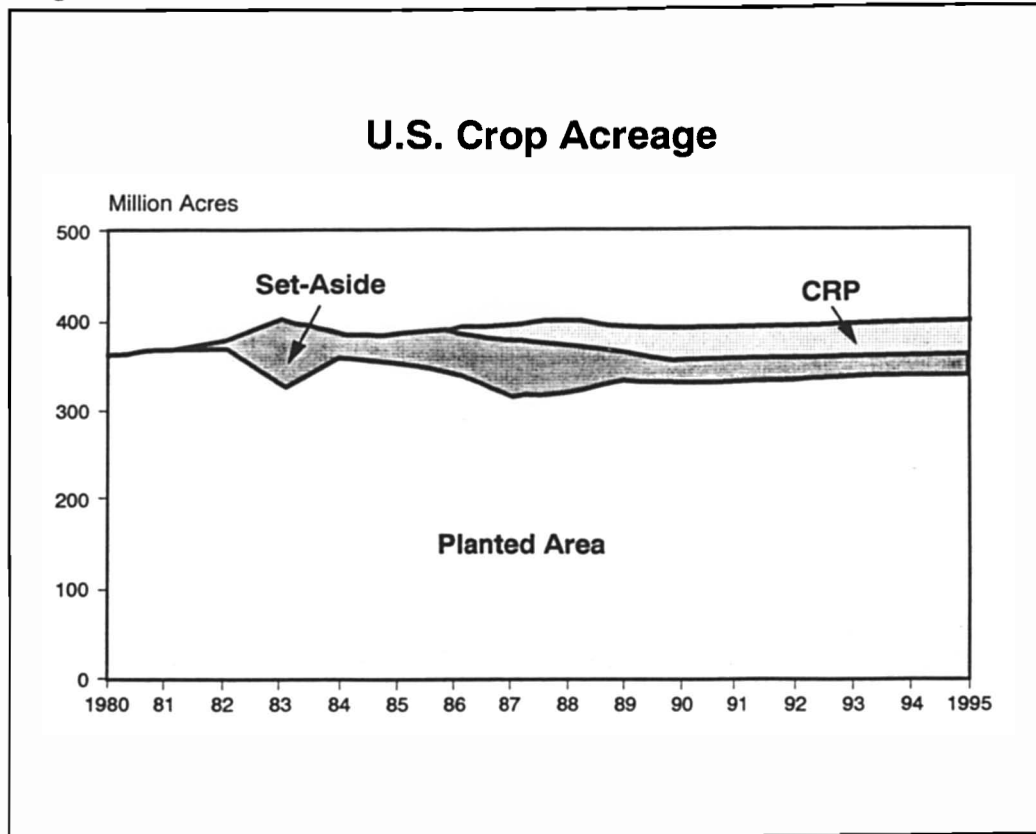
**Figure 15.**



**Figure 16.**



**Figure 17.**



**Figure 18.**

- ### Environmental Challenges
- Clean Air Act
  - Resource Conservation & Recovery Act
  - OSHA Regulations
  - 1990 Farm Bill - Conservation Title - LISA
  - Groundwater Protection
  - Reauthorization of Hazardous Materials Transportation Act
  - Reauthorization of Superfund

Figure 19.

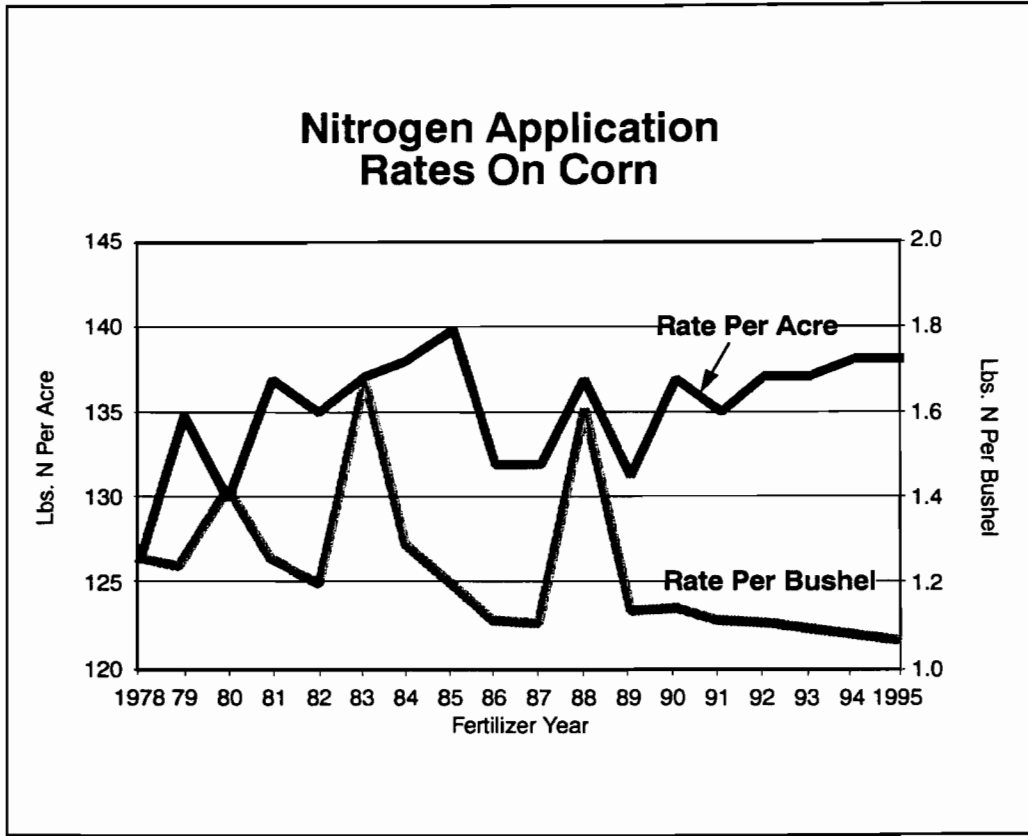


Figure 20.

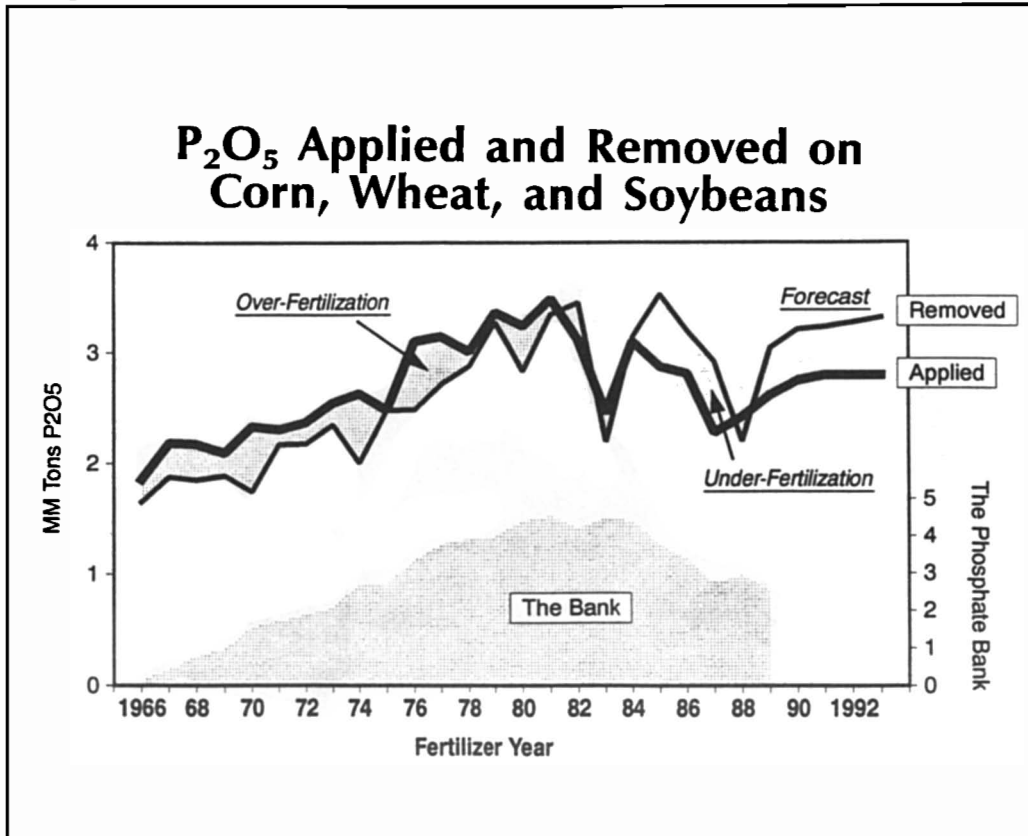


Figure 21.

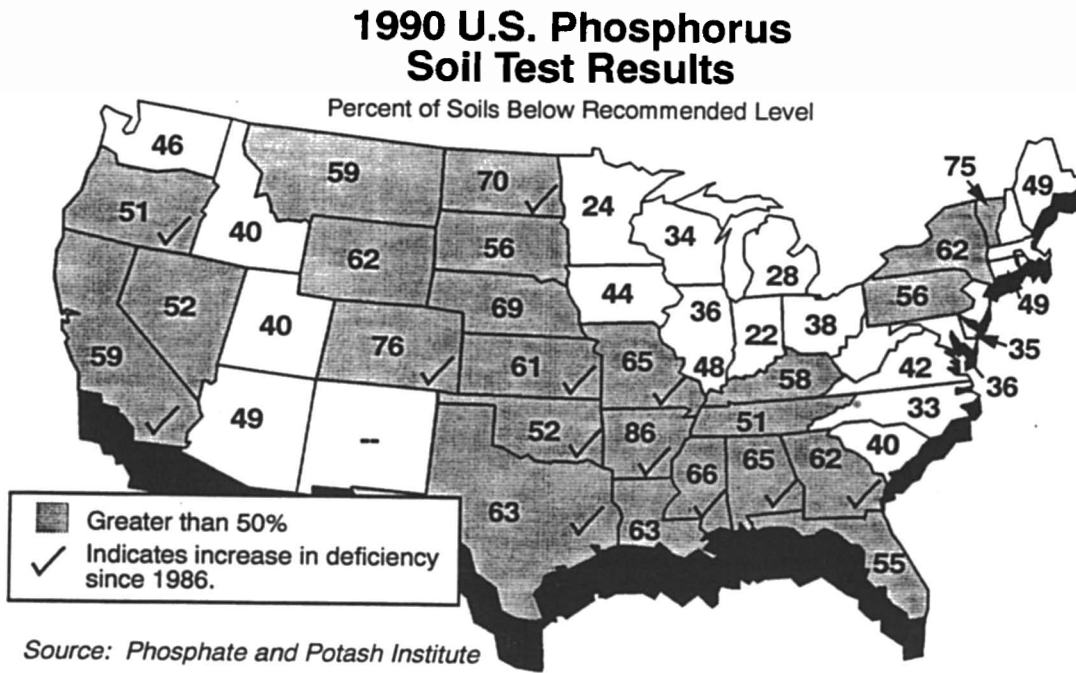


Figure 22.

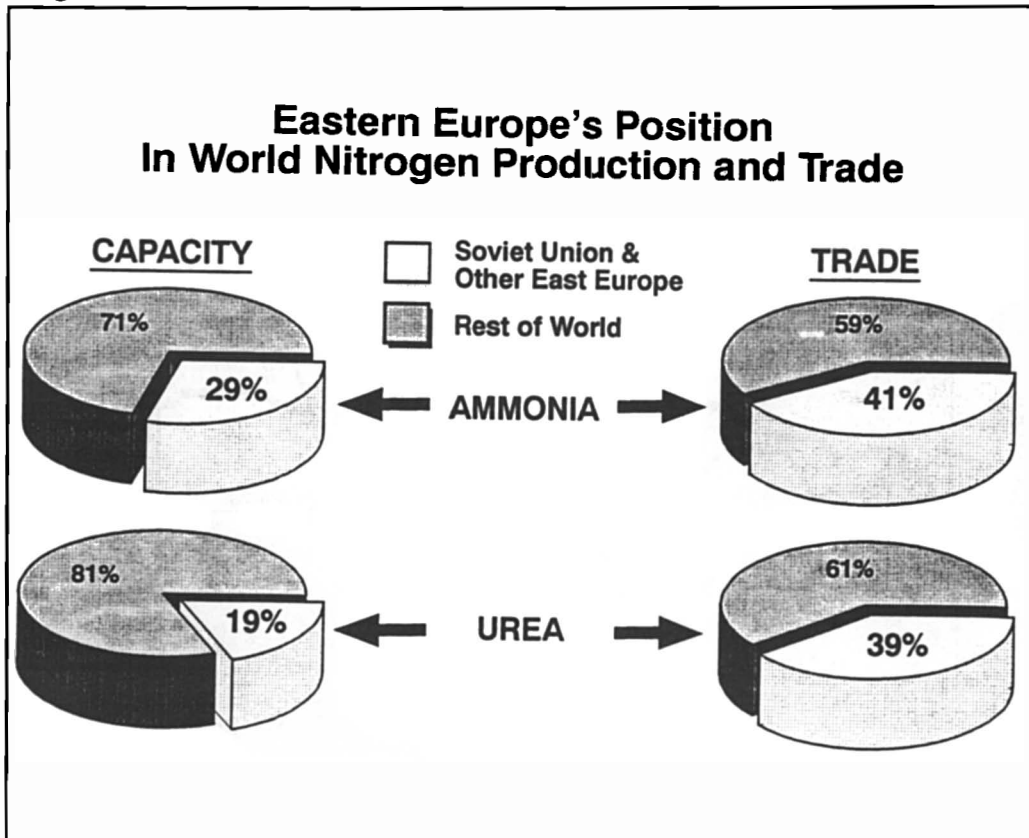


Figure 23.

<b>East Europe: Ammonia Capacity Start-Up 1970 or Earlier</b>			
(000 Tonnes of N)			
	<u>Capacity 1970 or Earlier</u>	<u>Total Capacity</u>	<u>% 1970 or Earlier</u>
Albania	50	91	55%
Bulgaria	556	1,211	46%
Czechoslovakia	192	736	26%
East Germany	139	1,475	9%
Hungary	427	792	54%
Poland	1,393	2,208	63%
Romania	1,029	3,748	27%
<b>Total East Europe</b>	<b>3,786</b>	<b>10,261</b>	<b>37%</b>

Figure 24.

<b>Impact of Soviet Gas On East European Capacity</b>		
<u>Country</u>	<u>Capacity</u>	<u>Percent Soviet Gas</u>
Bulgaria	1,324	50%
E. Germany	1,238	80%
Hungary	497	50%
Poland	1,400	100%
Romania	3,481	50%
USSR	15,046	100%

Figure 25.

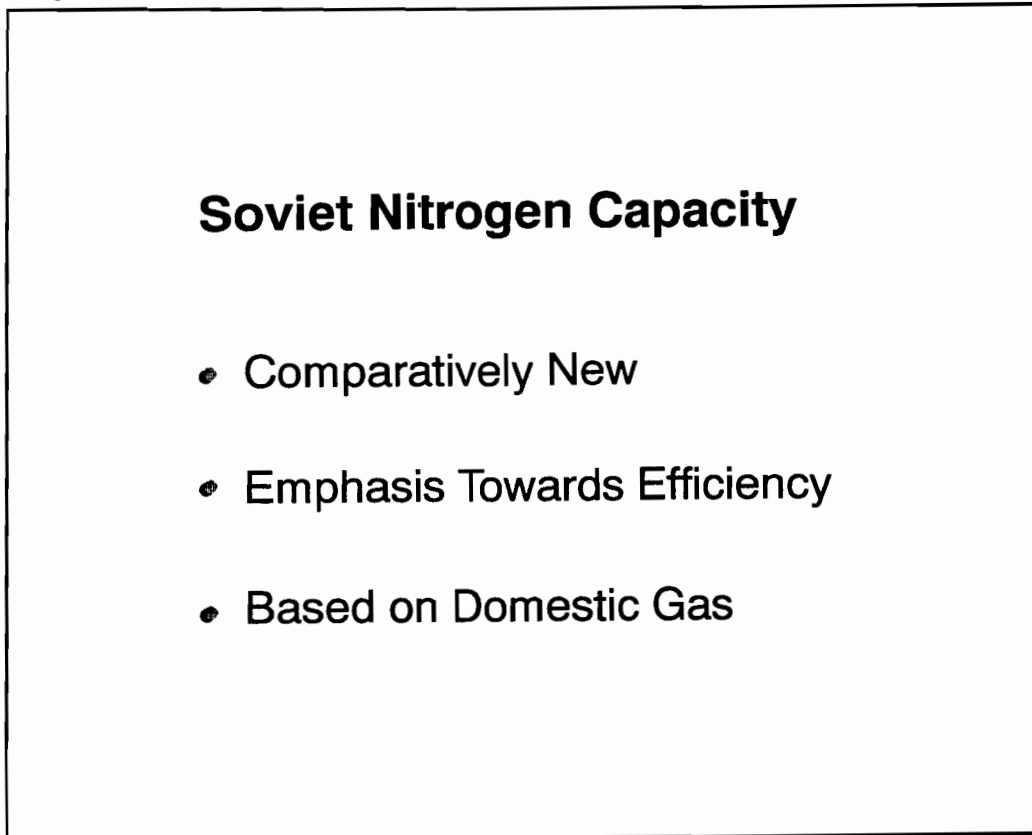


Figure 26.

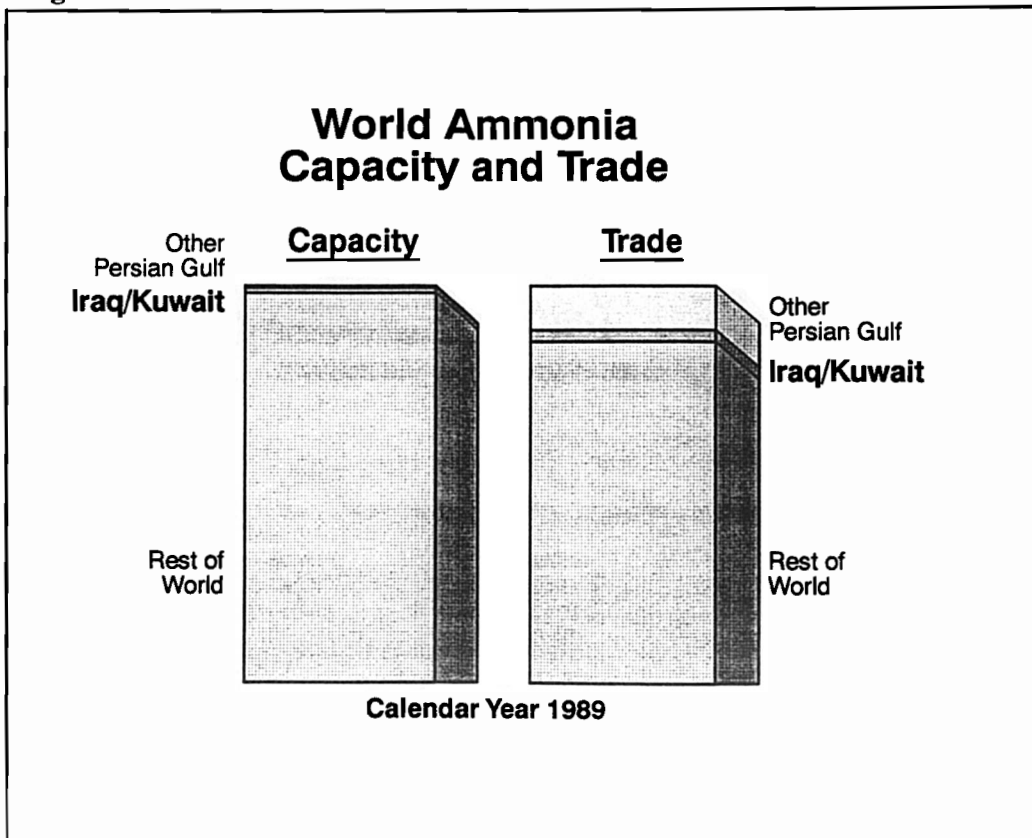


Figure 27.

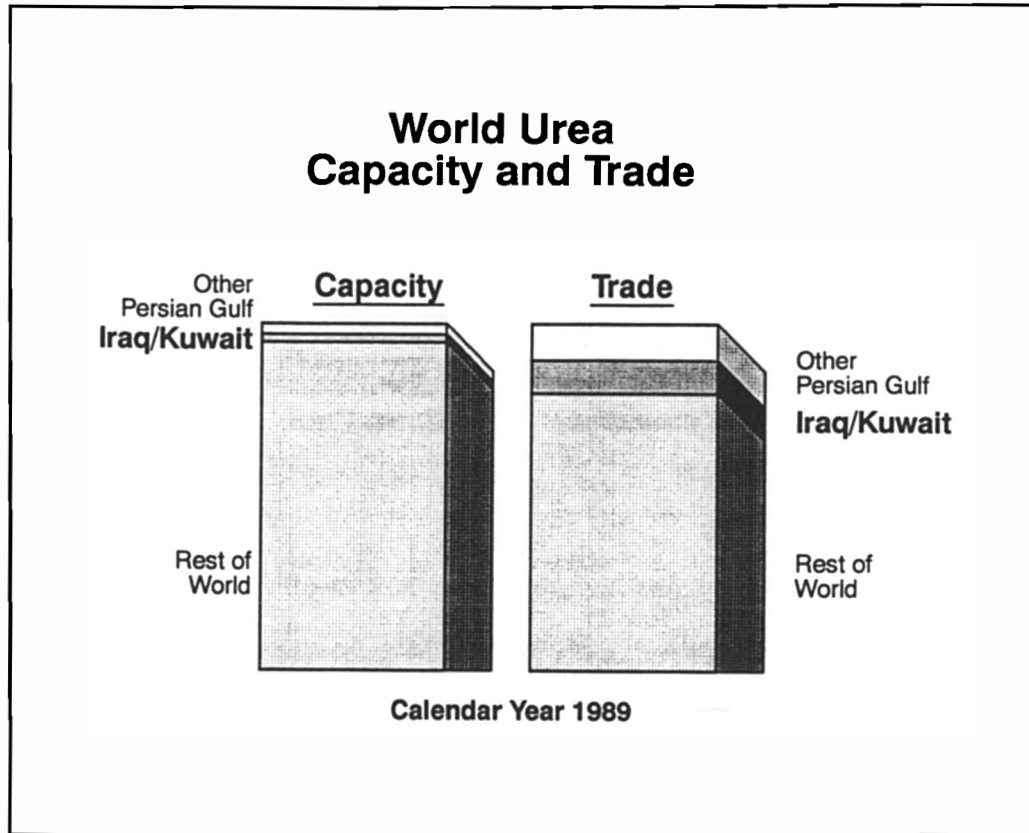
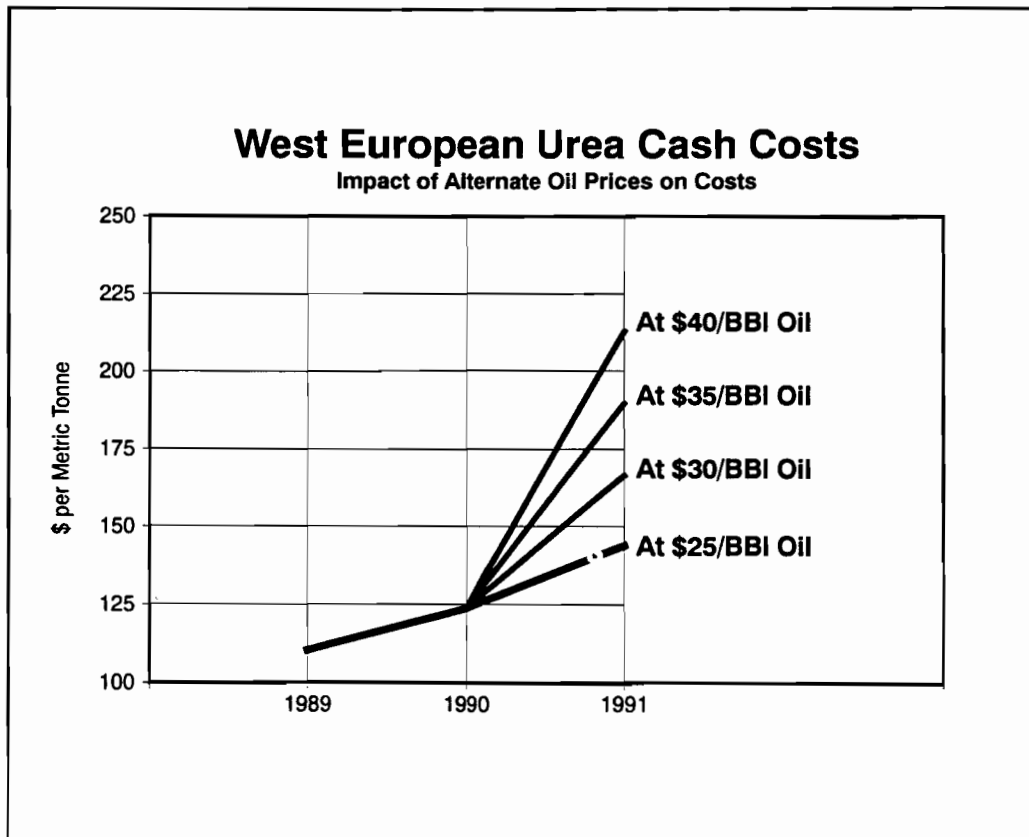
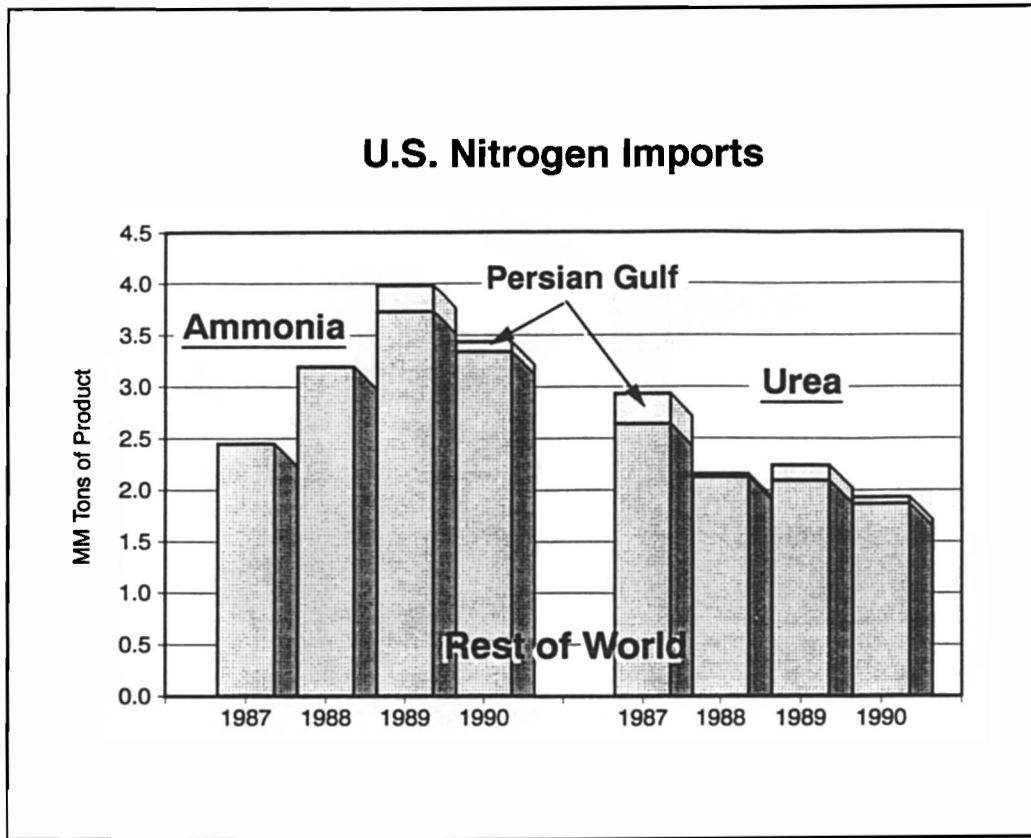


Figure 28.





**Figure 29.**



**Figure 30.**

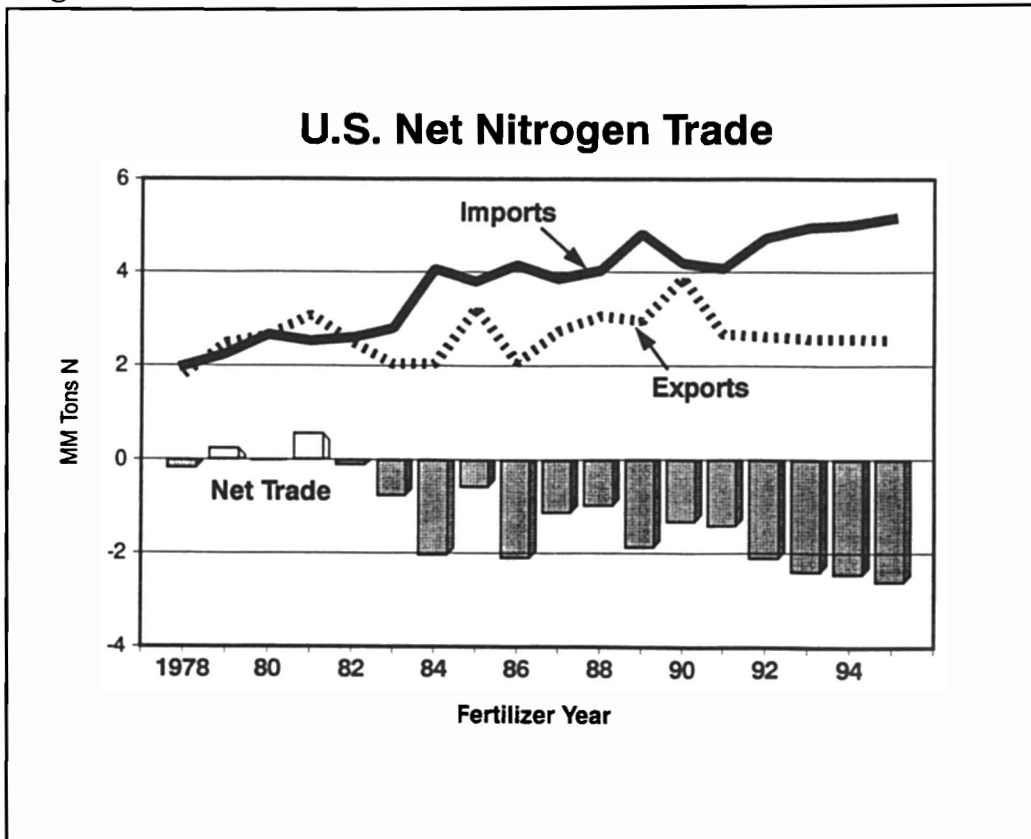


Figure 31.

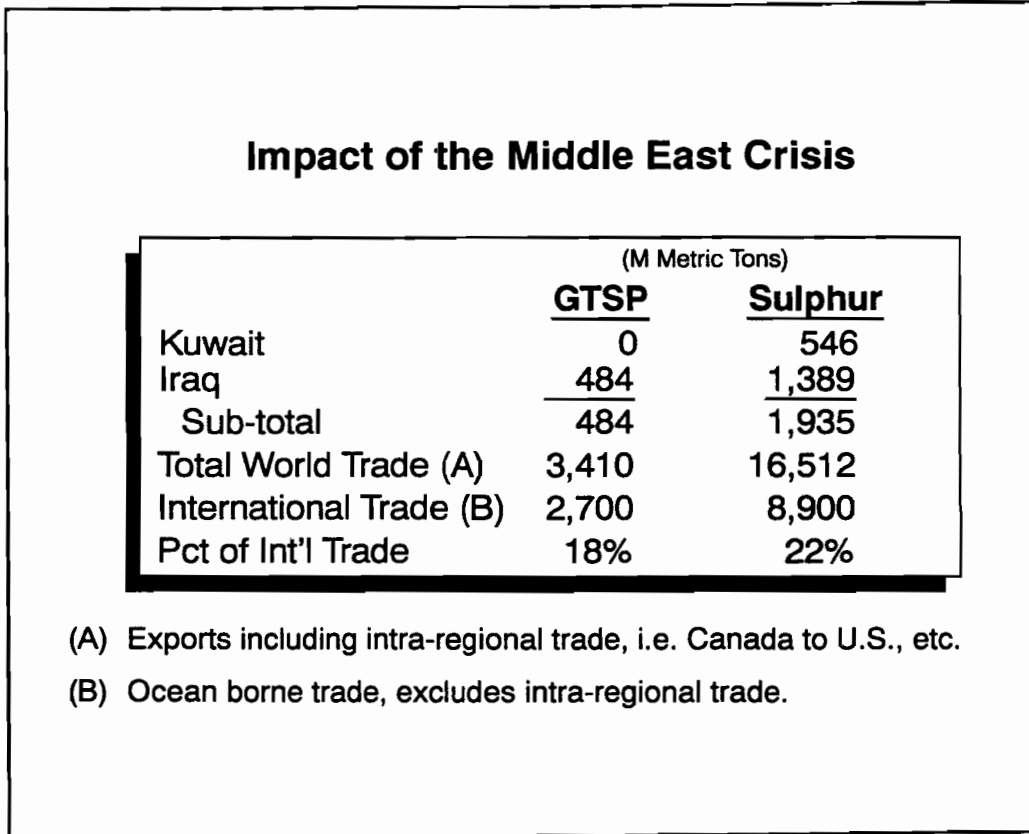


Figure 32.

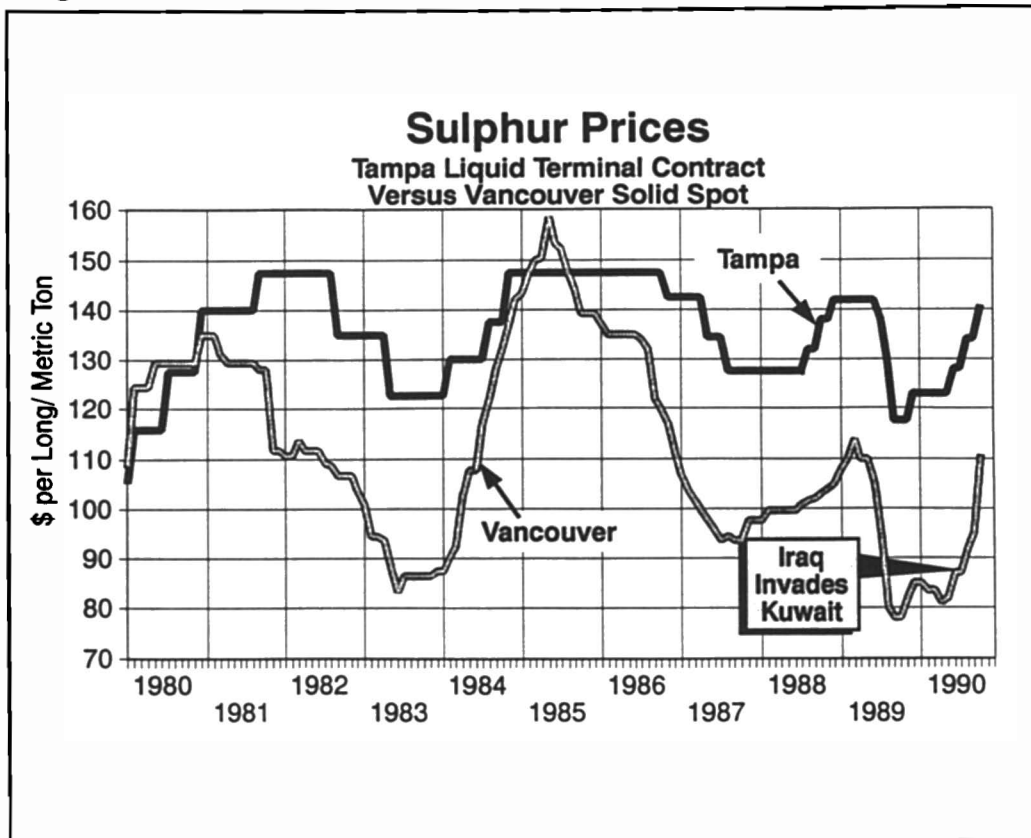


Figure 33.

<b>SAFERCO</b>		
	<u>Share of Equity</u>	<u>Share of Risk</u>
Cargill	50%	15%
Saskatchewan Government	49%	85%
Other	1%	-

Figure 34.

<b>Major Phosphoric Acid Capacity Changes</b>			
MM Metric Tons P2O5			
	<u>1990</u>	<u>2000</u>	<u>Change</u>
Africa	5.5	7.7	+2.2
Western Europe	3.9	2.8	-1.1
Eastern Europe	8.9	7.9	-1.0
Latin America	1.9	2.6	+0.7
Asia	4.0	8.1	+4.1
Oceania	0.2	0.2	NC
North America	11.7	11.6	-0.1
<b>World</b>	<b>36.1</b>	<b>40.9</b>	<b>+4.8</b>

Figure 35.

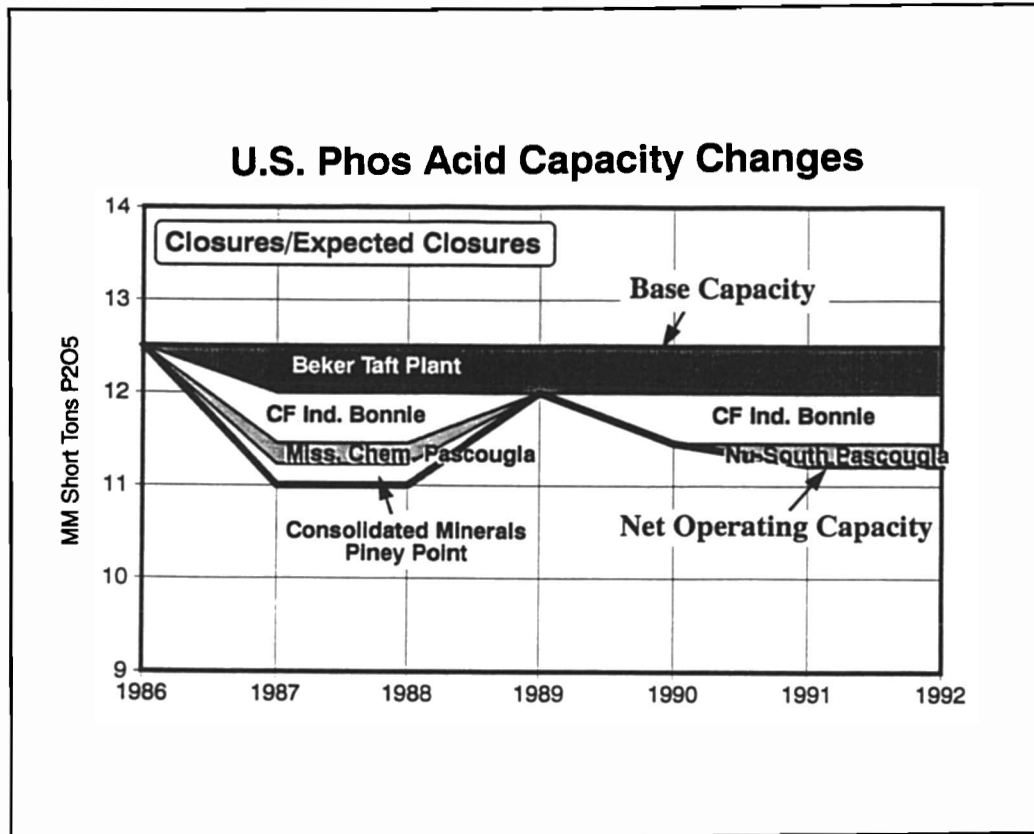


Figure 36.

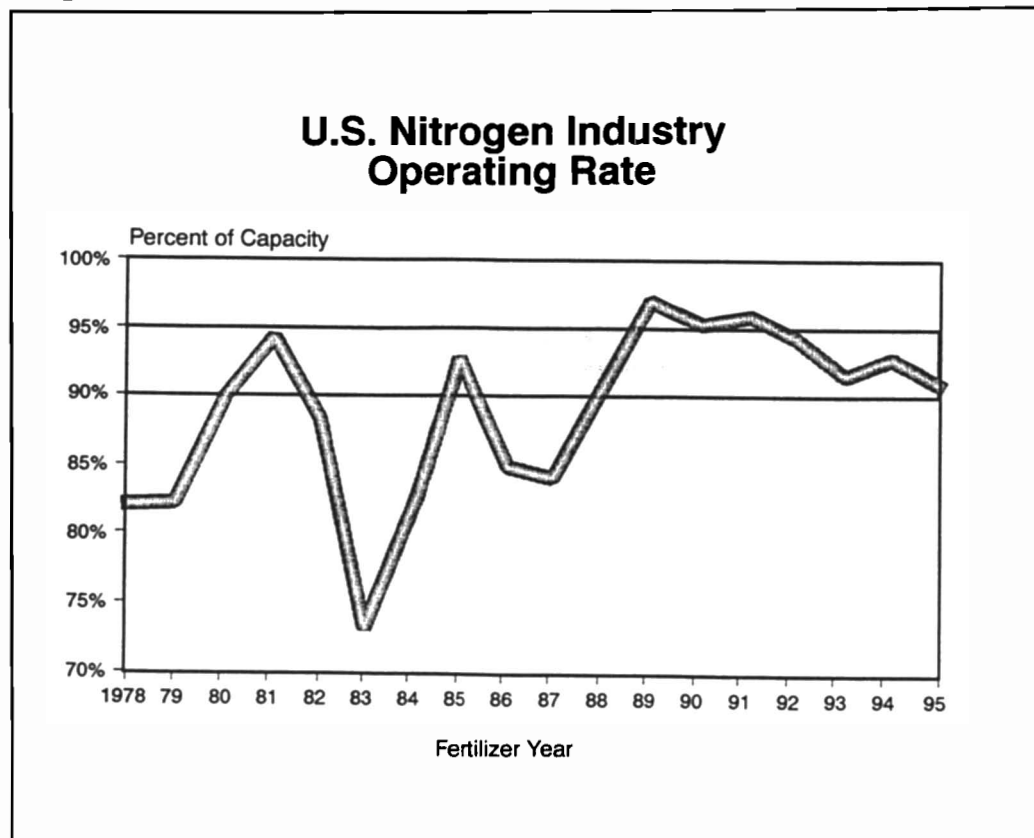


Figure 37.

### Restructuring of the U.S. Nitrogen Industry

	<u>1978</u>	<u>1983</u>	<u>1990</u>
Capacity	21,689	19,312	17,416
Number of Plants	104	78	62
Average Capacity	209	248	281
Number of Companies	56	46	32
Percent of Companies			
Top 5	40.9%	42.7%	45.4%
Top 10	57.5%	62.1%	65.7%

Figure 38.

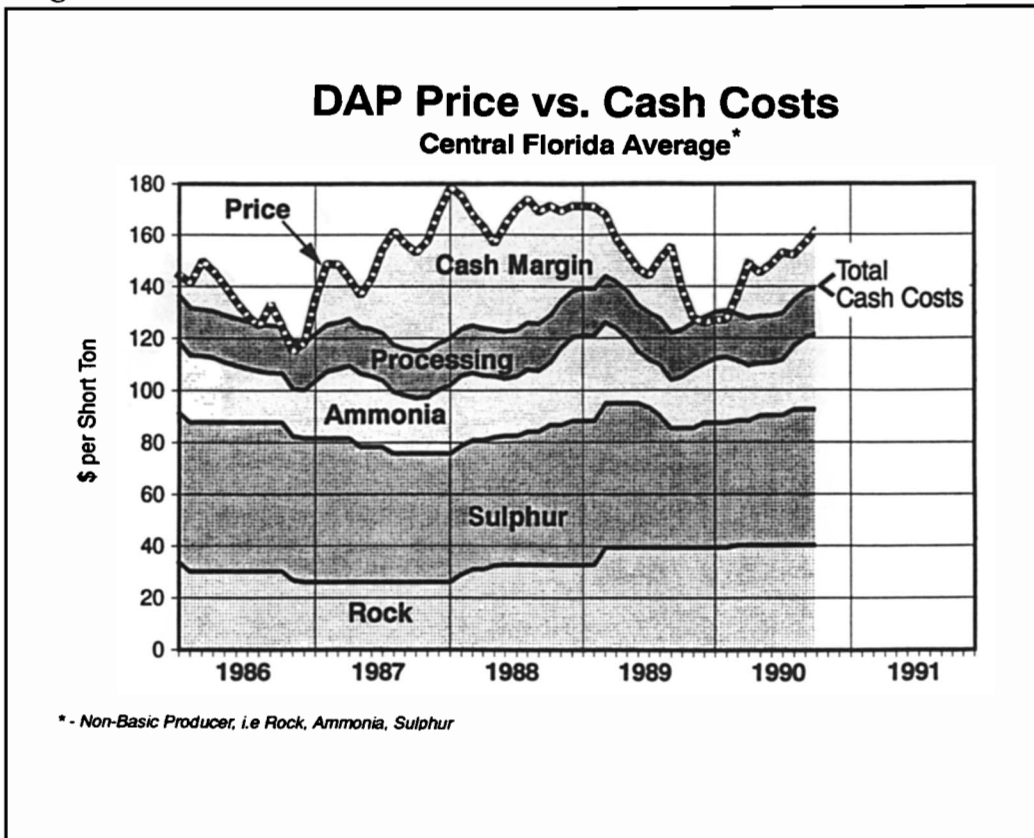


Figure 39.

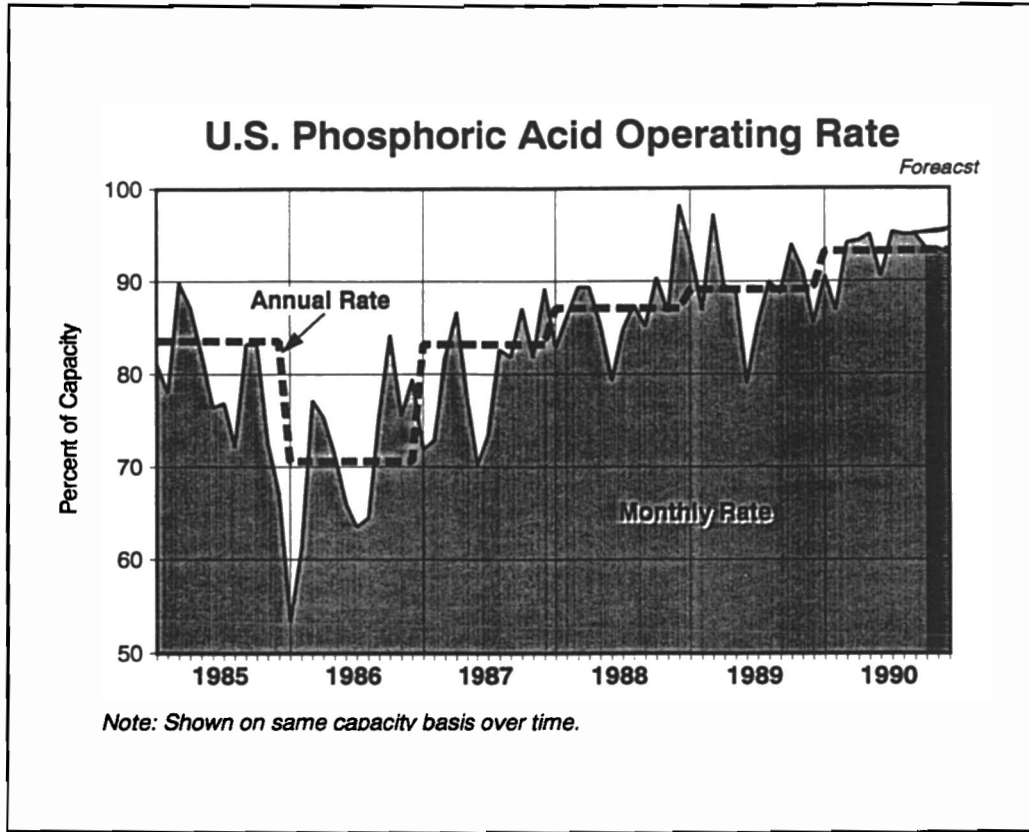


Figure 40.

### India's Comparative Economics for Phosphate Supplies

As of September 1st

From Acid		As DAP (U.S. Product)	
	<u>\$/MT DAP</u>		
Phos Acid @ \$400 <sup>(1)</sup> CIF	\$ 190	Current Market	\$ 170
NH <sub>3</sub> @ \$180 <sup>(2)</sup> CIF	41+	Plus Freight (+/-)	<u>45</u>
Conversion Costs (Minimum)	<u>15+</u>		
	<b>\$ 246+</b>		<b>\$ 215</b>

**\$31/Ton Advantage**

(1) Assumes all phos acid suppliers will achieve \$25/MT P<sub>2</sub>O<sub>5</sub> increase in SEP negotiations.  
 (2) Based on recent sale to Taiwan (AUG 22).

Figure 41.

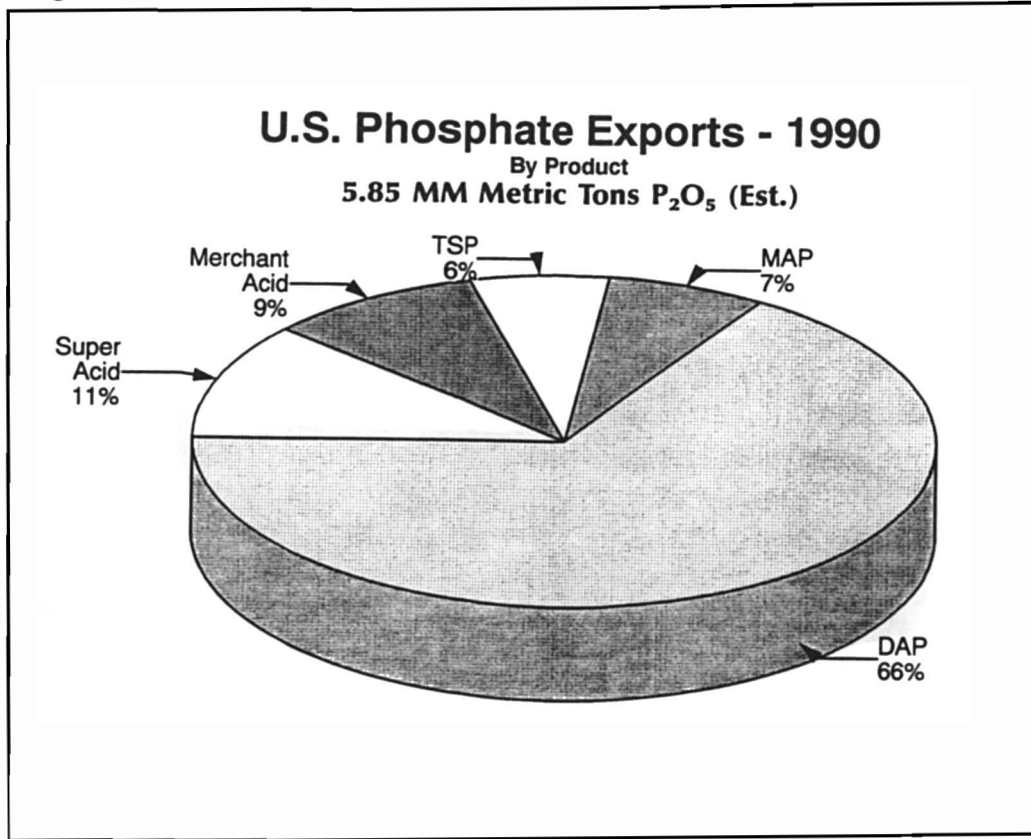


Figure 42.

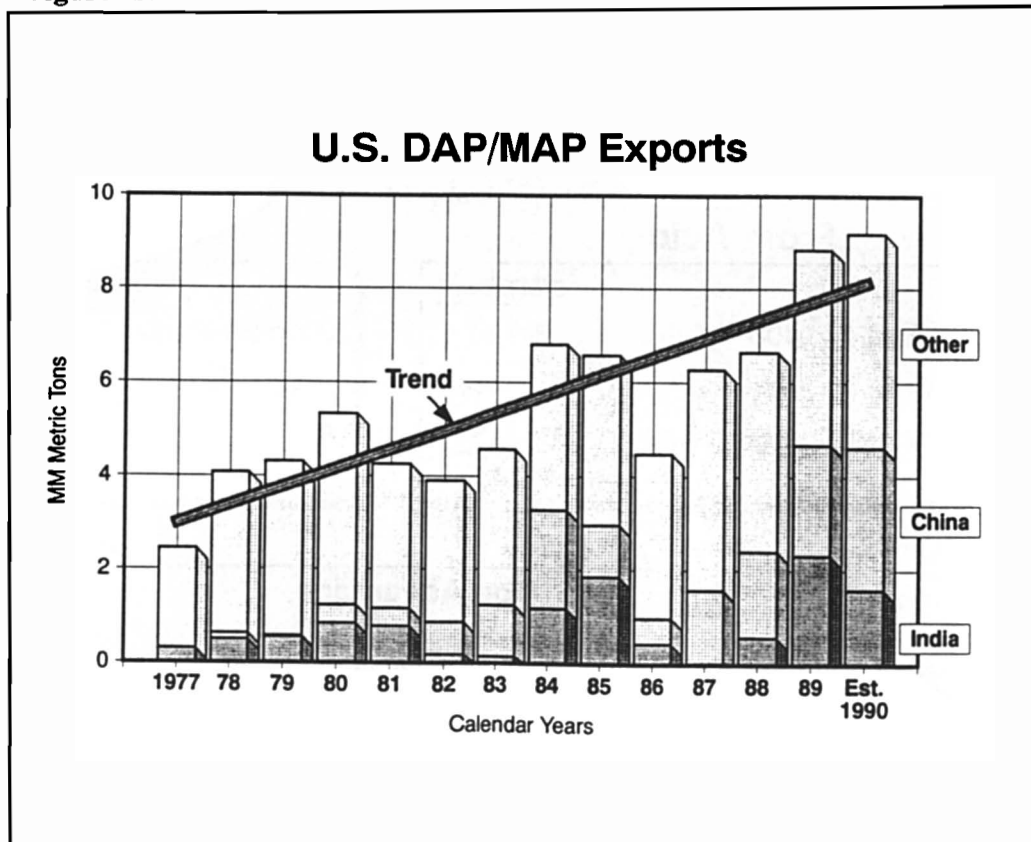




Figure 43.

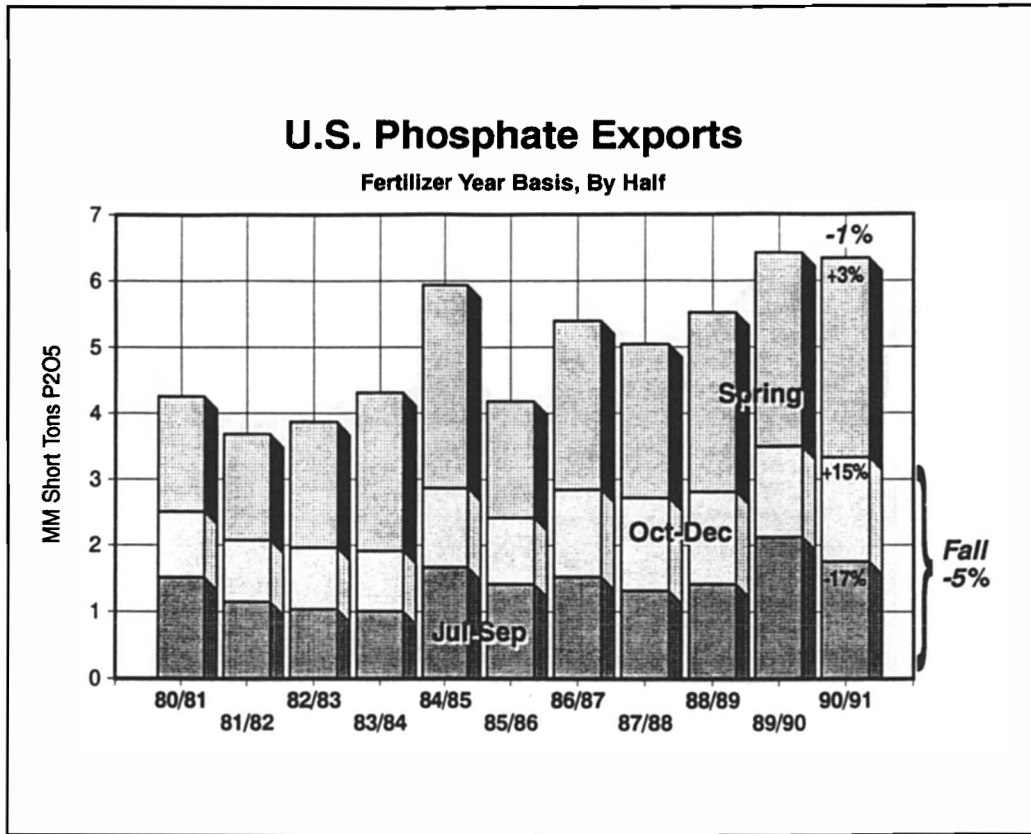


Figure 44.

### Key Aspects of the DAP Contract

Diammonium Phosphate (18-46-0)	Plus or minus .5% N or P
Contract Size	100 Short Tons
Product Origin	Plants in Polk, Hillsborough, Manatee Counties
Trading Months	(DEC/MAR/JUN/SEP)
Daily Trading Limit	\$10 per ton
Trading Limit - Speculators	400 contracts (40,000 tons)
Trading Limit - Hedgers (producers)	Up to 12 months production
Free-Flowing	90% on a -6+16 Tyler Mesh
Weights tested by certified plant scales	

Figure 45.

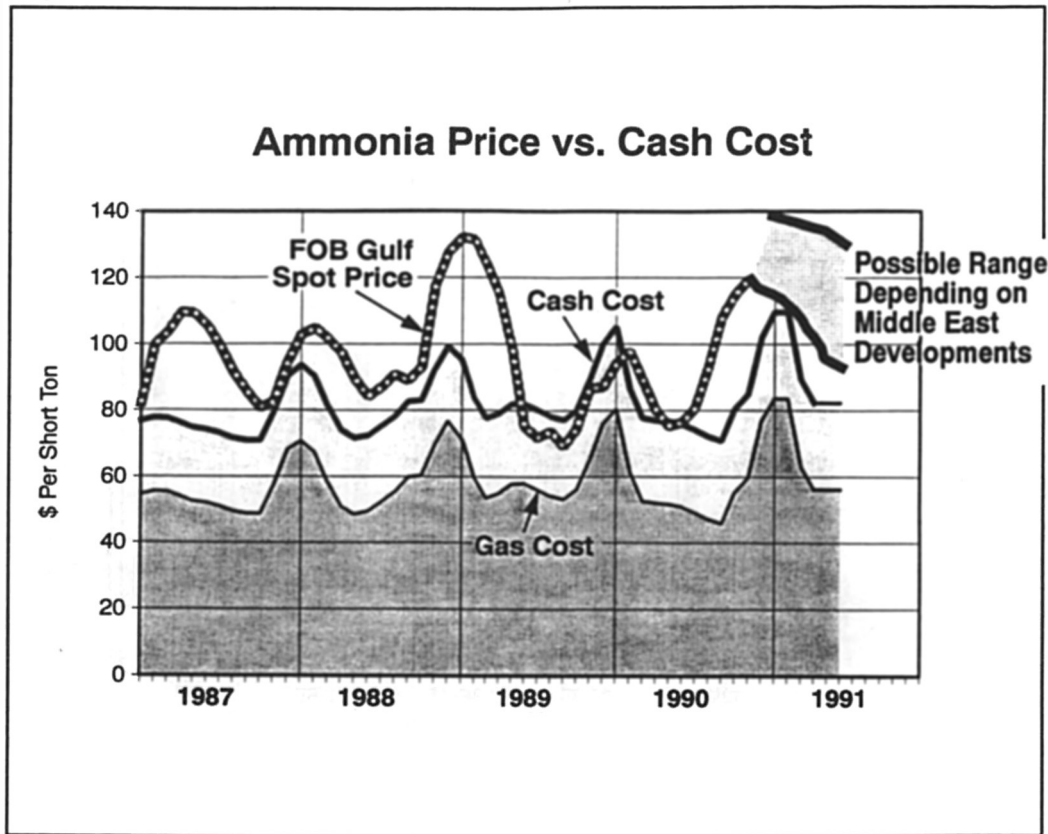


Figure 46.

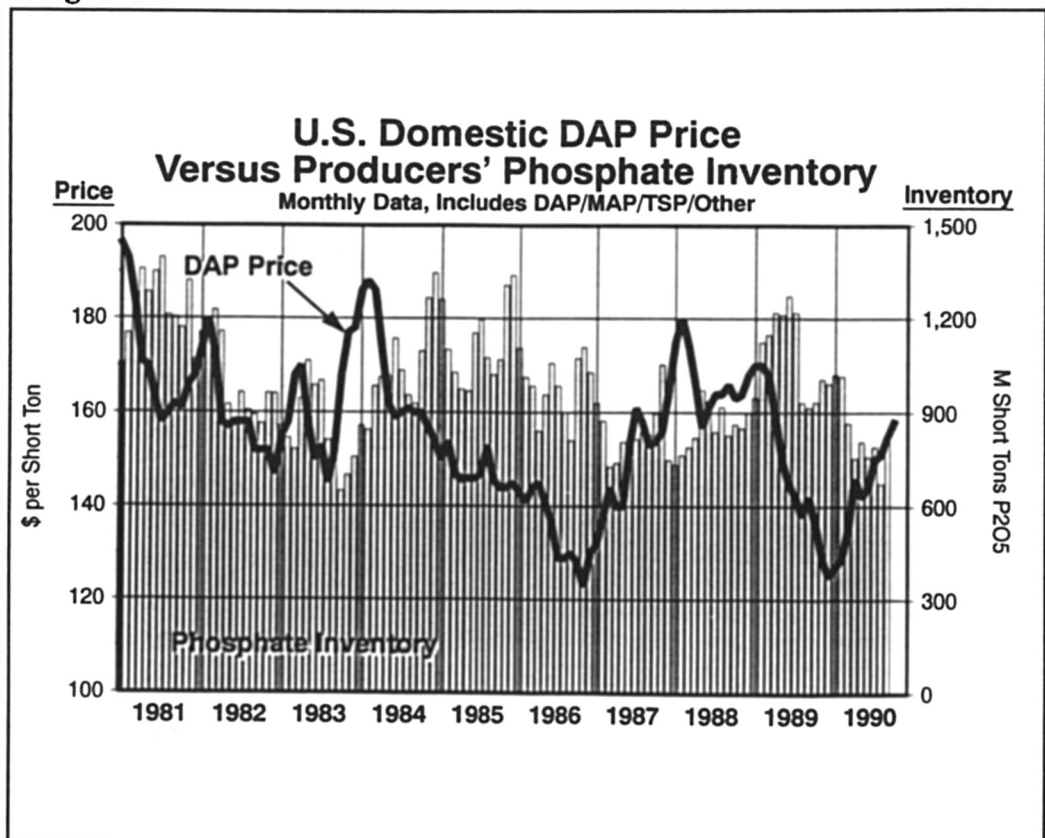


Figure 47.

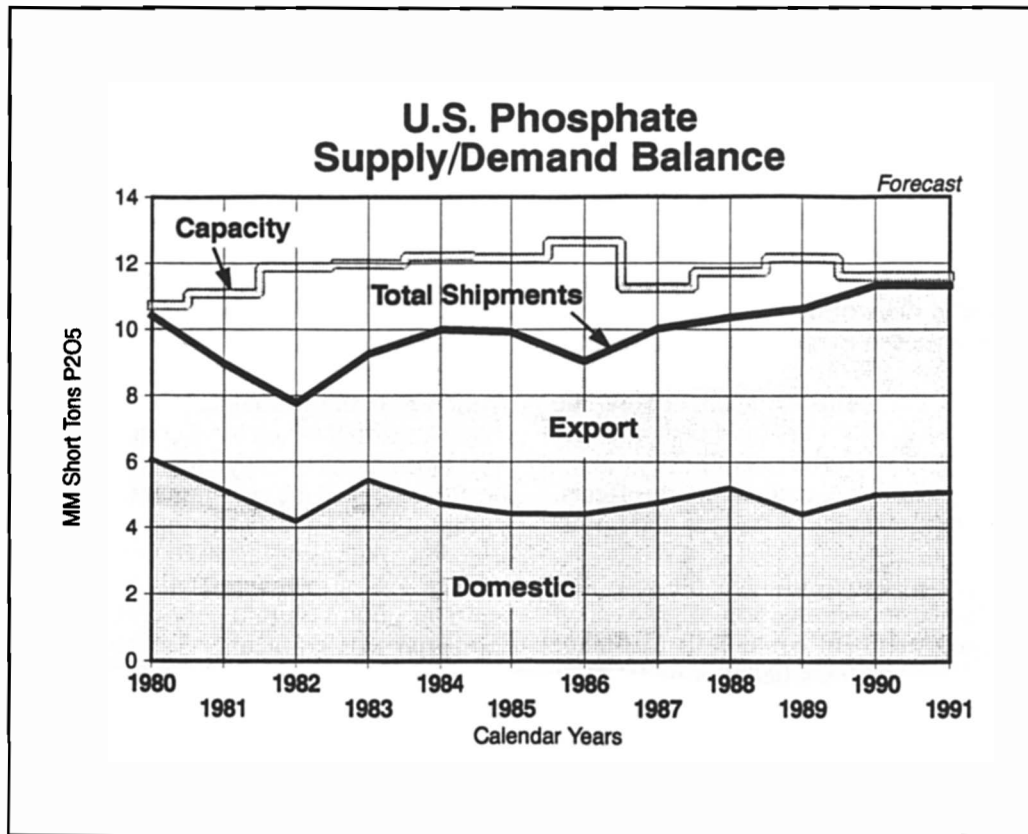
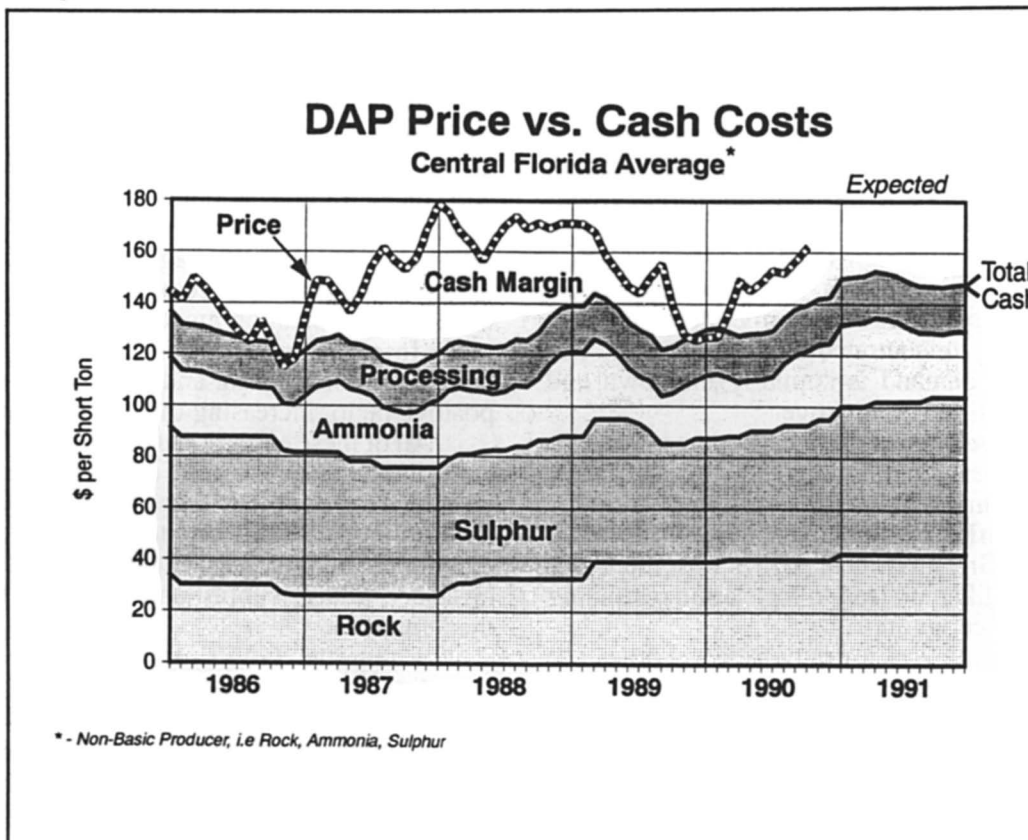


Figure 48.



## The Outlook for Potash

Rod Heath  
Canpotex Limited

The outlook for the potash industry for the balance of this decade contains more uncertainties than at any time in the past. Even for an industry that has encountered many surprises in its history, the current outlook is particularly challenging because of the many dramatic changes taking place in the world.

These changes are both evolutionary and revolutionary in kind. Individually they can each have a significant impact on the industry. Collectively the effect could be substantial, or there could be some off-setting interactions which limit the overall impact.

The evolutionary changes include climatic effects, environmental pressures, efficiency changes and population growth.

**Climatic changes** are exemplified by the so-called greenhouse effect. Increasing production of gases such as carbon dioxide and methane could lead to higher average global temperatures. This belief is widely but not universally held. Skeptics suggest that unusually warm conditions experienced in recent years fall within the short-term fluctuations that have always occurred. If there is a long-term trend towards higher temperatures the effect on agriculture and on potash demand is unknown.

It would appear that higher temperatures would result in less ice at the poles and more water in the oceans. This would increase the ocean area which, together with higher temperatures, would increase total evaporation and in turn increase total rainfall. What is unknown is where this extra rain would fall. An adequate model of the atmosphere has yet to be developed, and so the effect of climatic warming on world agriculture cannot be predicted. The results could be positive with extended growing seasons and more precipitation increasing crop production in the Northern Plains. Negative results would follow if temperature and rainfall increases were concentrated in tropical areas. The impact on potash demand is similarly unknown and could be either positive or negative.

**Environmental pressures** are another evolutionary trend that will act on potash demand. The emergence of a strong environmental movement in the developed countries, exemplified by LISA in the United States and the formation of Green political parties in some European countries, is likely to lead to legislation restricting the application of certain fertilizers.

None of the proposed restrictions target potash so far, and it is not clear how potash consumption would be affected by limits on application rates, for example, nitrogen fertilizers. Would farmers apply larger amounts of other nutrients in an effort to maintain yields, or would they cut back proportionately on all nutrients?

It is clear that concern for the environment will be a dominant issue for the rest of the decade, and that this will have some, presently unknown, effect on both supply and demand for potash. Environmental pressures will tend to reduce or eliminate production from existing mines which do not meet contemporary pollution standards, and will have an unqualified effect on the demand side of the equation.

**Efficiency** is another major factor influencing potash demand. There is a long-term trend towards more efficient operations both on and off the farm. This trend is well advanced in developed countries and will inevitably become more important in the developing regions in the future.

On the farm the development of high yielding varieties, better pesticides and herbicides, and fertilizer blends tailored to suit local conditions, have collectively produced much better yields. More precise placement of fertilizer to feed the crop rather than the soil will increase on-farm efficiency another step.

Off the farm, improved distribution systems that reduce losses to rodents and insects and maintain the crop in good condition through processing, have the potential to significantly increase the food supply in developing countries with no increase in potash application.

In Russia, for example, forty percent of the potato crop is lost between the farm and the consumer. Improvements in this area are very necessary in Russia and in many other countries to increase the food supply, and are clearly part of an evolutionary trend.

The effect of efficiency improvements both on and off the farm is to reduce potash application per unit of food consumed which is a negative factor for the potash industry, although positive in every other way.

**Population growth** continues to be a major driving force for potash demand. World population is increasing at the rate of almost 1 billion per decade. This is equivalent to adding a country with a population the size of the United States every two and a half years! There is relatively little unutilized agricultural land and so most of the additional food required to feed this startling increase in population must be produced by increasing yields from existing farmland. This requires more inputs including more potash, and is a major and continuing positive factor increasing the demand for potash.

All of these evolutionary factors—climatic changes, environmental pressures, efficiency improvements, population growth—will continue to influence potash consumption over the long term. In addition there are a number of revolutionary changes occurring which will influence potash supply and demand in the short to medium term.

Within the GATT organization, discussions to liberalize world trade have been underway now for four years, and have finally reached the stage of serious consideration of cutting farm subsidies and support programs. Governments in Western Europe, the United States, and Canada have been spending billions each

year on agricultural support. These programs have resulted in overproduction of many food items. If the GATT members reach agreement on cutting subsidies, food production will decline in the developed countries and so will fertilizer consumption. The effect on potash demand cannot be estimated until the discussions are concluded. At this time it is one more uncertain factor.

Major political and economic changes are taking place in many parts of the world, including Brazil, China, East Europe, and Russia, and all of these changes have an impact on the potash situation.

**Brazil** has been the largest potash importer among the offshore markets. The new economic program introduced by President Collor had a dramatic effect on business activity and resulted in a sharp drop in potash imports, as companies struggled to adapt to the new environment. The success or failure of the new economic program is still far from clear, and the result will directly affect potash requirements. While the intent of the new direction is positive, there is much opposition to the changes and the outcome is uncertain.

After last year's disturbances in **China**, the situation is now relatively quiet. The substantial reduction in tourist and trade revenues following Tiananmen Square reduced foreign reserves and required offsetting import cutbacks. Currency reserves have now been rebuilt and trade is returning to normal. The advanced age of the senior Chinese leaders and reported discontent with the existing political system among educated Chinese add some uncertainties to the future outlook for potash demand in China.

The most rapid political changes are occurring in **East Europe** and **Russia**, and it is the changes in this region that produce the largest uncertainties for the potash industry.

The area is a large consumer of potash, and both the U.S.S.R. and what, until recently, was the G.D.R. are significant potash producers. Under the centrally planned system that was in effect in all the Comecon countries until recently, potash requirements were determined by the planners. Food production almost invariably fell short of targets, and the standard response was to call for higher application of fertilizers to increase yields. Timely delivery of fertilizers to the farm was often delayed by difficulties in the distribution system, application was delayed by equipment breakdown and on-farm facilities were often inadequate. The result of these inefficiencies was that application rates increased to the levels used in developed countries, while crop yields stayed at the levels of developing countries.

With the shift toward a market economy that started last year, farm managers now have much greater control over inputs. Subsidies on fertilizers have been greatly reduced with resulting major price increase—in some cases the cost of fertilizers has tripled—while crop prices have generally remained controlled. The predictable result has been a significant drop in potash application. Consumption in East Europe and Russia fell from 10.8 million tons K<sub>20</sub> in 1988 to 9.5 million in 1989—

and the changes away from a centrally planned system occurred only in the second part of the year. A further large drop in potash demand is anticipated for 1990, possibly down to 8.2 or 8.3 million tons K<sub>20</sub>. This amounts to a cut of almost 25 percent from the 1988 level, which corresponds to a reduction in world potash consumption of about 9 percent if demand had remained unchanged in the rest of the world.

The outlook for potash demand in East Europe and Russia will depend on their success in converting from a centrally planned to a market economy. There are no precedents for such a change. At best, it will be a painful and lengthy process. At worst, it may prove an impossibility for certain countries. The major difficulty is that the conversion to a market economy requires the dismantling of much of the state sector, and the creation of an equivalent number of jobs in the market sector. The transition requires a substantial part of the working population, literally millions of people, to become unemployed for an indefinite and possibly extended period of time. The unknown factor is whether a popularly-elected government can carry through such a program, while retaining the support of a majority of the voters in a country without the resources to provide an adequate safety net for the unemployed.

Each of these nations face major difficulties in achieving such transformation, although the degree of difficulty varies from case to case.

Success is certain in the case of the G.D.R. through unification with West Germany, although the time required for the Eastern part of the country to approach the level of prosperity in the West may be a decade or more. The U.S.S.R. is at the other end of the scale with the added complexity of many ethnic groups with different languages, cultures, and aspirations. In the best case we may hope for a progressive transition of the U.S.S.R. economy to a market base with political solutions developed to satisfy minority groups. In the worst case we could see a breakdown into factions unable to reconcile their differences or develop a stable political and economic framework.

As a general observation on the longer range outlook for potash demand, consumption in the U.S.S.R. and East Europe in 1988 amounted to about 26 tons K<sub>20</sub> per thousand population, and the region was a net importer of food. By comparison, potash consumption in North America and West Europe was 16 tons K<sub>20</sub> per thousand population and these regions were large net exporters of food. This suggests that a market system in East Europe and Russia might eventually satisfy local food requirements with potash consumption at 60 percent of the 1988 level. If this did happen potash demand in the region would be reduced from the forecast 1990 number of 8.3 million tons K<sub>20</sub> to about 6.5 million tons.

While the demand outlook is particularly uncertain at this time, it is quite clear that there is the possibility of a substantial drop in consumption in East Europe and the U.S.S.R..

Because East Germany and Russia are also large

potash producers, the dramatic political changes also affect the production side of the question. In the case of East Germany there are three mining areas. The Sud-Harz consists of six small mines with individual capacities ranging from 160 to 350 thousand tons K20 per year. These mines were constructed between 1895 and 1915, and most are clearly uneconomic now that all costs are in hard currency. The Volkenroda mine has already been closed, and in the longer term only Bischofferode may be viable.

The Werra district contains three mines that were originally built around 1900. Total capacity of the three mines used to be about 1.1 million tons K20, but this was reduced by a major rockfall last year caused by leaving insufficient ore in the pillars. These mines are a major source of salt pollution in the river Werra and require large investments to reduce emissions. The Dorndorf mine with an annual capacity of 200,000 tons will be closed next year, while production may continue for the other two.

By contrast the Zielitz mine is both relatively modern—built in 1973—and is an efficient size (900,000 tons K20 per year) although overmanned and expensive to operate by Western standards. This mine will undoubtedly require some expenditures to improve efficiency but will continue to operate.

The net effect is that production from East German mines which fell from 3.5 million tons K20 in 1988 to 3.2 million in 1989 may be no more than 2.5 million this year and will be further reduced, possibly to the 1.3-1.7 million ton level during the next few years.

The outlook for production in the U.S.S.R. is just as obscure as the outlook for demand. Russia is the world's largest potash producer, and in past years, production increased steadily to reach 11.3 million tons K20 in 1988. There are large potash reserves in Russia, and plans had been made to increase capacity up to the 16-17 million ton level during the 1990's. The political upheavals have changed all this. Production fell by 1.1 million tons in 1989 from the 1988 peak, apparently in response to the fall in demand, and the ambitious expansion plans have been abandoned. Some further fall in output is likely this year, possibly to about the 9.5 million ton level, and the current view is that future production will continue in the 9-10 million ton range.

Clearly, future production will be influenced by the outcome of the political changes that are taking place in Russia, and any forecasts made at this time must be treated with considerable reserve.

If the forecasts mentioned above turn out to be realistic then the effect of the lower demand from this region on the world potash balance will be more than offset by the lower production from this area.

In 1988 U.S.S.R. and G.D.R. production of 14.8 million tons K20 supplied regional demand of 10.8 million, leaving about 4.0 million tons for export to customers outside the area. Both production and demand in the region fell by about the same amount in 1989 with little change in exportable surplus. Over the next

five to ten years, we may anticipate production of about 10.5 million tons K20 and a regional demand of about 7.0 million, with a surplus for export of 3.5 million or about 12 percent less than has been available recently.

In the shorter term, other pressures will influence Soviet export availability. A number of traders have offered so-called "perestroika potash" recently, outside traditional Russian trading channels at relatively low prices. The mines have been able to use the hard currency obtained from these sales to purchase equipment not available within the country and also obtain scarce consumer goods for their workers, and these pressures will continue. A limiting factor has been the availability of railcars and terminal capacity to service exports, and this also will continue to be a constant.

In the shorter term we may see an increase in Russian potash shipped offshore, while in the longer term a reduction is more probable. The current instability in the Middle East has had no direct effect on the potash market, but any development that interfered with shipments from the port of Aqaba would cut off potash supply from the Arab Potash Company in Jordan. This would remove about 800 thousand tons K20 per year from the supply side, with an immediate impact on the world market.

Other changes in production are also helping to reduce the current imbalance between demand and potential supply. The Cardona mine in Spain will close at the end of this year (-200,000 tons). The Petromisa mine in Brazil is being closed as part of the new economic program, having absorbed more than \$500 million of investment with no return (-150,000 tons). Production continues to decline in France, as ore grades go down. Similarly in New Mexico, reserves of mineable ore are rather limited.

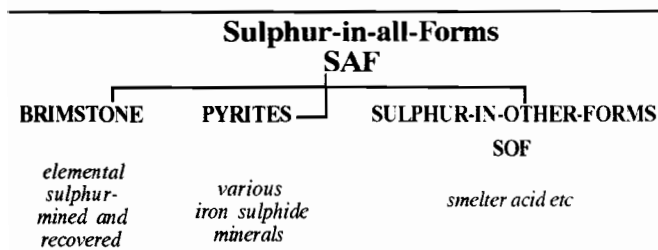
No major new potash mines are under development anywhere. Depending on the net effect of the different forces acting on the demand side, which have been described earlier, world potash consumption could stay flat, fall slightly or increase over the coming decade. Whatever the trend, Canpotex has access through its Saskatchewan members to sufficient resources to meet all likely market requirements.



# The Outlook for Sulphur

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## Terminology



Sulphur exists in a variety of forms. The term **brimstone** is used to refer to elemental sulphur, whether it is of mined origin (Frasch and native refined sulphur) or recovered during the processing of sour natural gas, crude oil etc (recovered sulphur).

The term **pyrites** is loosely used to refer to any iron sulphide mineral with the empirical formula  $Fe_nS_{n+1}$ . Some deposits of relatively pure pyrites are mined for their sulphur content (crude pyrites) while others are associated with base metals ores from which the pyrites is separated during processing (flotation pyrites).

The term **sulphur-in-other-forms** (SOF) refers to all sulphur values other than brimstone and pyrites. This category is dominated by the sulphuric acid produced as a means of purifying stack gases from metals smelters (smelter acid).

The sum total of brimstone, pyrites and SOF is referred to as **sulphur-in-all-forms** (SAF).

## World Sulphur Production and Consumption: 1989

**SAF Production: 1989**  
(million tons S/S-equivalent)

<b>Brimstone</b>		<b>39.86</b>	<b>64.5%</b>
Mined	14.63		23.7%
Recovered	25.23		40.8%
Gas	14.82		24.0%
Oil	9.02		14.6%
Other	1.39		2.2%
<b>Pyrites</b>		<b>10.41</b>	<b>16.9%</b>
<b>SOF</b>		<b>11.47</b>	<b>18.6%</b>
<b>Total SAF</b>		<b>61.74</b>	<b>100.0%</b>

**SAF Production: 1989**  
(million tons S/S-equivalent)

<b>Sulphuric Acid</b>		<b>55.57</b>	<b>89.2%</b>
Fertilizer Acid	34.29		55.1%
Industrial Acid	21.28		34.1%
<b>Non-Acid Sulphur</b>		<b>6.70</b>	<b>10.8%</b>
<b>Total SAF</b>		<b>62.27</b>	<b>100.0%</b>

## North America-(Table 1.)

### Key assumptions

- Main Pass Frasch mine comes on stream in 1992, taking US Frasch production from 3.3 million tons in 1991 to 4.7 million tons in 1995.

- Caroline sour gas field in Alberta comes on stream in 1993. Canadian gas recovered sulphur production rises from below 5.5 million tons in 1991 to about 6.5 million tons in 1995. US gas recovered sulphur production stays below 2.5 million t/a, but output increases steadily from oil refineries.

- Phasing out of pyrites use (in Canada) is more than offset by rising SOF production.

- Fertilizer sulphuric acid demand remains at relatively high levels buoyed up by strong export demand for DAP. Industrial acid use increases as growth in some sectors (e.g. ore leaching) outweighs contractions in others (e.g. HF). Steady but unspectacular increases occur in non-acid sulphur demand.

### Major uncertainties

- *Effects of recession, especially on smelter acid production and industrial acid consumption.*

- *Effects of pricing and policy on energy sourcing and demand.*

- *Strength of the fertilizer export market. Effects of policy decisions on domestic fertilizer demand.*

- *Potential for additional output of brimstone and/or SOF from flue gas desulphurization, coal gasification etc.*

## Latin America-(Table 2.)

### Key assumptions

- Mexican Frasch sulphur production totals 1.5 million tons this year, rising to 1.7 million tons in 1994 before declining again.

- There are no other major changes in brimstone production (including native refined sulphur in Chile etc) but SOF output increases significantly, particularly in Chile.

- Substantial increases occur in both fertilizer and industrial sulphuric acid consumption, principally in Mexico, Brazil and Chile, but there is relatively minor growth in non-acid sulphur demand.

### Major Uncertainties

- *Economic growth rates throughout the region.*
- *Effects of high oil prices: windfall profits in Mexico and Venezuela, but further problems in Brazil.*

- *Impact of the privatization and liberalization of the Brazilian fertilizer market.*

- *Smelter acid supply/demand balance: new acid-consuming projects based on the expectation of additional supply.*

- *Recession and the demand for non-ferrous metals.*



### West Europe-(Table 3)

#### Key assumptions

- Gas recovered sulphur production remains stable in Germany but rises to around 0.8 million t/a in France. Regional oil recovered sulphur output continues to rise steadily.

- SOF output rises but this is more that offset by declines in pyrites production and use, resulting in an overall fall in combined pyrites/SOF supply and demand.

- Further net losses are experienced in both fertilizer and industrial sulphuric acid consumption. Non-acid sulphur demand is fairly stable.

#### Major uncertainties

- *Crude oil prices and sourcing.*
- *The energy policy of the unified Germany.*
- *The contribution of flue gas desulphurization and coal gasification to brimstone and/or SOF supply.*
- *Future EC policy on farm subsidies.*
- *The effects of the environmental lobby and/or recession on industrial sulphuric acid demand.*
- *Demand growth for plant nutrient sulphur.*

### East Europe & USSR-(Table 4)

#### Key assumptions

- Polish mined sulphur production declines to around 4.6 million tons in 1991 before rising again to above 5.0 million tons in 1995 following the start-up of the new Osiek mine in 1992.

- Total USSR brimstone production rises from 7.0 million tons in 1991 to 9.2 million tons in 1995, largely resulting from the rehabilitation of the Astrakhan sour gas project (1991 onwards) and the start-up of the first two phases of the Tengiz sour gas project (1991 and 1992), partially offset by a decline in mined sulphur output.

- There is little overall change in combined pyrites and SOF production and use.

- SAF consumption for all end uses declines in the near term, but grows steadily towards the mid-1990's.

#### Major uncertainties

- *The potential for economic collapse and political upheaval.*
- *The break-up of Comecon and the impact of hard-currency trading.*
- *Future policies on subsidies, privatization and land ownership.*
- *Technological change and the activity of by-product sulphuric acid.*
- *Energy policies: environmental and safety factors.*

### Africa-(Table 5)

#### Key assumptions

- There is very little increase in SAF production: no new output of mined sulphur in Egypt is included in the forecasts.

- A steady build-up of capacity utilization rates occurs in vertically integrated P<sub>2</sub>O<sub>5</sub> producing countries, but there is no major increase in industrial sulphuric acid demand.

- Capacity expansions totalling above 1.3 million t/a P<sub>2</sub>O<sub>5</sub> are brought on stream in Morocco in 1994, and the additional capacity is utilized rapidly.

#### Major uncertainties

- *Development of export markets for P<sub>2</sub>O<sub>5</sub> in intermediates and finishing products.*
- *Timing and nature of the Moroccan expansions.*
- *Tentative projects in countries such as Egypt and Algeria.*
- *The political stability of South Africa.*

### Middle East-(Table 6)

#### Key assumptions

- The current Gulf crisis is resolved by mid-1991, allowing recovered sulphur production in Iraq and Kuwait to return to and eventually exceed previous levels.

- The proposed doubling of capacity at the Mishraq Frasch sulphur mine in Iraq to 2.0 million t/a takes effect in 1993, two years behind schedule, but production in the meantime remains around 1.0 million t/a.

- New brimstone projects in Qatar and Abu Dhabi proceed approximately to schedule, and output in Iran rises steadily.

- Demand growth is focused primarily on Iran in the near term and Iraq in the longer term. Phosphoric acid projects in other countries are not considered in the demand forecasts.

#### Major uncertainties

- *The manner in which the current crisis is resolved and the longer-term political stability of the region as a whole.*
- *Re-assessment of investment risks, particularly in respect of non-vertically integrated phosphate fertilizer projects.*
- *Natural gas production and gas processing capacity developments, particularly in Saudi Arabia and Iran.*

### Other Asia-(Table 7)

#### Key assumptions

- The main growth in SAF production occurs in the form of smelter acid, chiefly in the Far East, and in pyrites, almost entirely in China. Increases in brimstone

output are modest.

- There is a significant rise in demand for fertilizer and industrial sulphuric acid in countries throughout the region, but most notably in India and China. A rise in world nitrogen prices gives a boost to a more balanced pattern of fertilizer application.

#### **Major uncertainties**

- *The fertilizer production and import policies of India and China, and their success in implementing these policies.*
- *The political stability of China and India.*
- *The time-lag between the industrial and the financing cycles.*
- *Crude oil sourcing.*
- *Environmental legislation.*

#### **Oceania-(Table 8.)**

##### **Key assumptions**

- The only production increments occur in the form of increased smelter acid output in Australia. Brimstone production is static.
- Fertilizer sulphuric acid demand is fairly stable in New Zealand but fails to recover significantly from its currently depressed level in Australia. Consumption growth occurs primarily in the non-fertilizer sector, particularly in ore leaching.

#### **Major uncertainties**

- *The outcome of the current GATT round.*
- *Australia's future energy policy: crude oil sourcing, exploitation of oil shales.*

#### **Total World-(Table 9.)**

- The effective supply deficit will be larger than is indicated so long as UN sanctions against Iraq are in place, as assumed production at the Mishraq Frasch mine will be stockpiled but will not form part of available supply.

#### **Producers' Stocks**

- Producers' stocks of elemental sulphur are estimated to have totalled 10.14 million tons at December 31, 1989, distributed as follows:

Canada	4.28
United States	1.31
West Europe	1.86
Saudi Arabia	1.89
Others	80
<b>Total</b>	<b>10.14</b>

The forecast of producers' year-end stocks derived from world balance is therefore as follows (in million tons):

<b>Year-end stocks</b>						
<b>1989</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>
10.14	9.01	8.34	9.47	13.60	19.83	25.17

#### **Conclusion:**

In theory, a tight sulphur market is indicated for the next two years, with a substantial and rapidly rising supply surplus developing from 1993 onwards.

In fact, recent events (the 1989 Morocco-India dispute and the 1990 Gulf crisis) have reemphasized the unpredictability of sulphur supply/demand relationships, and the many uncertainties currently underlying the market make any forecast extremely speculative.

**Table 1. North America**  
**Production, Consumption and Balance**  
(million tons S/S-equivalent)

	1988	1989	1990	1991	1992	1993	1994	1995
<b>Production</b>								
Brimstone	15.65	16.27	16.15	16.18	16.53	18.18	19.16	19.18
All forms	18.63	19.35	19.41	19.58	20.03	21.68	22.76	22.78
<b>Consumption</b>								
Brimstone	12.36	12.27	12.55	12.35	12.25	12.10	12.15	12.20
All forms	15.34	15.35	15.85	15.81	15.83	15.72	15.88	15.94
<b>Brimstone</b>								
<b>Balance</b>	3.28	4.00	3.60	3.83	4.28	6.08	7.01	6.98

**Table 2. Latin America**  
**Production, Consumption and Balance**  
(million tons S/S-equivalent)

	1988	1989	1990	1991	1992	1993	1994	1995
<b>Production</b>								
Brimstone	2.48	2.43	2.43	2.54	2.68	2.78	2.85	2.81
All forms	3.07	3.11	3.23	3.49	3.72	3.98	4.11	4.19
<b>Consumption</b>								
Brimstone	3.06	3.02	3.17	3.34	3.44	3.54	3.62	3.70
All forms	3.66	3.70	3.93	4.22	4.40	4.62	4.76	4.94
<b>Brimstone</b>								
<b>Balance</b>	-0.58	-0.59	-0.74	-0.80	-0.76	-0.76	-0.78	-0.91

**Table 3. West Europe**  
**Production, Consumption and Balance**  
(million tons S/S-equivalent)

	1988	1989	1990	1991	1992	1993	1994	1995
<b>Production</b>								
Brimstone	3.60	3.59	3.78	4.02	4.10	4.09	4.15	4.21
All forms	8.37	8.08	8.29	8.48	8.50	8.43	8.47	8.51
<b>Consumption</b>								
Brimstone	5.48	5.48	5.32	5.18	5.14	5.05	4.97	4.91
All forms	10.23	9.97	9.83	9.64	9.54	9.39	9.29	9.21
<b>Brimstone</b>								
<b>Balance</b>	-1.88	-1.89	-1.54	-1.15	-1.04	-0.96	-0.82	-0.70

**Table 4. East Europe & USSR**  
**Production, Consumption and Balance**  
(million tons S/S-equivalent)

	1988	1989	1990	1991	1992	1993	1994	1995
<b>Production</b>								
Brimstone	12.29	11.50	11.27	11.51	12.68	13.75	14.58	14.67
All forms	18.24	17.35	17.09	17.43	18.69	19.85	20.60	20.60
<b>Consumption</b>								
Brimstone	9.97	9.89	9.26	9.15	9.50	9.78	9.93	10.15
All forms	15.56	15.38	14.74	14.75	15.21	15.60	15.69	15.84
<b>Brimstone</b>								
<b>Balance</b>	2.32	1.61	2.01	2.36	3.18	3.97	4.65	4.52

**Table 5. Africa**  
**Production, Consumption and Balance**  
(million tons S/S-equivalent)

	1988	1989	1990	1991	1992	1993	1994	1995
<b>Production</b>								
Brimstone	0.20	0.23	0.25	0.26	0.26	0.26	0.26	0.26
All forms	1.17	1.21	1.24	1.26	1.27	1.28	1.29	1.30
<b>Consumption</b>								
Brimstone	5.15	3.76	4.61	5.07	5.32	5.39	5.79	6.32
All forms	6.13	4.74	5.60	6.07	6.33	6.41	6.82	7.36
<b>Brimstone</b>								
<b>Balance</b>	-4.95	-3.54	-4.36	-4.81	-5.07	-5.13	-5.53	-6.06

**Table 6. Middle East**  
**Production, Consumption and Balance**  
(million tons S/S-equivalent)

	1988	1989	1990	1991	1992	1993	1994	1995
<b>Production</b>								
Brimstone	3.65	4.12	4.00	4.24	5.16	5.74	6.56	6.62
All forms	3.65	4.12	4.00	4.24	5.16	5.74	6.56	6.62
<b>Consumption</b>								
Brimstone	1.00	1.10	1.05	1.11	1.36	1.50	1.60	1.85
All forms	1.00	1.10	1.05	1.11	1.36	1.50	1.60	1.85
<b>Brimstone</b>								
<b>Balance</b>	2.65	3.02	2.95	3.13	3.80	4.24	4.96	4.77

**Table 7. Other Asia**  
**Production, Consumption and Balance**  
(million tons S/S-equivalent)

	1988	1989	1990	1991	1992	1993	1994	1995
<b>Production</b>								
Brimstone	1.55	1.68	1.77	1.85	1.91	2.02	2.12	2.15
All forms	8.22	8.53	8.72	8.94	9.19	9.56	9.82	10.05
<b>Consumption</b>								
Brimstone	4.13	4.37	4.37	4.57	4.65	4.79	4.88	4.96
All forms	10.90	11.31	11.41	11.76	12.02	12.42	12.62	12.90
<b>Brimstone</b>								
<b>Balance</b>	-2.58	-2.69	-2.60	-2.72	-2.74	-2.77	-2.76	-2.81

**Table 8. Oceania**  
**Production, Consumption and Balance**  
(million tons S/S-equivalent)

	1988	1989	1990	1991	1992	1993	1994	1995
<b>Production</b>								
Brimstone	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
All forms	0.33	0.33	0.34	0.38	0.41	0.46	0.51	0.56
<b>Consumption</b>								
Brimstone	0.63	0.52	0.51	0.57	0.59	0.59	0.57	0.52
All forms	0.85	0.74	0.74	0.84	0.89	0.94	1.02	1.02
<b>Brimstone</b>								
<b>Balance</b>	-0.57	-0.46	-0.45	-0.51	-0.53	-0.53	-0.51	-0.46

**Table 9. Total World  
Production, Consumption and Balance**  
(million tons S/S-equivalent)

	<b>1988</b>	<b>1989</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>
<b>Production</b>								
Brimstone	39.47	39.86	39.70	40.64	43.36	46.85	49.71	49.93
All Forms	61.36	61.74	62.01	63.50	66.69	70.71	73.88	74.38
<b>Consumption</b>								
Brimstone	41.77	40.39	40.83	41.31	42.23	42.73	43.49	44.60
All forms	63.66	62.27	63.14	64.17	65.56	66.59	67.66	69.05
<b>Brimstone Balance</b>	-2.29	-0.53	-1.13	-0.67	1.13	4.13	6.23	5.34

# Monday, November 12, 1990

## Session II Moderator:

Robert Mitchell

### State and Federal Legislation on Fertilizers and Environment - 1990 Update

*Roland D. Hauck*

Tennessee Valley Authority

Environmental issues continue to be prominent in the legislative arena, both on Capitol Hill and throughout the nation. Much of the legislative activity is focused on water quality protection and, on the Federal level, also on global climate change.

At the 1988 Round Table meeting, I briefly summarized the approaches taken to protect water quality after passage of the Water Pollution Control Act Amendments of 1972, and pointed out the importance to agriculture of the 1986 Safe Drinking Water Act (SDWA) and 1987 Clean Water Act (CWA) Amendments. A main provision of the CWA was giving states the primary responsibility of developing and implementing their respective ground water protection strategies, and mandating the Environmental Protection Agency (EPA), rather than the U.S. Department of Agriculture, to assume responsibility as the lead agency on the Federal level providing guidance, technical assistance, and oversight.

Most states and territories, (42) have received EPA approval for their ground water protection plans, as required under section 319 of the 1987 CWA, a provision relating to nonpoint sources of pollution, including run-off and seepage from agricultural operations. Twelve other states or territories have received partial approval for their management plans. Although upon approval of their plans, states are eligible to receive Federal grants to cover 60% of the cost of implementation, no funds were appropriated until 1990 (\$38.6 million appropriated, 100 million authorized).

#### *State Legislation*

More than 300 ground water protection bills affecting agriculture were introduced into 44 state legislatures during 1989. At least 84 of these bills are now law. Some aspect of fertilizer storage, handling, distribution, and use was addressed in 58 bills by 26 states. During 1990, at least 49 additional fertilizer and environment bills were introduced in the legislatures of 22 states. Altogether, during the 1989-90 legislative sessions, 107 such

bills were considered in 32 states.

Iowa led the way with passage of the 1987 Ground Water Protection Act which generates funds specifically for ground water protection education, demonstration, and research. Fees from many sources were increased, including pesticide registration and sales fees and a nitrogen fertilizer tonnage fee (based on \$0.75/ton of ammonia). During 1989, 17 states earmarked fees on fertilizer registration or sales for environmental activities, including; Illinois (raised from 10 cents to 20 cents/ton of product); Indiana (fertilizer registration fee of \$40 per product in package less than 5 lb. and \$10 per product in package of more than 5 lb.); Kansas (fee increased from \$0.30 to \$1.70/ton of fertilizer); Minnesota (redirected use of, and placed surcharge on fertilizer and pesticide fees); Missouri (allows use of fees - 50 cents/ton fertilizer, 60 cents/ton lime - to be used for nutrient use education). Illinois, Indiana, Oklahoma, and Wisconsin laws allow or direct tonnage fees to be used for research and education related to ground water protection. In South Dakota, the 30 cent/ton increase goes into a ground water protection fund.

The number and wide range of issues being addressed show that states are serious about protecting their waters and that the issues are complex. The 1989-90 laws cover such diverse topics as composting of garbage and sawdust (two bills introduced, one passed in Illinois), the definition of a person as an agent of pollution (North Dakota), and a state-wide policy of establishing water quality protection areas where health-threatening contaminants are found in water (Missouri). Kansas and Minnesota now require a chemigation permit and registration fee (\$50 annually, plus in Kansas, \$10 for each additional point of diversion). Nebraska amended its Chemigation Act to require inspectors to obtain farmer consent or a warrant prior to inspection but to allow them to suspend operation if a chemigation system is a threat to personal health or the environment. Illinois and Minnesota passed but Ohio failed to pass a sustainable agriculture bill. The Illinois law establishes a committee to seek funds for research in this area and the Minnesota law calls for a clearinghouse for information on the sustainability of its agriculture.

The most active states during 1989-90 in terms of number of bills considered relating to agriculture and water quality were: Minnesota with 14; New Jersey and New York, 8 each; California, Illinois, and Virginia, 7

each; and Idaho, 5 (1 groundwater and 4 surface water protection bills).

Not all bills could be considered burdensome to the industry, e.g., those that revised existing fertilizer laws to incorporate a water protection provision, those that redefined terms relating to fertilizers, or those that sought exemption or limitations from liability or taxes.

In contrast to the above, other bills enacted into law increase the cost of doing business. For example, 8 states now have regulations concerning storage and secondary containment of fertilizers: Illinois, Iowa, Minnesota, Ohio, Oklahoma, Pennsylvania, South Dakota, and Wisconsin. Efforts to pass such legislation failed in Indiana, Kansas, and Nebraska but the bills will be reconsidered during 1991. Containment legislation also will be introduced into the Kentucky, Michigan, and Missouri legislatures.

To the above array of legislation can be added many additional water bills that became law during 1989-90. Future bills will be passed in response to provisions found in ground water, farm policy, and global climate change bills passed by the 101st Congress, and those following.

Currently, States tend to favor the adoption of mandatory controls against point sources of pollution such as spills at fertilizer dealer sites, and, for nonpoint source control, voluntary adoption of best management practices by farmers, but with provisions for mandatory action when voluntary practices result in demonstrable environmental stress.

### *Federal Legislation*

On the Federal level, food safety, clean air and water, and the Farm Bill were the main environmental focus of the 101st Congress. There were at least 175 separate committee or subcommittee actions on 130 ground water bills considered by the House and Senate. Twenty seven of these bills (10 in the House, 17, Senate) made some reference to fertilizers or plant nutrients, especially nitrogen. There was relatively little action on these bills because of Congress' preoccupation with other environmental issues, but several provisions were moved from the ground water protection bills directly, or in modified form, into the 1990 Farm Bill. For example, S. 2024 (Daschle, D-SD) became part of the research title of the Senate version of the Farm Bill. (A similar bill, HR. 3574 [Grandy, D-IA] failed to move into the House version). These bills were to establish within USDA an office of ground water policy coordination; this provision was revised in the Farm Bill as passed by the Congress to create a Council of Environmental Quality within USDA rather than a new office.

Much of the conservation title of the Farm Bill was based on S. 2409, the second of two sustainable agriculture bills introduced by Fowler (D-GA). The first bill, S. 970, had been unacceptable to many in the agribusiness community. The second bill was crafted in concert with

commodity and farm group, and had general approval by environmental interest groups as well.

A major change in the 1990 Farm Bill was to allow for some flexibility of farmer choice in the kind of Program crops that could be grown without loss of base acreage. A new triple base plan combines the Acreage Reduction and Conservation Reserve Programs with a "flex plan" that reduces acreage eligible for crop subsidies at least 15% and could, under some circumstances, 40% (a 25% decrease would be more usual).

The Conservation Reserve Program was expanded to include at least 40 million but no more than 45 million acres by 1995, with an additional 10 million that could be enrolled in a new Water Quality Initiative Program. Research and education activities which promote environmentally sound agricultural practices were emphasized in the Farm Bill. The bill authorized \$20 million annually for training and information transfer to agricultural producers, \$20 million for integrated resource management research, and \$40 million annually for low input sustainable agriculture research.

Looking ahead, the 102nd Congress will be considering the reauthorization and amendment of the SDWA and CWA. Pesticides, heavy metals (lead), and nitrate contamination of waters will be in the forefront. Well head protection and use of land use zoning for sole source aquifer protection probably will be re-examined. Approaches to energy conservation may include imposition of a carbon tax, which could impact ammonia producers. Agrichemical use taxes also may be considered.

Important to note is the large number and make-up of Congressional committees that now are involved in legislation affecting agriculture, for example, House Committee on Agriculture; House Committee on Science, Space, and Technology; House Committee on Public Works and Transportation; House Committee on Governmental Operations; and Senate Committees on Agriculture, Nutrition, and Forestry and on Environment and Public Works. These committees and their subcommittees represent interests other than those solely of agriculture.

### *Conclusion*

Current and future enactments on both state and Federal levels reflect public concern for health and safety and legislative desire to protect the public and environment while sustaining a viable agriculture. The legislation is a nuisance to some businesses, increases costs for most, but also creates opportunities for new kinds of customer services. Clearly, keeping abreast of the legislative scene is a requirement for staying in business.



# AAPFCO Model Containment Legislation

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## INTRODUCTION

In the past, AAPFCO has developed model laws (or rules) for regulating fertilizers, liming materials, soil amendments, ammonia and chemigation. The last model in this list obviously points toward a new area of interest for both the state control officials and the fertilizer industry, protection of environmental quality. Ground water protection is the primary motivator for our newest thrust into the environmental arena: primary and secondary containment of bulk fertilizer in storage. Besides ground water protection, the prevention and/or containment of discharges at bulk facilities will also provide an element of protection for streams, rivers and reservoirs.

What might be the benefits to industry, beyond environmental protection, of bulk storage containment rules? Many times we have heard that compliance with storage rules will add costs that can not be recovered; however, one might envision some rather real intangible, if not tangible, benefits to those firms complying with storage requirements. Since many insurance companies may not write policies, or only write them at very high costs to the insured, where fertilizer is stored in bulk without containment provisions, firms will likely either benefit through lower insurance rates, or at least find they can obtain insurance and remain in business as a result of compliance. Also, as more and more states develop environmental audit/review requirements for the environmentally responsible transfer of property, it will become increasingly important to demonstrate good environmental husbandry in order to assure smooth property transactions. No doubt, safe, contained chemical storage will help to substantiate that property has been managed in an environmentally responsible manner.

With many states/groups actively engaged in the area of regulating or developing regulations for bulk fertilizer storage by 1988, AAPFCO began working in this area and gave tentative approval to model rules in August 1989 at its annual meeting in San Antonio, TX. Several examples, particularly the existing Wisconsin rules, the National Fertilizer Solutions Association guidelines and the Indiana draft rules, along with most of the other available information, formed the basis for the AAPFCO model. The tentative rules, as now written, contain six sections, but will be discussed here as made up of seven different components as follows: 1. definitions, 2. primary containment, 3. operational area containment, 4. secondary containment, 5. dry fertilizers, 6. discharge response plan, and 7. record keeping.

Before looking at the model rules in detail, it is best to deal with a few general features. First, the model rules are, hopefully, adequate to protect the environment,

flexible to allow for the future, uniformly applicable and enforceable, and affordable for those who must comply. No compliance dates/time lines are included in the rules, but states would certainly need to provide these to assure orderly compliance. In most cases one would probably expect time lines to differ for various rule requirements, such as: X years for primary containers, Y years for secondary containment and Z years for operational area containment. Finally, although the states will likely find it necessary to modify the rules somewhat to meet various environmental conditions or political realities, the general intent and nature of the AAPFCO model rules will probably form the basis for rules to be adopted in the future.

## Definitions

As for most rules, certain definitions are fairly critical for interpretation of the AAPFCO model. Among the most important definitions are:

1. Fluid bulk fertilizer - begins with containers larger than 55 gallons.
2. Fluid fertilizer - includes solutions, emulsions, suspensions and slurries, while excluding anhydrous ammonia.
3. Storage container - excludes mobile containers under most circumstances, but includes them when actually used for storage.
4. Storage facility - does not specify, but could so specify, what is or is not to be covered by the rules - i.e., this is a potential place for exemptions.

Comments have been received suggesting that the definition of fluid bulk fertilizer begin at a larger volume, such as 1,000 or 2,500 gallons. A definition for low pressure nitrogen solutions has been recommended for addition, with specific stipulation that it be made obvious that the definition does not include "28, 30 and 32% nitrogen solutions", or aqua ammonia. Further, constructive comments are still welcomed on this and all other portions of the rules, but such comments need to be made soon if they are to receive adequate consideration before a revised proposal is presented to the AAPFCO Board of Directors in February 1991 for official adoption.

## Primary Containment (storage containers)

Not all fertilizers may be stored in containers made from all potential construction materials, and not all potential container, valve and fitting materials may be used in combination. The model rules require compatibility. For example, "low pressure nitrogen solutions" - solutions of ammonium nitrate and/or urea and/or other nitrogen carriers exceeding 2% free ammonia - may not be stored in mild steel, fiberglass, polyolefins or plastic tanks; yet, these tank materials may be used for the storage of 28, 30 and 32% nitrogen solutions. Low pressure nitrogen solutions may be stored in stainless steel tanks and low pH (pH 5 or less, herein added and

not in the model rules) solutions are to be stored in stainless steel, or if other ferric materials are to be used, a protective tank liner will be required. For storage of fluid fertilizers containing potassium chloride in tanks of ferrous materials other than stainless steel, the tank and valves, etc., must be protected, or storage is limited to three months at a time with tank cleaning and inspection required between storage periods. An allowed storage period of six months has been suggested.

Containers must be so designed as to handle any operating stress, considering the pressure build up from pumps, hydrostatic head, and any other mechanical stress that may be envisioned/predicted as a result of changes/future operations. External liquid level gauges are only allowed if securely attached to the container wall and provided with a shut off valve, which is kept locked except when measuring the liquid level.

Underground storage in tanks or lined pits will not be allowed for fertilizers except in the case of stainless steel tanks or other approved containers, provided these tanks/containers sit within acceptable liners and a means of monitoring is provided and approved for leak detection. There are some pits currently in existence that were installed to provide monitoring between the primary container walls and bottom, and a separate pit liner, that appear acceptable.

When tanks are abandoned, the model rules require that they be completely cleaned, the valves, etc. removed, and the hatches left open. Comments indicating secured hatches would be better, since rain waters would not enter and accumulate, are being taken into consideration as assuring greater safety and a lower risk of accidents. Underground tanks are to be removed from the ground, cleaned, etc. If not removed, underground tanks are to be filled with an inert substance and sealed, after first having been well cleaned. Records must be made of all abandoned underground tanks and the records kept permanently.

To prevent flotation and secure against instability from other causes, tanks must be anchored or tied down. Security must be provided by fencing or other approved means to protect against unauthorized access and/or vandalism. Also, as a security measure, valves must be locked whenever a storage facility is not attended by a responsible person.

Inspection and maintenance of containers is required and storage volumes must be measured on a periodic basis for inventory purposes. Written records of these activities must be made and kept for review by regulatory officials. Suggestions have been made that language be added to specify that these requirements only apply during periods of container use for storage. Also, the frequency of inspection with maintenance as needed, currently weekly, has been the subject of debate.

#### *Operational Areas* (loading/mixing pads)

Areas for loading or unloading fertilizer storage containers, washing or rinsing application equipment,

or cleaning out mobile tanks are required and must be curbed and paved. Such "pads" need to be large enough to hold the entire mobile containers used at or servicing the facilities, and they must be so designed and constructed to withstand all stress expected to accompany operations at the storage facility. As currently worded, the rules would include the motor vehicle along with the tank or mobile container, if attached, in determining the size of the pad required. Limiting the pad size to the length of the mobile container, only, has been very strongly encouraged.

The paved surface of an operational area needs to form a liquid tight catch basin, which may contain or drain to a sump, but only if the sump is provided with an automatic pump to remove accumulations from the sump to an above ground storage container. The automatic nature of removal of liquid from the sump has been discussed and suggested for change. The curbed pad plus catch basin must be large enough to hold 125% of the volume of the largest mobile container to be loaded or unloaded at the facility, but under no circumstances may it be less than 1,500 gallons.

As for the primary container, the rules provide for the inspection and maintenance of operational areas. Records of the activities are to be made and they are to be available for inspection.

Operational area requirements do not apply to mobile containers when in use to nurse field operations. Under these circumstances, the actual operational site is very likely to change and, thus, there would be reduced long term risk of repeated spills at the same location. Repeated spills, of course, are more likely to lead to saturation conditions and potential runoff/leaching.

#### *Secondary Containment* (dikes)

Dikes will be needed around primary storage containers to contain any discharge. To prevent the possible intermixing of different products such as fertilizers and pesticides, the diked secondary containment for fertilizers has to be separate from any pesticide containment area at the facility. To account for the potential of rain, and perhaps other contingencies, the volume of the diked area is specified as 125% of the volume of the largest storage container within the diked area plus the submerged portions of all other containers. Comments have been received concerning the volume of the dike if the secondary containment area is covered. Something less than 125% would likely be required under such circumstances, perhaps as little as 100%.

The walls of a dike may be constructed of soil, steel, concrete or solid masonry as long as it is designed to withstand the loads it might be subject to from a full dike as well as the load of material used in construction. It will be necessary to monitor the walls for cracks and to be sure cracks and seams are sealed. If walls are over six feet tall, provisions will be needed for normal access and any emergency access that might be necessary.

The base of a secondary containment area and

earthen walled dikes must be lined with asphalt, concrete, an approved synthetic liner, or a clay soil liner designed to limit permeability of the base and walls. In the case of clay soil liners, the downward movement of water should not be greater than one-millionth of a centimeter per second ( $1 \times 10^{-6}$  cm/sec) at construction and be maintained at one-one hundred thousandth of a centimeter per second ( $1 \times 10^{-5}$  cm/sec). also, the floor of the earthen containment area must be protected by a layer of gravel or stone.

For very large, field constructed tanks of 100,000 gallon capacity or greater, it will not be necessary to directly install a liner under those tanks already in use when the rules become effective. Instead, a second bottom can be constructed for such storage containers. A smooth layer of fine gravel or coarse sand six inches thick would be placed over the original bottom and the new bottom installed on top. Leak tests will be necessary and a means of monitoring between the two bottoms required. A separating layer of only three inches of sand or gravel has been suggested.

For tanks up to 3,000 gallons, secondary containment may be provided by a secondary storage container or "elephant ring". It will be necessary to assure the tank and elephant ring are made of compatible materials to avoid electrolytic corrosion. An elephant ring needs to have the capacity of 115% of the primary container and its walls may not exceed four feet in height. It has been suggested that walls of a greater height be allowed as long as provisions are made for escape upon flooding.

Secondary containment areas will accumulate storm water which can be discharged over the containment walls by pump provided such disposal is in accordance with local requirements for the disposal of storm water. The rules provide for recess catch drains and allow for a sump under certain conditions. Drainage is, of course, clearly necessary to make the diked containment volume available to hold primary container discharges, should such occur.

As for the primary containers and operational areas, inspection and maintenance is required for secondary containment areas. Records of inspections and maintenance must be kept and made available for inspection.

### *Dry Fertilizers*

Dry fertilizers must be stored and handled in such a manner that losses to the air, surface water, ground water and subsoil are minimized. Generally, storage requires cover either under roof or by a tarpaulin, if outside. Operations such as loading, unloading, mixing and handling must be accompanied by containment (method, device, structure, etc.) such as to minimize emission of dust or vapors. Several potential approaches to dry bulk fertilizer containment are mentioned in the rules.

### *Discharge Response Plan*

A plan to cover what will be done in an emergency is becoming common place where chemicals are stored. We need to know what is stored and who to contact in

case of a discharge. A plan is needed covering procedures to use in controlling and recovering a discharge of each type of fertilizer being stored. Procedures for use or disposal of recovered discharges are also necessary. The overall plan, procedures, and who to contact in case of a discharge needs to be on file at the storage facility and copies provided to the local fire and police departments and the state environmental agency. The emergency response plans must be changed to keep current as changes occur at storage facilities.

### *Record Keeping*

Several record keeping aspects of the model rules have already been covered, especially for the inspection and maintenance of various storage facility components. Also, records must be made of discharges and the responses which occur as a result to recover and clean up discharges. A semi-annual inventory reconciliation is required and records must be made of what is found. There are set periods for keeping various records required under the rules.

ASSOCIATION OF AMERICAN PLANT FOOD CONTROL OFFICIALS

PRIMARY AND SECONDARY CONTAINMENT OF FERTILIZERS

RULES

1. Primary Containment Of Fluid Bulk Fertilizer

(a) Definitions - For the purposes of these rules the following definitions shall apply:

- (1) "Primary containment" means the storage of fluid bulk fertilizer in storage containers at a storage facility.
- (2) "Fluid bulk fertilizer" means fluid fertilizer in a container larger than 55 gallons.
- (3) "Fluid fertilizer" means fertilizer in fluid form, and includes solutions, emulsions, suspensions and slurries. "Fluid fertilizer" does not include anhydrous ammonia.
- (4) "Storage container" means:
  - a. A container used for the storage of fluid bulk fertilizer.
  - b. A rail car, nurse tank, or other mobile container used for the storage of fluid bulk fertilizer.
- (5) "Storage container" does not include:
  - a. A mobile container storing fluid bulk fertilizer at a storage facility for less than 15 days, if this storage is incidental to the loading or unloading of a storage container at the storage facility.
  - b. A mobile container located other than on property owned, operated or controlled by an owner or operator of a storage container.
  - c. A container used solely for emergency storage of leaking fertilizer containers that are 55 gallons or smaller.
- (6) "Storage facility" means a location at which fluid bulk fertilizer is held in storage.
- (7) "Secondary containment" means any structure used to contain product spills from bulk storage containers and prevent runoff or leaching.
- (8) "Operational area containment" means any structure or system used to intercept and contain operational spills and contaminated wash water and prevent runoff or leaching.
- (9) "Elephant ring" means a storage container with open top serving as a secondary containment vessel into which a smaller primary storage container(s) is placed.
- (10) "Control official" means the enforcing official of the state of \_\_\_\_\_ or his appointed agent.
- (11) "Approved" means approval by the control official or his agent except where otherwise stated.
- (12) "Field operations" means the application of bulk fluid fertilizer to soil or plants in the course of normal agricultural or horticultural practice.

(b) Storage Containers and Appurtenances.

- (1) Basic Requirements.

- a. Storage containers and appurtenances shall be constructed, installed and maintained so as to prevent the discharge of fluid fertilizer.
- b. Storage containers and appurtenances shall be constructed of materials which are resistant to corrosion, puncture or cracking.
- c. Materials used in the construction or repair of storage containers and appurtenances may not be of a type which react chemically or electrolytically with stored fluid fertilizer in a way which may weaken the storage container or appurtenances, or create a risk of discharge.
- d. Metals used for valves, fittings and repairs on metal containers shall be compatible with the metals used in the construction of the storage container, so that the combination of metals does not cause or increase corrosion which may weaken the storage container or its appurtenances, or create a risk of discharge.
- e. Storage containers and appurtenances shall be designed to handle all operating stresses, taking into account static head, pressure buildup from pumps and compressors, and any other mechanical stresses to which the storage containers and appurtenances may be subject in the foreseeable course of operations.
- f. Every storage container connection, except a safety relief connection, shall be equipped with a shut-off valve located on the storage container dictated by standard engineering practice. Except during use periods, shut-off valves shall be left closed and secured.

(2) Prohibition Against Underground storage, exemptions.

No person shall store fluid fertilizer in an underground or lined pit storage container. This prohibition does not apply to:

- a. A watertight catch basin used for the temporary collection of runoff or rinsate from transfer and loading areas.
- b. Storage in a 316 or 317 stainless steel storage container, or in another approved container, if the storage container is enclosed within an approved liner and an approved program of ground water monitoring to detect leakage is established.

(3) Abandoned Containers.

- a. Storage containers and other containers used at a storage facility to hold fluid bulk fertilizer or fertilizer rinsate are considered abandoned if they have been out of service for more than 6 months because of a weakness or leak, or have been out of service for any reason for more than 2 years.
- b. Abandoned underground containers, including abandoned underground catch basins, shall be thoroughly cleaned and removed from the ground or thoroughly cleaned and filled with an inert solid. All connections and vents shall be disconnected and sealed. A record of the catch basin size, location, and method of closing shall be maintained at the storage facility or as otherwise provided for in these rules.
- c. Abandoned aboveground containers shall be thoroughly cleaned. All hatches on the containers shall be left open, and all valves or connections shall be severed and sealed.
- d. A secondary containment facility is not considered abandoned merely because there have been no discharges into the secondary containment facility.

(4) Prohibited Materials.

- a. Storage containers and appurtenances may not be constructed of copper, brass, zinc,

or copper base alloys.

- b. Storage containers and appurtenances used for the storage of fluid fertilizers containing phosphates or chlorides may not be constructed of aluminum or aluminum alloys.
- c. Storage containers and appurtenances used for the storage of low pH fluid fertilizers may not be constructed of ferrous materials other than stainless steel unless the materials are coated or treated with protective substances which are adequate to inhibit corrosion.
- d. Storage containers and appurtenances used for the storage of low pressure nitrogen solutions may not be constructed of mild steel, fiberglass, polyolefins or plastic.
- e. Storage containers and appurtenances used for the storage of phosphoric acid may not be constructed of ferrous materials other than 316 or 317 stainless steel unless the container is lined with a suitable substance to prevent corrosion.
- f. Storage containers and appurtenances used for the storage of fluid fertilizers containing potassium chloride (muriate of potash) may not be constructed of ferrous materials other than stainless steel, unless:
  - 1 The containers and appurtenances are coated or treated with protective substances which are adequate to inhibit corrosion, or
  - 2 The container or appurtenance is used for storage periods of not more than 3 months, and is completely emptied between storage periods, and, the empty containers and appurtenances are cleaned and inspected for leaks prior to being refilled for any subsequent period.

(5) Anchoring Storage Containers.

Storage containers shall be anchored, as necessary, to prevent flotation or instability which might occur as a result of liquid accumulations within a secondary containment facility constructed in accordance with these rules.

(6) Security.

- a. Storage containers and appurtenances shall be fenced or otherwise secured to provide reasonable protection against vandalism or unauthorized access which may result in a discharge.
- b. Valves on storage containers shall be locked or otherwise secured except when persons responsible for facility security are present at the facility.
- c. Valves on rail cars, nurse tanks, and other mobile fertilizer containers parked overnight at a storage facility shall be locked or secured except when persons responsible for facility security are present at the facility.
- d. Valves on empty containers need not be secured.

(7) Filling Storage Containers.

Storage containers may not be filled beyond the capacity for which they are designed, taking into account the density of the fluid being stored and thermal expansion during storage.

(8) Pipes and Fittings.

Pipes and fittings shall be adequately supported to prevent sagging and possible breakage because of gravity and other forces which may be encountered in the ordinary course of

operations.

(9) Liquid Level Gauging Device.

- a. Every storage container shall be equipped with a liquid level gauging device by which the level of fluid in the storage container can be readily and safely determined.
- b. A liquid level gauging device is not required if the level of fluid in a storage container can be readily and reliably measured by other means.
- c. Liquid level gauging devices shall be secured, in a safe manner, to protect against breakage or vandalism which may result in a discharge.
- d. External sight gauges are prohibited unless they comply with Rule 1(b)(1)f.

(10) Labeling of Storage Containers.

Every storage container shall be clearly labeled to identify its fertilizer contents as provided in \_\_\_\_\_ .

(11) Inspection and Maintenance.

- a. The operator of a storage facility shall routinely inspect and maintain storage facilities, storage containers and appurtenances to minimize the risk of a discharge.
- b. The operator shall inspect valves and other appurtenances for leakage at least weekly.
- c. The operator shall measure and record the fluid fertilizer level in each storage container at least weekly.
- d. A written record of all inspections and maintenance shall be made on the day of the inspection or maintenance.
- e. Inspection and maintenance records shall be kept at the storage site, or at the nearest local office from which the storage site is administered.

2. Operational Area Containment for Fluid Fertilizer

(a) Loadout and Unloading Pads.

- (1) Areas used for the loading of fluid bulk fertilizer into storage containers, or for unloading fluid bulk fertilizer from storage containers into mobile containers shall be curbed and paved with asphalt, concrete or other approved material.
- (2) The curbed and paved area shall be sufficiently large to hold the entire mobile container and motor vehicle, if attached, during loading or unloading. The pad shall be designed, constructed and maintained to handle all loading conditions to which it is exposed. Cracks and seams shall be kept sealed.

(b) Catch Basins.

- (1) The curbed and paved surface shall form or drain into a liquid-tight catch basin. If the curbed and paved surface drains to a sump, the catch basin may include the sump and an above ground container, provided a pump is installed which automatically transfers the contents of the sump into the above-ground container.
- (2) The curbed surface and catch basin shall be of adequate design and size to contain a combined total of 125% of the largest vehicle to be loaded or unloaded or a minimum of 1,500 gallons of discharged fluid.



(c) **Recovery of Discharges.**

Discharges incident to loading or unloading shall be promptly recovered from the paved surface and catch basin, such that the capacity required in Rule 2(b)(2) is available at all times.

(d) **Protection Of Containers and Appurtenances.**

Storage containers and appurtenances, including pipes, shall be protected against reasonably foreseeable risks of damage by trucks and other moving vehicles engaged in the loading or unloading of fluid bulk fertilizer.

(e) **Exemption for Mobile Containers at Field Unloading Sites.**

Rule 2 does not apply to mobile containers used to nurse field operations when at a field unloading site.

(f) **Inspection and Maintenance.**

(1) The operator of a storage facility shall routinely inspect and maintain loadout and unloading pads and catch basins. Such inspections shall be conducted at least weekly during operational periods and monthly during other periods.

(2) A written record of all inspections and maintenance shall be made on the day of inspection or maintenance. Inspection and maintenance records shall be kept at the storage site, or at the nearest local office from which the storage site and operational area is administered.

3. **Diked Secondary Containment of Fluid Bulk Fertilizer**

(a) **General**

(1) **Dike.**

Primary storage of fluid bulk fertilizer shall be located within a diked area constructed with a base, perimeter wall and sloped floor drain, except as noted in Rule (b)(3).

(2) **Separation of Secondary Containment Areas.**

The diked area shall be separate from a secondary containment area for other materials and used only for containment of primary storage of fluid bulk fertilizer. Adjoining secondary containment areas may share common walls.

(3) **Capacity.**

The diked area for containment of storage facilities shall contain, below the height of the dike, 125% of the volume of the largest storage container within the diked area plus the submerged portions of all other storage containers, fixtures, and materials in the area.

(4) **Existing Drainage Tile.**

Except where used as a method of monitoring a secondary containment system, drainage within or underlying the area to be diked shall be eliminated.

(b) **Diking Requirements. (When in Doubt, the Recommendations of an Engineering Firm Should be Sought to Comply with the Following Requirements)**

(1) **Walls.**

a. The walls of a secondary containment facility shall be constructed of earth, steel, concrete or solid masonry, and be designed to withstand a full hydrostatic head of any



discharged fluid and weight load of material used in construction.

- b. Cracks and seams shall be sealed to prevent leakage.
- c. Walls constructed of earth or other permeable materials shall be lined as provided under Rule 3(b)(2).
- d. Earthen walls shall have a horizontal-to-vertical slope of at least 3 to 1, unless a steeper slope is consistent with good engineering practice, and shall be packed and protected from erosion. An exterior slope of 30 degrees or less shall be protected with grass or crushed stone. Slopes greater than 30 degrees and all interior slopes shall be protected with flat road stone or a similar crushed stone material.
- e. The top of earthen walls shall be no less than 2.5 feet wide.
- f. Walls may not exceed 6 feet in height above interior grade unless provisions are made for normal access and necessary emergency access to tanks, valves and other equipment, and for safe exit from the secondary containment facility.
- g. Walls constructed of concrete or solid masonry shall rest upon a floating base of concrete prepared as in Rule 3(b)(2), or upon suitable concrete footings which extend below the average frost depth to provide structural integrity.

(2) Lining.

- a. **General requirement.** The base of a secondary containment facility, and any earthen walls of the facility shall be lined with asphalt, concrete, an approved synthetic liner, or a clay soil liner designed to limit permeability of the base and walls. Liners shall meet the requirements of this subsection.
- b. **Asphalt or concrete liners.** Asphalt or concrete liners shall be designed according to good engineering practices to withstand any foreseeable loading conditions, including a full hydrostatic head of discharged fluid and static loads of storage containers, including appurtenances, equipment, and contents. Cracks and seams shall be sealed to prevent leakage.
- c. **Synthetic liners.**
  - 1 Synthetic liners and installation plans shall be approved by the control official. A synthetic liner may not be approved by the control official until the manufacturer of the liner provides the control official with a written confirmation of compatibility, and a written estimate of the life of the liner.
  - 2 Synthetic liners shall have a minimum thickness of 30 mils (0.8 millimeters), and be chemically compatible with the materials being stored within the facility.
  - 3 Synthetic liners shall be installed under the supervision of a qualified representative of the manufacturer, and all field constructed seams shall be tested, and repaired if necessary in accordance with the manufacturer's recommendations.
- d. **Soil liners.** The surface soil shall be sealed, including the berm of an earthen dike and 10 feet beyond the berm, with a sealing agent such as sodium bentonite, attapulgite or a similar clay material. The liner shall be constructed in accordance with reliable civil engineering recommendations to establish a barrier layer which will maintain a water level up to the working height of the containment structure for 72 hours, or a clay application which results in a downward water movement of not greater than one-millionth of a centimeter per second ( $1.0 \times 10^{-6}$  cm/sec) at construction and maintained at one-one hundred thousandth of a centimeter per second ( $1.0 \times 10^{-5}$  cm/sec). The floor

of the containment area shall be protected with a layer of gravel or crushed stone at least 6 inches thick placed on top of the clay liner.

e. Exemptions.

1 A liner need not be installed directly under a storage container having a capacity of 100,000 gallons or more which has been constructed on site and put into use prior to the effective date of this rule provided that all of the following conditions are met:

a A second bottom made of steel shall be constructed for the storage container. The second bottom shall be placed over the original bottom and a layer of smooth, fine gravel or coarse sand having a minimum thickness of 6 inches.

b The original bottom of the storage container shall be tested for leaks before the sand layer or second bottom are installed. A record of the test shall be kept on file at the storage facility.

c The newly constructed bottom shall be tested for leaks before any fluid fertilizer is stored on the newly constructed bottom. A record of the test shall be kept on file at the storage facility, or at the nearest local office from which the storage facility is administered.

d There shall be a method by which leaks from the newly constructed bottom into the sand layer may be readily detected.

e The newly constructed bottom shall be tested at least once every 2 years for leaks. A record of the tests shall be kept at the storage facility.

2 The secondary containment requirements under this section do not apply to rail cars which are periodically moved from the storage facility.

(3) Use of Elephant Rings in Lieu of a Diked Containment Area.

a. Individual storage containers not exceeding 3,000 gallons may be contained within a secondary storage container ("elephant ring") in lieu of a diked containment area. The "elephant ring" serves as a second containing wall in the event that the primary storage container develops a leak.

b. Both the primary storage container and the "elephant ring" shall be fabricated of material compatible with each other and with the fertilizer being stored.

Dissimilar metals between the primary storage container and the "elephant ring" contribute to electrolytic corrosion and such use is prohibited.

c. The height of the "elephant ring" wall shall not exceed 4 feet. The volume contained within the secondary storage walls up to the working height of the "elephant ring" shall be sufficient to contain a volume 15% greater than the volume contained in the primary storage container plus the volume displaced by the footings of any equipment (i.e. pumps, meters, etc.) placed within the secondary containment vessel.

d. The "elephant ring" shall be free of leaks and structural defects. The base shall be protected from corrosion, both from inside and outside, and shall be underlain by a concrete pad or with eight inches of compacted gravel beneath four inches of compacted sand, or as recommended by the manufacturer of the "elephant ring" and approved by the control official.

e. All piping connections to the primary storage container shall be made over the wall

of the "elephant ring" and shall be adequately supported and braced. Pumps and other fixtures, if located within the "elephant ring" containment structure, shall be placed on an elevated platform.

- f. Accumulations of storm water and other material shall be pumped over the wall of the "elephant ring" by means of a sump pump within the secondary container, or by means of an exterior portable pump, and disposed of in accordance with Rule 3(b)(3)b.7.
- g. Inspection and maintenance of the primary storage container and of the "elephant ring" shall be conducted and records of inspections and maintenance maintained as in Rule 3(c).

(4) Drainage from Contained Areas Within Dikes.

a. Earthen or Prefabricated Diked Area.

An earthen or prefabricated diked area shall not have a relief outlet and valve. The base shall slope to a collecting spot where storm water can be discharged by pump over the berm for use in the blending process or for proper disposal in accordance with local requirements for disposal of storm water.

b. Asphalt or Concrete Lined Areas.

1 Asphalt or concrete lined areas shall have a recessed catch drain running through the center of the base or, as an alternative, a sump as provided for in Rule 3(b)(4)c.

2 The catch drain shall be at least 6 inches deep and 12 inches wide with an open gate cover.

3 The asphalt or concrete slab located beneath the catch drain shall be at least the same thickness below and to the sides of the drain as the base is throughout the contained area and in compliance with Rule 3(b)(2)b.

4 The asphalt or concrete base shall slope to the drain, and the drain shall slope to a discharge valve at the edge of the dike.

5 The discharge valve shall be closed and secured except when used as noted in Rule 3(b)(4)b.6 at which times it shall be attended by responsible personnel.

6 The discharge valve shall drain to an underground concrete sump tank with a capacity of 1200 gallons. A self priming recovery pump shall be used to move all materials from the tank to alternate storage. The sump tank shall be used as a temporary catchment only. It shall be pumped periodically to remove any water and/or fertilizer material which it collects.

7 Storm water may be used for make-up water in fertilizer mixes or disposed of in accordance with local requirements if found to be free of contaminants.

c. Alternative to a Recessed Catch Drain in Asphalt and Concrete Lined Containment Areas. A sump may be located within the containment area as an alternative to the recessed catch drain provided:

1 The sump construction conforms to the thickness specifications for the remainder of the containment base.

2 The sump shall be drained by means of a portable sump over the wall of the containment structure.

3 No valve shall be plumbed into the sump unless a permanent catchment system described in Rule 3(b)(4)b. exists.

4 Materials removed from the sump shall be disposed of in a manner consistent with Rule 3(b)(4)b.7.

(c) Inspection and Maintenance Requirements.

- (1) Every secondary containment shall be inspected by the operator of the storage facility at intervals of not greater than six months and be maintained as necessary to assure compliance with these rules.
- (2) A written record of all inspections and maintenance shall be made on the day of the inspection or maintenance, and kept at the storage facility or at the nearest local office from which the storage facility is administered.
- (3) All secondary containment areas shall be maintained free of debris and foreign matter.

4. Storage and Handling of Dry Bulk Fertilizer.

- (a) Dry fertilizer materials shall be stored and handled in a manner to prevent pollution by minimizing losses to the air, surface water, groundwater, or subsoil.
- (b) Non-fluid fertilizers shall be stored inside a sound structure or device having a cover or roof top, sidewalls, and base sufficient to prevent contact with precipitation and surface waters. If stored outdoors, it shall be covered with a tarpaulin or other suitable covering to prevent seepage or runoff.
- (c) All loading, unloading, mixing and handling of dry fertilizer, unless performed in the field of application, shall be done using a containment method, device, or structure. The containment method, device, or structure shall be of a size and design that will contain the fertilizer and operated to minimize emission of dust and/or vapors beyond the facility boundaries. Any collected materials shall be applied at agronomic fertilizer rates or otherwise recycled.
- (d) Containment devices or structures include, but are not limited to, the following methods:
  - (1) Paving and curbing of outdoor handling areas with materials which allow for collection and recycle or reuse of storm water, and which are sealed or otherwise maintained to provide a permeability rate not to exceed  $1 \times 10^{-6}$  centimeters per second.
  - (2) Enclosing conveyors and equipping conveyors with dust control boots. Manually extendible boots may be adaptable to upright and auger type conveyors.
  - (3) Enclosing handling areas.
  - (4) Collection and recycle of contaminated precipitation from rooftops or roof-filled storage structures.
  - (5) Daily cleanup of the outside areas when in use.

5. Discharge Response Plan

- (a) The operator of a storage facility shall prepare a written "discharge response plan" for the storage facility. The plan shall include:
  - (1) The identity and telephone number of the persons or agencies who are to be contacted in the event of a discharge, including persons responsible for the stored fertilizer; and,
  - (2) For each bulk fertilizer stored at the facility, a complete copy of the storage container labeling required by these rules and the labeling required under \_\_\_\_\_ to accompany

sale of the fertilizer; and,

- (3) An identification, by location, of every storage container located at the storage facility, and the type of bulk fertilizer stored in each storage container; and,
  - (4) For each type of bulk fertilizer stored at the facility, the procedures to be used in controlling and recovering, or otherwise responding to a discharge; and,
  - (5) Procedures to be followed in using or disposing of a recovered discharge.
- (b) The operator shall keep the plan required in Rule 5(a) current at all times.
  - (c) A copy of the plan required in Rule 5(a) shall be kept readily available at the storage facility and at the nearest local office from which the storage facility is administered, and shall be available for inspection and copying by the control official or his agent.
  - (d) The operator of the storage facility shall inform the local fire and police departments, and the State Department of Environmental Management, of the existence of the plan required in Rule 5(a) and shall provide a current copy of the plan to the local fire and police departments and the State Department of Environmental Management.

## 6. Record Keeping

### (a) Records Required to be Maintained.

- (1) A record of all discharges at the storage facility, including the date and time of discharge, the type of fluid bulk fertilizer or dry bulk fertilizer discharged, the volume of the discharge, the cause of the discharge, any action taken to control or recover the discharge, and the method of use or disposal of any recovered discharge. The discharge record shall be completed on the day the discharge is discovered, and shall be promptly updated to show measures taken to control, recover, use or dispose of the discharge.
- (2) A regular record of the fluid fertilizer levels in each storage container. The level in each storage container shall be measured and recorded at least weekly.
- (3) A semi-annual inventory reconciliation, showing the amount of fluid bulk fertilizer and of dry bulk fertilizer from each storage container which is lost or unaccounted for at the end of each semi-annual period.
- (4) Inspection and maintenance records pertaining to storage containers, appurtenances, operational area containment, and secondary containment facilities, as required by these rules.
- (5) A record of abandoned underground containers, if any, as provided for in these rules.

### (b) Period Required for Maintenance of Records.

- (1) Records required under Rule 6(a) shall be maintained for at least 5 years.
- (2) Records required under Rule 6(a)(5) shall be maintained as permanent records.
- (3) All other required records shall be maintained for at least 3 years.
- (4) Records shall be available for inspection and copying by the control official or his agent.

(Tentative 1989)

## Ammonium Nutrition Increases Nitrogen Efficiency and Protects Groundwater

*Allen Sutton*

**Agrico Chemical Company**

Agrico Chemical Company has devoted considerable time, effort and research to this challenge over the past 10 years. Our work has been directed at modifying nitrogen solution (UAN) and urea fertilizers to facilitate ammonium nitrogen nutrition and to increase nitrogen uptake efficiency and reduce the amount of nitrate nitrogen exposed to groundwater.

The company's initial work was launched to explore ways to reduce the amount of nitrate nitrogen exposed to loss from UAN and urea fertilizers. Although nitrogen excels other fertilizers. Although nitrogen excels other fertilizer elements in uptake efficiency, there are 5 well documented avenues of nitrogen loss. These include nitrogen loss to the crop by immobilization, erosion, denitrification, leaching and ammonia volatilization, most nitrogen is lost when it is in or when it reaches the nitrate nitrogen form. Like legions of others who have conducted research in this field, our work started with review and study of a host of nitrification inhibitors, urease inhibitors, slow release products, organic nitrogen materials and selected N-P and N-S compounds. It was our objective to find products or product combinations that could be surface-applied without loss of effectiveness. We also searched to find combinations and effective application rates that might prove economical feasible for field crop use. Dow chemical company's N-SERVE is the only nitrification inhibitor that has made significant penetration into the field crop market.

An added direction was given to our work during the mid-1980's. The promise that enhanced ammonium nitrogen feeding could add yield potential presented a two-goal approach to Agrico's research. The goals were (1) to slow the conversion of ammonium nitrogen to nitrate nitrogen and (2) to facilitate ammonium nitrogen nutrition. Obviously, if these two goals could be attained a more responsive nitrogen fertilizer that was environmentally safer would result.

There is growing evidence that a predominantly nitrate nitrogen environment in the root zone is not ideal for maximizing growth and yield. Doctor Sterling Olsen of Colorado State University presented a paper in 1985 entitled "The Role of Ammonium Nutrition in Higher Yields". He concluded, "yield (corn) increases from 12 to 36 bushels per acre were obtained from treatment that increased the amount of available N in the NH<sub>4</sub> form". ATVA newsletter stated "in a recent greenhouse experiment, research soil chemist Bert Bock compared spring wheat fertilized only with nitrate with wheat fertilized with nitrate plus ammonium to which a nitrification inhibitor had been added. With the latter, the yield

plateau rose by a very impressive 45 percent." Research by Olsen, Bock and others point to the importance of finding ways to deliver at least part of the nitrogen as ammonium nitrogen during the critical grain-filling period.

In our search for nitrification inhibitors, Doctor Roland Hauck and others at TVA plus a number of university workers directed our attention to dicyandiamide (DCD). DCD has been studied as both a slow release nitrogen and as a nitrification inhibitor since the early 1900's. Although yield response has varied, some DCD research has been extremely impressive. Work by Doctor G. Malzer at the University of Minnesota serves as a highlight of positive DCD research. Agrico workers were also impressed by SKW sponsored research at the Soil Technology Institute, Bremen, Germany. This long time lysimeter study has shown that nitrate in groundwater can be significantly reduced by incorporating DCD with nitrogen fertilizers could enhance yield and reduce the amount of nitrate nitrogen exposed to groundwater loss made it a logical choice as one ingredient in Agrico's formulation. DCD could be surface-applied without fear of lost effectiveness. It's major drawback, in our judgement, centered around the rate necessary for effective action. Most of the original research was conducted with DCD as 10 percent of the total nitrogen rate. At this rate DCD had cost limitations for most field crops.

Our work was concentrated on developing formulations with rates of DCD less than 10 percent and screening other compounds that might add to effectiveness and/or provide synergistic action. More recent work by Doctor R. J. Goos and others at North Dakota State University has helped to confirm our approach. Dicyandiamide (DCD) and ammonium thiosulfate (ATS) form the core of a host of compounds we have used in our formulations. A number of nitrification inhibitors, urease inhibitors, phosphate compounds and organic nitrogen materials have been used in trial formulations. Our interest was to select several materials rather than selecting a single compound. An example of early research that convinced Agrico workers there could be synergistic action was conducted by Midwest Research Farms, York, NE.

N Source	N Rate lbs/N/A.	Corn Yield BU./A/
UAN	140	156
UAN + DCD + ATS	140	159
Agrico Super N	140	167

Agrico's formulations for modifying nitrogen fertilizer behavior have been given the following brand names-Super N (28% UAN nitrogen solution), Super N plus (UAN nitrogen solution with 28% N and 4% S) and Super U (46% urea). All three products have essentially the same modifying formulation based on the nitrogen percentage. Research and comparisons with these 3 products over the past 5 years have demonstrated that these formulations with UAN and Urea can alter nitrogen

behavior in several ways:

- To hold N in the ammonium nitrogen form longer
- To enhance ammonium nitrogen nutrition
- To reduce nitrate nitrogen exposed to loss
- To increase N efficiency and crop yield
- To provide economic nitrogens on a cost/benefit basis

Research studies involving Super N (Virginia, 1989) and Super U (Ohio, 1988) indicate that the products are holding in the ammonium nitrogen form longer. Since yields were higher, one could assume that the super products may have contributed to greater uptake of ammonium nitrogen and/or have had less nitrogen loss as nitrate nitrogen. (Figure 1 & Figure 2).

A greenhouse study conducted by the University of Florida also provides evidence that the modified Agrico urea has less nitrogen exposed to leaching loss. Super U was compared to standard urea and sulfur coated urea (SCU) in this trial.

Features that deliver agronomic as well as environmental benefits are obviously of paramount importance. Such features and the resulting benefits have guided our work. Yet the acid test in a commercial enterprise revolves back to economics. Are such products viable on a cost/benefit basis? With hundreds of yield comparisons over the past 5 years, we conclude that the answer is yes. On the average at a 140 lb. N rare on corn has produced a yield increase of 9 BU/A. At an added cost of 6 cents per pound of N, equating to \$8.40 per acre has produced \$22.50 in added return (at \$2.50 per BU). We feel confident that products of this type have agronomic, environmental and economic benefits. (Figure 3).

As control officials, we know you are confronted with a docket of questionable fertilizer products. We also recognize that we are dealing with a field of plant nutrition science that is rarely predictable. We know, for example, that corn hybrids vary in their response to such products and to ammonium nitrogen nutrition. The table below serves as an example of how response typically varies by the hybrid selected. (Figure 4).

Someone once said "I would rather see a crooked furrow than a field unplowed." Progress always involves risk. It's hard to steal second base if you keep your foot on first. We are not so naive to think the ultimate has been found in nitrogen fertilizers of this type. However, we do believe that we have found the closest thing to it.

Figure 1.

Super N Increases Soil NH <sub>4</sub> Nitrogen and Corn Yields				
Yield (Bu/A)	NO <sub>3</sub>	UAN	Super N	
		<u>136</u> NH <sub>4</sub>	NO <sub>3</sub>	<u>148</u> NH <sub>4</sub>
Soil Test				
0-12'	31	12	31	34
12-24"	31	8	23	11
24-36"	25	6	20	8
Ave. 3 reps - silking stage				
Wrightsboro fine sandy loam				
Nitrogen rate - 85# in sidedressed				
VA. - 1989				

Figure 2.

Super U Increases Corn Yield - Holds In The Ammonium Nitrogen Form Longer		
YIELD PER ACRE AND PERCENTAGES OF NITRATE AND AMMONIUM NITROGEN FOUND AT 3 TO 7 WEEKS		
NITROGEN SOURCE YIELD (BU/A)	UREA	SUPER U
	124	148
SOIL TESTS AT 3 WEEKS		
SOIL NH <sub>4</sub> -N	34	42
SOIL NO <sub>3</sub> -N	17	13
SOIL TEST AT 7 WEEKS		
SOIL NH <sub>4</sub> -N	14	20
SOIL NO <sub>3</sub> -N	14	13
Corn - Washington Court House, Ohio - 1988		
Nitrogen rate @ 105#/A		

Figure 3.

AGRICO DEALER COMPARISONS PLOTS THREE-YEAR SUMMARY OF YIELD INCREASE SUPER N VS. UAN ON CORN			
SURFACE APPLIED	PRE-PLANT INCORPORATED	SIDE DRESS	3-YEAR AVERAGE YIELD INCREASE OVER UAN
1986 + 9.4 BU/A	+7.1 BU/A	+12.3 BU/A	+9.6 BU/A
1987 + 9.6 BU/A	+9.1 BU/A	+11.5 BU/A	+10.4 BU/A
1988 + 5.9 BU/A	+11.9 BU/A	+5.6 BU/A	+7.8 BU/A
3-YEAR SUMMARY			
+8.3 BU/A (117 COMPARISONS) (AVG. 146# N/A)	+9.3 BU/A (52 COMPARISONS) (AVG. 154# N/A)		+9.8 BU/A (35 COMPARISONS) (AVG. 147# N/A)

Figure 4.

CORN YIELD (BU/A) AND CORN GRAIN MOISTURE % AS AFFECTED BY HYBRID AND N SOURCE				
Hybrid Code	N SOURCE		N SOURCE	
	UAN	SUPER N	UAN	SUPER N
1	145.6	158.8	22.8	21.8
2	155.1	158.1	21.5	18.9
3	160.4	164.8	23.7	21.4
4	161.1	172.0	21.8	20.9
N Source Avg.	155.6	163.4	22.4	20.8



## Gypsum Avoidance—Single Superphosphate Revisited

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State and Federal environmental regulating agencies, as well as some private environmental groups, have become concerned about the phosphoric acid industry's practice of disposing of by-product gypsum by the stacking method. The level of concern is such that some regulators have proposed a moratorium on the permitting of new gypsum stacks. As a consequence, there is concern that phosphoric acid producers will have to find alternate methods of producing phosphate if the permits on existing stacks expire. Such a moratorium could result in the closing of all U.S. phosphoric acid plants. The U.S. phosphate industry currently exports about 50% of its production capacity and supplies the domestic market with 4 million tons of  $P_2O_5$  phosphate annually.

The National Fertilizer & Environmental Research Center (NFERC) at TVA has responded to this issue by undertaking studies aimed at estimating the cost of phosphate fertilizers if the production of by-product gypsum is banned. Researchers at TVA are studying low-cost technologies that produce phosphate fertilizers without producing by-product gypsum. These fertilizers avoid gypsum by incorporating calcium within the product. Products being considered include single superphosphate (SSP), ammoniated single superphosphate (ASSP), triple superphosphate (TSP) with granulation of by-product gypsum and a granular nitric phosphate. The granular nitric phosphate is produced in a modified rotary-drum granulation plant. We refer to this product as environmentally benign phosphate fertilizer (EBPF).

The purpose of this study is to estimate the cost of producing and distributing fertilizers based on these technologies. Results of this work are intended to be useful in evaluating the economic impact of regulatory policy on the phosphate industry. The results of this study could be used to (1) estimate added cost if gypsum avoidance is mandated, (2) provide an evaluation of gypsum avoidance options, and (3) estimate the price at which phosphate could be imported.

Table 1 is a list of the products considered in this study. As discussed below, the production and distribution costs are determined for each of the products and these costs are compared with the equivalent diammonium phosphate (DAP) and DAP/urea products.

Process descriptions are provided for the following products:

- Single superphosphate
- Ammoniated single superphosphate
- Environmentally benign phosphate fertilizers

- Granular gypsum from a TSP plant.

Descriptions for the DAP and TSP processes are available in texts such as *The Fertilizer Manual* by T. P. Hignett.

### Single Superphosphate

Single superphosphate can be produced by a combination of existing technologies in a continuous system. The processing sequence (Figure 1) would be:

- (1) Mixing of ground rock and sulfuric acid
- (2) Denning the acidulate to increase phosphate conversion
- (3) Granulating
- (4) Drying
- (5) Screening
- (6) Recycling crushed oversize and undersize

For this study, the TVA cone mixer is used in the mixing step, the Broadfield Den in the denning step, and the TVA rotary granulator in the granulation step. A slight excess of sulfuric acid and fine grind of phosphate rock is used to enhance  $P_2O_5$  conversion. The undersize and crushed oversize from the screens are recycled to the granulator. In addition to phosphate, the granular product contains substantial quantities of three secondary nutrients—calcium, sulfur, and magnesium.

### Ammoniated Single Superphosphate

Ammoniated single superphosphate (Figure 2) can be produced in a SSP plant by ammoniating in the granulator drum. TVA has extensive experience in ammoniation-granulation. The reasons for making AASP are to increase the nutrient content of the product and to improve product physical properties.

### Environmentally Benign Phosphate Fertilizer (6-18-0)

The 6-18-0 EBPF product can be made as shown in (Figure 3) by adding equipment to the rotary drum granulation system to continuously acidulate phosphate rock with nitric acid. The acidulate from the nitric acid-rock reactor flows to the granulator along with the fresh superphosphate from the den and ammonia is added under the bed in the granulator. The other steps (drying, screening, and recycling) are the same as would be carried out in production of granular SSP, but a supplemental step of product cooling might be required to prevent caking in storage. The granular product consists of ammonium nitrate, monocalcium phosphate, and dicalcium phosphate. The product can be formulated by controlling the amount of monocalcium phosphate to provide  $P_2O_5$  water solubility in the range of 40 to 50% of the total  $P_2O_5$ . This process requires only about 0.3 tons of sulfur per ton of product  $P_2O_5$  as compared with about 1.0 ton of sulfur per ton for ammonium phosphate products.

### Environmentally Benign Phosphate (13-13-0 and 14-14-0)

The flow configuration for 13-13-0 and 14-14-0 EBPF is the same as shown for 6-18-0 EBPF (Figure 3) except that more ammonia and nitric acid would be added to the process.

#### Granulation of Gypsum

(Figure 4) shows an improved process that has been developed by TVA for economically and effectively granulating solid, finely divided, particulate feedstock comprising phosphogypsum, sulfogypsum, and natural or mineral gypsum. Products produced by the process exhibit excellent physical and chemical properties relative to dustiness, storage, and handling. Also, when the granules come into contact with moist soil or water, they rapidly disintegrate to substantially their original ungranulated, fine particle size for realizing and effecting maximum crop response or other utilization. The granulation process involves introducing the finely divided feedstock, together with recycle material, into a rotary drum where granulation is effected with use of a relatively small amount of a granulation aid.

New plants for the process described previously were assumed to be constructed on a Louisiana waterway that has suitable rail, barge, and highway facilities. Costs are in December 1988 dollars. The Chemical Engineers index used in this study is 342.5. In order to make comparisons on a common basis, the production rate for all phosphate plants was set at 350,000 tons of  $P_2O_5$  per year. (Table 2) is a list of the assumptions used in determining the capital investments. A construction time of 2 years has been assumed for construction. A 50-50 debt to equity ratio is assumed with borrowed capital at 10% and equity capital at 20%. Depreciation is for a fifteen year period or 6.7%. (Table 3) is a list of the costs for raw materials, utilities, services and transportation.

The capital costs are summarized in (Table 4). The lowest capital investment is for SSP. The facilities for producing SSP are less costly than for DAP primarily because a phosphoric acid plant is not required and because a smaller sulfuric acid plant is required. The production costs are summarized in (Table 5). The grades of the various products are different and cost comparisons need to be made on a unit nutrient basis. Before making these comparisons we need to determine the costs of distribution.

The delivered cost per unit nutrient is higher for the lower grade fertilizer, so comparisons of costs need to be on a delivered basis. In this study 350,000 tons of  $P_2O_5$  is produced and distributed from a single producer near New Orleans, Louisiana. The fertilizer is transported by barge to terminals up the Mississippi River system into the Midwest. The fertilizer is stored at the terminals for an average of 2 months, and then shipped by truck to fertilizer dealerships 200 miles away. The barge/truck transportation system provides for the movement of fertilizer to 17 states (Figure 5). About 2.4 million tons of phosphate fertilizer is consumed in these states.

The 350,000 tons in this study represents about 15% of the tonnage in this market. The cost of distribu-

tion including transportation in this scenario is \$26.18/ton. (Table 6) summarizes the total plant investment requirements for the phosphate plant complexes.

(Table 7) shows the delivered costs in dollars per unit nutrient when distribution cost is added to the production costs. In order to make comparisons two sets of delivered costs are presented. First are presented the delivered costs of each of the phosphate products. Following that is the delivered costs of blends of each of these products with urea. The blends are formulated to produce 1-1-0 grades.

When comparing either the phosphate products or the 1-1-0 grades, the delivered per-unit-nutrient costs of the DAP and TSP products are lowest of all the products. This was expected. What was not expected is that the delivered cost of the other products are not much higher (generally less than 10%) than the DAP and TSP products. If environmental regulations limit our ability to produce DAP and TSP, costs will increase somewhat, but our domestic needs for phosphates can be supplied by SSP, ASSP, and EBPF type products. The largest impact on the manufacturer, dealer, and farmer will be the necessity to produce and distribute about twice the total tons of material to furnish the consumer with the same amount of plant materials now used.

**Table 1. Fertilizers for Which Production Costs are Estimated in This Report**

Product	Grade
Diammonium phosphate (DAP)	18-46-0
Triple superphosphate (TSP)	0-46-0
Single superphosphate (SSP)	0-20-0
Ammoniated single superphosphate (ASSP)	3-19-0
Environmentally benign phosphate fertilizer (EBPF)	6-18-0
Environmentally benign phosphate fertilizer (EBPF)	13-13-0
Environmentally benign phosphate fertilizer (EBPF)	14-14-0
Urea	46-0-0
Granular gypsum from TSP	0-0-0

**Table 2. Basis for Investment Cost**

Item	Value
Startup allowance (% of plant investment)	5
Cost of construction capital (% of plant investment)	20
Spare parts (% of plant investment)	2
Average capital investment	
Portion of total depreciable capital	0.53
Portion of spare parts and land	1.00
Portion of total working capital	1.00
Depreciation (% of total depreciable capital)	6.7
Insurance and taxes (% of capital investment excluding working capital)	2.5
Interest (% of average capital investment)	10
Pretax return on investment (ROI) for in-house capital (% of average capital investments)	20
Borrowed capital (% of average capital investment that is borrowed)	50
Working capital variables	
Days raw material purchases are carried	30
Days operating costs are carried	90
Days depreciation costs are carried	90
Days insurance and taxes are carried	90

**Table 3. Basis for Operating Costs**

<b>Raw Materials</b>	
Ammonia, \$/ton	108.19
Urea, \$/ton	129.44
Phosphate rock, \$/ton rock	30.00
Sulphur, \$/ton	95.00
Calcium LS, \$/ton	94.10
<b>Natural gas</b>	
Price, \$/MSCF	1.85
Heat content, mm-Btu/MSCF	1.00
<b>Reagents / catalysts prices</b>	
For DAP plant, \$/ton	0.58
For TSP plant, \$/ton	0.38
For phosphoric acid plant, \$/ton P <sub>2</sub> O <sub>5</sub>	0.98
For sulphuric acid plant, \$/ton H <sub>2</sub> SO <sub>4</sub>	0.28
For nitric acid plant, \$/ton HNO <sub>3</sub>	2.04
<b>Service / utilities prices</b>	
Labor cost, \$/man hour	16.00
Electricity, \$/Kwh	0.04
Cooling water, \$/m-gal	0.04
Process water, \$/m-gal	0.15
Boiler feed water, \$/m-gal	1.30
Energy content of steam, mm-Btu/m-lb	1.0
<b>Gypsum disposal</b>	
Operating cost, \$/ton gypsum	0.38
Pile closer cost, \$/ton gypsum	0.55
Tons gypsum/ ton phosphoric acid as P <sub>2</sub> O <sub>5</sub>	5
Analysis (% of direct labor)	10
Supplies (% of maintenance)	20
Plant overhead (% of direct labor)	75
General sales and administration charge, \$/ton	10.00
<b>Average freight cost</b>	
From plant to barge terminal, \$/ton	10.18
From barge terminal to dealer, \$/ton	16.00
From plant to dealer, \$/ton	26.18

Table 4. (per 1,000)

<b>Capital Requirements for Phosphate Plant Complexes</b>								
<u>Investment \$</u>	DAP	TSP	SSP	ASSP	EBPF	EBPF	EBPF	Granular gypsum
	<u>(18-46-0)</u>	<u>(0-46-0)</u>	<u>(0-20-0)</u>	<u>(3-19-0)</u>	<u>(6-18-0)</u>	<u>(13-13-0)</u>	<u>(14-14-0)</u>	
Depreciable capital investment								
Plant investment								
Battery limits	102,585	82,060	066,430	67,399	85,763	138,773	133,998	31,324
Storage: Production & Materials	18,494	12,990	021,796	25,390	31,011	44,489	42,810	12,512
Offsites	68,977	54,774	017,184	23,562	17,422	38,027	36,696	8,050
Start-up allowance	9,503	7,488	005,270	5,509	7,017	11,064	10,676	2,594
Cost of construction capital	<u>28,507</u>	<u>22,462</u>	<u>015,813</u>	<u>16,531</u>	<u>21,051</u>	<u>33,196</u>	<u>32,026</u>	<u>7,782</u>
Total depreciable capital	228,066	179,693	126,493	132,251	168,404	265,594	256,206	62,262
Nondepreciable capital investment								
Working capital								
Raw materials purchased								
Ammonia	1,620	0	0	668	1,463	4,177	4,177	0
Sulfur	2,691	1,818	1,603	1,603	1,225	1,226	892	0
Phosphate rock	3,289	3,152	3,064	3,064	2,976	2,978	2,968	0
Calcium LS	0	0	0	0	0	0	0	705
Reagents	94	63	14	14	61	153	150	0
Product inventory	23,082	15,098	14,043	16,047	17,176	25,600	24,560	2,113
Operating cost and production loss	7,172	6,830	5,338	5,592	7,847	12,691	12,295	3,095
Depreciation	4,187	3,269	2,387	2,491	3,104	4,840	4,651	1,104
Insurance & taxes	1,587	1,239	905	946	1,177	1,835	1,764	419
Spare parts	<u>3,802</u>	<u>2,995</u>	<u>2,109</u>	<u>2,206</u>	<u>2,807</u>	<u>4,427</u>	<u>4,270</u>	<u>1,038</u>
Total nondepreciable capital	47,524	34,464	29,463	32,631	37,836	57,927	55,727	8,474
<b>Total capital investment</b>	<b>275,590</b>	<b>214,157</b>	<b>155,956</b>	<b>164,882</b>	<b>206,240</b>	<b>323,476</b>	<b>311,933</b>	<b>70,736</b>

Table 5.

Production Costs for Phosphate Plant Complexes									
Production cost \$/ton product	DAP (18-46-0)	TSP (0-46-0)	SSP (0-20-0)	ASSP (3-19-0)	EBPF (6-18-0)	EBPF (13-13-0)	EBPF (14-14-0)	Granular gypsum	
<b>Direct Production cost</b>									
<b>Raw materials</b>									
Ammonia	24.13	0	0	4.18	8.63	18.39	19.35	0	
Sulfur	40.24	27.09	10.41	10.01	7.22	5.40	4.13	0	
Phosphate rock	49.19	46.96	19.91	19.15	17.54	13.12	13.74	0	
Calcium LS	0	0	0	0	0	0	0	7.53	
Reagents	1.41	94	9	9	36	67	69	0	
Subtotal, raw materials	114.97	74.99	30.42	33.42	33.75	37.58	37.91	7.53	
<b>Operating cost</b>									
Direct labor	3.94	3.74	2.19	2.19	3.23	3.97	4.03	1.72	
Maintenance	15.21	11.64	3.48	3.48	3.78	4.10	4.10	2.62	
Supervision	59	56	33	33	48	60	60	26	
Electricity	4.57	4.32	1.66	1.66	3.06	4.66	4.81	1.42	
Cooling water	53	36	9	9	21	36	37	0	
Process water	14	11	60	60	60	60	60	0	
Boiler feed water	55	37	14	14	15	19	18	0	
Steam production	-08.73	-06.15	-02.40	-02.31	-02.59	-03.10	-02.96	0	
Fuels	4.81	5.13	1.23	1.22	1.19	1.14	1.10	1.78	
Analysis	39	37	22	22	32	40	40	17	
Operating supplies	3.04	2.33	70	70	76	82	82	52	
Gypsum disposal operating cost	.90	.61	0	0	0	0	0	0	
Gypsum disposal pile closure cost	1.30	1.02	0	0	0	0	0	0	
Plant overhead	2.96	2.81	1.65	1.64	2.42	2.98	3.02	2.18	
Subtotal operating cost	30.22	27.22	9.89	9.94	13.62	16.72	17.07	10.66	
Production loss	0	2.78	89	95	1.08	1.28	1.30	36	
Subtotal, direct production cost	145.19	104.99	41.21	44.32	48.44	55.59	56.28	18.55	
<b>Capital cost</b>									
Depreciation	21.38	16.78	4.86	4.88	5.86	6.92	7.01	3.93	
Insurance & taxes	8.10	6.37	1.85	1.85	2.23	2.62	2.66	1.49	
Interest	11.68	8.97	2.77	2.84	3.31	3.86	3.91	1.96	
Pretax return on investment	23.35	17.93	5.54	5.66	6.61	7.72	7.83	3.91	
Credit	0	0	0	0	0	0	0	0	
Subtotal capital cost	64.51	50.06	15.01	15.23	18.01	21.12	21.41	11.29	
Total cost, production and capital	209.70	155.04	56.22	59.55	66.45	76.71	77.69	29.85	
<b>General</b>									
Sales and administration	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	
Exit gate cost	219.70	165.04	66.22	69.55	76.45	86.71	87.69	39.85	
Freight	26.18	26.18	26.18	26.18	26.18	26.18	26.18	26.18	
Delivered cost	245.88	191.22	92.40	95.73	102.63	112.89	113.87	66.03	

Table 6.

<b>Plant Investment Requirements for Phosphate Plant Complexes</b>								
Investment \$	DAP (18-46-0)	TSP (0-46-0)	SSP (0-20-0)	ASSP (3-19-0)	EBPF (6-18-0)	EBPF (13-13-0)	EBPF (14-14-0)	Granular gypsum
<b>Plant investment</b>								
<b>Processing plant battery limits</b>								
Granulation plant	24,094	26,647	43,749	44,678	46,880	62,627	60,993	31,324
Phosphoric acid plant	40,310	32,106	NA	NA	NA	NA	NA	NA
Sulfuric acid plant	34,397	20,763	19,176	19,176	16,229	16,238	13,380	NA
Nitric acid plant	NA	NA	NA	NA	19,303	56,180	56,193	NA
Steam plant	3,784	2,544	3,505	3,545	3,351	3,728	3,432	NA
Subtotal, battery limits	102,585	82,060	66,430	67,399	85,763	138,773	133,998	31,324
<b>Storage facilities</b>								
Granulation plant	13,579	8,978	20,577	24,171	25,937	36,104	34,596	12,512
Phosphoric acid plant	3,277	2,621	NA	NA	NA	NA	NA	NA
Sulfuric acid plant	1,638	1,310	1,219	1,219	1,046	1,047	873	NA
Nitric acid plant	NA	NA	NA	NA	4,028	7,338	7,341	NA
Subtotal, storage & facilities	18,494	12,909	21,796	25,390	31,011	44,489	42,810	12,512
<b>Offsites</b>								
Granulation plant	6,578	7,275	10,806	11,034	12,797	17,096	16,652	8,050
Phosphoric acid plant	51,596	40,912	NA	NA	NA	NA	NA	NA
Sulfuric acid plant	9,838	5,938	5,484	5,484	4,641	4,644	3,827	NA
Nitric acid plant	NA	NA	NA	NA	5,270	15,336	15,342	NA
Steam plant	965	649	894	904	854	951	875	NA
Subtotal, offsite	68,977	54,774	17,184	17,422	23,562	38,027	36,696	8,050
Start-up allowance	9,503	7,488	5,270	5,509	7,017	11,064	10,676	2,594
Cost of construction capital	28,507	22,462	15,813	16,531	21,051	33,196	32,026	7,782
<b>Total plant investment</b>	<b>228,066</b>	<b>179,693</b>	<b>126,493</b>	<b>132,251</b>	<b>168,404</b>	<b>265,549</b>	<b>256,206</b>	<b>62,262</b>

Table 7.

Cost of Products and Blends on a Per Unit Nutrient Basis							
Production cost	DAP (18-46-0)	TSP (0-46-0)	SSP (0-20-0)	ASSP (3-19-0)	EBPF (6-18-0)	EBPF (13-13-0)	EBPF (14-14-0)
Product							
Grade	18-46-0	0-46-0	0-20-0	3-19-0	6-18-0	13-13-0	14-14-0
Actual nutrient contents, units of nutrient	64.00	46.00	20.07	22.47	24.60	27.20	28.60
Delivered cost, \$/ton product	245.88	191.22	92.40	95.73	102.63	112.89	113.87
Delivered cost, \$/unit nutrient	3.84	4.16	4.60	4.26	4.17	4.15	3.98
1-1-0 urea/product blends							
Grade	28-28-0	23-23-0	14-14-0	14-14-0	14-14-0	13-13-0	14-14-0
Actual nutrient content, units of nutrient	57.18	46.00	27.92	28.58	28.97	27.20	28.60
Delivered cost, \$/ton blend	211.70	173.42	111.58	111.26	113.45	112.87	113.87
Delivered cost, \$/unit nutrient a	3.70	3.77	4.00	3.89	3.92	4.15	3.98

\* To maintain a reasonable degree of accuracy, the actual nutrient content is used to calculate per unit nutrient cost.

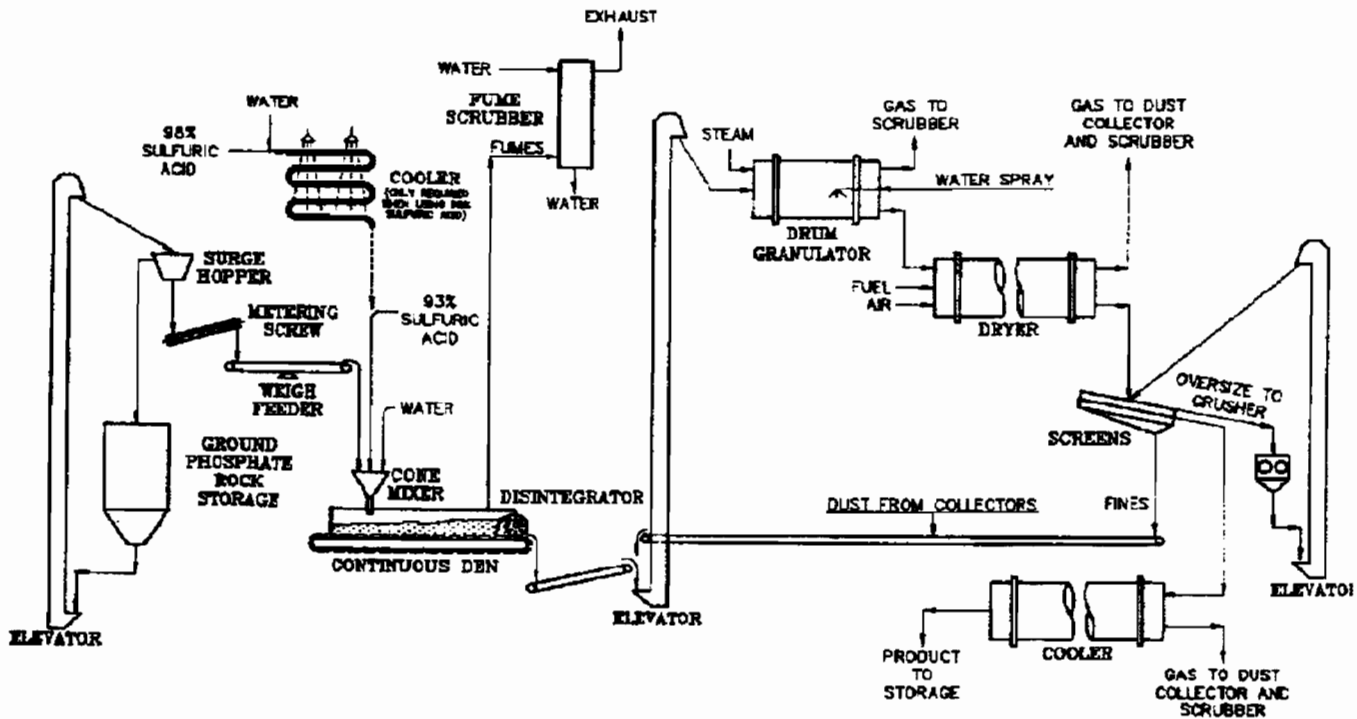


Figure 1.  
CONTINUOUS PROCESS FOR THE MANUFACTURE OF GRANULAR SINGLE SUPERPHOSPHATE

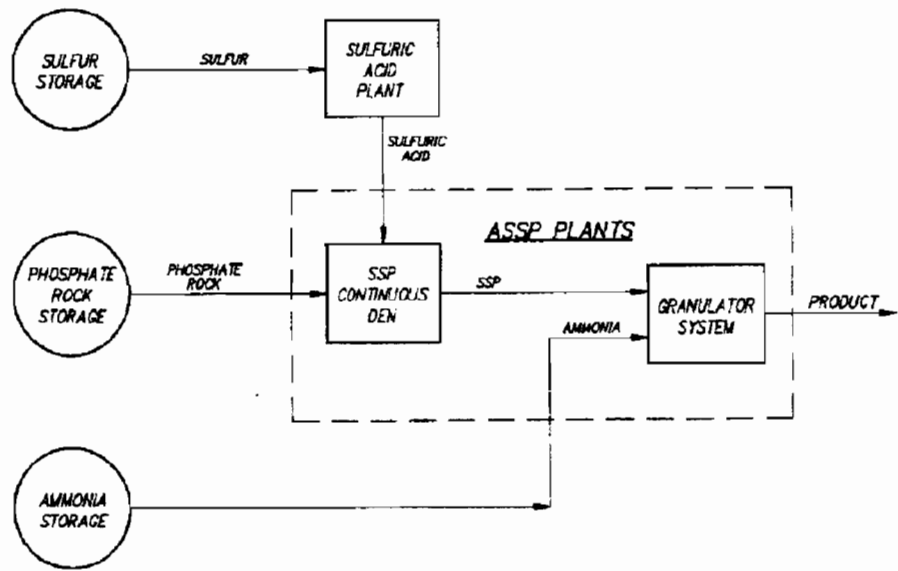


Figure 2.  
FLOWSHEET FOR GRANULAR AMMONIATED SINGLE SUPERPHOSPHATE



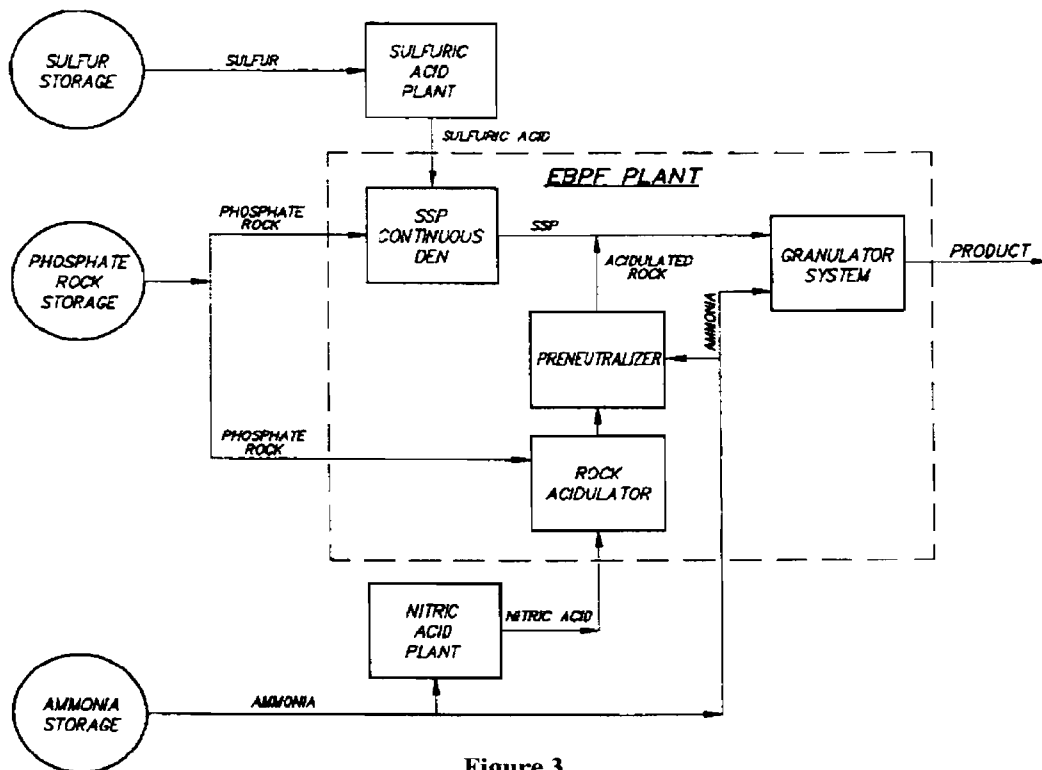


Figure 3.  
FLOWSHEET FOR PRODUCTION OF GRANULAR NITRIC PHOSPHATES

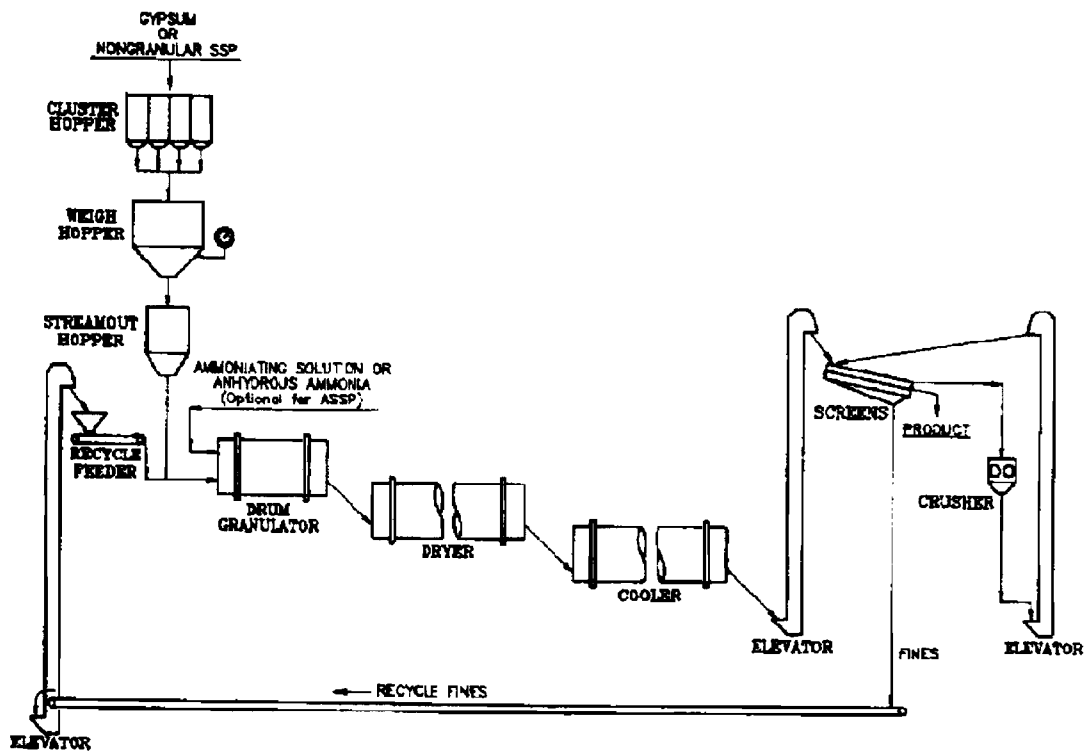


Figure 4.  
FLOW DIAGRAM OF TYPICAL GRANULATION PLANT

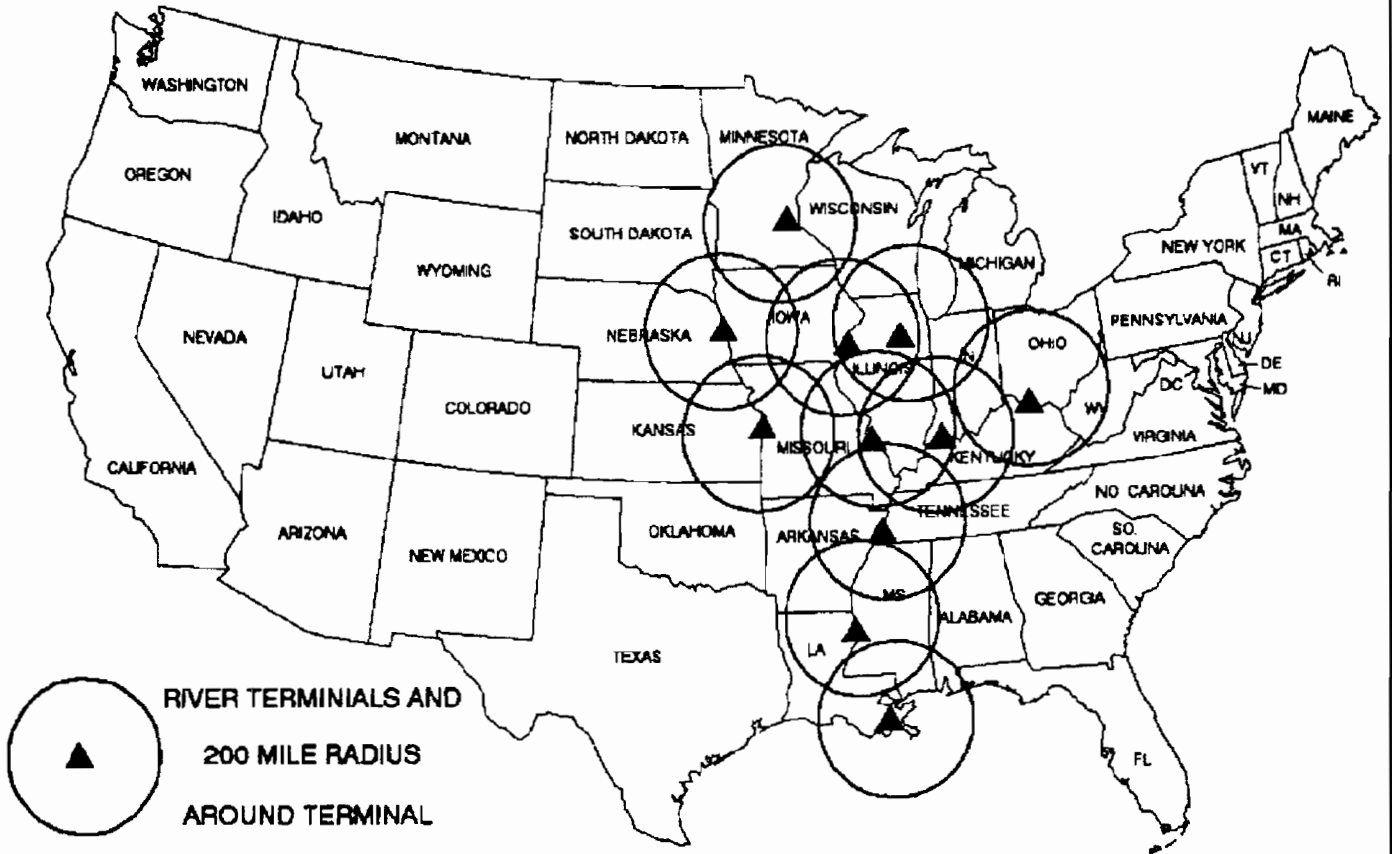


Figure 5.  
 TERMINALS AND DISTRIBUTION AREAS ON THE MISSISSIPPI RIVER SYSTEM

# Phosphate and Potash Update Environmental Challenges and Solutions

G. W. Wallingford  
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Concern about groundwater and surface water contamination with plant nutrients has led to increased scrutiny of the use of commercial fertilizers. Members of the environmental community, for example, often link the increase in fertilizer tonnage over the last several decades to perceived degradation of water quality. They also cite the greater consumption of commercially produced plant nutrients as evidence of their waste and inefficient use.

## *Fertilizer Use Efficiency*

From the environmental standpoint, one of the best measures of efficiency is the ratio of food produced to quantity of inputs expended. While U.S. farmers are indeed using more commercial fertilizer now than they were 30 years ago, the facts clearly show that major improvements have been made in fertilizer use efficiency.

Corn receives more commercial fertilizer than any other crop in the U.S. and nutrient management of this crop rightfully sees the greatest environmental inquiry. (Figure 1) shows that corn yields in the U.S. have continued an upward trend since 1970. Even the droughts of 1983 and 1988 did not hold back the long-term trend toward higher yields. There are many management factors which determine yield, but providing adequate plant nutrients is an essential for a successful high yield program. Fertilizer use increased on corn until the early 1980's when the total pounds of NPK applied to corn began a downward trend, also shown in (Figure 1).

Fertilizer efficiency is the ratio of bushels produced to pounds of fertilizer applied. It can be improved either by increasing the yield or by reducing the amount of fertilizer applied. The trend in (Figure 2) shows clearly that fertilizer efficiency is improving. U.S. farmers in 1986, 1987 and 1989 produced more bushels of corn grain for every pound of fertilizer applied than at any time since record keeping began in the mid-1960's. This is a remarkable achievement considering corn yields have almost doubled since 1964.

Nitrogen use on corn generally increased until the mid-1980's and has declined slightly since while yields continued to increase (Figure 3). The result has been a substantial improvement in N-use efficiency (Figure 4). In 1989 U.S. corn farmers averaged 116/buA using just 127lb/A of N. This produced an efficiency ratio of 0.91 bushels per pound of N applied. Since 1967, the ratio has only exceeded 0.9 in 1986, 1987 and 1989.

Figure 5 shows that P and K use on corn began declining during the early and mid-1980's, respectively,

while yields continued to increase. Unlike N, which must be applied to corn annually in most rotations used in the U.S., P and K needs can be satisfied either by direct application of commercial fertilizer or by allowing the crop to feed from residual supplies already in the soil. U.S. farmers have been taking advantage of residual soil supplies which had been built up on some fields by previous fertilizer and manure applications. This showed up in the steady improvement in the efficiency of P and K use as illustrated in Figure 6.

## *Farmers Are Adopting Best Management Practices*

Improvements in fertilizer use efficiency show clearly that corn farmers are adopting Best Management Practices (BMP's) which help to minimize the potential for off-farm losses of nutrients. BMP's are agronomic practices which have been shown through research to conserve resources, to minimize environmental impacts and to allow profitable farming.

BMPs helping to raise corn yields and improve fertilizer use efficiency include early planting dates, improved hybrids, better weed and pest control, and higher, more uniform plant populations. Nitrogen efficiency has also been improved by BMPs which directly improve plant N uptake or reduce losses from the soil. Examples include using split applications, sidedressing of fertilizer, the use of nitrification inhibitors and careful matching of N rates with expected yield goals.

BMPs affecting P and K use efficiency include soil testing, fertilizer placement and timing of application. Farmers use soil testing to identify soils in greatest need of P and K and those on which applications may be omitted for a year or more without harming yields. Many farmers are also taking advantage of research showing that placement techniques such as the banding of P and K at planting produce yields equivalent to their current practice of broadcasting while allowing for smaller total application rates.

There is a limit, however, to how much further P and K use efficiency can be improved. Many U.S. soils have been depleted of P and K to the point where higher yields cannot be achieved without larger amounts being applied. Reports of visible nutrient deficiency symptoms, for example, became more common during the 1989 and 1990 growing seasons. Yields would have been even higher without this yield-limiting factor. While many fields still have enough left in their "bank account" for continued depletion before plant growth problems occur, it is important that soils be tested regularly to avoid problems. It costs no more to maintain high soil test levels because eventually all of the P and K removed by harvested crops will have to be replaced. Higher soil test levels allow crops to take fuller advantage of better hybrids, optimum growing conditions and improved management.

## *Effect of P and K on N-use efficiency*

Fertilizer nutrients are often lumped together when

considering the environmental impact of farming. This approach is an over-simplification because it omits the effects of interactions between nutrients on fertilizer use efficiency. An example with corn shown in Table 1 demonstrates the importance of balancing nutrients for top yields and optimum nutrient efficiency. Only when adequate amounts of P and K were applied were the highest corn yield and the most efficient use of applied nutrients obtained.

Placement of P in the row has been shown to be the most efficient application method in many situations. Even on soils testing high in P responses to row applications are often found. An example from Wisconsin is shown in Table 2. Note that both the N and P efficiencies were improved significantly as the P rate increased.

#### *Other Agronomic factors affecting fertilizer use efficiency*

Often the most effective way to improve fertilizer use efficiency is through the control of other agronomic factors not directly related to plant nutrition. The goal should be to remove any factor which limits yield. If the yield of a corn crop, for example, is being restricted by late planting the farmer is not making the most effective use of his fertilizer investment and is increasing the chances that residual nutrients not be used by the crop will be lost from the field. Table 3 contains several examples of research illustrating how the improvement of non-fertility management can have a pronounced impact on fertilizer use efficiency.

#### *The value of soil testing*

Soil testing is perhaps the best single BMP for improving fertilizer use efficiency for P and K. Soil testing is also good for the environment in other ways: it conserves limited resources, protects water quality, aids soil conservation, builds natural pest resistance, and identifies yield-limiting factors. Soil testing is an important tool for building profitable, environmentally responsible farming systems and gives farmers the assurance that fertilizer nutrients are being applied for reasons backed by solid science.

Soil testing was originally developed to identify soils which would respond profitably to commercial fertilizer and thus eliminate one of the most common and controllable yield-limiting factors in farming. This remains the primary purpose of soil testing today and is also the most important environmental benefit of soil testing. Unless a farmer can make a reasonable living for his family, his concerns for the environment will not receive a high priority. The prospect of achieving profitability in his farming operation must be an essential part of any environmental action plan.

While soil testing has long been known as a valuable tool for determining the most economical rate of fertilizer, only recently has its value in developing BMP's for environmentally responsible farming been recognized.

Soil testing is similar to a fuel gauge. If the soil is close to running out of nutrients - such as phosphorus or potassium - a soil test tells the farmer it's time to replenish the nutrient supply. If the "tank" is full, he has the option of adding just the nutrients needed by the current crop or waiting until next season before replenishing the soil. By not adding any more fertilizer than necessary he conserves a valuable resource and improves his own production efficiency.

#### *Natural sources of N and P are dominate in the environment*

Nitrogen and phosphorus are the fertilizer nutrients which cause the greatest environmental concern. When N - in the form of nitrate - contaminates water supplies it becomes a human health hazard if the concentrations are high enough. The concern with P relates to its affects on stimulating the growth of algae in lakes and rivers. Potassium has not been found to have any deleterious effects on the environment.

When all plant-available sources of N and P are considered in U.S. cropland, fertilizer represents only 26.6% of the total N and 29.2% of the total P sources (Table 4). When the entire continental U.S. is considered including cropland, the contribution of fertilizer drops to 12.9% for N and 21.6% for P. This shows that natural sources of N and P are dominate in the environment. Attempts to reduce environmental problems associated with N and P are likely to fail if only the sources from fertilizer are targeted.

Commercial fertilizers are the most controllable source of nutrients for crop production. Through careful selection of rates, placement, sources, and timing it is possible to supply nutrients at rates close to the optimum levels to achieve economical and environmental efficiency. By contrast, it is difficult to fine-tune the amount, or the timing, of N release from animal manures, forage legumes, or other types of organic wastes. This difficulty with manure and legumes actually increases the environmental risk - compared to commercial fertilizer - when they are used as the primary source of plant nutrients.

There are many ways in which increased use of commercial fertilizer has had positive impacts on the environment. Examples include:

- Fertilizer has stopped and even reversed the decline in the fertility of our soils. When our soils were first farmed the nutrient levels started down and continued down, only slowed by manure and legumes, until about 1940 when commercial fertilizer came into wide use.
- Fertilizer has reduced sediment runoff, the major vehicle for P transport to streams, by enabling farmers to turn more marginal lands (too wet, too hilly, too erosion prone) into grass or natural cover.
- Fertilizer has allowed multiplying food demands to be met with less environmental impact by

actually reducing the number of acres needed to produce food. Without fertilizer, more land, now valued for its wildlife and recreational uses, would be needed to produce food.

#### *Fertilizer use in the U.S. compared to other countries*

Increased use of commercial fertilizer has allowed the U.S. to remain the world's most dependable food supplier and the dominant provider of food aid. The U.S. compares favorably to other major food producing countries in its ability to produce the most grain from each ton of fertilizer used. Even though the productivity of U.S. agriculture is much higher, the amount of grain produced per ton of fertilizer used is similar to that of China and India and is much higher than that of the Soviet Union (Table 5).

#### *Nutrient balance for the U.S. has turned downward*

A nutrient budget is a balance sheet showing nutrient exports and imports from a farm. Nutrients are exported when plant material or animal products are sold off the farm. Nutrients can be imported in animal feeds, off-farm waste products or commercial fertilizers. For a farm to be sustainable its nutrient budget must balance. If there is a net loss of nutrients, then eventually the farm's soils will be depleted of nutrients and productivity will decline. If there is a net gain of nutrients, which most often occurs on farms with relatively large numbers of livestock, environmental problems can occur due to the accumulation of nutrients in the soil.

The nutrient budget concept can also be applied to U.S. cropland as a whole. (Figure 7) shows the nutrient balance for U.S. crops since 1965. The total removal of nutrients in the harvested portion of the major U.S. crops was subtracted from the amount of nutrients applied in commercial fertilizer. This approach provides a reasonably accurate picture of the trends in nutrient balance over the entire U.S. Shortcomings of this approach include not taking into account the loss of nutrients through soil erosion, not accounting for the reapplication of nutrients in animal manures and crop residues, and the masking of regional differences.

Nitrogen balance has been fairly stable since 1980. Phosphorus balance has turned negative after being positive for most of the 1960's and 1970's. Potassium balance in the U.S. continues to be strongly negative. In 1989, for example, U.S. soils gave up 2.6 million more tons of potassium than they received in commercial fertilizer.

A long-term experiment in Tennessee shows what can happen when farmers allow depletion of soil nutrient levels (Table 6). Where K was left out of the fertilizer program for several years, adding extra increments of K, in a single year, did not return the low-testing soil to the production level of the soil maintained at the higher nutrient level. An average of 52bu/A was lost because the soil was allowed to become depleted of K.

Superior land stewardship and crop management are not achieved in a single year; stewardship is a cumulative process and must be practiced each year to achieve and maintain a productive and profitable cropping system. Judicious use of commercial fertilizer remains an essential component of a good stewardship program.

<sup>1</sup> The historical data shown in Figures 1 to 7 are five-year running averages. The data cited for 1989, for example, are averages of the annual figures for 1989 and the four previous years. Using five-year running averages smooths out yearly variations and makes long-term trends easier to identify and illustrate.

<sup>2</sup> Wallingford, G.W. 1990. U.S. Fertilizer Use Efficiency Near All-Time High. *Better Crops*. Vol 74:4, p. 28-30.

<sup>3</sup> USDA/ERS data analyzed by G.W. Wallingford, PPI

**Table 1. Illinois corn research demonstrates the importance of balanced nutrition for yield and fertilizer efficiency.<sup>1</sup>**

Fertilizer Rate			Grain yield bu/A	Efficiency		
N lb/A	P <sub>2</sub> O <sub>5</sub> lb/A	K <sub>2</sub> O lb/A		N bu/lb N	P bu/lb P <sub>2</sub> O <sub>5</sub>	K bu/lb K <sub>2</sub> O
0	60	90	41	--	--	--
180	60	0	96	.53	1.60	--
180	0	90	111	.62	--	1.23
180	60	90	143	.79	2.38	1.59

**Table 2. Response of corn to row applications of phosphorus (University of Wisconsin).<sup>2</sup>**

P Rate		Corn Yield bu/A	Efficiency	
lb/A	P <sub>2</sub> O <sub>5</sub>		N bu/lb N	P bu/lb P <sub>2</sub> O <sub>5</sub>
0		143	.64	--
35		159	.71	4.54
70		165	.73	2.36

**Table 3. The effects of several production inputs on corn yield and fertilizer use efficiency from various sources.<sup>2</sup>**

Production Factor	Corn Yield bu/A	Efficiency		N Balance Sheet soil applied (-) unused fert. N (+) lb/A	State
		N bu/lb N	P bu/lb P <sub>2</sub> O <sub>5</sub>		
Rotation:					
continuous	105	.88	2.10	+ 14	NC
rotation	120	.96	2.40	-6	
Irrigation:					
without	127	.51	1.02	+85	NJ
with	214	.86	1.71	-28	
Planting date					
late May	132	.66	1.32	+28	IN
early May	163	.86	1.63	-12	
Hybrid selection:					
bottom 5	149	.60	.99	+106	FL
top 5	250	.83	1.67	-25	
Plant population:					
low (12,000)	155	.52	1.44	+39	FL
high(36,000)	231	.96	2.14	-60	
Compaction:					
compacted	123	.62	2.46	+33	IN
not compacted	167	.84	3.34	-17	
pH X P:					
low pH, low P	90	.60	--	+33	WI
high pH, high P	138	.92	1.97	-29	

<sup>1</sup> Wagner, R. E. 1980. Interactions of plant nutrients in a high yield agriculture. Special Bull. No. 1:16. Potash & Phosphate Institute, Atlanta, GA.

<sup>2</sup> Conventional and Low-Input Agriculture. 1989. A White Paper Report. Potash & Phosphate Institute, Atlanta, GA. p. 10.

**Table 4. The major sources contributing soluble, plant-available N and P to U.S. cropland (330 million acres) and to the continental U.S. including cropland (1.9 billion acres).<sup>3</sup>**

<u>Source</u>	<u>U.S. Cropland</u>	<u>Continental U.S.</u>
	Percent	
<b>Nitrogen Source</b>		
Fertilizers	26.6	12.9
Wastes, crop residues	23.5	12.3
Soil N	21.8	30.4
Biological fixation	19.4	29.0
Atmosphere	7.7	14.9
Irrigation	0.1	0.4
<b>Phosphorus Source</b>		
Fertilizers	29.2	21.6
Wastes, crop residues	48.9	33.7
Soil P	17.5	38.2
Feedgrade, industrial P	4.4	6.5

**Table 5. Grain production and fertilizer use in four countries.<sup>4</sup>**

Country	Grain Production million tons	Fertilizer Use million tons	Grain Produced Per Ton of Fertilizer ton/ton
United States	314	17.8	18
China	300	16.9	18
India	137	8.5	16
Soviet Union	202	25.4	8

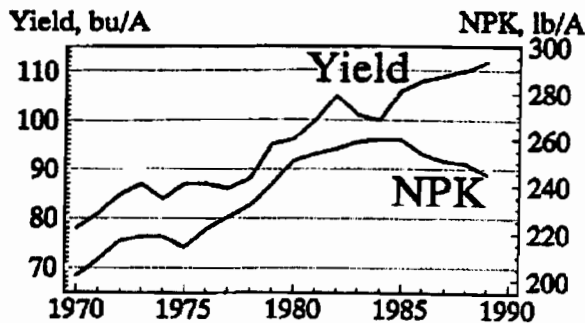
**Table 6. Effects of residual K and rates of added K on corn grain yields (Tennessee).<sup>5</sup>**

K <sub>2</sub> O Applied lb/A	Low-K Soil Test bu/A	Medium-K Soil Test bu/A	Yield Lost bu/A
0	59	136	77
30	95	158	63
60	128	153	25
90	119	162	43
		Average loss	===== 52 bu

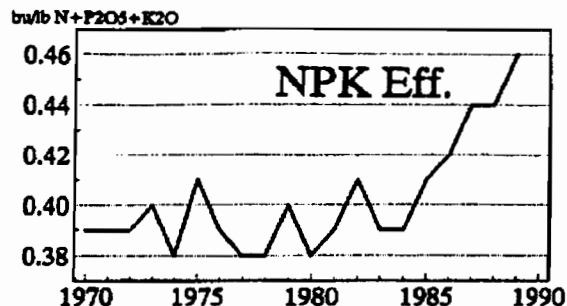
<sup>3</sup> White, W.C. 1990. Uncovering natural sources of N and P. Farm Chemicals. June 1990, p. 26-27.

<sup>4</sup> Brown, L.R. 1990. State of the world 1990. The Worldwatch Institute. W.W. Norton & Co., New York. p. 74.

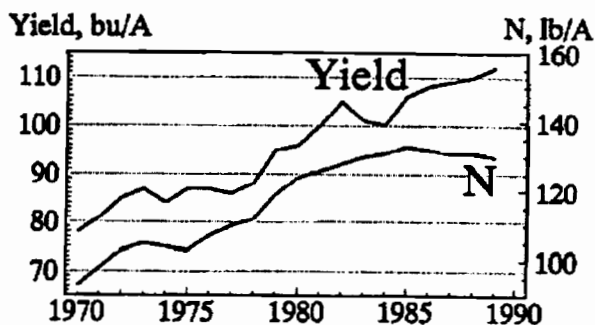
<sup>5</sup> Potash & Phosphate Institute (PPI). 1983. Corn production for maximum profit. p. 56-64. In Maximum Economic Yield Manual. Atlanta, GA.



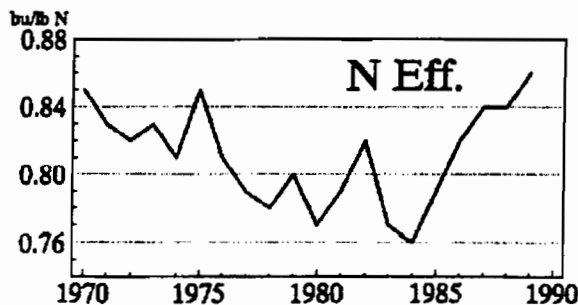
**Figure 1.** Average corn yields (bu/A) and fertilizer rates (lb/A of N+P<sub>2</sub>O<sub>5</sub>+K<sub>2</sub>O) on corn in the U.S. (five-year running averages).



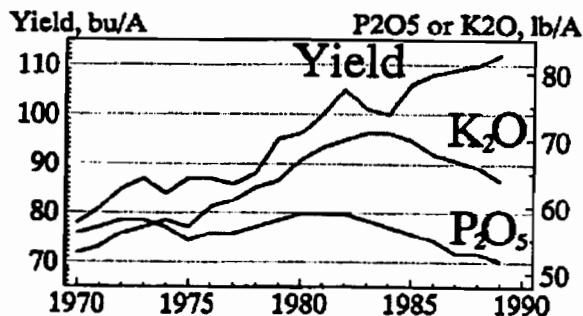
**Figure 2.** Fertilizer use efficiency of U.S. corn grain. Fertilizer use efficiency is the average corn yield (bu/A) in the U.S. divided by the total application rate (lb/A) of N+P<sub>2</sub>O<sub>5</sub>+K<sub>2</sub>O (five-year running averages).



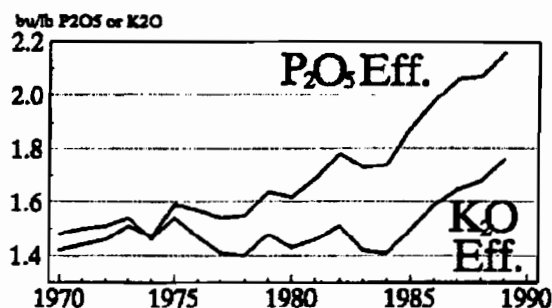
**Figure 3.** Average corn yields (bu/A) and nitrogen application rates (lb/A) on corn in the U.S. (five-year running averages).



**Figure 4.** Nitrogen use efficiency of U.S. corn grain. Nitrogen use efficiency is the average corn yield (bu/A) in the U.S. divided by the application rate (lb/A) of nitrogen (five-year running averages).

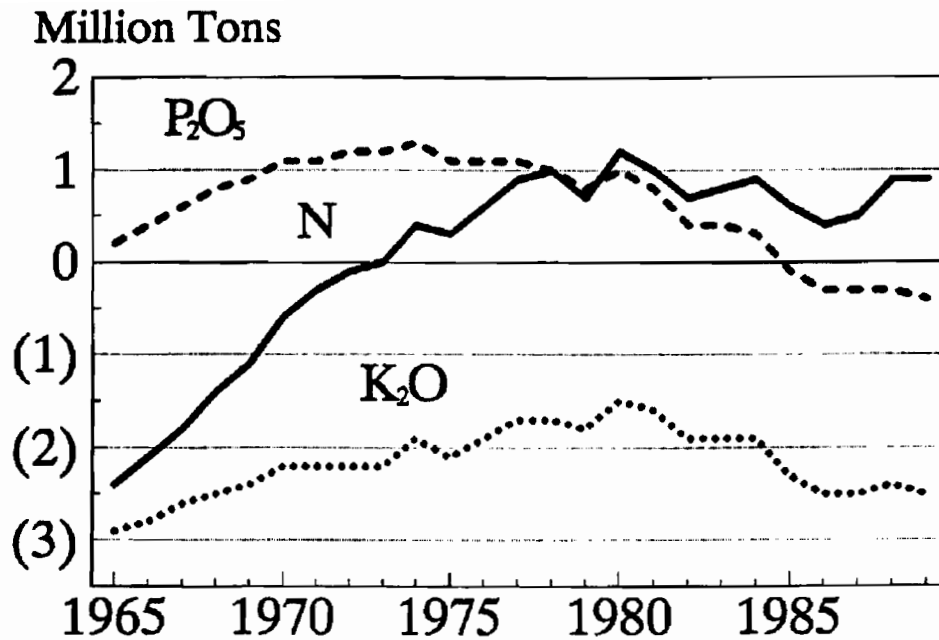


**Figure 5.** Average corn yields (bu/A) and phosphate (P<sub>2</sub>O<sub>5</sub>) and potash (K<sub>2</sub>O) application rates (lb/A) on corn in U.S. (five-year running averages).



**Figure 6.** Phosphate and potash use efficiency of U.S. corn grain. Phosphate and potash use efficiency is the average corn yield (bu/A) in the U.S. divided by the application rate (lb/A) of phosphate (P<sub>2</sub>O<sub>5</sub>) and potash (K<sub>2</sub>O) (five-year running averages).





**Figure 7.** NPK balance for all U.S. crops. The total removal of nutrients (N,  $P_2O_5$ , and  $K_2O$ ) in the harvested portion of the major U.S. crops was subtracted from the amount of nutrients applied in commercial fertilizer (USDA data analyzed by the author).



# Tuesday, November 13, 1990

Session III  
Moderator:

James J. Schultz

## NPK Granulation in Perspective - A Look at Its Past and Future

James J. Schultz

International Fertilizer Development Center

On this 40th Annual Meeting of the Fertilizer Industry Round Table, it is appropriate to reflect back upon the sector of the fertilizer industry that was, perhaps, the most responsible for the Round Table's creation. The sector, of course, was NPK granulation. The great majority of papers presented at the early meetings of the Round Table dealt directly with ammoniation/granulation, the granulation technology used in most of the NPK granulation plants operated in the United States and Europe during the 1950's and 1960's.

The invited speakers for today's session on NPK granulation will focus on a number of agronomic, commercial, marketing, and technical facets of the NPK business. References made to the historical development of the NPK granulation industry should help us better understand its current status and at the same time provide a basis for projecting the future developments that are likely to occur in this relatively small but unique segment of the industry.

### World Overview of NPK Granulation

#### Introduction

At present, approximately 360 million tonnes of fertilizer products are consumed annually worldwide (Table 1). Of this amount, an estimated 60 million tonnes is in the form of homogeneous granular NPK products produced in about 275 plants, up modestly from about 55 million tonnes produced in 1980 (unless otherwise noted, all tonnage values are reported in metric tons of product indicated by tonnes or t). Another 25 million tonnes consists of double-nutrient products produced in a range of granular sizes. These double-nutrient products are represented by such typical grades as 18-46-0 (DAP), 11-52-0 (MAP), 16-20-0, and 20-20-0. Fluid fertilizers, including anhydrous ammonia used for direct application, account for another 30 million tonnes annually. The large majority of products, however, are of the single-nutrient type. These single-nutrient products account for about 250 million tonnes of consumption annually. Among these, urea is the most popular, accounting for nearly 40% of the world's total nitrogen consumption. An estimated 22 million tonnes

of the single- and double-nutrient materials is dry mixed (blended) before finally being used by the farmer.

The production and use of high-quality homogeneous granular NPKs, while quite stagnant during the 1980's, are likely to show some increase during the next decade, especially in the developing world, in response to (1) the growing need for more balanced plant nutrition, including secondary and micronutrients which may be conveniently incorporated into granular NPKs, and (2) pressures to improve fertilizer use efficiency in order to lower the farm-level cost of crop production and also to lessen any adverse effects that fertilizers may have upon the environment. The convenience offered by NPKs with regard to application may also be an important factor in developing regions where farm-level education in fertilizer use and extension are lacking and where labor is either in short supply or costly. The ultimate future status of the granular NPK industry will, of course, depend upon economic pressures on the one hand, environmental (legislative) pressures on the other, and the ability of the granulation plants to economically supply domestic and export markets with high-quality products that can be used directly or incorporated into a fertilizer-blending supply and marketing system.

#### Regional Share of NPK Production

Quantifying actual world granular NPK production is difficult because definitive statistics are not uniformly maintained and reported. Furthermore, data for single- and binary-nutrient products such as superphosphates, ammonium phosphates, and sometimes blended NPKs are often mixed, thus adding to the confusion.

Nevertheless, reasonable accurate estimates of granular NPK production have been made through interpretation of reported data and through collaboration with a number of industry sources. The distribution of granular NPK production on a regional basis as shown in Table 2 and Figure 1 is believed to be fairly accurate for the 1988/89 statistical year. It is important to note that whenever possible the tonnage values reported do not include DAP and MAP. In some cases, however, the values do include such binary NP products as 20-20-0 and 16-20-0 where these grades are included in the overall product mix of a production unit. The regional classification (Table 3 and Figure 2) used in this discussion was developed by IFDC to facilitate uniformity in data collected and maintained by IFDC.

### *United States and Canada*

In the United States about 37 NPK granulation plants operated in 1989. This does not include those plants producing DAP/MAP and 16-20-0. In comparison, approximately 280 NPK granulation plants were operating in 1960. The current operating plants produced about 2.4 million tonnes of product in 1989 (Table 4). Most of the plants produced 25,000-100,000 tonnes per year (tpy); only eight plants reported production in excess of 100,000 tpy. Total fertilizer consumption for 1989 in the United States amounted to about 46 million tonnes of product; thus the granular NPKs accounted for only about 5% of the market. This is in sharp contrast with the situation in 1960 when homogeneous granular NPKs accounted for about 52% (about 12 million tonnes) of total fertilizer consumption, which amounted to nearly 23 million tonnes of material. Eight of the U.S. NPK plants still produce single superphosphate (SSP) which is normally incorporated into the NPKs. Total SSP production amounted to about 300,000 short tons in 1989.

Canada currently reports no granular NPK production. All NPK products are blended using granular materials such as urea, ammonium sulfate, ammonium phosphate, ammonium phosphate/sulfate, and potash. These blends have also largely replaced granular 16-20-0, a very popular product. Current production of blends in Canada is approximately 3 million tonnes annually.

The rapid decline of the NPK granulation history in North America since the early 1960s can be attributed to a number of technical and economic factors including (1) the widespread adoption of nitrogen-responsive varieties of wheat and corn and the consequent need for high-nitrogen NPK ratios and multiple applications of nitrogen; (2) development of large-scale and cost-effective basic nitrogen and phosphate fertilizer production units; (3) widespread adoption of the technology for direct application of anhydrous ammonia and nitrogen solutions; (4) improvements in transport facilities resulting in the economic long-distance transport of high-analysis fertilizers from the major production sites to the consuming regions, including pipeline transmission of ammonia and nitrogen solutions; and (5) the development of integrated marketing systems by most major producers based on blending near the point of consumption, thus offering greater product (nutrient) flexibility and services than could be offered by the relatively small and often independent, NPK granulator.

### *Central and South America*

The tonnage of granular NPKs produced in Central and South America is also quite small (Table 5). Seven countries accounted for a total of about 1.6 million tonnes of NPKs in 1989. Total fertilizer consumption in the region amounted to an estimated 22 million tonnes of product (8.8 million tonnes nutrients).

It is interesting to note that one new NPK granulation plant was recently constructed in the region. In 1987

a granulation plant based on a compaction/granulation process began operation in Guatemala (1). This plant currently produces about 50,000 tpy of compacted products, many of which are used as feedstock for blending plant operated at the same facility. The compacted granular feedstock for blending often contains secondary and micronutrients uniformly dispersed in an NP or NPK granular base. In this particular example, NPK granulation complements and helps to improve the economics of a blended fertilizer production and marketing strategy. NPK granulation is also used to some extent in Brazil and the United States to complement blending.

### *Africa*

Seven countries in Africa are known to produce granular NPKs (Table 6). Total annual production currently amounts to about 1.5 million tonnes of product. The most recent entry into NPK granulation, and the largest single producer, is Nigeria. This NPK granulation plant owned and operated by the National Fertilizer Company of Nigeria Limited (NAFCON), began operation in 1988. Although the plant is designed to also produce DAP, it is most often used to produce 15-15-15, a very popular grade in Nigeria. The NAFCON plant produces about 300,000 tpy of NPKs.

Another relatively new NPK plant began operation in 1983 in South Africa. This plant, originally constructed by Triomf Fertilizer (Pty) Limited, is a combination DAP/NPK plant, however, after startup, unlike the plant in Nigeria, it was dedicated primarily to production of DAP instead of NPKs.

### *Asia*

The whole of Asia (West, South, and East) accounts for about 6.4 million tpy of granular NPKs (Table 7). India leads the ranking with about 1.7 million tonnes of NPKs produced in 43 plants during the 1988/89 accounting year. Other major producers include Turkey (1.2 million tpy), Korea (1.0 million tpy), Japan (0.85 million tpy), Taiwan (0.46 million tpy), Thailand (0.40 million tpy), and Malaysia (0.39 million tpy).

The most recent NPK plants constructed in the region are operated by Philippine Phosphate Fertilizer Corporation (PHILPHOS) on the Island of Leyte and FPM Sendirian Berhad (FPM) in West Malaysia (2,3). The PHILPHOS plant, consisting of two granulation trains having an NPK granulation capacity of about 250,000 tpy each, was designed to produce DAP, 16-20-0, and a number of NPKs primarily for export; the plant began operation in 1985. The FPM plant began commercial operation 2 years earlier (1983) and produces a number of NPK grades designed for the domestic market. Total annual production from the FPM plant amounts to about 120,000 tonnes of granular NPKs and an additional 100,000 tonnes of nongranular mixtures (blends). A relatively small (10 tonnes per hour [tph]) compaction/granulation plant was also recently commissioned by Atlas Fertilizer Corporation in the Phil-

ippines (4). This plant, like the one in Guatemala, is expected to complement conventional granulation and blending by providing a number of homogeneous granular NPKs for specialty markets that do not prefer blends.

The situation in China is less clear. A large (3,000 tonnes per day [tpd]) nitrophosphate-type NP/NPK plant was recently constructed, but its current operating status is not known.

#### *Western Europe*

Most of the world's granular NPKs are produced in Western Europe. Ninety-five NPK plants currently account for about 27 million tonnes of NPK capacity. As a result of massive restructuring of the industry, current NPK capacity is down substantially from the production reported for 1980, i.e., about 32 million tonnes and a total of 140 plants (5).

The Western Europe NPK granulation industry, like the U.S. industry, is quite old. Most plants are at least 15 years old, many much older. The majority of the smaller plants have been closed. The remaining plants are rather large, having an average capacity of 280,000 tpy, with about 40% of the total capacity represented by plants with capacities greater than 500,000 tpy (5).

Additional plant closures, already announced, will further consolidate and shift the industry to even larger and, presumably, more cost-effective production units. The independent producers, which numbered 70 in 1970, have declined to 29 today. Currently, the top ten producers own 80% of the Western Europe NPK granulation capacity (5).

Most of the granular NPKs are consumed in the producing country or other Western European countries (5). Thus, only about 10% of the total production is exported outside of Western Europe.

#### *Eastern Europe and Russia*

The total annual production of granular NPKs in this block of countries is not well documented but is believed to be about 20 million tonnes assuming a 70% utilization of reported capacity (Table 8); six Eastern European countries reportedly produce about 7 million tpy of granular NPKs, whereas Russia alone produces about 13 tpy which amounts to about 20% of their total annual fertilizer consumption of about 64 million tonnes of product (27.2 million tonnes nutrients).

#### *Outlook for Granular NPKs*

It is quite clear that the commodity-type fertilizers, such as urea, DAP, MAP, triple superphosphate (TSP), and potash (KCl), will continue to account for the bulk of the world's fertilizer needs. For example, as shown in Figures 3 and 4 solid urea currently accounts for about 35% (not including solutions) of world nitrogen consumption while DAP, MAP, and TSP together account for about 44% of the total  $P_2O_5$  consumption. It is interesting to note, however, that solid compound fertilizers, NPs and NPKs, represent nearly 20% of the

world's annual nitrogen consumption and about 34% of total  $P_2O_5$  consumption.

Homogeneous granular NPKs are expected to continue to give way to their blended counterparts in locations where access to granular "raw materials" is convenient and economical. The future development of blending as an alternative to the use of "straights" and granular NPK compounds will depend heavily upon the availability of high-quality granular raw materials having the particle size needed to avoid the problem of segregation that currently plagues much of the NPK blending industry. The problem of segregation and caking of blends becomes especially acute in fertilizer supply systems based on bagged product distribution and long-term storage - the norm for most of the developing world. The abundance of high-quality granular materials in Western Europe will most likely enhance further development of blending in the region, which currently amounts to an estimated 4.2 million tpy of products (Table 9).

The conventional NPK granulation plants will continue to serve traditional and "niche" markets. These plants are also expected to maintain, or possibly expand, their activity by supplying essential granular feedstocks to the blenders. This is already occurring quite widely in the United States, Western Europe, and selected locations in Latin America, Africa, and Asia. These essential granular feedstocks are often in the form of granular base materials fortified with secondary and micronutrients required for specific crops and agroclimatic zones. These granular base materials facilitate the uniform distribution of essential micronutrients throughout the blend and lessen the probability of segregation thus improving the quality and agronomic effectiveness of the blended products.

With regard to urea, the most significant single source of nitrogen, it is interesting to note that only about 10% of the world's fertilizer-grade urea is produced in granular form (Table 10). The majority (about 75%) of this granular production occurs in North America. This limits the scope for the production of high-quality blends in many of the developing countries. Also, the lack of compatibility of urea with ammonium nitrate-based NPs and NPKs further limits the scope of blending in locations where one may wish to blend locally produced urea with imported NPs and NPKs to produce a range of products that may also include secondary and micronutrients.

The ever-increasing environmental pressures on agriculture will continue to call for improved management of fertilizer use. More precision with respect to fertilizer application rate, timing, and placement will be required. This precision will necessitate a more refined family of solid and fluid fertilizer products that are of better quality in terms of composition, particle size, predictable flow characteristics, and agronomic performance. It is in this context of product quality and precision that elements of the NPK granulation industry of the 1960s and 1970s may again emerge as a major

asset in the future. Of course, the degree of future development of the NPK granulation sector will be determined largely by the economics of fertilizer production and use on one hand and by legislative decrees designed to protect the environment on the other hand.

The continued consolidation of the European NPK granulation industry (including Russia), which currently produces about 80% of the world's granular NPKs, is expected to result in large, cost-effective production centers, which undoubtedly will be well positioned to serve their own needs as well as a growing export market in the developing regions of the world where domestic production of granular NPKs is often not practical or economic.

Finally, while it is generally true that blending is less costly on a delivered nutrient basis, granular NPKs offer unique benefits with regard to physical quality and the ease with which secondary and micronutrients can be uniformly incorporated thus facilitating improved agronomic performance. These benefits are often of particular value to the marketing community as they continue to face increased competitive pressures in the domestic and export markets.

#### *Acknowledgment*

Unlike primary-nutrient data, or data on such commodities as ammonia, urea, phosphoric acid, and potash, data on the production and use of compound NPK fertilizers are not widely reported. Thus, a considerable amount of investigative-type searching is required to determine not only installed capacity figures for the NPK granulation industry, but more importantly, actual production on a product basis, separating homogeneous granular NPKs from their blended counterparts.

The data reported in this paper on the world status of NPK granulation could not have been assembled had it not been for the assistance of a large number of organizations and industry colleagues whose help was essential in verifying the current status of the world's granular NPK industry. The unselfish help offered by the Agrico Chemical Company (United States), Agro Linz Chemie (Austria), Akdeniz Gubre Sanayii AS (Turkey), British Sulphur Corporation Limited (United Kingdom), Canadian Fertilizer Institute, Centro de Estudos de Fertilizantes (Brazil), Fertilizantes Mexicanos, S.A. (Mexico), IMC Fertilizer, Inc. (United States), INCITEC Limited (Australia), Jacobs Engineering Group Inc. (United States), Kemira OY (Finland), Norsk Hydro A.S. (Norway), the World Bank (United States), and a number of NPK plant managers and industry colleagues from the United States and abroad calls for a special note of thanks and appreciation.

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**Table 1. Proportion of Total Fertilizer Produced in the Form of Homogeneous Granular NPKs**

<u>Region<sup>a</sup></u>	<u>Total Annual Consumption (1988/89)</u>		<u>Homogeneous Granular NPKs</u>	
	<u>Nutrients</u>	<u>Product<sup>b</sup></u>	<u>Estimated Production (1988/89)</u>	<u>% of Total Consumption</u>
	--- (Million Tonnes) ---			
North America	19.9	46	2.4	5
Central America and South America	8.8	22	1.6	7
Western Europe	20.4	51	27.0	53
Eastern Europe	11.9	30	7.0	23
Russia	27.2	64	13.0	20
Africa	3.7	9	1.5	17
Asia	51.9	130	6.4 <sup>c</sup>	5
Oceania	1.9	5	0.1	2
<b>World</b>	<b>145.7</b>	<b>357</b>	<b>59.0</b>	

a. Refer to Table 3 and Figure 2 for regional classification of countries.  
b. Derived from reported FAO nutrient (N + P<sub>2</sub>O<sub>5</sub> + K<sub>2</sub>O) data for 1988/89 fertilizer year.  
c. Estimated production does not include China.

**Table 2. Regional Distribution of World Granular NPK Production**

<u>Region<sup>a</sup></u>	<u>Estimated Production<sup>b</sup></u> (Million tonnes product)
North America	2.4
Central America	0.3
South America	1.3
Western Europe	27.0
Eastern Europe <sup>c</sup>	7.0
Russia <sup>c</sup>	13.0
Africa <sup>d</sup>	1.5
West Asia	1.3
South Asia	1.7
East Asia (excluding China)	3.4
Oceania	0.1
<b>Total</b>	<b>59.0</b>

a. Refer to Table 3 and Figure 2 for regional classification of countries.  
b. For 1988/89 fertilizer year.  
c. Estimated production based on reported installed capacity.  
d. Includes North, Sub-Saharan, and South Africa.

**Table 3. IFDC Regional Classification of Countries**

North America	Western Europe	Eastern Europe	USSR	Africa	Latin America	Asia	Oceania
Canada	Austria	Albania	USSR	<i>Sub-Saharan</i>	<i>Central America</i>	<i>West Asia</i>	Australia
United States	Belgium-Lux.	Bulgaria		Angola	Bahamas	Bahrain	New Zealand
	Denmark	Czechoslovakia		Benin	Barbados	Cyprus	Papua New Guinea
	Finland	Germany DR		Botswana	Belize	Iran	Samoa
	France	Hungary		Burkina Faso	Bermuda	Iraq	Fiji
	Germany FR	Poland		Burundi	Costa Rica	Israel	
	Greece	Romania		Cameroon	Cuba	Jordan	
	Iceland	Yugoslavia		Central Af. Republic	Dominica	Kuwait	
	Italy			Chad	Dominican Republic	Lebanon	
	Malta			Congo	El Salvador	Oman	
	Netherlands			Cote d'Ivoire	Guadeloupe	Qatar	
	Norway			Ethiopia	Guatemala	Saudi Arabia	
	Portugal			Gabon	Haiti	Syria	
	Spain			Gambia	Honduras	Turkey	
	Sweden			Ghana	Jamaica	United Arab Emirates	
	Switzerland			Guinea	Martinique	<i>South Asia</i>	
	United Kingdom			Kenya	Mexico	Afghanistan	
				Lesotho	Nicaragua	Bangladesh	
				Liberia	Panama	Bhutan	
				Madagascar	Puerto Rico	Burma	
				Malawi	St. Chris, etc.	India	
				Mali	Saint Lucia	Nepal	
				Mauritania	St. Vincent	Pakistan	
				Mauritius	Trinidad, etc.	Sri Lanka	
				Mozambique	Virgin Islands	<i>East Asia</i>	
				Niger		China	
				Nigeria	<i>South America</i>	Indonesia	
				Rwanda	Argentina	Japan	
				Senegal	Bolivia	Kampuchea	
				Seychelles	Brazil	Laos	
				Sierra Leone	Chile	Malaysia	
				Somalia	Columbia	Mongolia	
				Sudan	Ecuador	Korea, DPR	
				Swaziland	French Guiana	Korea, Republic	
				Tanzania	Guyana	Philippines	
				Togo	Paraguay	Singapore	
				Uganda	Peru	Taiwan	
				Zaire	Suriname	Thailand	
				Zambia	Uruguay	Viet Nam	
				Zimbabwe	Venezuela		
				<i>South Africa</i>			
				Republic of South Africa			
				<i>North Africa</i>			
				Algeria			
				Egypt			
				Libya			
				Morocco			



**Table 4. NPK Granulation in the United States**

<u>State</u>	<u>Number of Plants</u>	
	<u>NPK</u>	<u>SSP</u>
Alabama	2	2
California	1	
Florida	1	
Georgia	6	4
Idaho	1	
Illinois	1	
Indiana	2	
Michigan	1	
Maryland	2	
Minnesota	1	
Missouri	1	
North Carolina	3	
New York	2	
Ohio	2	
Pennsylvania	2	
South Carolina	2	1
Texas	1	
Virginia	4	1
Washington	1	
Wisconsin	1	
Total	<u>37</u>	<u>8</u>

**Reported Actual Production in 1989**

<u>Production</u> (short tonnes)	<u>Number of Plants</u>	
	<u>NPK</u>	<u>SSP</u>
Less than 10,000	0	1
10,001-25,000	8	2
25,001-50,000	11	2
50,001-100,000	10	3
Greater than 100,000	8	0
Total	<u>37</u>	<u>8</u>
Total Reported Production (Million short tonnes)	2.61	0.31

**Table 5. NPK Granulation Plants in Central and South America**

<u>Country</u>	<u>Number of Plants</u>	<u>Estimated or Reported Production in 1989</u> (thousand tonnes product)
<b>Central America</b>		
Costa Rica	1	100
Guatemala	1	50
Mexico	1	140
<b>South America</b>		
Brazil	8	400 <sup>a</sup>
Colombia	2	550
Ecuador	1	30
Venezuela	1	300
Total	15	1,570

a. Value uncertain; may include some blending NPKs.

**Table 6. NPK Granulation Plants in Africa**

<u>Country</u>	<u>Number of Plants</u>	<u>Estimated or Reported Annual Production<sup>a</sup></u> (thousand tonnes product)
Algeria	1	125
Côte d'Ivoire	1	150
Nigeria	1	300
Senegal	1	150
South Africa	3	500
Zambia	1	100
Zimbabwe	1	130
Total	9	1,455

a. Except for Nigeria, production varies widely from year to year. Estimates typical of performance between 1987 and 1989.

**Table 7. NPK Granulation Plants in Asia**

<u>Country</u>	<u>Number of Plants</u>	<u>Estimated or Reported Production in 1989 (thousand tonnes product)</u>
China	1	a
Cyprus	1	200
India	43	1,650
Japan	12	850
Korea	3 <sup>b</sup>	1,000
Malaysia	2	390
Philippines	2	290
Taiwan	2	456
Thailand	2	400
Turkey	<u>6<sup>c</sup></u>	<u>1,123</u>
Total	73	6,359

a. Newly constructed nitrophosphate complex, operational status not known.

b. Value uncertain, may include some blends.

c. Six plants at four factory sites.

**Table 8. NPK Granulation Plants in Eastern Europe and Russia**

<u>Country</u>	<u>Number of Plants</u>	<u>Total Reported Annual Capacity (thousand tons product)</u>
Bulgaria	2	1,070
Czechoslovakia	6	1,676
East Germany	2	335
Hungary	3	1,282
Poland	2	1,285
Romania	5	4,196
U.S.S.R.	<u>27</u>	<u>18,469</u>
Total	47	28,313
Estimated Annual Production <sup>a</sup>		19,800

a. Estimated assuming 70% average capacity utilization.

**Table 9. Estimated Current World Production of Blended Fertilizers**

<u>Country</u>	<u>Estimated Annual Production</u> (million tonnes)
United States	9.0
Canada	3.0
Central America/Caribbean (total)	0.6
Brazil	2.8
United Kingdom	1.1
Ireland	1.0
France	0.9
Western Europe (total others)	1.2
Japan	0.6
Others	<u>2.0</u>
Total	22.2

**Table 10. Estimated Current World Production of Granular Urea**

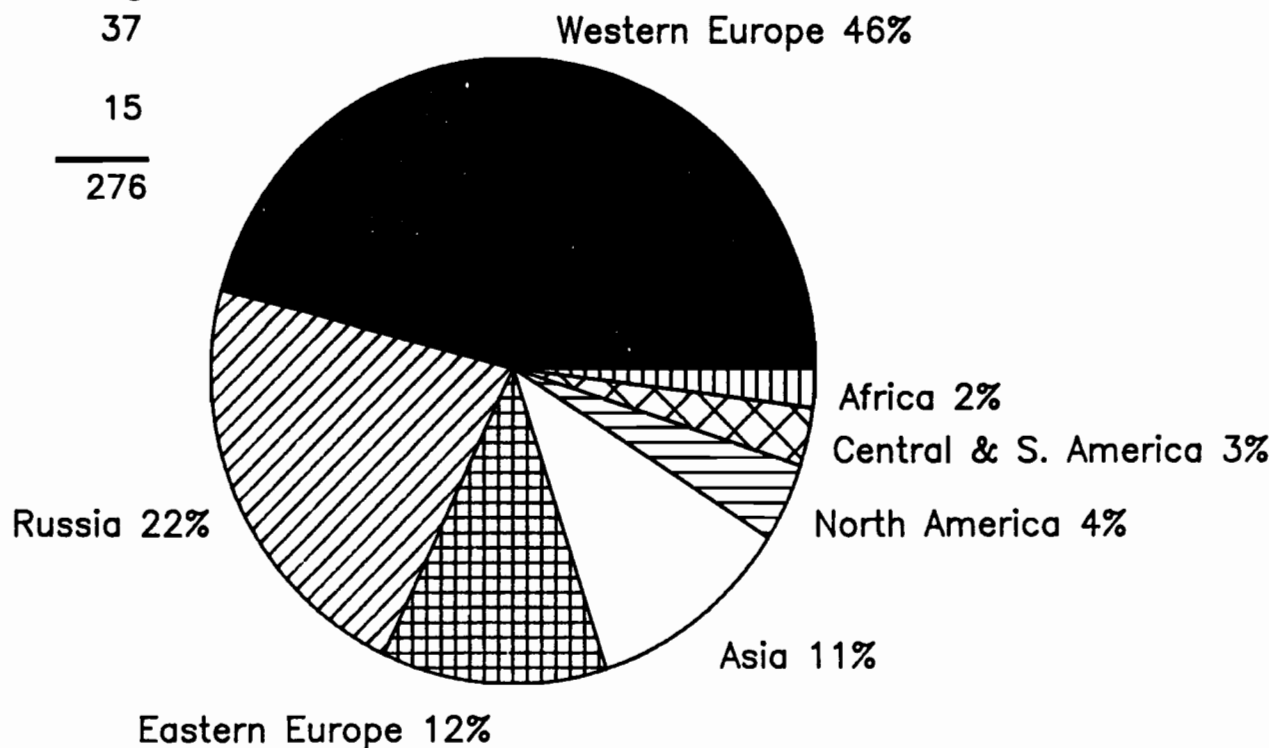
<u>Region</u>	<u>Annual Production<sup>a</sup></u> (million tonnes product)
North America (Canada & United States)	5.3
Central and South America	0.4
Asia and Oceania	0.6
Africa	0.4
Western Europe	0.4
Total	<u>7.1</u>
World Total Urea Consumption	68 <sup>b</sup>

a. Estimates based on 90% of reported installed capacity and 300 operating days per year. Values rounded.

b. Estimated for 1988/89 fertilizer year including about 3 million tonnes urea (dry basis) in the form of nitrogen solutions.

## Estimated Number of Plants

Western Europe	95
Eastern Europe	20
Russia	27
Asia	73
Africa	9
North America	37
Central & S. America	15
Total	<u>276</u>



Estimated Total  
Annual Production  
in 1989—  
59 million tonnes

Figure 1. Regional Distribution of Granular NPK Production—1989  
(Excluding China).

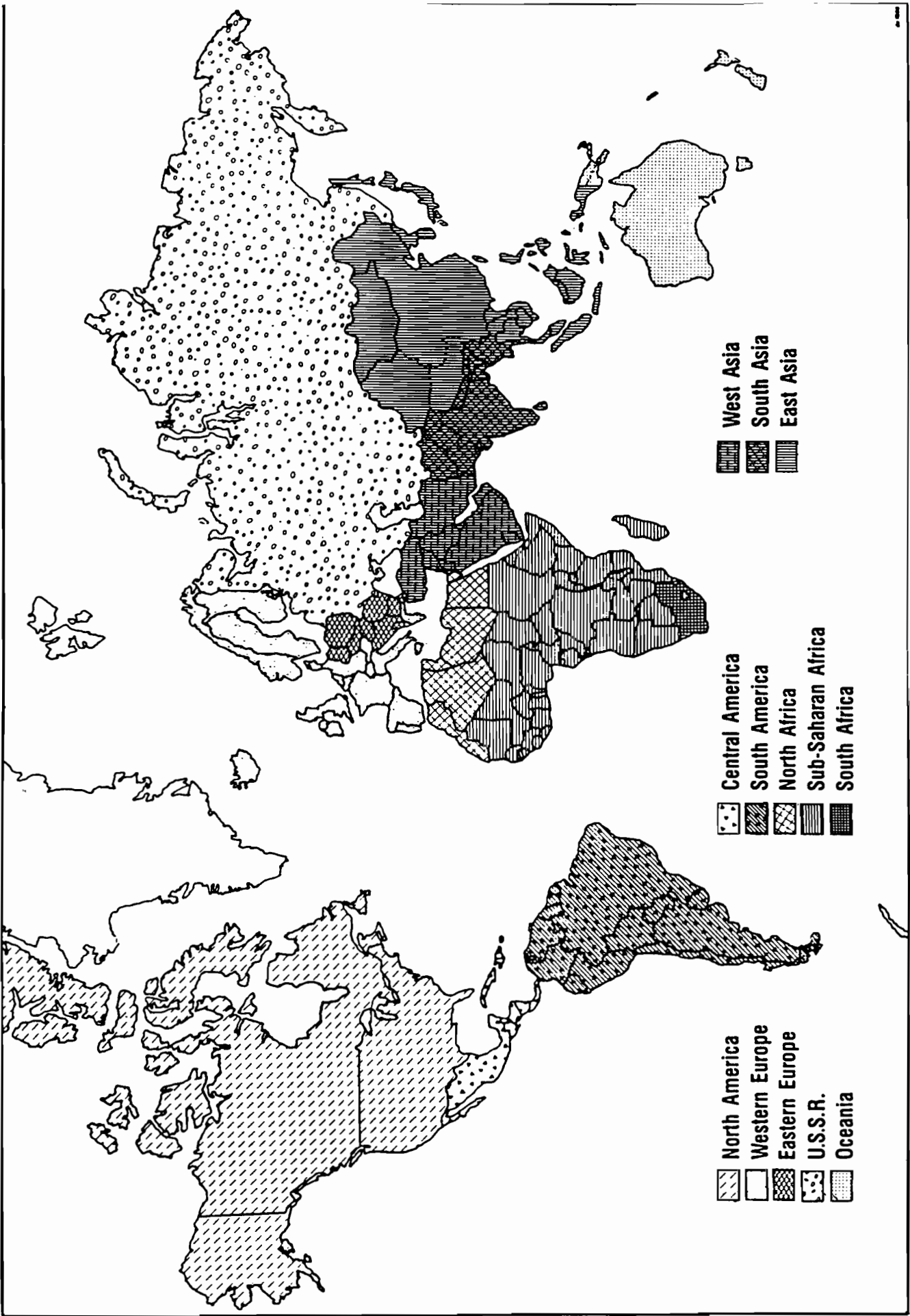


Figure 2. IFDC Regional Classification of Countries.

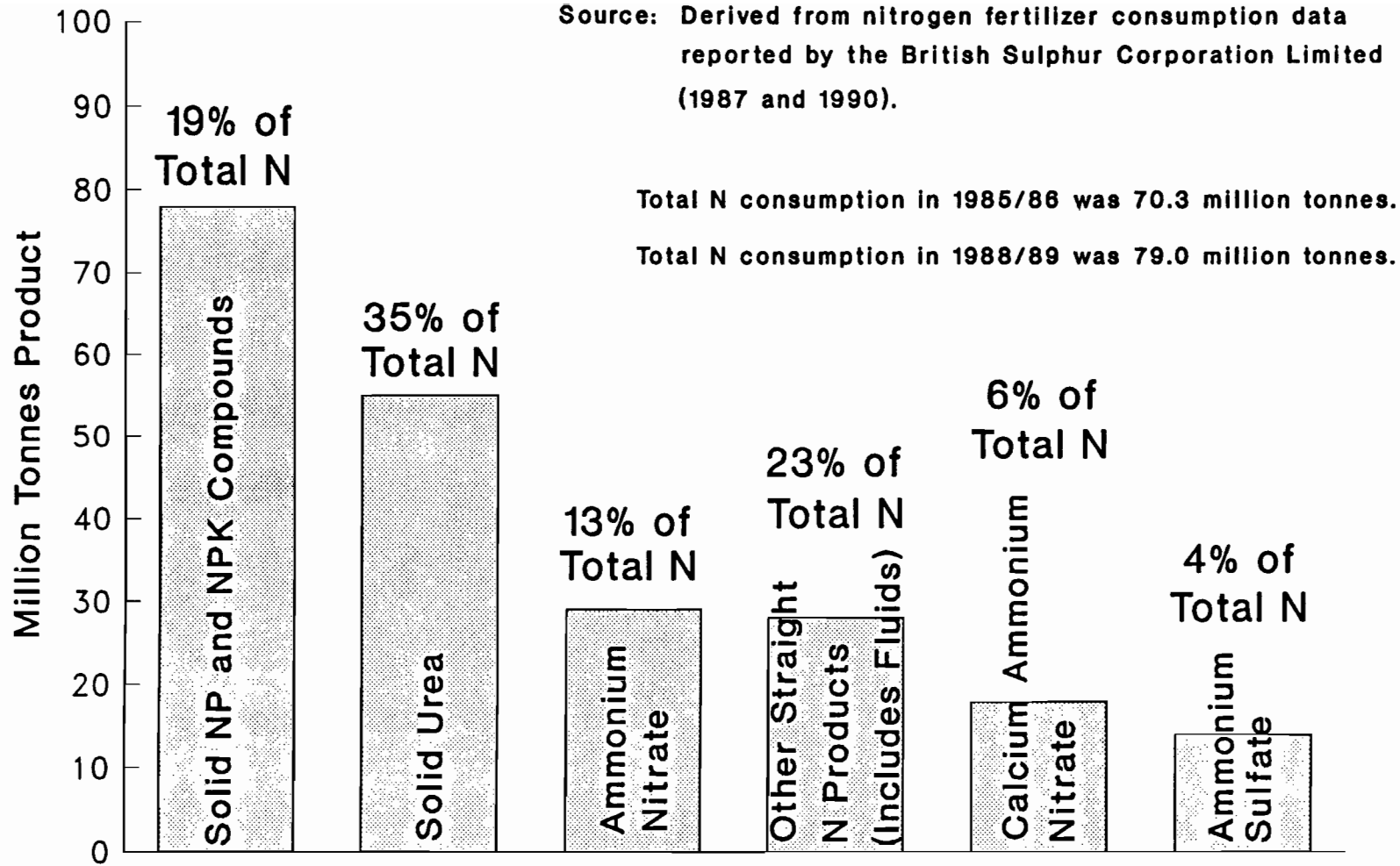


Figure 3. Approximate Distribution of World Nitrogen Consumption by Product.

Source: Derived from phosphate fertilizer consumption data reported by the British Sulphur Corporation Limited (1987 and 1990).

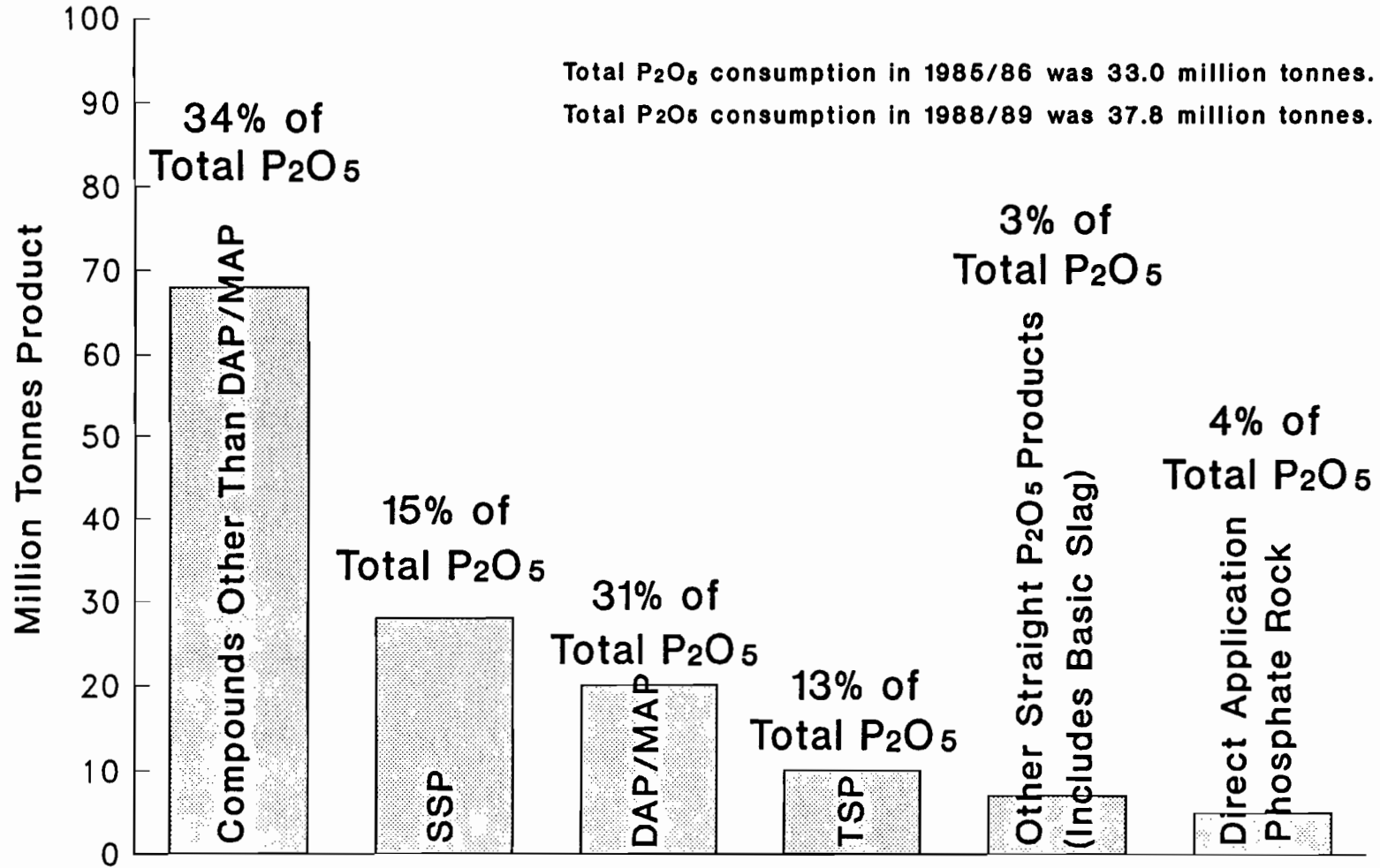


Figure 4. Approximate Distribution of World Phosphate Consumption by Product.



# The Role of Homogeneous Fertilizers in Achieving Balanced Nutrition

Dr. James T. Thorup

Chevron Chemical Company

Optimum crop production occurs when every plant on each acre is provided a balanced diet of plant nutrients. Uniform distribution of plant nutrients is necessary in order to achieve this goal.

At least two criteria are important for uniform distribution of nutrients. First is the use of homogeneous fertilizers to prevent segregation of plant nutrients. Second is the use of fertilizers having uniform size, shape and density. Size is the most critical of these three factors. Of course, it is necessary to use properly adjusted and well maintained equipment also.

Some people take the attitude that uniform distribution is not all that important. Their perception is that higher production in the heavier applied areas will compensate for lower production in the lighter applied areas. There may be some validity to this if farmers are not fertilizing at high enough rates for optimum production. However, if farmers are supplying sufficient nutrients, uneven distribution will result in reduced yields.

A typical yield curve (Figure 1) relating to yield to increasing nutrient application is not linear. In reality, a curvilinear relationship exists in which at some point of nutrient application, optimum production is achieved. Further applications of nutrients do not increase yields.

Uneven fertilizer distribution may therefore result in less than optimum yields where insufficient material is applied and wasted fertilizer dollars where excessive material is applied. Excessive material may also be detrimental to the environment if conditions exist to move nitrate nitrogen below the root zone and eventually into groundwater.

How do homogeneous fertilizers help to achieve balanced nutrition? To answer this question, we will discuss three areas in which benefits are derived from homogeneous fertilizers.

## 1. Uniform nutrient distribution...

It is very difficult to achieve uniform distribution using blended fertilizers. Segregation of particles occurs each time the blended materials are handled. Choosing materials of uniform size will help prevent segregation in blends, but this is difficult in most situations. It also increases the costs for blends to use sized materials.

Transferring of blended fertilizers from the blender to the transporting vehicle and then to the applicator causes segregation. Finer materials accumulate in the center of the pile while coarser materials accumulate outside.

As fertilizer is pulled from the bin by chain or auger, the finer materials tend to be removed first. Where a spinner is used to spread the fertilizer, additional ballis-

tic segregation occurs since larger particles are thrown farther than smaller ones. This segregation results in non-uniform distribution of plant nutrients.

Field demonstrations have been used on many occasions to show the extent of this problem. Data from one of these demonstrations is shown below. A wide variance of rates and analyses occurred when 700 lbs. per acre of blended 20-10-10 fertilizer was broadcast.

Rate of application . . . . .	504 to 1040 lbs/acre
Nitrogen . . . . .	67 to 143 lbs/acre
Phosphorus . . . . .	40 to 99 lbs/acre
Potassium . . . . .	52 to 96 lbs/acre

Optimum production of crops is impossible with this kind of non-uniform nutrient distribution. The use of homogeneous fertilizers eliminates nutrient segregation and, when equipment is properly adjusted, uniform rates of application can also be achieved.

## 2. Synergistic effect of nutrients in the same feeding zone . .

Research dating back 30 years or more called attention to a nitrogen-phosphate interaction which improved the efficiency of phosphate uptake by plants (Miller and Ohlrogge, *Agronomy Journal*, Feb. 1958) (Figure 2). Several researchers over the years have shown this same synergism.

Homogeneous fertilizers have the advantage of supplying nutrients from the same feeding zone. Each pellet contains all nutrients in the particular grade.

## 3. More feeding sites for non-mobile nutrients . . . .

Increasing the number of potential root-fertilizer contact sites is important for non-mobile nutrients such as phosphorus. The greater the number of contact sites, the greater is the probability of root contact and increased phosphate uptake.

Homogeneous fertilizers provide a feeding site at each pellet for all applied nutrients. Blended fertilizers provide fewer contact sites for each nutrient.

If a comparison is made between a homogeneous 20-10-10 and a blended 20-10-10 using diammonium phosphate (18-46-0) and potassium chloride (0-0-60) to provide phosphorus and potassium, the homogeneous fertilizer provides approximately 4.6 times as many phosphorus contact sites and six times as many potash contact sites as the blend (Figure 3). The probability for root contact and nutrient uptake would be increased proportionately.

## Research

Considerable research has been done over the years which provides evidence of the superiority of homogeneous fertilizers over blends.

Data from several of these are presented for consideration.

A study in the Columbia Basin of the Pacific North-

west used several blended fertilizers compared to a homogeneous fertilizer for the production of corn. The homogeneous fertilizer produced 12 bu/acre more than the highest producing blend.

Fertilizer*	Yield (bu/acre)
Check (no fertilizer)	30
Urea + TSP + KCL	75
UAN + TSP + KCL	81
Unipel 20-10-10	128

#### Corn Trial - Columbia Basin

Fertilizer*	Yield (bu/acre)	Increase (bu/acre)
Check	108.0	—
11-52-0 + ANS + KCL	148.5	40.5
22-22-0 + KCL	151.0	43.0
21-21-0 + KCL	152.8	44.8
16-20-0 + AN + KCL	153.1	45.1
16-16-16 (homogeneous)	165.0	57.0

\* All treatments applied at 100-100-100

Several studies in the Midwest over a period of 15 years (1969 - 1984) also demonstrated the superiority of homogeneous fertilizers over blends.

State	No. of tests	Range	Acreage
Iowa	10	8-27	16
Illinois	2	8-11	10
Missouri	7	12-40	22
Ohio	6	10-42	23
Indiana	1	12	12
Total	26	8-42	19

A replicated test (4 reps) comparing Unipel 20-10-10 (a homogeneous fertilizer) with blends using various nitrogen sources with treble super phosphate and potassium chloride was conducted at Purdue University in 1985. No-till corn was planted into wheat stubble. Data showed a 47 bushel per acre yield increase for the homogeneous fertilizer over the highest yielding blend.

\* All treatments applied at 100-50-50

The same experiment was performed using 150 lbs. per acre of nitrogen. Results were even more spectacular. A yield increase for the homogeneous fertilizer of 62 bushels per acre was obtained.

Fertilizer*	Yield (bu/acre)
Check (no fertilizer)	33
Urea + TSP + KCL	99
UAN + TSP + KCL	104
Unipel 20-10-10	166

\* All treatments applied at 150-75-75

Results are the only true measure of the value of fertilizer. Results of many field trials have demonstrated the superiority of homogeneous fertilizers over blends.

#### FERTILIZER AND THE ENVIRONMENT

No discussion would be complete today without some reference to environmental considerations. Homogeneous fertilizers are environmentally sound. A well-balanced fertilizer program improves the efficiency of nutrient utilization by crops. Less nitrate nitrogen remains for movement into groundwater where conditions are conducive to leaching losses.

Research in the Great Plains and elsewhere has demonstrated the increased N use efficiency where nitrogen applications balanced with P and/or K. Data from one such study is shown below.

P increases wheat yield and improves N use efficiency					
Fertilizer (bu/acre)		Yield (lbs/acre)	Plant Composition		N Removed
N	P <sub>2</sub> O <sub>5</sub>		N%	P%	
75	0	42	3.95	0.18	56
75	40	73	4.38	0.28	89

Where nitrogen was balanced with phosphorus, 14 lbs. per acre more nitrogen was removed in the crop than was applied as fertilizer. The crop *mined* the soil for nitrogen, thus reducing the potential for leaching losses.

One of the keys to improved nitrogen use efficiency is balanced nutrition. Homogeneous fertilizers provide a tool for ensuring balanced nutrition.

Figure 1. A NORMAL YIELD RESPONSE CURVE TO APPLIED NUTRIENTS

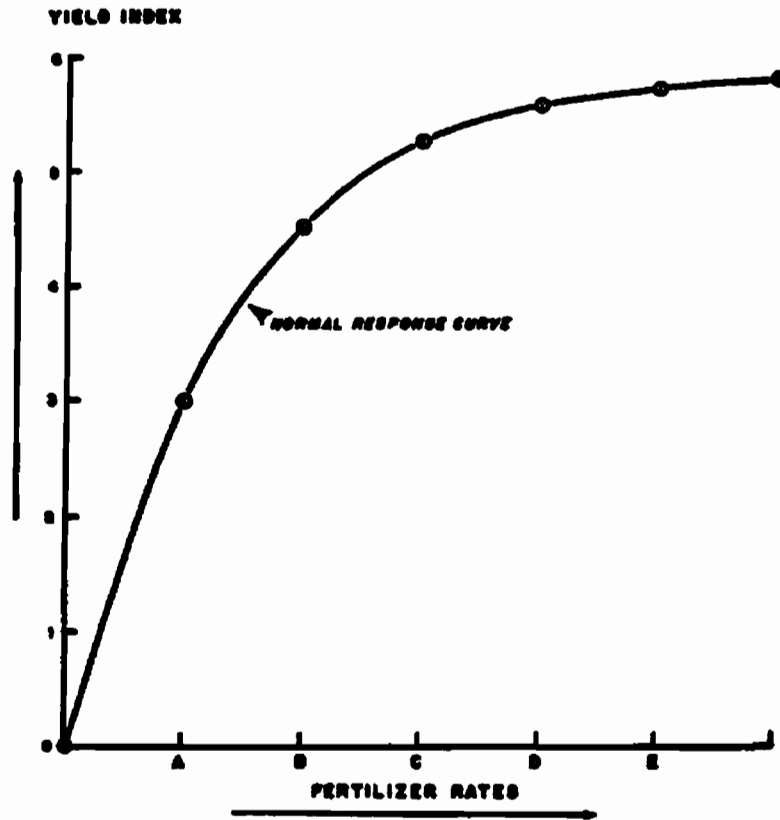


Fig. 2.—The influence of soil phosphate level on the total phosphorus absorption by corn plants showing the effect of nitrogen additions.

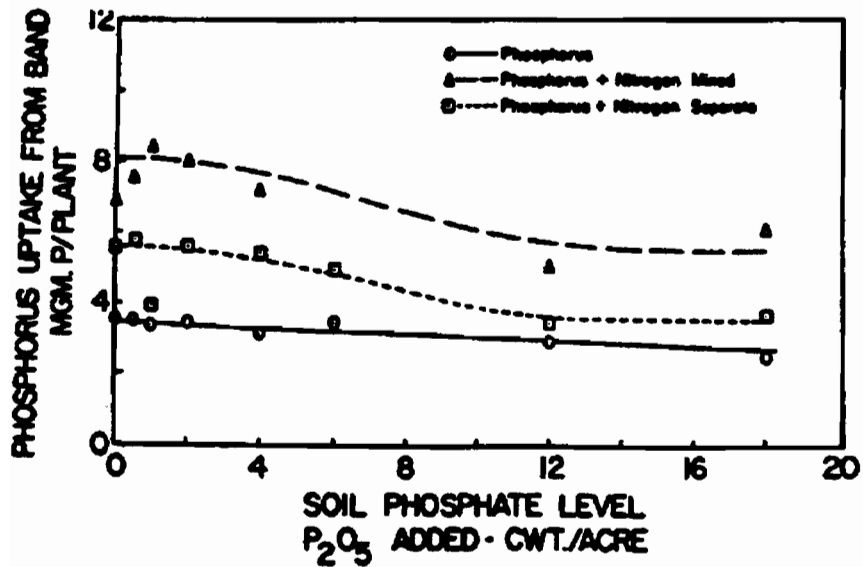
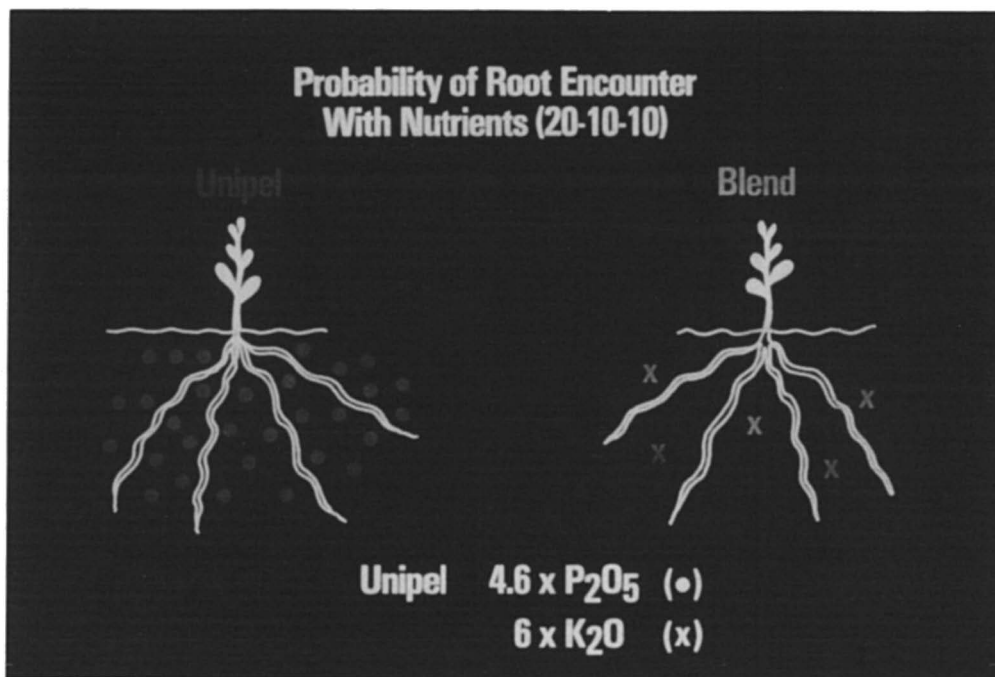


FIGURE 3



## Current Role of Granular NPKs

Edward P. Sowa  
Crop Production Services

Today there are going to be at least two Canadians on the program, myself and Jean Louis Cheval who is at least partially Canadian by naturalization.

Jean and I have known each other a long time. In fact, he was my boss when I first started in the fertilizer business in 1960.

Anyway, I thought that it's something that I would like to brag about a little bit.

Today, I would like to expand my topic of "*Complementary Role of Homogenous Granular NPK's in a Bulk Blending Supply System*" to relate to some of the experiences and happenings that have occurred to a NPK granulation facility located near Saginaw, Mich.

When I first started in agri business, there were hundreds of NPK granulation plants in the U.S.A. Today there are 40 or so left. I came to the United States from Canada in 1972 to work and operate an NPK plant close to Saginaw, Michigan. At that particular period, 1972 thru 1974, we produced and sold 100,000 to 130,000 tons of manufactured NPK's annually. From the mid 1970's that volume has dwindled to something in the area of one third.

You all know the reason for the reduction of volume and that is the introduction and acceptance of blenders and blend fertilizers in the agricultural market place. It is a "Hell of a Thing" to lose two thirds of this segment of business in a span of 8 to 15 years. As a result, we started to look at areas to take up this slack before you were put out of business entirely.

Since it is pretty much taken for granted that blenders were here to stay, it seemed very logical to join them rather than to fight them. Thus, as a result it was decided to provide blend products ourselves and also provide goods that blenders could buy and use from us.

In Michigan, particularly in the Saginaw area, Manganese and Zinc were used in many NPK fertilizers. As a result, we looked at and provided blend bases containing Manganese, Zinc and in some instances Sulfur.

The first blend bases were 8-40-0 with 10% MN and 8-40-0 10% Zn. These were great products from a quality and an agronomic stand point. However, economically, they were relatively expensive to use and we did not merchandise them for more than 2 years.

We also produced and sold a 10-10-0 10% MN, 10% Zn, 10% S. This blend base was used strictly for edible beans and sold only for one or two years to a specific customer.

After these blend bases, we contacted and sold some other bases namely, 10-9-0 20% Mn, 9% S and 15-9-0 10% Zn, 11% S to a relatively large firm in Michigan.

All these blend base products were made and sold for a fair margin to blenders.

Currently, we are looking at some other blend bases, however, we are not quite ready to announce what they will be.

Another product coming into the market place is 19-5-0 22% S. This is being promoted by a large national fertilizer firm. We have experimented with a very similar type of granular product using standard ammonium sulfate as a feed stock. We believe it will be an excellent product for blenders, particularly if it competes fairly close to the price of granular ammonium sulfate. This is probably a biased opinion, but I believe the 19-5-0 can fit into blends better than granular ammonium sulfate because of the particle size. One problem of making and selling 19-5-0 lies in the fact, that feed stocks of standard ammonium sulfate have to be costed low enough to help establish decent margins when competing against granular ammonium sulfate.

We have already touched on Micros being used in Michigan particularly Manganese, Sulfur and Zinc. Over 6 years ago we started producing granular Manganese Oxy Sulfate 40% Mn and Granular Zinc Oxy Sulfate 36%. Both these products were suited to Michigan crops such as edible beans, corn, sugarbeets and soybeans. It was not too long after that, that we got established into micronutrient business.

For several years we expanded our product lines in Manganese and Zinc. Two and a half years ago we introduced our own brand registration of micronutrients with a full line of dry granular products. These products include Calcium, Magnesium, Boron, three Zinc products, three Manganese products, two Iron products, a Corn Mix and a Bean Mix. Both of the latter two have a number of micros in combinations. These products have helped us gain recognition and some status as well as recuperate some of the lost NPK business mentioned earlier.

In addition to these micronutrient products, we also produce and sell other dry granular micros on a contract or purchase order basis. These are made according to customer specifications and a minimum tonnage basis.

We have been a NPK producer for many years and we are still in this business. However, our thrust today is to specialize row starter fertilizers with balanced amounts of NPK, secondary and micronutrients. This balance varies from crop to crop. We believe this is the right time to consider proper fertilizer band placement in the row to minimize run offs etc., and a balance of NPK with secondaries and micronutrients so that maximum utilization of these ingredients is taken up by the plant leaving minimal residual amounts of plant food to the environment.

We will also continue to make and sell some of our traditional NPK's with micros. We continue to offer special NPK mixes upon customer request with a minimum tonnage basis.

We are also a blend fertilizer supplier and we will stress micros in blend fertilizers through the use of blend basis or other micronutrients so as to enhance these

blend products.

We, therefore, have five main lines of products that we are making, selling and promoting. These round our overall business, but we do sell others. We do not attempt to make or sell to everyone nor do we sell or make everything, but we are attempting to "niche" produce and market products that others may not be able to copy. As a result, we are able to accomplish what others cannot, although, there are a lot of things we cannot do we are good at some specific things as I have already stated.

## A Look At A Survivor

*Ronald Dreese*

**Agway, Inc.**

Maintaining quality and added value has been the objective of the Agway organization since its inception. At one time being able to boast of nine ammoniation plants, Agway now is reduced to three plants, but with the same goal, to produce premium N P K fertilizer. The three plants remaining are:

**Big Flats, New York:** Constructed as a tobacco processing plant in 1902, purchased and new construction on the site in 1955 as a fertilizer plant. This plant was refurbished in 1967 to its present form. Presently there are 34 employees in peak season and a truck delivery service operates from here year round.

**Lyons, New York:** Constructed in 1904 as an electric power plant and converted to a fertilizer plant in 1941, this plant has undergone several changes and upgrading since then. Presently there are 16 employees at this plant.

**York, PA:** The York plant was built starting in 1870 as a fertilizer plant, with most of the main buildings being added by the year 1895. This has always been a fertilizer plant with constant updating as the technology advanced through the decades since then. The last thorough revamping was in 1964 when the ammoniation system now in use was installed. Presently there are 33 employees with peak employment reaching 40 employees.

Although similar, each plant has a unique niche to fill in the requirements of the organization. For example, the Big Flats plant has been designated as the lawn and garden plant and is producing virtually all of the homeowner and professional fertilizer for Agway.

The workhorse of the lawn and professional line has been the Greenlawn Plus product. This product was introduced at Big Flats, with the first production run being made in 1971. This product is a low bulk density product and has been widely accepted as a standard for the industry. This product lends itself readily to impregnation of pesticides and herbicides, and has excelled in every respect for almost 20 years. Used as a base for many finished products, it has done many jobs success-

fully for homeowners and professionals alike.

Other grades have been manufactured over the years, some on contract to specialists in their field, such as nurseries, and various special mixes are produced today to meet the needs of the customer.

Professional fertilizers are manufactured and marketed by Agway for athletic fields, golf fairways and roughs, greens and tees, and other specialty fertilizers as the needs arise.

The Big Flats plant also bags blended products for the farm market. This is done on a St. Regis valve packer and palletizer that has been in service for some 20 years. Special mixes and 22 standard grades of blended product that coincide with the varied requirements of north-east agriculture provide incremental tonnage and fiscal stability to the operation.

The Lyons, NY plant remains a farm fertilizer plant, and supplies a variety of ammoniated starter and other premium fertilizers that are in demand seasonally. The crops that are treated to these premium grades are cranberries, corn, potatoes, and onions. The soil and its variations as well as the unique requirements of these crops require the special attention of our production department. Also produced at this location is 10-34-0 polyphosphate to supply the surrounding area with a liquid starter so much in demand. Along with ammoniated bulk and bagged products, approximately 20 grades of bulk and bagged blended products are carried on inventory for immediate shipment. Premium products and customer service go hand in hand to maintain a customer base that will support a regional plant.

The York, PA plant is probably the most diversified of the Agway ammoniating plants. A list of the operations at York is as follows:

- Ammoniated farm fertilizer ( Bulk & Bag )
- Farm blends ( Bulk & Bag )
- Lawn & garden blends ( Bagged )
- Lawn & garden ( Small package )
- Clear liquid ( Farm )
- Clear liquid ( Turf )

Over the years, the ammoniated starter fertilizers have been the mainstay of the York plant, with approximately 35% of the production in these grades. Next to the starter fertilizers, special use fertilizers for side dressing of vegetable crops, potato production, and others have been developed. These formulations each have their own characteristics such as: color added so that visual observation of flow from the applicator can take place without stopping, single source nitrogen to withstand high humidity and temperature without causing buildup in application equipment, and trace elem-

ents added to supplement light soils on a regular basis. These types of value added products support the regional concept.

Bagged farm blends help supplement the tonnage base and supply those patrons that are without a source of bulk product close to the farm.

Professional blends, both standard grades and prescription mixes with timed and slow release nitrogens, as well as other requirements, make up approximately 10% of the annual shipments. Lawn and garden blends geared to homeowner purchase along with the small package line of 5, 10, and 25 lb. packages with the same customer in mind add another 5% to 7% to the total tonnage.

Clear liquid farm and turf fill a niche for those who use liquid starters and specialty fertilizers in the immediate area.

There are other aspects to the survival of an ammoniation plant other than product mix or specialization, such as customer service, flexibility or the ability to change to the demands of a changing market. Some other prerequisites are constant such as diligent maintenance and repair. Neglect can find you in the situation of deciding whether to replace buildings and equipment at a sizable investment, or discontinuing the operation.

Other problems have plagued the ammoniator during the last few years, such as fewer materials suited to the process and even fewer suppliers for those limited products. We do not feel that this situation will improve as suppliers strive to improve the particle size of their products to serve the blenders with quality materials.

Environmental concerns have been a hurdle to clear, and as controls tighten, many of the remaining ammoniators may decide to stop producing rather than stay abreast of the requirements.

We as a group of ammoniators are a dying breed and the day may come when we will exist no more, but until then we will continue to supply our customers with a quality product as yet unequalled in the marketplace!

## **Premium NPKS - A Key To Survival**

*Mabry M. Handley*  
**IMC Fertilizer, Inc**

IMC Fertilizer started in 1909, mining phosphates in Tennessee and Florida. The corporation, then called International Agricultural Corporation, quickly acquired a number of plants. By 1925, eighteen of them were each producing 18-20,000 tons of mixed fertilizer annually.

In these early days, the fertilizer business was simple - manufacturing a few low analysis, basic NPK grades of pulverized mixed fertilizer.

Many early plants, found at seaport locations, depended on imported materials: potash from Europe; nitrates from South America; bones from India; and fish meal from locally based fishing fleets. Others were generally in cities where a substantial livestock processing industry offered tankage, bone meal, blood, hoof and horn meal.

In-plant movement was done by two-wheeled carts which were called "Georgia buggies" around the south. Generally, one man worked at each side of the cart using shovels to load them. That operation was streamlined by pairing a left handed man with a right handed one.

Many of the plants had added acidulation units during the "teens". These units combined sulfuric acid with phosphate rock to make 16-19% superphosphate as a raw material for mixed fertilizers.

In 1925, IMC Fertilizer, still known as IAC, International Agricultural Corporation, produced their first premium grade fertilizer at their Montgomery, Alabama plant.

The pulverized fertilizers of that time were extremely prone to caking in bags. This premium fertilizer, designed for cotton, contained 200 pounds of cottonseed meal to prevent caking and to provide slow release nitrogen. Secondary minerals, calcium and sulfur, were registered and boron was added and registered. I believe Royster to be the first company to register secondary elements and IMC to be the first with minors.

By 1950, we had perhaps 30 plants located in the east, midwest, south and southwest. In the early 1950's, when granular fertilizer technology was developed, the plant food division, as it was then known, installed small granulation units at several of its midwest and southwest plants. Most of these plants were shut down in the late 60's.

In the mid 60's, we built our first large granulation plants in the southeast. Six were constructed during 1964 and 1965. Four of these are operating today.

For these many years, the thrust of our marketing and distribution effort has been toward premium fertilizers. There are three brands with three different quality and price levels:

**INTERNATIONAL** - The commodity line containing the basic NPK nutrients.

**RAINBOW** - Contains soluble Mg and S and at least one minor element along with the primary nutrients.

**SUPER RAINBOW** - Our top of the line. It contains extra secondary elements (calcium, magnesium, and sulfur) and minor elements (boron, copper, iron, manganese, molybdenum, and zinc).

Super Rainbow is formulated to meet the nutrient needs of a specific crop in a specific area. These needs



depend on soil types and will vary from one marketing area to another.

For us, the production of a premium quality fertilizer begins with a grade review meeting attended by Division Management, Agronomic Services, and each area's sales and production managers. Each Area Sales Manager outlines the products they would like to sell and make preliminary nutrient content recommendations.

These recommendations are then reviewed by our Director of Agronomic Services, Dr. Sam Kincheloe, and are changed as necessary. He uses personal experience; IMCF soil test data; and extension service information during this process.

After nutrient content has been finalized, the production manager calculates a formula and variations on a computer. This allows us to look at many possible formulas and to select the one that will give the best physical and chemical properties.

Our granulation plants use a variety of materials; sulfuric acid to supply sulphur and heat; anhydrous ammonia, nitrogen solutions, and ammonium sulfate to supply the various forms of nitrogen.

DAP, MAP, triple superphosphate and normal superphosphate are all used as sources of phosphate. Normal superphosphate, which is produced at Americus, Florence and Hartsville, is the preferred phosphate source. Not only does it supply phosphate, but large quantities of sulfur, calcium, and iron.

Muriate of potash, sulfate of potash and sulfate of potash-magnesia (Sul-Po-Mag) supply potassium. All Rainbow and Super Rainbow grades contain Sul-Po-Mag which, in addition to potassium, supplies water soluble magnesium and sulfur.

Sodium borate supplies boron. Copper, manganese and zinc are obtained from metallic powdered oxides or sulphates. Special handling techniques are required, but, by using these fine materials, each granule will contain the desired amount of the minor elements.

Granulation is by agglomeration which involves wetting the particle surfaces and then employing surface tension to draw the wetted particles together into sub-assemblies. These are then further consolidated into larger granules by the rolling action of the ammoniator drum. Each granule contains all the nutrients called for in the product specifications.

Premium fertilizers (as do all fertilizers) need to be dried to a low enough moisture and be cool enough not to cake in bags or storage. We also add coating agents for dust suppression. The difference between coated and uncoated material is dramatic.

Quality control is an essential part of the production of premium fertilizers. Each of our plants has a fully equipped analytical laboratory. In these analytical laboratories, we have the capability of analyzing for each nutrient that is guaranteed in the formula. Each shift's production is completely analyzed within twenty-four hours.

Each of the various states collect samples of

Rainbow fertilizers. Last year, 2628 samples were collected with an average of 10 nutrients per sample. If any one element was deficient, the entire sample was considered deficient. If we look at one plant producing over 90% premium, the state analyses showed a deficiency rate of 3% and 99.6% of nutrient guarantees to be on spec.

One other factor necessary with a premium fertilizer program is an aggressive marketing and sales program. Conditions and goals change. For example, today we are looking at environmentally conscious production agriculture. So, it is necessary to continue to work with successful, innovative growers who use premiums. 27% of the 2.2 million farmers in the U.S. produce 80% of the marketable crops in the U.S. The top of the group may be there due to extremely large land use, but, from the middle down, one finds many of the premium fertilizer users.

As to the demise of the granulation industry, let me paraphrase Mark Twain and say "Reports of its death are greatly exaggerated". Where the industry has taken advantage of taking the high road to premium or diversified into specialties, you find plants.

## **NPK Granulation Plant Design, 1950 to Today**

*Walter J. Sackett, Jr.*

**The A. J. Sackett & Sons Company**

As you may, or may not know, our company has been involved with fertilizer plants of one sort or another for almost a century now.

My grandfather, Gus Sackett, a millwright by trade, was designing and installing milling, shipping and bagging units back as early as 1887. At that time, he was working for the Walker and Elliott Company out of Wilmington, Delaware. He started his own company in 1897 on the advice of Ed Baugh of the Baugh Chemical Company.

Our company was incorporated in 1929 with Gus and his two sons, Joe and Walt, the sole stockholders. They survived the depression, with some scars, and got through World War II in acceptable shape.

This brief company history is given merely to show why we should have been logically involved in many of the early NPK Granulation Plants of the 1950's.

We were ideally situated to take advantage of the tidal wave of changes that came out of Muscle Shoals when "Slugger" Nielsson started to spin his drum. It was undoubtedly the biggest revelation in the recent history of the industry, especially when you think of the additional accomplishments that it spawned. The huge DAP and TSP complexes that we see today are offspring's of Frank's brainchild. These complexes began bulk blending as we know it today. Bulk blending, in turn, has come full circle and spelled the end of



NPK Granulation as we knew it during its two decade reign of the mid 50's to the mid 70's. In other words, NPK Granulation's own child, Bulk Blending, has almost run it out of the fertilizer business. Indeed, it would seem that with the gaining popularity of compaction and its obvious environmental advantages, we might well see the complete demise of NPK Granulation, domestically in any case, in the next ten years. I say that with a tear in my eye, not only because I have a soft spot in my heart for the process, which I do, but more important because it takes a whole lot of bulk blend plants to fill the shop time of one granulation plant.

Enough of this, however. What we are talking about today is the anatomical history and evolution of the NPK Granulation Plant.

As with any new process, the unknowns were many and everybody was groping for answers to the many problems involved.

The typical granulation plant of the early 1950's started with the dry materials in the formula being fed to an ammoniation drum which was normally sized with a length equal to its diameter. Because we were not sure of what the optimum rotation should be, the drum was run by a mechanical variable speed drive. Liquids were metered through roto-meters and introduced under the mass by means of spargers supported by a heavy pipe frame which extended through the drum. Cleaning of the drum was by means of a bar scraper also supported by the pipe frame. This scraper, by the way, was a real power hog.

Because we felt that it was possible that optimum shell speed for granulation might be different than for ammoniation, we had a separate granulator. This drum was roughly the same dimensions as the ammoniator. It, of course, was also powered with a variable speed drive. The granulated mass then spilled over a dam ring and into the dryer.

The dryer was a flighted drum, much as we use today, except that flight arrangements had not been given as much study at that time and consequently, drying was not as efficient as it is today. We used a substantially sized combustion chamber, tuyere or double shell design, usually refractory lined, as did most of our legitimate competition. There were some of the "get in the business cheap" guys out there then, of course, that merely hung a burner on the feed or discharge breeching and shot the flame down the barrel. Naturally, they didn't last long and neither did their equipment. Because the turndown ratios of the burners were not great, we usually used from 2 to 4 burners to get the proper range that was desired to cover all grades. We used a gear pinion drive powered by a constant speed gearmotor or motor with reducer. There was some sympathy for and experimentation with counter current dryers. Most plants had their dryer discharging to a cooler.

The cooler was also a flighted drum, similar in size to the dryer if you were screening cool. If you were

screening hot, however, the cooler could be considerably smaller since it was handling only product. The only difference between the two drums normally was that the cooler air was running counter to the flow of material. Because of this, the cooler was normally pitched slightly steeper than the dryer. Normal plant design had the cooled material being discharged to a screen elevator.

Most elevators were of a centrifugal chain design, mainly because that was what had historically been used in fertilizer plants.

The elevator discharged directly to the screens, normally double deck. Also, I might mention they were almost always Tyler Hummers. Nobody did a better sales job on the industry than our old friend, Wayne King.

Oversize was handled by a variety of mills in those days with many claims being made for the efficiency of each, but most leaving room for improvement.

Early on, dust collecting was relegated to the category of "second class citizen". In most cases, environmental regulations were not clearly defined. In most plants, the only areas considered for air pick-up were the dryer and cooler, because large amounts of air were required to properly perform these functions, and the ammoniator, because some steam and fumes could be created there. In most cases, the dryer and cooler air streams were handled by cyclonic dust collectors only. Ammoniators often were vented directly to the atmosphere. Some of the systems were sized correctly for the proper air velocity. Some were not. In some plants, air systems were considered only as necessary nuisances with the attitude being, "just make the ducts big enough". Consequently, you got many systems that filled up with dust until they reduced the inside diameter to the point of proper velocity, and then were a constant source of dusty stacks, especially at start-ups. Most of the old timers here remember some rusty duct systems that contained beaucoup tons of fertilizer hovering over their heads as they walked through some of the old Norfolk plants.

Basically, that's how it was thirty five years ago. Some plants were better than others, as has always been the case.

In our case, because my Uncle Joe believed that gravity beat the hell out of bucket elevators as a means of moving materials from one piece of equipment to another, the plants got pretty high.

As years went on, many advances were made, but NPK Granulation Plants seemed to keep their same character. There were variations, but the basic steps remained the same. Changes, large and small, as I saw them over the ensuing years, I'll try to relate. I'll do it according to flow, rather than chronologically, because I feel it will be more comprehensive that way.

As we learned more about ammoniation and granulation, we became confident of proper speed, residence time and power. What had been two drums now became one. Proportions of the drum were a length

slightly longer than twice the diameter. For example, a typical 30 Ton Per Hour Unit now would be 8' Diameter x 18' Long with a Dam Ring approximately 2' from the end to allow freeboard for additional granulation before going to the dryer.

Because higher grade patterns became required and in order to take advantage of low priced raw materials, pre-neutralizer reactors were added to a majority of the granulation plants starting in the late 1950's.

Today, most of these plants are using TVA Pipe Reactor.

By the early 60's, magnetic and mass flow metering had replaced all of the old flo-rators, thus improving formulation immensely.

Venting the ammoniator to the atmosphere became less popular with the emergence of the EPA. Small impingement type or venturi scrubbers were installed to handle air flow from ammoniators and pre-neutralizers. The amount of effluent generated could usually be absorbed back into the system with no great strain.

The old bar scraper was replaced by more efficient and less power costly methods. Reciprocating scrapers were successfully used. Rotary scraper with both helical and straight blades were rarer, but largely successful. The most popular method, after much design trial and error, is the rubber lining. Our own John Medbery was responsible for much of the design work done in that area.

I would be remiss if I did not mention that pan granulation was given a hard look in the late 50's and early 60's, but while granulation was good, ammoniation posed problems.

Also I wish to mention that pug-mill granulation, which was favored by some in the industry, was employed in many plants throughout the granulation years. Another past chairman, Mr. Joe Reynolds, was a leading exponent of this method.

For the production of low nitrogen goods, most plants installed steam boilers for a source of auxiliary heat to promote good granulation.

Larger combustion chambers with high limit temperature controls were installed to prevent nitrogen losses in the dryer. Burner technology improved turn-down ratios tremendously, thus eliminating the need for multiple burners. Where space was at a real premium and gas was acceptable fuel, line burners were installed. These gained prominence near the end of domestic granulation plant building, consequently not many were installed, but they were quite satisfactory.

Dryer and Cooler lifting flight pattern design was refined, thus improving efficiencies in both areas.

In the late 50's, we started using chain drives in lieu of gears on all drums 10' diameter or less. Economy in original equipment cost, installation and maintenance was substantial. Fluid Couplings came to be in common usage, which helped normal wear and tear of drive components.

In the mid 60's, there were a number of manufac-

turers who opted for combination dryer-coolers. There were several variations of design, but the norm was to have the common exhaust duct extend approximately halfway through the drum from the discharge end, pulling hot air from the furnace in a co-current manner and ambient air from the discharge in a counter current direction. The machines worked effectively and cut space requirements somewhat, but control of air flows was not as good as with separate drums.

Screening is not a lot different now from what it was then, except that Wayne King is no longer with us and today, we have several companies that supply acceptable classifiers for this type of operation.

Milling of oversize has been narrowed, at least in our opinion, to two main types. If you are operating a closed circuit, where milled oversize is returned to the screen for re-classifying, we feel a double rotor chain mill or combination chain-cage mill is the most effective. We would advise the same type of mill if you return material to the dryer. If, on the other hand, you return this material to your ammoniator, we would install a double cage mill.

In the late 60's, many plants were installing coating drums and polishing screens. After all, if you take care in making a good product, you should endeavor to keep it that way.

In that same vein, centrifugal elevators, while still acceptable in most applications, were dropped in favor of the gentler handling continuous elevator, when moving finished product.

Dust laden air is now picked up, not only at the obvious dryer, cooler and ammoniator exhausts, but also at screens, mills and transfer points. The two most common methods of air clean-up are bag filters and wet scrubbers. There are points in favor and against each. Wet scrubbers with venturi inlets are much easier to operate and maintain than bag houses. However, you have an effluent disposal problem with the scrubber that you do not have with the bag house. If you have room for a settling pond, the scrubber's okay, but you may merely be postponing your problems.

I know there are many changes that I have not discussed, but there is only so much that can be covered on a subject this broad in twenty minutes.

Suffice it to say, that just about the time that we machinery guys had really learned how to build these things, you fertilizer guys said they were no longer needed. It is a story that has been told many times.

## **Compaction-Granulation of Fertilizers**

*Pascal Hervieu*

**Sahut Conreur & Cie**

*Christian Fayard*

**Technifert S.A.**

*Presented by Christian Fayard*

## I - PRINCIPLES OF COMPACTION

The compaction process is mainly the agglomeration process of various solid materials, powdery or not under a more or less high pressure and with or without the use of binders.

One of its oldest and most famous applications is the production of coal briquettes.

The action of pressure on specially prepared blends creates very strong bonds between the particles and enables to obtain dense and compact solid products.

These bonds may be of various origins : ionic forces, Van der Waals forces, etc...

### THE COMPACTION PROCESS

There are several means to apply the pressure. The equipment used in the compaction process of fertilizing agents is a machine named "compactor" made of 2 parallel axle cylinders. These two rollers are pushed very strongly one against the other by means of a force which is generally constant, each roller rotating slowly in a reverse direction. (Sketch 1.)

- Axis of roller 1 is fixed

- Axis of roller 2 moves horizontally; it is pushed by a constant force F2 towards the roller 1 by means of 2 or 4 hydraulic jacks. The pressure in these jacks is regulated by means of an hydraulic circuit.

If one applies the combined forces F1 and F2 on a particle M (frictional forces generated by the rotation of the rollers), this particle will move downwards, run through the rollers and undergo a very high compression.

The choice of the feeding to the compactor is critical. This feeding can be achieved in different ways (Sketch 2).

Figure I : Screw force-feeder systems

These can be multiple, vertical or inclined but as a rule, the rotational screw speed is variable and the feeding screw should be tapered to ensure good product deaeration.

Figure II : Feeding hopper system. The level in the hopper is adjustable and has to be kept constant.

Figure III : Vibrated horizontal screw system used when the products are fine and cannot be easily deaerated.

Figure IV : - Horizontal feeding screw system for superposed compaction cylinders.

The design of the intermediate part between these various systems and the nip point is very important and each manufacturer has his own design.

As far as we are concerned, it took us more than five years to determine the optimum shape (yield factor, life-time factor for the cylinder surface quality, etc).

### OPERATING PARAMETERS FOR THE COMPACTION PROCESS (Sketch 3.)

We know by experience that there is an optimum pressure zone for a given blending:

- a lower pressure leads to a bad cohesion of flakes.
- a higher pressure leads to the cleavage of flakes (fish bone phenomenon), prejudicial to the plant yield and the final product quality (production of needles).

Depending on this pressure, we can determine the optimum apparent density of flakes ( $d_o$ )

The output of the press (Q) is given in the following formula:

$$Q = K \times P_i \times D \times N \times L \times E \times d_o$$

Obviously the adjustment of the unit aims at increasing the output (Q) as much as possible, for:

*A given power consumption*  
involved in:

- drive of cylinders
- force-feeding drive
- hydraulic circuits

*A minimum investment*

The mechanical stresses increase together with the width of the cylinders (e.g. : radial load on the roller bearings).

*A minimum maintenance cost*

Wear of cylinders increase together with the rotational speed for a given cylinder diameter.

There is an existing complex relationship between the angular rotational speed and the diameter of the cylinders for a given product. Under particular conditions, one can reach a critical angular speed leading to a self-feeding of the press and to a loss of control on compaction.

Consequently the parameters D, L and N are to be determined once and for all at the design stage, according to the required products.

Therefore the equation of output will be the following one, for a given product:

$$Q = K' \times E$$

Thickness (E) will be influenced by:

- 1) Power available on drive
- 2) Force-feeding pressure
- 3) Compaction pressure
- 4) Surface quality of cylinders (roughness)
- 5) The shape of the cylinder surface which can be :
  - smooth

- corrugated
- herring-boned
- pocketed, etc...

#### 6) Deaeration condition of product.

As a matter of fact the relations are relatively complicated.

However various systems will enable us to control them :

- System of regulation of the force-feeding pressure to maintain a constant power consumption.
- System of regulation of the force-feeding pressure to maintain a constant flake thickness.
- Interlocked regulation systems acting up on force-feeding, gap between rollers, rotational speed and power consumption.

As a matter of fact, the optimum choice of parameters will be a compromise between the compaction theoretical optimum value and the operation optimum value. Under such conditions, the experience of the manufacturer is particularly important. (Chart 1.)

## II - COMPACTION-GRANULATION : THE MAIN STEPS OF THE PROCESS

A compaction-granulation unit includes five main steps:

### STEP 1 : SECTION OF RAW MATERIAL PREPARATION

This section usually includes :

- Feeding hopper with a rough screening system (elimination of big lumps) and possibly, a lump-breaking system and a magnet.
- Material storage hopper before dosing or weighing
- Weighing system (in batch) or dosing system (continuous)
- Raw material grinding system if need be. It is advisable to have particles smaller than 1 mm to improve the homogeneity of final products and the production yield.
- Homogenizing system (mixing)
- Controlled feeding system to compaction

As a matter of fact, the same section can be found in traditional granulation plants or in bulk-blending plants (compaction can be judiciously associated with bulk blending).

### STEP 2 : COMPACTION SECTION

The compactor includes the following main sub-units :

- Feeding hopper
- Force-feeding system
- Compacting cylinders
- Flake-breaker

At the outlet of the compaction section, we get very rough lumps (approx. < 40 mm or 2").

### STEP 3 : GRANULATION SECTION

This section includes :

- A system to reduce the size of the granules (More or less complicated combination of granulators).
- Sizing system (by means of combined screens).

This section has many effects upon the plant capacity. According to the system chosen or for instance according to the choice of screen grids, the yield can double.

### STEP 4 : FINISHING SECTION

This section includes :

- Dry polishing unit with :
  - a.) A polishing drum to improve the quality of the final product by rounding off the sharp edges of the granules. This limits the generation of dust and removes weaker granules.
  - b.) The finishing screen(s) to remove the dust generated by the abrasion of polishing drum.

- The granule polishing and hardening unit with :

- a) impregnation and regranulation drum where water, steam or slurry are introduced in small quantity.
- b) Drying system which enables to adjust the water content of final product and is very important to avoid caking later on.
- c) Possible cooling system (fluidized bed) which can be a mere injection of cold air under the finishing screen.
- d) The finishing screen(s) which enable to remove fine or large particles which have been agglomerated during the process.

- The coating unit which enables - as in traditional granulation plants - to limit caking and sometimes to treat the external surface of the granules (production of slow release fertilizers).

This unit includes :

- a) a coating drum fed with solid or liquid coating products.
- b) and as previously said, a rough safety screen to remove the lumps formed in the coating drum.

**However, it should be observed that, as a rule, compacted fertilizers have a lesser tendency to cake.**

### STEP 5 : STORAGE AND PACKING SECTION

This section can be found in other fertilizer plants.

Note that fertilizers obtained by compaction - except for rare exceptions such as fertilizers with a very high urea content - do not require any curing period before delivery.

The optimization of the process is the result of the combination of three main stages which are interdependent :

- I - Compaction  
Agglomeration of components
- II - Granulation  
Shaping and granulation
- III - Finishing Processes  
Which will determine the quality of the final products

As a rule, in simple units processing materials which are easy to produce, the first two stages are generally sufficient.

### III - HISTORY OF THE PROCESS - THE EXPERIENCE OF TIMAC FRANCE

The compaction-granulation process has been used for a very long time for potassium chloride granulation.

More than 20 years ago, small units (5 to 10 tonnes/hour) were set into operation in Europe by small producers (1 PK and NPK unit in Switzerland, 1 PK and NPK unit in Germany, 1 potassic slag unit in France); these units are still operating.

Since then, new plants have been built with capacities up to 60 tonnes/hour : in France (6), in Belgium, in Switzerland (1), in Germany (2), in Portugal (1), in Guatemala (1), in the Philippines (1), in Greece (1), in Turkey (1) and very recently in Finland (1).

Numerous projects all over the world are in the feasibility stage at the present time, As a general rule, they correspond to various motivations such as :

- multiple formulations combining highly specific materials adapted to local farming conditions and to economical supply facilities.
- Production of fertilizers which are difficult to produce in the traditional way, for technical reasons.
- Raw material granulation for bulk blendings (ammonium sulphate).
- Production of intermediate fertilizing agents between fertilizers and amendments.
- Minimizing investments and easy operation.

This process is mainly of interest to medium-sized firms acting as 'processing companies' and does not

concern the 'big manufacturers' as their production policy aims at producing a limited number of standardized raw products (DAP, TSP) or highly concentrated formulas (18-24-12, 17-17-17, etc...) on a large scale.

### THE EXPERIENCE OF TIMAC FRANCE

We learned a lot from the experience of the French fertilizer company TIMAC S. A.

In 1975, TIMAC SA was a medium-size producer of amendments and powdery fertilizers containing soft ground phosphate (for direct application). They then decided to build a compaction-granulation unit to process these materials.

This unit was set into operation in 1976 in St. Malo (France) and included 3 compaction lines, each one with a 10 metric tonnes/hour capacity.

After difficult starts, TIMAC began to control the process gradually while :

- diversifying their range of products and the use of raw materials (see Table 1 of manufactured products and raw materials used),
- automatizing the plants as much as possible
- optimizing the compaction technique (see flow-sheets #1-7) and increase instantaneous production.

These units are now under perfect control, with a constant improvement of the working costs and the production quality.

The daily production is around 900 to 1250 metric tonnes/day.

At the present time, the plant in St. Malo is the largest in the world. It is also the only one capable of processing such a wide range of raw materials and of producing such a wide selection of finished products.

This firm, a subsidiary of the Roullier group, has now control over 12 granulation units and therefore has a perfect knowledge of the respective advantages and limits of the different processes.

### A SHORT BRIEFING ON THE PRODUCTION COST PRICE IN A COMPACTION PLANT

It is always difficult to provide accurate data about the production cost prices and the finished product costs (raw materials + production), because they depend on factors that vary very strongly from a plant to another.

So we will merely outline :

- 1 - the main expenses headings
- 2 - a concrete example corresponding with French conditions of operation.

## 1 - Main expenses headings

### 1-1 Energy

Electricity :

- Raw material dressing 3 to 8 kwh/Mt
- Compaction line 15 to 25 kwh/Mt
- Finishing line 2 to 15 kwh/Mt
- Air conditioning, dust removal 4 to 8 kwh/Mt

Oil or gas :

Generally used to produce hot gas or steam for the workshop air conditioning.

### 1-2 Maintenance

a. Expenses corresponding with the maintenance of the specific compaction equipment and that generally depend on the time of use.

Life duration of	
Compaction wheels	5 to 15 000 h
Force feeders	> to 3 500 h
Granulator grids	300 to 1 000 h
Compactor rollers	> to 25 000 h

b. Fixed workshop cost maintenance.

### 1-3 Manpower

From 1 to 2 operators per shift for production  
From 0 to 2 maintenance workers per shift

### 1-4 Depreciation

Generally the biggest heading.

### 1-5 Overheads

This heading generally is low because the production technical staff is not significant due to the simplicity and the flexibility of the operation.

## IV - ADVANTAGES AND LIMITS OF THE PROCESS

### ADVANTAGES

#### 1 - AGGLOMERATION BY DRY OR LOW MOISTURE CONTENT PROCESS

Being carried out dry or with a low moisture level, compaction granulation has the following advantages :

- a very low or non existent energy consumption for drying
- use of electricity as energy.
- few corrosion problems and therefore a low maintenance cost.

nance cost.

- low pollution level for this process (no liquid or gas effluents to be processed)

- possibility to manufacture products which are hard or even impossible to obtain by wet process (high urea content fertilizer for instance).

- Less important caking problem and better conservation of fertilizers.

## 2 - MECHANICAL TECHNOLOGY PROCESS

This generally implies :

- Low investment cost (use of simple equipment and materials)

- Shorter delivery time

- Wide adaptability to local conditions (products, raw materials, technological level, production capacity)

- Plants with flexible capacity and sophistication (from the 5 MT/h unsophisticated plant to the fully automated plant with a capacity of 60 MT/h or more).

- Compact plant lay-out due to simple circuits.

- Very high service factor, usually over 90%.

- The operation and maintenance of such a plant are easy and the staff do not need special training.

- Reduced staff required to operate the plant.

## 3 - A FLEXIBLE AND VERSATILE PROCESS

The cost of the raw materials selected can be optimized thanks to the flexibility of the process.

We have developed a computer program which enables at any time to adjust the optimization of the cost of raw materials according to the evolution of the market and the restrictions in formulation.

This process allows quick changes in the production while limiting mistakes in formulation. A change in fabrication requires 30 minutes at the most to drain the circuit and start a new product.

Thanks to this process, we could produce in the same workshop :

- a fertilizer which contains soft ground phosphate
- a traditional concentrated NPK (17-17-17)
- very specific formulas such as 14-6-24 + MgO + B203.
- a NK product (14-0-20).

The plants should be designed from the start to take



thorough advantage of these 'a la carte' formulas.

The interest of this process is the direct consequence of:

- A low fabrication cost
- A raw material cost which can be optimized at any time (savings under this heading can pay the production cost).

The flexibility in the use of raw materials enables to eliminate the supply constraints as the plant can easily adapt to the change of raw materials.

The formulation flexibility and the width of the spectrum of feasible formulas enable to have a high rate of utilization of the plant all the year round while following closely the seasonal needs and diversifying the manufactured products.

On the basis of the above mentioned points, we can say that an interesting and original type of production management can and even has to be adopted. And as the instantaneous overcapacity of production does not bring a significant increase in the operating fixed charges, the plant can adapt its production to the market demand and work with minimal stocks of finished products.

### *LIMITS OF THE PROCESS*

#### *1 - A DRY AGGLOMERATION PROCESS*

There are very strict limits for the free moisture content of mixtures before compaction.

The compaction of superphosphates is tricky and a pre-drying or at least a long-time ageing of the superphosphates is required.

The thermic balance remains however favorable to the compaction process.

#### *2 - PROCESS SOLELY ADAPTED TO THE PROCESSING UNIT/FORMULATOR*

This process is not suitable for the production of basic raw materials. Arrangements can be made however for the production of partially solubilized phosphates where water and free acidity can be easily controlled.

#### *3 - A SPECIFIC COMMERCIAL PRESENTATION OF THE FINISHED GRANULES*

The shape of the granules is not as spherical as the shape obtained with a conventional granulation process.

The granule size-range is more irregular.

Some products which have not been submitted to a surface hardening treatment during the finishing stage, generate dust during handling.

Under these conditions the end-user can be slightly reluctant; he needs to get used to the new appearance of the product and consequently a marketing effort could be considered there.

On the other hand, the quality/price ratio makes the

sale easy.

### *GENERAL CONCLUSION*

We do not say that compaction is the universal solution to fertilizer granulation problems or that this process is capable of solving all the issues.

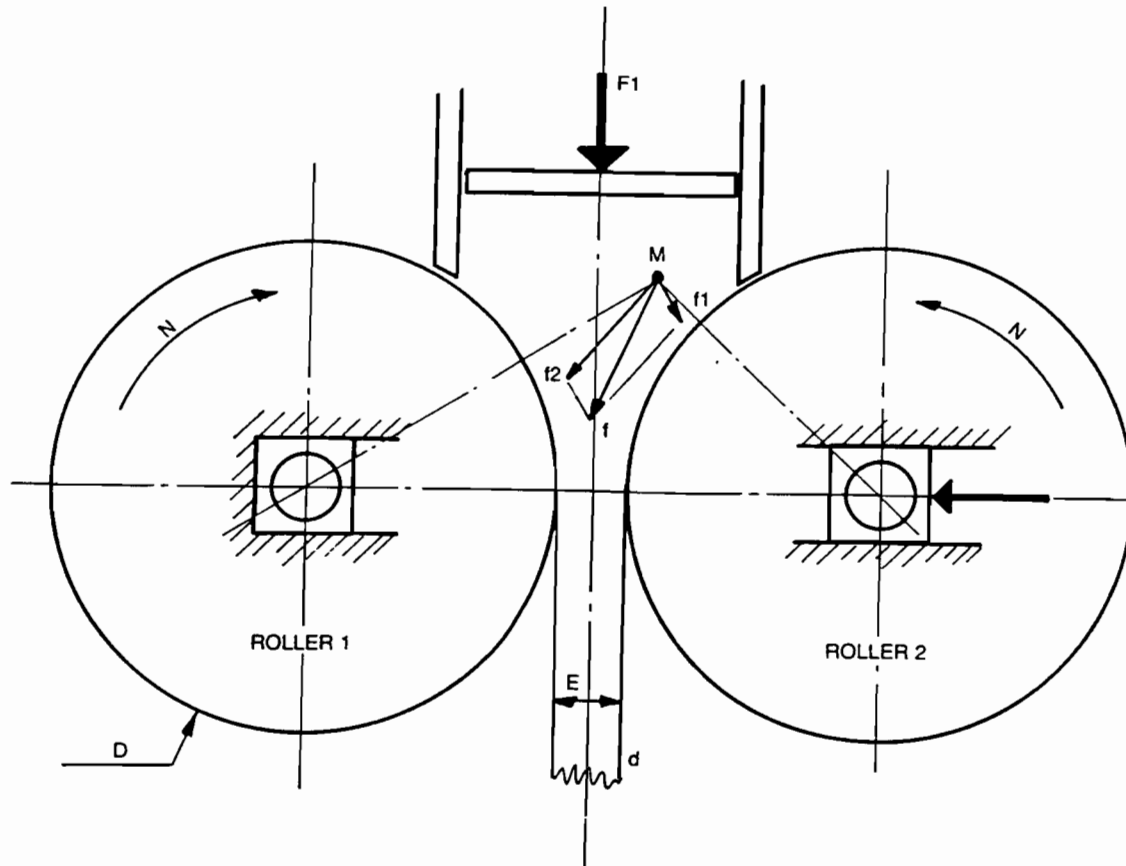
We think that this process has a role to play and that its versatility and flexibility can sometimes be of great interest when a new fertilization project is being developed, based on the production of fertilizers totally adequate to the soil and crop needs ('a la carte' fertilizers).

Here we come very close to the bulk blending philosophy, with a system which is more costly but which has the following advantages :

- Use of many powdery raw materials (KCl, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, crushed phosphate, etc...), which cannot be easily used in bulk blending.
- Formula reconstituted in each granule and in some instances, it is an interesting factor agronomically speaking.
- Disappearance of segregation phenomena
- Even wider spectrum of feasible formulas
- More stable products in the long run

The experience of TIMAC shows that this process can also be very profitable provided that the interested company acts as a processing unit and makes the necessary promotion and marketing efforts.

Sketch 1.



- F1 : FEEDING PRESSURE
- F2 : COMPACTING PRESSURE
- D : ROLLER DIAMETER
- L : ROLLER WIDTH
- N : ROLLER SPEED (rpm)
- E : FLAKE THICKNESS
- d : FLAKE DENSITY
- f1 : FRICTIONAL FORCE FROM ROLLER 1
- f2 : FRICTIONAL FORCE FROM ROLLER 2
- f : RESULTANT FORCE



Sketch 2.

## VARIOUS FEEDING SYSTEMS FOR COMPACTORS

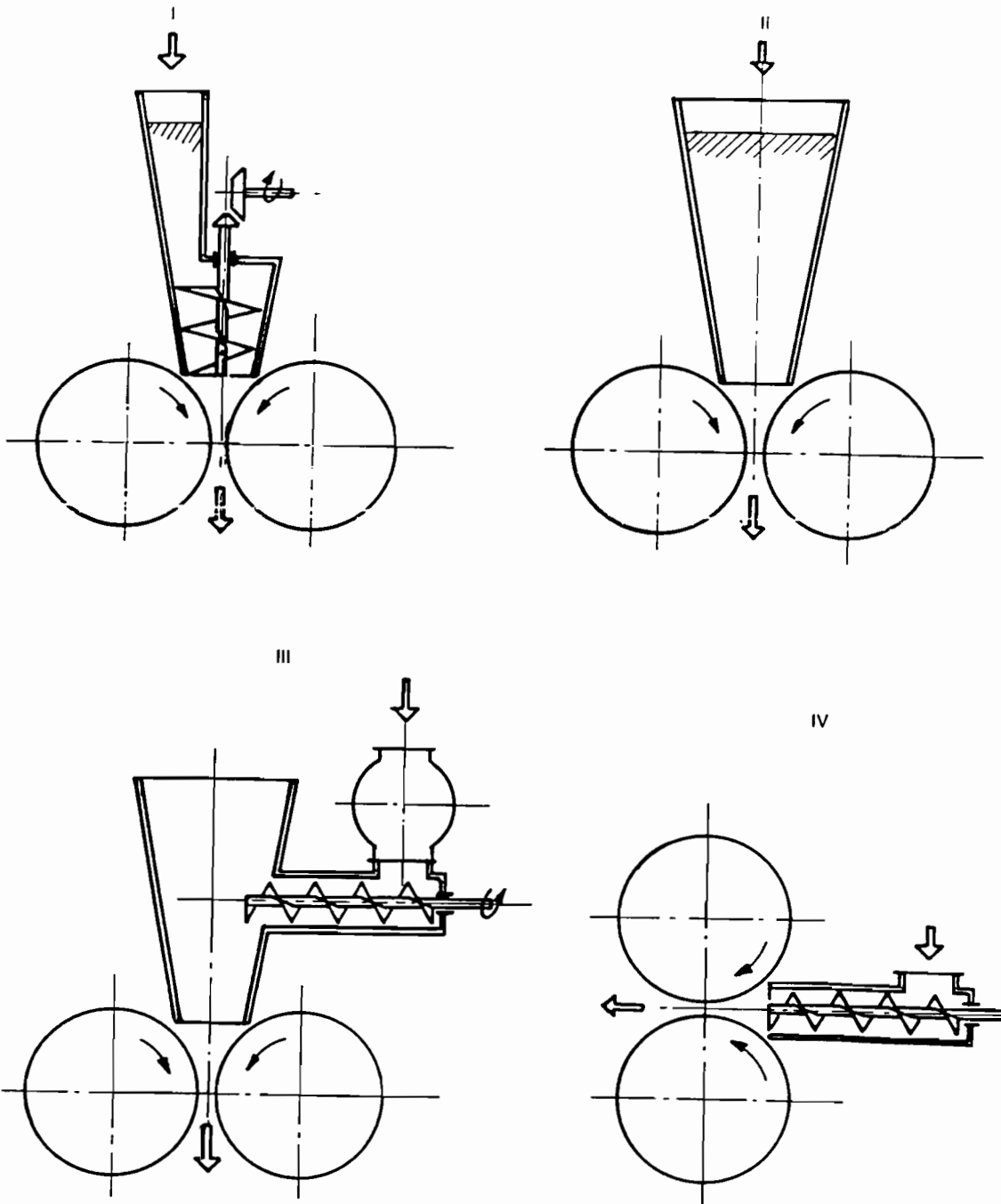


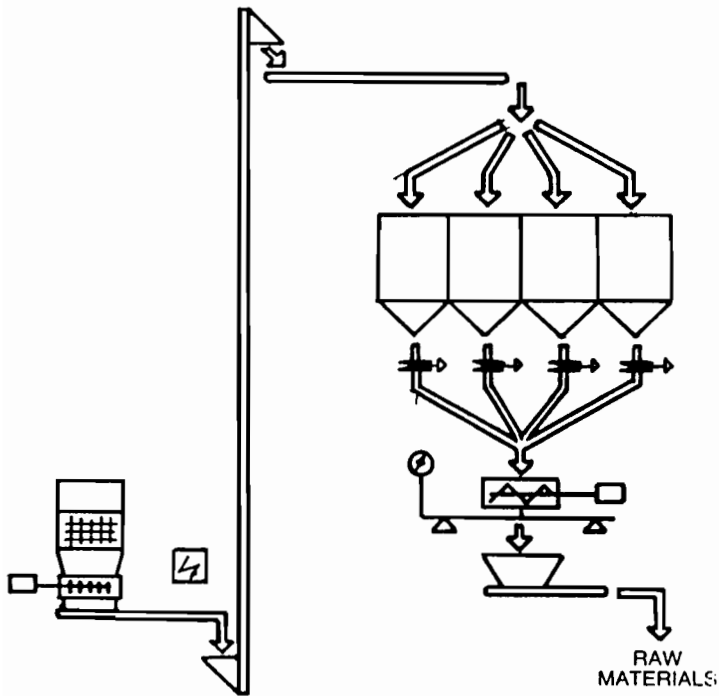
Chart 1.

## VISUAL VARIATIONS OF COMPACTION PARAMETERS

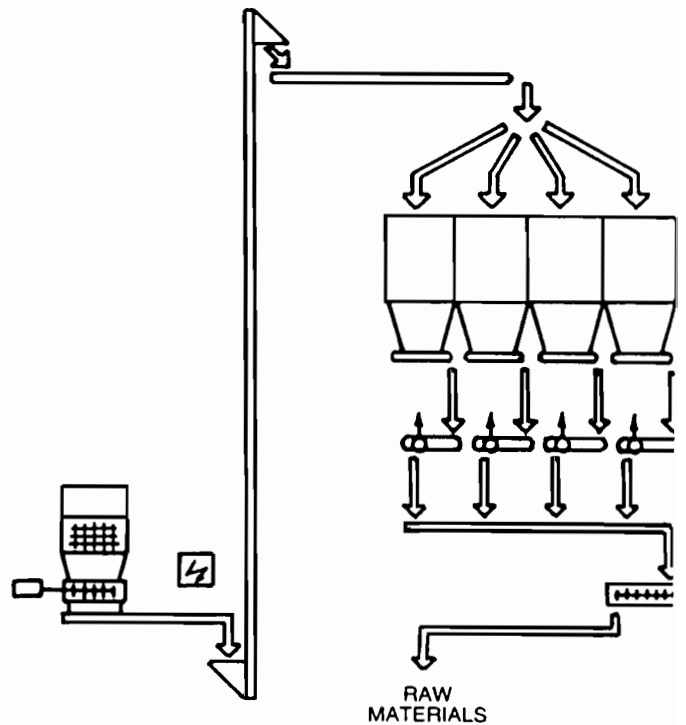
		MIN.	MAX.
ROLLER DIAMETER	(m)	0.6	1.2
	(in.)	14"	48"
ROLLER	(m)	0.2	0.8
	(in.)	8"	32"
COMPACTION PRESSURE	(T/linear cm)	1	10
	(T/linear in)	2.5	25
ROLLER SPEED	rpm	10	22
FLAKE THICKNESS	(mm)	8	25
	(in)	1/3"	1"
COMPACTOR THOROUGHPUT	(T/H)	10	100
COMPACTOR DRIVE POWER	(HP)	75	1000
FLAKE DENSITY	(g/cm <sup>3</sup> )	0.8	2.5
	(pcf)	50	160

Figure 1.

## PREPARATION OF RAW MATERIALS



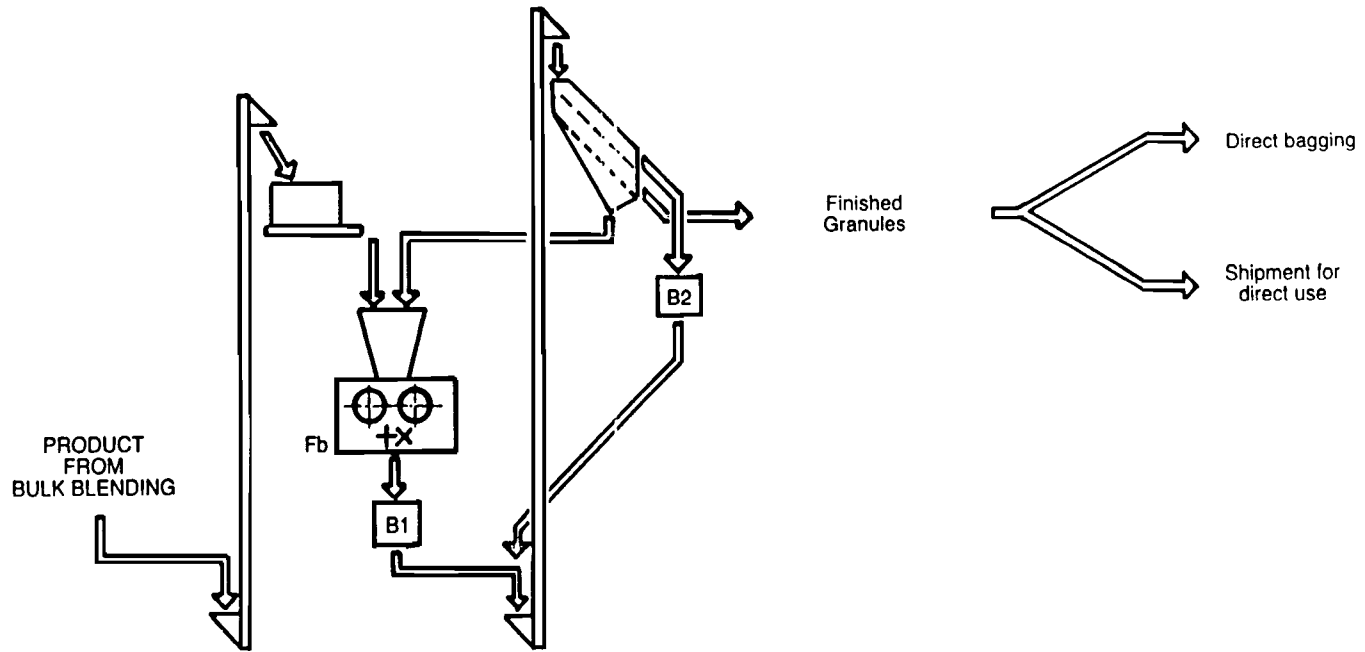
BATCH PROCESS



CONTINUOUS PROCESS

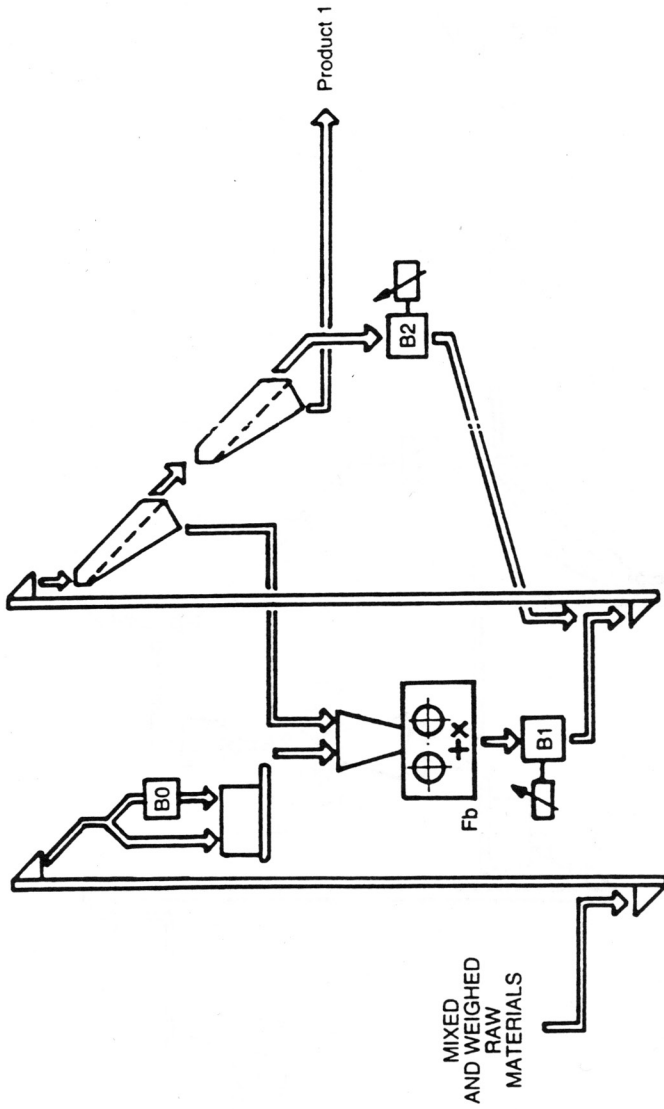
# COMPACTION GRANULATION PLANT (SIMPLIFIED PROCESS)

Figure 2.



Fb = Flake breaker  
B1 = Primary granulator  
B2 = Secondary granulator

# COMPACTION GRANULATION PLANT (IMPROVED PROCESS)



Fb = Flake breaker  
B0 = Raw material crusher  
B1 = Primary granulator  
B2 = Secondary granulator

Figure 3.

# FINISHING LINE

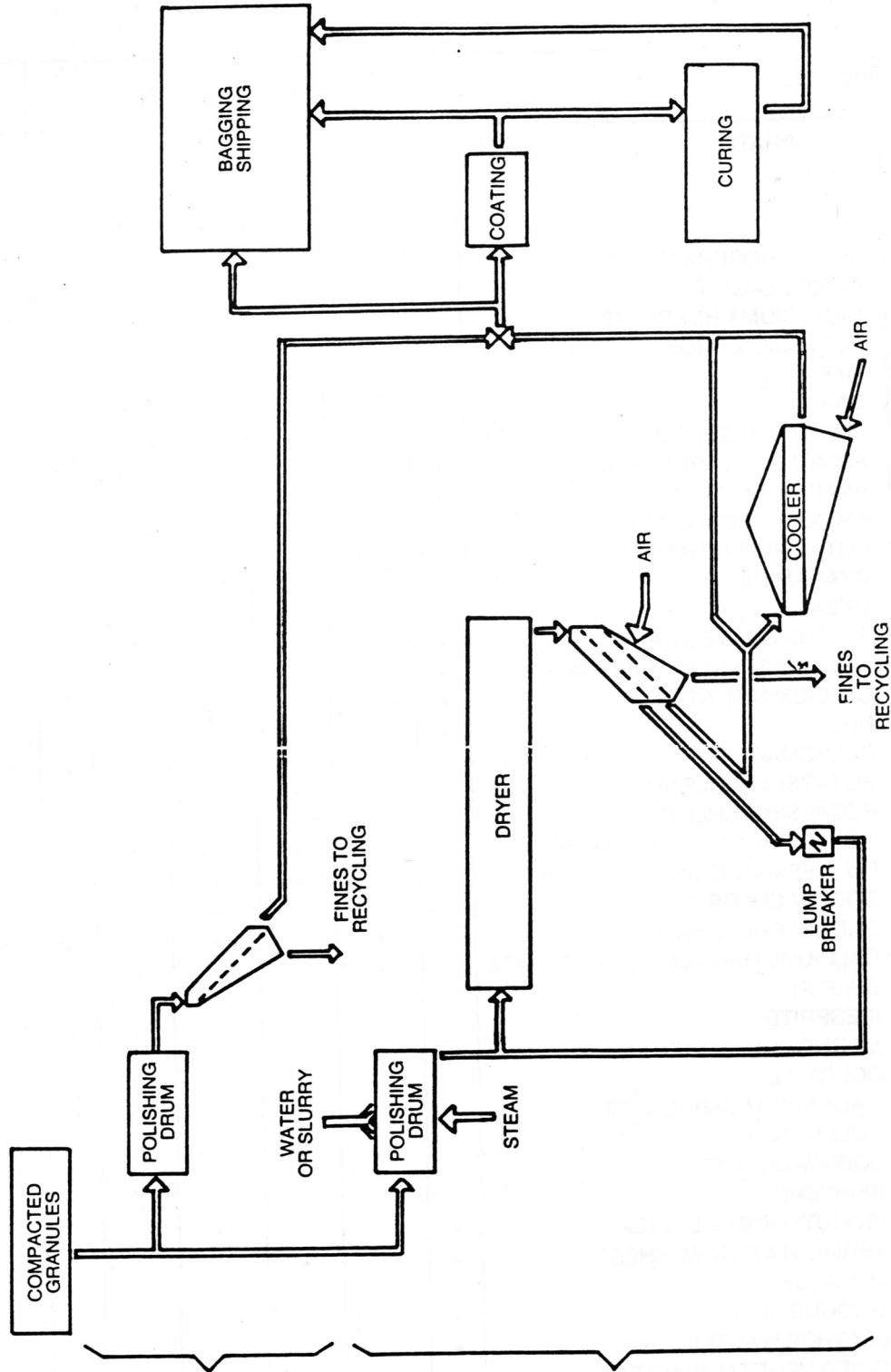


Figure 4.

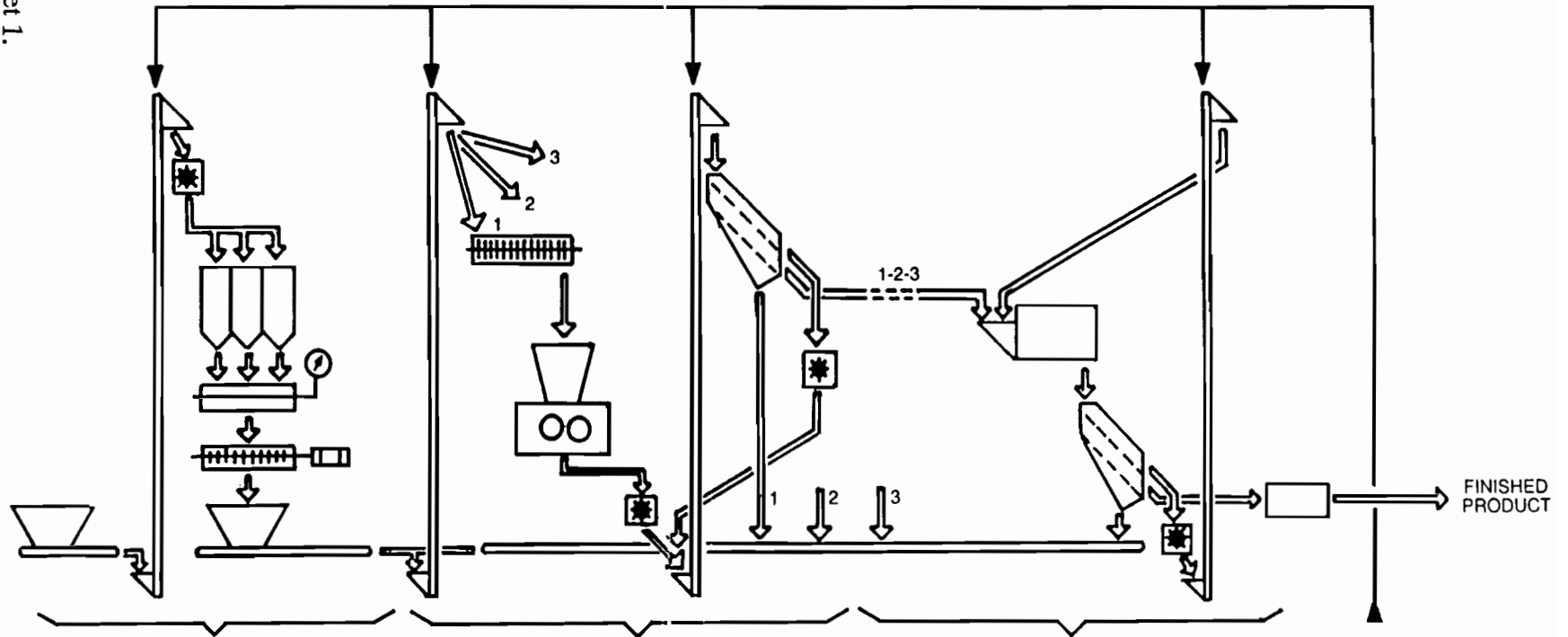
# EXAMPLES OF RAW MATERIALS USED IN COMPACTION

Table 1.

	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Na <sub>2</sub> O	MgO	S	MICRO-NUTRIENTS	ORGANIC MATTERS
PHOSPHATE		•						
PARP		•				•		
SSP		•				•		
TSP		•						
AL-CA PHOSPHATE		•						
BASIC SLAGS		•					•	
DICALCIUM PHOSPHATE		•						
POTASSIUM PHOSPHATE		•	•					
MAP	•	•						
DAP	•	•						
AMMONIUM SULFATE	•					•		
AMMONIUM CARBONATE	•							
AMMONIUM NITRATE	•							
AMMONIUM CHLORIDE	•							
POTASSIUM NITRATE	•		•					
CYANAMIDE	•							
UREA	•							
SULFUR COATED UREA	•					•		
AMMONIUM SULFATE-NITRATE	•					•		
CALCIUM NITRATE	•							
NH <sub>3</sub>	•							
SULPOMAG			•		•	•		
POTASSIUM SULFATE			•			•		
POTASSIUM CHLORIDE			•					
LISYNE PRODUCTION WASTES	•		•			•		•
POTASSIUM SODIUM CHLORIDE			•	•				
SODIUM CHLORIDE				•				
SODIUM PHOSPHATE		•		•				
CALCIUM - MAGNESIUM PHOSPHATE		•			•			
SULFUR						•		
KIESERITE					•	•		
MAGNESIUM OXIDE					•			
DOLOMITE					•			
MAGNESIUM CARBONATE					•			
COLEMANITE							•	
SODIUM BORATE				•			•	
SEAWEED					•		•	
ISOBUTYLIDENE DIUREA	•							
FERMENTATION WASHES	•		•			•		•
MOLASSES								•
GROUND HORN	•							•
LEATHER WASTES	•							•
DRIED VEGETAL WASTES	•							•
POULTRY DROPPINGS	•	•	•		•			•
Cu SO <sub>4</sub> Cu <sub>2</sub> O							•	
Zn SO <sub>4</sub> ZnO							•	
Mn SO <sub>4</sub> MnO							•	
ETC...								

# TIMAC - SAINT MALO ENERGY CONSUMPTION DIAGRAM COMPACTION - GRANULATION PLANT

Flow Sheet 1.



**RAW MATERIALS  
PREPARATION**

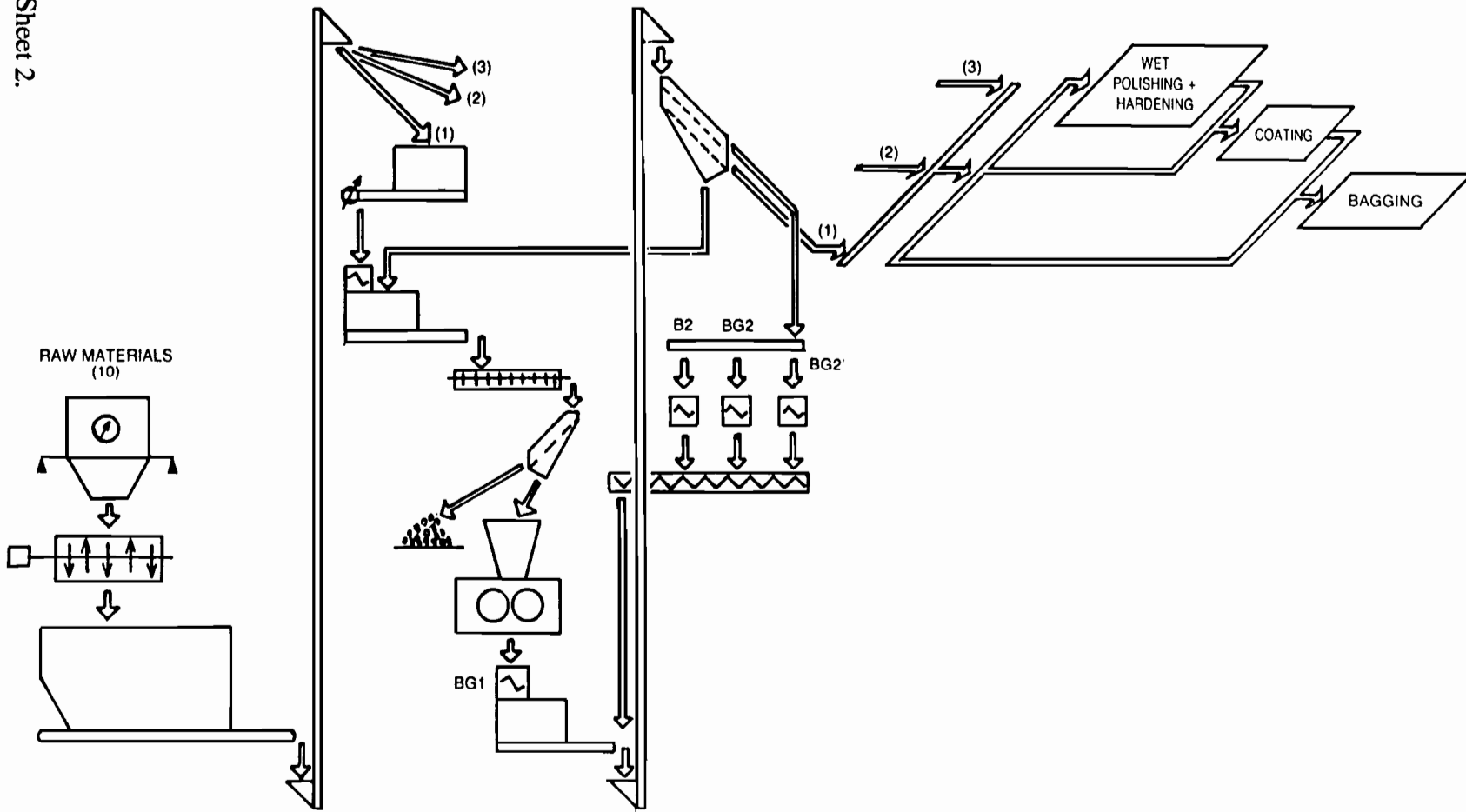
**COMPACTION LINE  
3 LINES**

**FINISHING LINE**  
 • GRANULATION ADJUSTMENT  
 • POLISHING DRUM  
 • COATING DRUM

**AIR CONDITIONING  
DUST REMOVAL**

FINISHED  
PRODUCT

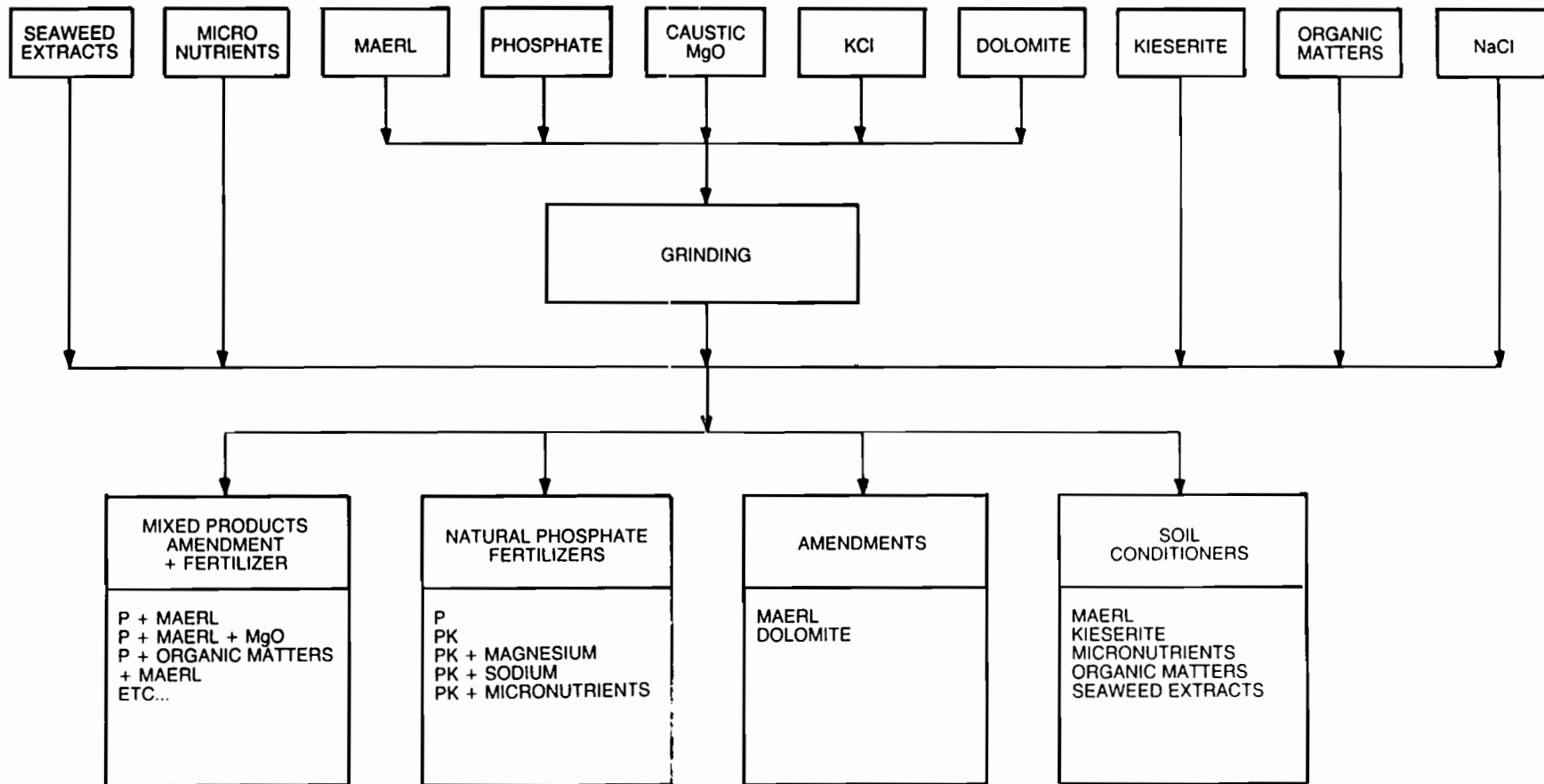
INSTALLED POWER (Kw)	342	1413	343	596	2694
CONSUMED POWER (Kw)	285	1050	122	320	1777
PRODUCTION (MTH)	51	3x17			51
CONSUMED POWER (Kw/Ton)	5,6	20,6	2,4	6,3	34,8



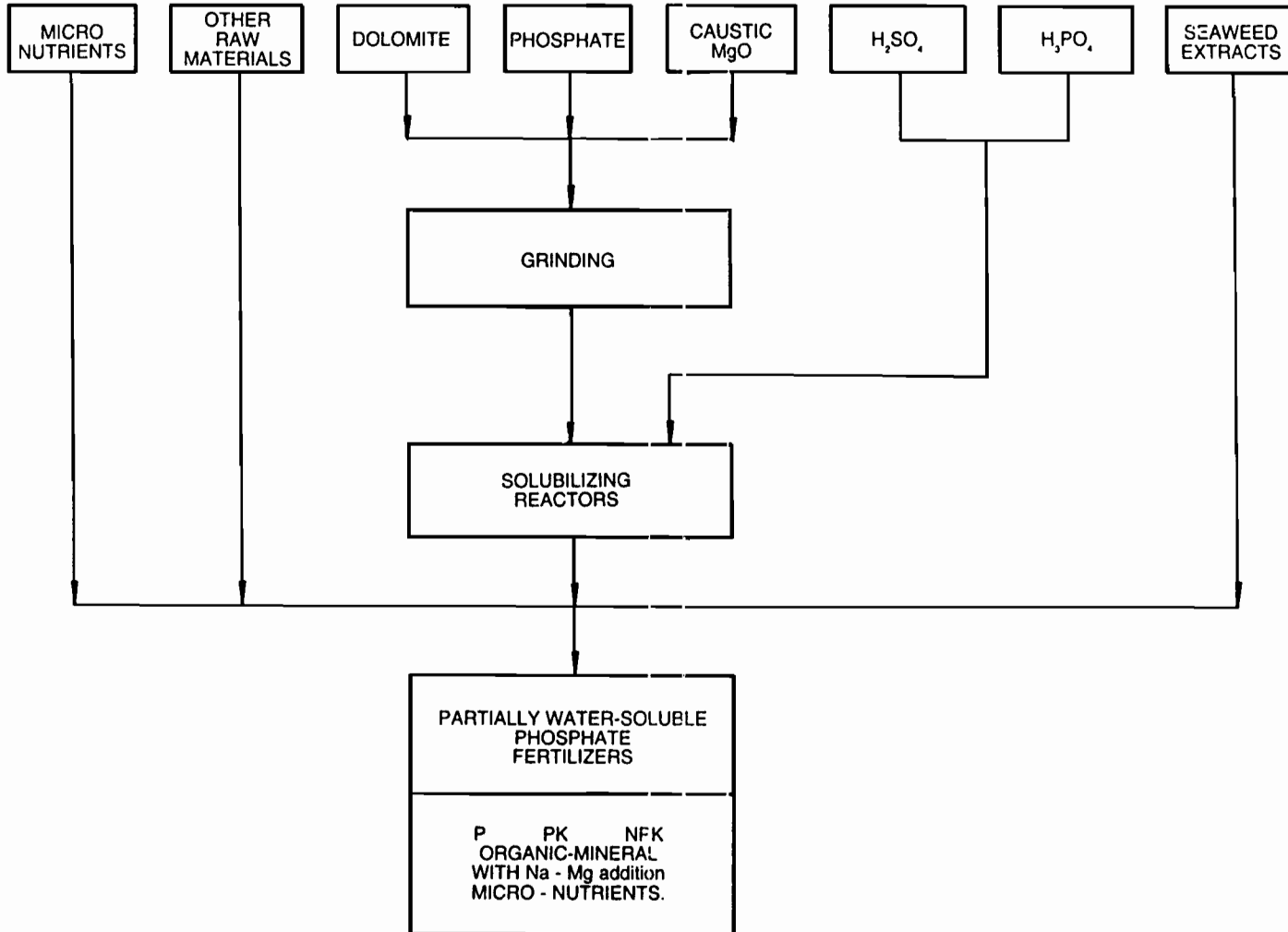
FLOW - SHEET OF TIMAC COMPACTION - GRANULATION PLANT  
SAINT MALO - FRANCE

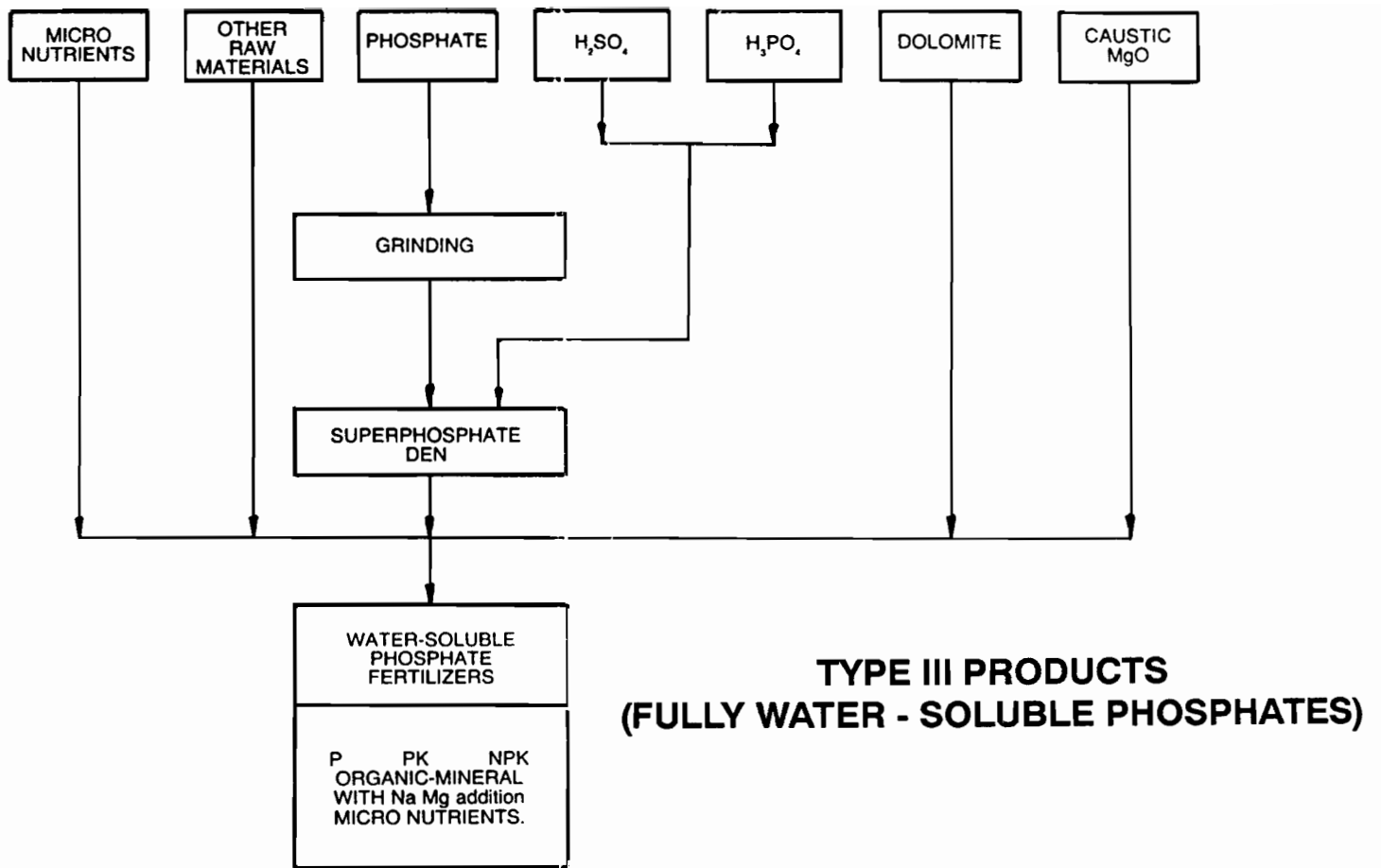


# TYPE I PRODUCTS (ACID SOILS)

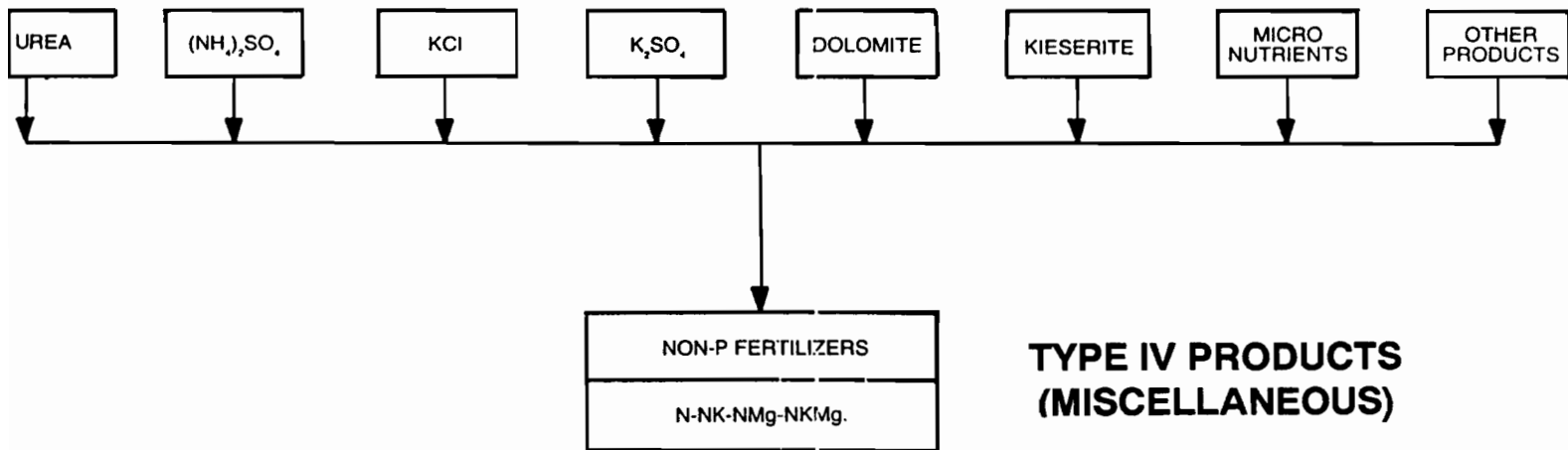


## TYPE II PRODUCTS (PARTIALLY WATER-SOLUBLE PHOSPHATES)



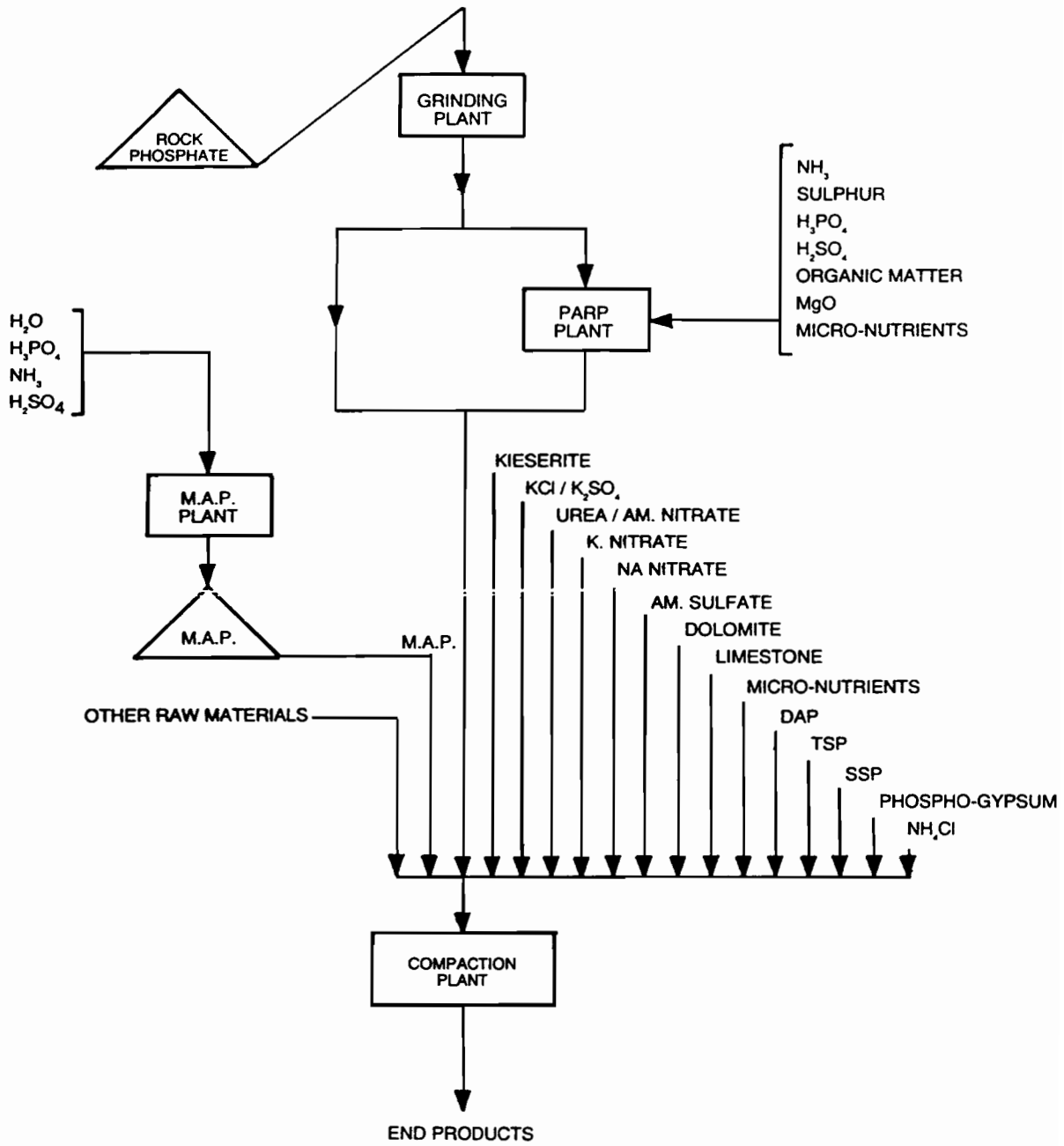


Flow Sheet 5.



Flow Sheet 6.

# PRODUCTION OF FERTILIZERS BY COMPACTION



Flow Sheet 7.

# Tuesday, November 13, 1990

Session IV  
Moderator:

Paul Warner

## Least Cost Formulation of Granular NPK Fertilizers

*Jean L. Cheval*

United Co-Operatives of Ontario

The Fertilizer Industry Round Table started with plant people meeting to discuss, and solve, common manufacturing problems. Vincent Sauchelli, at the 13th annual meeting, said "Our purpose in coming here is to pool our thoughts and experience toward increasing efficiency in fertilizer technology. This is a forum where operating personnel, particularly, assemble for this main purpose. The ultimate aim of our pooled efforts is to provide farmers with improved fertilizer materials with which they will be helped to grow food, feed and fiber at lower per crop unit cost of production." (Ref. 1)

It is in that spirit that I am offering this paper. Progress towards greater efficiency is a never ending process, I hope that you will look past the historical content of my remarks to find the spark necessary to improve on your formulation models and to lower the cost of the fertilizers you produce.

This paper deals with the application of the mathematical technique invented by George Dantzig and known as Linear Programming, to the formulation of fertilizers. Time does not allow even a quick review of the matrix algebra foundation on which L.P. is based, nor of the technique itself or its mathematical prerequisites and limitations. I will instead concentrate on a model developed, twenty five years ago, for the least-cost formulation of granulated fertilizers. The model is to the linear program what the engine is to the car. The model can be described as the equations and inequations representing the process. On paper, the L.P. model becomes a table of numbers (the coefficients) which define the contribution of the materials (the variables) to the specified properties (the constraints). As any operations research practitioner knows, L.P. models must meet certain conditions to generate answers which are truly least-cost solutions. These conditions were not met when, in 1964, we proceeded to translate the company's formulation rules for the computer program.

Advice No. 1: **Beware of simplistic models.** The company's rule, for a materials contribution to the dry weight of a finished product, was to deduct the materials moisture as measured by the vacuum-oven method. On the surface a simple and straight forward way, but as wrong as could be! This rule cost the company an

average of fifty cents per ton produced in unexplained "Inventory Adjustments" for six or seven years. There were two problems with this simplistic rule. First, it ignored the water of crystallization which is present in run-of pile single or triple superphosphates (mostly as monocalcium phosphate monohydrate), not measured by the vacuum-oven method of moisture determination, and released to the atmosphere in the drying step after ammoniation. In the case of triple super, in particular, it meant a difference of 5.5% if the ammoniation rate had exceeded 2.4 pounds of ammonia per unit of phosphate. The rule also ignored the loss of gases, mostly carbon dioxide, to the atmosphere as a result of chemical reaction during the ammoniation step.

Advice No. 2: **Beware of limits set on single variables.** Such limits are generally a short cut for a relationship which would be expressed in equation form if the model builder knew better. Such a rule stated that the formula should contain at least fifty pounds of anhydrous ammonia provided the nitrogen guarantee was higher than some value—possibly 2% (of course). What the rule-maker meant to say was: "We need enough heat of reaction to promote good granulation". This could be expressed much better in simple independent coefficients derived from research data. Ultimately, and following the lead of Robert J. Church (Ref.2), our model combined heat of reaction and liquid phase in a heat equivalent equation. The heat equivalent coefficients are shown in Table 1, in the HEX/HEN column. There were actually two inequations in the model, to provide some flexibility. Both had the same coefficients. One called HEX, for heat equivalent maximum, was of the "less than" type, limiting the heat equivalence to say 220,000 BTU's. The other called HEN, for heat equivalent minimum, was of the "greater than" type with a value 20,000 BTU's lower at 200,000 BTU's for instance. These specifications varied with plant characteristics and season. You will note that nitrogen solution 450 (25-69-0) is listed at 1,000,000 BTU's per ton. The 25% ammonia content contributed 720,000 BTU's and the balance came from the contribution to liquid phase, by the 69% ammonium nitrate content.

The ammonia neutralization was handled by two inequations. One called EQX, for equivalent ammonia maximum, showed the ammonia content (free ammonia) of the anhydrous ammonia and the nitrogen solution. It also recognized that diammonium phosphate would "come down" from its mole ratio of 1.85 (Ref. 3). The neutralizing materials were assumed to absorb the maxi-

mum amount of ammonia for the granulation units without scrubbing systems. The other inequation, called EQN for equivalent ammonia minimum, had the coefficients adjusted for the lowest mole ratio, right-hand side, in both cases, has a value of zero.

Advice No. 3: **Insure that the model represents completely and accurately the process.** The model that I have just described occasionally produced formulas with really good caking properties. The internal auditor was concerned about this drain on the company's profits. A simple experiment followed by regression analysis lead to an equation that turned out to be very effective in preventing caking. The regression analysis confirmed an earlier microscopic study of caked fertilizers. This study had identified the crystals of ammonium chloride as the main caking agent. This had surprised the manufacturing department staff. After all, we did not use any ammonium chloride at the plants. But we had, in these caked fertilizer mixtures, used a lot of potassium chloride, ammonia, sulphuric acid and ammonium sulphate. Obviously, unexpected chemical reactions were the cause of the problem.

The advices I have just given still apply for any type of least-cost formulation model, do not accept blindly that the formula is truly least-cost just because the computer has produced it. I recall a formulation system in which the linear programming software had been written by a company programmer, "in order to save \$5,000". When I came on the scene six years later and found some formulas that were not optimum, it did not take long to find where the "bug" was in the program. Unfortunately, the company, in those six years had wasted more than \$200,000!

Bad software should not be a problem today. I am not so confident about the models we use. The problem is certainly not restricted to the granulation plants. Table 2 shows the N-P-K values for some blending materials commonly used in the U.S. and Canada. If your blend formulation solves for N-P-K, weight, and occasionally nitrate nitrogen, secondary or micro nutrients, and nothing else, I will venture to suspect that you are wasting bottom-line money, a lot of it. Do your homework, put your brains to work. It is the best investment you can make.

Better optimization models are required if we, in the fertilizer industry, really want to improve the quality of the mixtures we sell and reduce our costs at the same time.

#### References:

- (1) Vincent Sauchelli, in proceedings of the 13th annual meeting Fertilizer Industry Round Table, 1963.
- (2) Robert J. Church, in proceedings of the 13th annual meeting, Fertilizer Industry Round Table, 1963.
- (3) John H. Payne, Jr. and Robert T. Webber, in *Agricultural and Food Chemistry*, Vol. 8, No.3, May-June 1960.

**Table 1**  
**Process Model Coefficients**  
**Of Some Granulation Materials**

Material	DW	EQX	EQN	HEX/HEN
Anhydrous Ammonia	1.000	1.00	1.00	2.88
N Solution 450 (25-69-0)	.945	.25	.25	1.00
Diammonium Phosphate	.990	.02	.04	0.0
ROP Triple (0-46-0)	.905	-.076	0.0	0.0
ROP Single (0-20-0)	.935	-.053	0.0	0.0
PHOS Acid (0-54-0)	.85	-.195	-.130	0.28
Sulphuric Acid 60 Be	.777	-.25	-.25	0.55
Dolomite	.950	.01	.01	0.0

**Table 2**  
**N-P-K Contribution of Some Blending Material**

Material	%N	%P	%K
Urea	46	0	0
Diammonium Phosphate	18	46	0
Monoammonium Phosphate	11	52	0
Triple Super Phosphate	0	46	0
White Potash	0	0	62
Red Potash	0	0	60.5

## Fertilizer Blending in Ireland - Potential Application of its Unique Features

*J.E. Leonard*

### Grassland Fertilizer Limited

#### INTRODUCTION

From its origin in the United States of America during the 1940's, Fertilizer Blending has developed in various markets in different ways and for different reasons. Methods of production and distribution are often adapted to suit traditional requirements of the particular region. Thus, the unique features of any system are determined by the techniques which are applied in the handling, mixing and subsequent marketing of the final blended product to the end user - the farmer.

Today, bulk blending and bulk distribution of granular fertilizers dominate the pattern of fertilizer marketing in the U.S.A. and the evolution of this system is related directly to the need to provide a high level of

customer (farmer) services.

The 1960's saw the development of the T.V.A. Ammoniation/Granulation Process and the Fertilizer Industry in the Republic of Ireland made the transition from the almost primitive mixing of powder compounds to the chemically produced high-analysis N.P.K. granule. However, following the energy crisis in the mid-1970's the chemical compound plants were shut down for economic reasons and, coupled with the availability of granular intermediates (D.A.P., T.S.P., C.A.N., Potash etc.) fertilizer blending became the logical alternative. At present, 70% of the Republic's total compounds market of 1.1 million tonnes per annum is distributed within a sophisticated low-cost marketing framework mostly in the form of blended product packed in 50 Kg. plastic bags which are palletized in two-tonne unit loads and covered with a shrunk-wrap film to withstand long periods (6 to 9 months) in outside storage.

### AGRICULTURE IN IRELAND

Ireland is an island (6.9 million hectares) off Western Europe, population is 3.6 million of which 16% of the active workforce is employed in Agriculture.

Gross Agricultural Output (11% of GNP) is valued at approximately 4.3 Billion U.S. Dollars of which livestock and livestock products account for 88% (mainly milk, dairy products and beef) ; arable crops account for the remainder.

Land Utilization is 5.7 million hectares of which pasture (for grazing) and hay or silage (for winter feed) accounts for 73%; arable crops (barley, wheat, sugar-beet and potatoes) 9%; the remainder is rough grazing and forestry.

Farm Size is small, the average being 23 hectares, with many small permanently fenced fields of 2 to 5 hectares.

### PATTERN OF FERTILIZER USAGE

Land utilization naturally reflects the type of agricultural activity, thus it is not surprising to find that almost 80% of fertilizer used in Ireland is applied to grassland (pasture, hay and silage) for livestock feed, the remainder being used on cereals, sugar beet and potatoes.

Approximately 1.7 million tonnes of product is used annually, all in the form of dry granular material, of this 35% is 'Straight' Nitrogen, mainly Calcium Ammonium Nitrate (C.A.N.) and Urea.

The "Compounds" (1.1 million tonnes) may be conveniently classified into three broad product groups, namely:

"P.K."

Binary Compounds containing *no Nitrogen*

"Low N Compounds"

NPK Compounds containing *less than 20 units of Nitrogen*

"High N Compounds"

NPK Compounds containing *more than 20 units of Nitrogen.*

The "P.K." and "Low N" Compounds are all "blends".

Some of the "High N" Compounds are imported as such from European Nitrogen Producers and being chemically produced by new improved technology are stabilized and can withstand longer periods in open air storage. (See Table 1).

(Table 1.) Range of Fertilizer Products Used in the Republic of Ireland (1990)

(Thousand Tons)	
<b>Compounds</b>	
PK (Binary) (0-16-36; 0-23-24)	215
Low N Compounds (less than 20 units N) (18-14-14; 14-16-16; 10-23-24; 9-14-18+B)	495
High N Compounds (greater than 20 units N) (24-6-12; 27-6-6)	418
Total Compounds (70% blends)	1,128
<b>Straight Products</b>	
Mainly CAN and Urea	623
<b>Total</b>	1,751

The full range of Compounds consists of 21 Standard Formulations of which only 8 account for 94% of total Compounds used. The remainder are mainly Special NPK grades incorporating Potassium Sulphate (for potatoes) or Boron as trace elements. A recent development has been the demand for Sulphur based Compounds and this can be met by the substitution of granular Ammonium Sulphate Nitrate (ASN) for C.A.N. in the formulation (a further demonstration of the versatility of fertilizer blending).

There is no "prescription blending", and, although the product range may appear small, there are sufficient formulations to give the Irish farmer a choice most suited to his specific needs and he has learned to tailor fertilizer usage to crop and soil requirements thus avoiding over usage of expensive nutrients.

### TYPICAL IRISH BLENDING OPERATION

A typical blending/bagging plant in Ireland produces between 50,000 to 200,000 tonnes per annum. There are nine such plants in the country operated by five companies, three of whom supply over 75% of the

market. (Figure 1).

Blending plants are located at - or convenient to - ports. Ships (2,500 to 3,500 T.D.W.) are discharged by grab crane and material is transported to the factory by truck. The materials are accurately proportioned to the desired formulation by automatic continuous electronically controlled belt weighers; conditioned for long term storage, by the application of special mineral oil and inert clay; screened to remove oversize etc., and bagged in 50 Kg. heat sealed plastic bags, which are automatically palletized in two ton unit loads and covered with a heat-shrunk plastic hood.

The palletized load is taken to an outside storage yard and stacked 3 pallets high where the product may be stored for periods ranging from one to nine months without impairing its shelf life. All fertilizer is sold by the Manufacturer to the Wholesaler i.e. Merchant or Co-Operative who retails to the Farmer. Spreading services are not common - the farmer usually performs this work with his own equipment.

### *FEATURES OF FERTILIZER BLENDING IN IRELAND*

Some of the features which emerge from the Irish system are as follows:-

#### *Product Standardisation*

From the marketing viewpoint, the standardisation of products, already referred to, could be considered a 'unique feature'. This 'standardisation' owes its origin to the time when Government Subsidies were paid on fertilizers and formulations were controlled by the Ministry for Agriculture - it simplified administration and helped to educate the farmer in the use of fertilizer. It now facilitates overall planning and efficiency within the industry. For example, it enables long production runs, thus minimising downtime for product changes.

However, it is in the areas of Production, Storage and Distribution that many of the features, unique to Irish Fertilizer Blending, have evolved.

#### *Continuous Operation*

The complete system - from batching of the blend Raw Materials through mixing, coating, screening, weighing, bagging, sealing, palletizing, shrink-wrapping and stacking outdoors - is one continuous operation. (Figure 2). Plants are normally run all year round except for summer maintenance.

#### *High Output, Accurate, Flexible, Modern units.*

Irish Blending Plants have a system of continuous Raw Material Feed. Materials are accurately proportioned from four feed hoppers onto a common collector belt - all electronically controlled. Grassland Fertilizers have recently installed PLC (Programmed Logic Control) Units. These are 'state of the art' modern control systems and, allowing for combined feed rates of over 100 T.P.Hr., give flexibility and accuracy to +/-0.5% for raw material feed and product formulations. Simi-

larly, the more modern bagging plants use computer controlled load cell mounted weighers which can achieve outputs of up to 20 weighments per minute (60 T.P. Hr.). These weighers are self-checking and self-correcting and when two of these weighers are used discharging alternately to a single bag spout (i.e. at half their capacity) they are extremely accurate - to 0.04%. The weighers can be separately programmed for each blend and memory storage greatly reduces the time required for weigher adjustments at grade changes.

Blending and bagging developed as one integrated operation with the blending plant feeding directly to a bagging unit and blended product being bagged as made.

Output is very high from these single line plants - peaking at 90 T.P.Hr. and averaging 60 T.P. Hr., with an on-line time of over 90%.

#### *Packaging*

Practically all product is bagged in 50 Kg. bags. Automatic machinery is available for placing bags onto the bag spout for filling and subsequent feeding to the heat sealer. However, their speed of operation tends to be much slower than can be achieved manually, and they require regular maintenance. Therefore, in general, manual bagging is still preferred in Ireland, which, as mentioned above can achieve outputs of 90 T.P.Hr. on a single line.

Bags used are polyethylene, thickness 175 to 200 microns. Once filled, each bag is vibrated (to settle the material and expel air) and then fed to a heat sealer where bags are sealed by squeezing between two heated bands.

All 50 Kg. bagged product in Ireland is automatically palletized in 2 ton unit loads on wooden pallets (5 ft. x 4 ft.). Bags contain microholes and pass through a series of bag presses to expel air and are placed in an interlocking fashion resulting in a very stable and neatly presented pallet.

The final palletized load is 'shrink wrapped', i.e. covered with a plastic hood, 75 to 100 microns thick, which is heat shrunk in a tunnel or frame at 120 degrees centigrade. This treatment gives weather protection during subsequent outside storage as well as giving added stability during transit. This is essential as the pallets are often driven over uneven yard and road surfaces.

Depending on the type of product or ingredients it is sometimes necessary to use opaque bags and white or ultra violet inhibited shrink wrap covers to give added protection for long periods in outdoor storage.

A recent development in the Irish Market is the use of the 500 Kg. Mini Bulk Bag - Intermediate Flexible Bulk Container (IFBC). This is also palletized and shrink wrapped (1 1/2 and 2 Tonnes per Pallet) to facilitate outside storage and transport. Another unique -but in this case a costly- feature!

#### *Product Conditioning*



The proportioned mix is normally fed through the coating unit for further mixing and conditioning prior to screening and bagging, to prevent the product from caking and to prolong its shelf life during subsequent storage.

The coating unit consists of a simple rotary drum (approximate dimensions 16 ft. x 6 ft. diameter, at speeds of 6-10 r.p.m., at an angle of 5 degrees) with no flights and no ribs in which the product is gently rolled in a continuous motion. A specially prepared mineral oil, at 80°C, is sprayed onto the material followed by application of a very fine inert clay e.g. China Clay or Talc, in the range of 1 to 10 microns.

The oil acts as a bonding agent to adhere the coating clay onto the granules. Selection of the best bonding agent is not easy - factors to be considered include temperature and porosities of the blend ingredients.

The choice of coating ingredients is critical - if clay fall-off is excessive the product becomes "dusty", the anti-caking efficiency is affected, and the products free-flowing properties can be impaired.

Given good quality raw materials in the first place, this process is the key to the successful marketing of good quality blended products following long term storage in bags out-of-doors.

#### *Quality*

If the raw materials used in blending are inferior, then the quality of the finished product will be impaired and, in a competitive market, such as Ireland, where product is sold on price, quality and service the manufacturer/blender will inevitably suffer the consequences.

Therefore, raw material specifications pay particular attention to moisture; granule size, shape and hardness; chemical analysis; colour and general appearance. Care is taken to ensure that materials when blended will be compatible to avoid deterioration in storage. Care is also taken to avoid deterioration in blends, and the modern plants are designed with this in mind. Materials of a similar granule size are used, which generally conform to a standard specification, - these are available from Europe, North Africa and U.S.A. (where a 2-4mm. sized granule is now produced for the European Market).

During production, materials are screened for oversize at least twice and sometime three times. Grids are installed at Raw Material intake points and over hoppers and finally the product is screened over vibrating horizontal screens prior to bagging. Likewise dust is removed from the product by dust extraction equipment at the bag spout.

Quality control standards for manufacture and analysis are rigidly enforced by the Ministry for Agriculture under European Community Regulations. The form and quantity of each Nutrient must be clearly stated on the bag for control purposes and analyses of the product must conform to specification within narrow tolerances.

Each plant normally has a well equipped laboratory and a full time Quality Control Chemist.

#### *Low Operational Costs*

##### *Labour:*

The high speed automated plants are capable of blending and bagging 500 Tonnes per eight hour shift with nine operatives, including three maintenance workers. Table 2 sets out the number of plant operatives for various levels of automation for a basic 60 T.P.Hr. continuous single line Blending and Bagging Plant. (A maximum output of 40 T.P.Hr. can only be obtained if manual palletization is adopted).

##### *Power:*

Approximate consumption figures for running electrical loads are:-

Basic Blending/Bagging Plant	100 KW
With Automatic Palletization	110 KW
Fully Automatic Plant	115 KW

##### *Gas:*

For shrink-wrap heating, 0.3-0.5 litres per ton.

##### *Packaging:*

Cost of Bags (50 Kg.), Hoods and Pallet is approximately 11 U.S. Dollars per ton.

#### *CAPITAL COSTS:*

*A typical blending operation in Ireland includes the following facilities:-*

- Multi-bay raw material storage, with (optional) automatic intake equipment.
- Continuous proportioning system, (fed by front-end loader).
- Coating, mixing, screening.
- Bagging - one or two 60 T.P. Hr. lines (some with automatic bag presenter).
- Continuous heat sealing - for 50 Kilo plastic open mouth bags.
- Automatic palletizer - 2 Ton Unit loads.
- Automatic hood placing and shrink wrapping.
- Out-door storage for palletized finished product.
- Mechanical handling equipment - front-end loaders (for bulk raw materials) and fork lift trucks (for palletized loads).
- Offices, laboratory, weighbridge etc.

Table 3 sets out estimated Capital Costs for a Basic 60 T.P. Hr. Blending/Bagging Plant with optional palletizing and shrink-wrapping, both manual and automated.

Additional costs (not mentioned) would include Civil Works and Buildings, e.g. a purpose built Bulk

Store for Raw Materials, with (optional) intake system and perhaps, Air Conditioning; a large area for Outside Storage; Weighbridge; Offices; Laboratory; Mechanical Handling Equipment etc.

### **POTENTIAL APPLICATION OF IRISH FERTILIZER BLENDED TECHNIQUES**

Many reasons contribute to the methods of fertilizer usage, marketing and handling in various countries. For instance, climatic conditions, soil fertility, type of agriculture, farm size, methods of transport, access and infrastructure, political, economic and social environment, etc. Other complicated factors require constant attention, such as conditions of storage, handling, compatibility of various materials, moisture uptake, physical characteristics, chemical stability and "shelf life" of the Finished Product.

Furthermore, the fertilizer producer may have to plan raw material intake, production, storage and offtake over an entire season in order to cope with farmer demand in Spring. The ideal would be to produce the Finished Product as near as possible to the time of use by the farmer, thus reducing cost of storage and working capital.

At this point one can but generalise with regard to the main topic of this paper, therefore, with the above problems in mind let us consider some key questions which may assist in determining certain applications for Irish Fertilizer Blending Techniques:-

#### 1. *Type of Agriculture & Soil Fertility*

Do crop and soil conditions vary to an extent that many varied formulations are required for optimum return or would a relatively small number of Standard formulations meet the Agronomic needs? As already mentioned, in Ireland 73% of Agricultural Output is Dairy and Livestock Products and farming is mainly pastoral, consequently 80% of fertilizer usage is on grass for animal feed.

#### 2. *Fertilizer Market*

The size, product range and potential demand of the local market must be considered. What forms of Nitrogen, Phosphorus and Potassium are most suited? Are other (micro) nutrient required? The flexibility of blending can be exploited to meet market requirements. The sophisticated high output plants used in the Irish system ensures a high degree of flexibility and accuracy.

#### 3. *Raw Materials Supply*

Where is the nearest source of raw materials? Are good quality Granular Intermediates available? What are the methods of Transport - Sea, Road, Rail Waterway? Ireland is an island, Blending Plants are conveniently located near good deep-water ports and strategically close to agricultural areas of fertilizer use. A wide range of good quality raw materials are sourced from Europe, North Africa and United States and

Suppliers generally adhere to the Raw Material Quality Standards requested by the blender.

#### 4. *Plant & Equipment*

Having regard to the market and the annual/seasonal output requirements, the size of the plant must be considered. This could range from 2,500 through 50,000; 100,000; 150,000; 250,000+ tons per annum. At the lower end of the scale a conventional batch-type blending unit with (optional) simple bagging plant may suffice. Over 50,000 T.P.A. would certainly warrant more sophisticated automated plant, e.g. continuous raw material feed, high-speed bagging and mechanical handling equipment.

#### 5. *Packaging*

The type of packaging (if any) will determine downstream plant facilities and mechanical handling requirements. For example,

- Bulk; Bags - 25/50 Kgs., Polyethelene, Polypropelene or Paper; Mini-bulk (Big) Bags-500/1,000 Kgs.

Polyethelene is most suited for outdoor storage of product (bagged and shrink-wrapped) in Irish conditions of temperate climate and high rainfall.

#### 6. *Finished Product Handling*

If palletization/outdoor storage is required a whole range of new criteria must be considered:-

(a) *Plant & Equipment*: Automatic Palletizer; Hood Placer; Shrink-Wrap Equipment; Outdoor Storage & Dispatch Areas.

(b) *'Shelf Life' of Bagged Product*: Conditioning Agents may be necessary, in which case equipment for the application of oil/clay or other suitable materials will be required.

(c) *Transport/Infrastructure*: Is adequate transport available and is the infrastructure suitable for palletized loads? Is mechanical handling equipment necessary or available at regional or farm level?

In Ireland the Wholesaler (Merchant or Co-operative) invariably has fork-lift equipment to handle palletized product.

#### 7. *Labour & Services*

Sufficient skilled and semi-skilled labour must be available to maintain sophisticated automatic plant. Similarly, supplies of spare parts and good service back-up are necessary. In Ireland, owing to the repetitive nature of the process, automation is applied wherever practical. A plant normally employs one Fitter and/or Electrician per shift and these craftsmen receive further training in handling the specialised equipment. Service/assistance is also available from the equipment Suppliers. All plant and equipment is thoroughly overhauled and refurbished during annual (summer) shutdown.

### IN CONCLUSION

The system of fertilizer blending in the Republic of Ireland is designed to blend and bag the raw materials and to get the palletized product into open-air storage as quickly as possible, thus minimizing storage and handling costs. The sophisticated equipment used is high speed with low operational costs. (Figure 3). Accuracy - in formulation, analysis, proportioning of the ingredients and weighing into bags - is maintained throughout and quality control for Raw Materials and Finished Product is an inherent feature.

Table 2.  
Operating Labor for 60-TPH Blending and Bagging Plant - Single Line Operation With Optional Palletizing

	Basic Plant	Palletizing Manual (a)	Automatic	Fully Automatic
	(number of persons)			
<b>Supervisor (Foreman)</b>	1	1	1	1
<b>Blending (Automatic)</b>				
Raw material feed-driver	1	1	1	1
<b>Bagging</b>				
Bag placing	1	1	1	0
Bag sealing	1	1	1	0
<b>Packaging</b>				
Palletizing	0	3	0	0
Hood placing	0	1	1	0
Stacking	(b)	0	0	0
Forklift drivers	0	2	2	2
<b>General</b>				
Supplies, cleaning, miscellaneous	1	2	2	2
<b>Maintenance</b>				
Fitter/electrician/helper	1	2	3	3
<b>Total</b>	6+(b)	14	12	9

a. Only 40 tph is possible if manual palletizing is employed.

b. Additional operators may be required for stacking bagged product.

Table 3. Capital Cost for 60-tph Blending and Bagging Plant – Single Line Operation With Optional Palletizing and Shrinkwrapping.

	Basic Equipment	Optional Equipment (US Dollars)	Fully Automatic
<b>Blending (automatic)</b>	130,000		
Continuous raw material feed			
Mixing			
Coating			
Screening			
<b>Bagging</b>	160,000		
Weighing			
Dust extraction			
Bagging			
Heat sealing			
<b>Automation</b>			150,000
Empty bag presenter (feeder)			
Sealer feed system			
<b>Packaging</b>			
Bag forming			
Palletizing		150,000	
Conveying system			
Shrinkwrapping		60,000	
<b>Automation</b>			100,000
Hood (shrinkwrap) placer			
<b>Subtotal</b>	<b>290,000</b>	210,000	250,000
		290,000	
<b>Total (a)</b>		<b>500,000</b>	500,000
<b>Total (a)</b>			<b>750,000</b>

a. +/- 20%

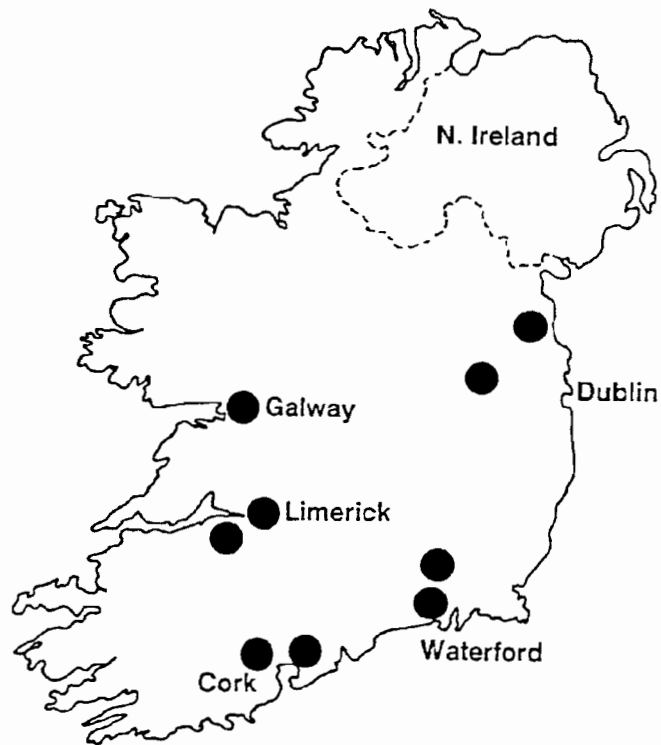


Figure 1. Location of Blending Plants in Ireland.

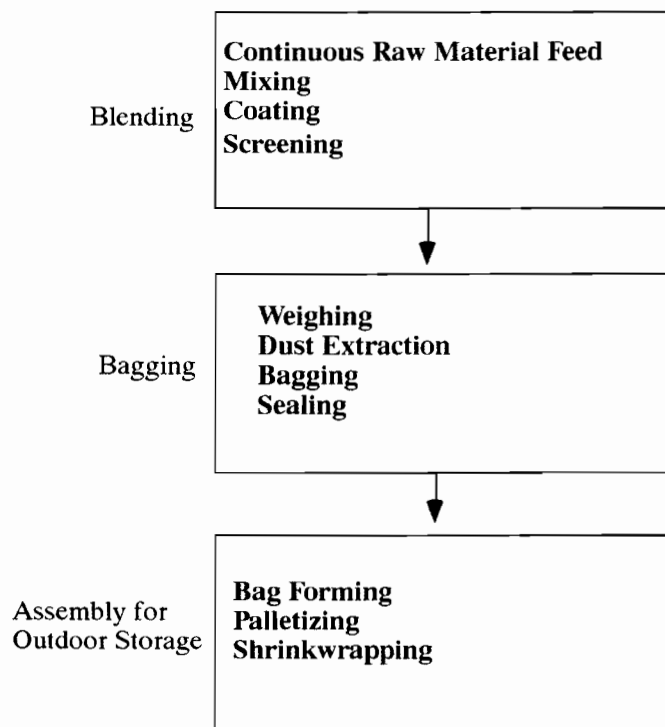


Figure 2. Main Features of Irish Blending Plants.

# Particle Characteristics of Alabama Fertilizer Materials - 1989

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## SUMMARY

In 1989 (January and February), 377 samples of fertilizer materials were collected from storage bins at fertilizer blending locations throughout the state of Alabama. These samples were sieve analyzed in the State Chemical Laboratory to determine the particle size characteristics of the various fertilizer materials marketed in Alabama. Size guide number (SGN) and the uniformity index (UI) were used to describe the particle size characteristics of the materials. The samples also were chemically analyzed to determine if raw materials were deficient. Comparisons were made of the raw materials used by different blenders to determine if a correlation existed between the SGN range and deficiency rate.

The SGN values of the following products indicated sales in a wide range of sizes: potash, triple superphosphate (TSP), diammonium phosphate (DAP), limestone filler, and ammonium sulfate (AS). Both ammonium nitrate (AN) and urea had narrow SGN ranges. UI values indicated that urea and AN had the most uniformly-sized particles, followed by DAP and TSP. Potash, filler, and AS had the least uniformly-sized particles. Less than one percent of all the samples were chemically deficient. The comparison of raw materials among different dealers revealed that those with high deficiency rates for blended products used raw materials with considerable variation in the SGN values. Conversely, dealers with few blend deficiencies used materials having similar SGN values.

## BACKGROUND

This study was initiated after the authors had conducted several workshops in Alabama dealing with bulk blend quality control. After several discussions concerning the importance of raw material quality, the decision was made to sample raw materials in Alabama to determine quality. The intention was to share the information at future workshops to increase dealer understanding of particle size characteristics and to enhance dealer purchasing decisions. Initially, fertilizer quality was to be based on SGN values and chemical analyses. Later, UI values were added to the study since little information on UI values is available for products sold in the United States. UI values have been cited as a useful tool in matching raw materials for blending (The Fertilizer Institute, 1987). The addition of UI values permitted a more thorough evaluation of materials.

## SIZE CHARACTERISTICS AND QUALITY CONTROL

Hoffmeister (1962) demonstrated that materials used in bulk blends could be physically incompatible. That is blended raw materials with different physical properties could segregate (unmix) during handling. Particle size is the property which needs to be matched to ensure physical compatibility of blended materials. Two materials with different particle densities of particle shape can segregate; but the amount of segregation will be small if the median size of particles in the two materials is similar. Whenever a fertilizer blend forms a cone while being piled, the distribution of material in the pile is size specific. Smaller particles tend to remain in the center of the pile while larger particles roll to the outside. This occurs because only small particles can come to rest in the crevasses between particles at the apex of the pile. Segregation is a major cause of blend deficiencies, particularly in bagged blends. Segregation of raw materials in storage causes the size of particles being taken from the pile to vary as the pile is worked. Consequently, materials which have similar composite size distributions will not be matched in size if taken from the center and the outside of their respective storage piles.

Prior to the development of the SGN concept by the Canadian Fertilizer Institute, the only way to determine the size compatibility of materials was to compare sieve analyses. In sieve analyses, two materials are matched in size if the cumulative percentage retained values on each sieve are within 10 percent of one another. The comparison may be made graphically or by comparing values in a table. Particle size comparison was made simple using the SGN system. Using SGN, size compatibility is based on a single number. This number is the median particle size multiplied by 100 and rounded to the nearest 5. The median particle size of a material is the size at which half the particles, by weight, are larger; and half, by weight are smaller. Or stated differently, median particle size is the size, in millimeters, corresponding to the 50 percent retained value on a cumulative sieve analysis (Figure 1). Materials are compatible if their SGN values are within 10 percent of the average SGN values for all the materials. For example, if five materials have SGN values which average 200, then all materials are compatible if their SGN values are between 180 and 220.

Since SGN only describes the median particle size of a material, two materials can have different distributions of particles on sieves and have identical SGN values. For example, a material such as urea with a narrow size range can have the same SGN value as potash with a wide distribution in particle size. Therefore, a measure of particle size uniformity is required to fully describe a material. Particle size uniformity can be described by the uniformity index. UI is the ratio of the size of fine to coarse particles in a material, ex-

pressed in percent. More precisely, it is the ratio, times 100, of the size, in millimeters, corresponding to 95 percent retained to 10 percent retained on a cumulative sieve analysis (Figure 1). UI values range from 20 percent to 70 percent - the higher value corresponding to the more uniformly sized material. The question which arises is whether two materials with similar SGN values but different size ranges are physically compatible. The National Fertilizer Development Center (1980) tested a blend of DAP, having a wide size range, with TVA's falling-curtain-process urea, having a narrow size range, and found the mixture to be nonsegregating when allowed to cone in a pile. The conclusion was that the uniformly sized urea would not segregate from a broadly sized material if the SGN values were similar. These results indicate that SGN alone can be used to determine the segregation tendencies of most fertilizer materials. There are extreme cases, however, where SGN alone fails to accurately predict a fertilizer's compatibility. For example, a material with large and small particles can be essentially devoid of particles between 8- and 12-mesh in size and have an SGN similar to a product comprised mostly of particles which are minus 8- plus 1-mesh in size. Nearly as important as segregation in blends is the segregation of raw materials prior to blending. UI values are a good indicator of the tendency for a material to segregate while coning in storage bins. Materials with low UI values will have a greater tendency to segregate during filling of bins than materials with high UI values. Consequently, low-UI products will have considerable size variation in storage bins if the products are allowed to cone while filling bins.

#### SAMPLE COLLECTION AND ANALYSIS

In 1989 (January and February), 377 samples were collected from storage bins at blender locations throughout the state of Alabama. All materials were sampled by probing fertilizers in storage bins. The samples were designated unofficial. In other words they were not included in official regulatory samples and were not subject to penalty if found deficient. Samples were split in the State Chemical Laboratory, sieve analyzed, and chemically analyzed. U.S. Standard test sieve with the following sieve were used for sieve analysis:

<u>Sieve Number</u>	<u>Opening (mm)</u>
6	3.35
8	2.36
12	1.70
16	1.18
20	0.85
30	0.60

SGN and UI were determined by mathematical interpolation of values from cumulative sieve analysis. Interpolation equations are shown in sample calculations in the appendix.

Of the 377 samples taken, 313 were fertilizer samples and 64 were limestone filler. At the time samples were taken, the bins were full in preparation for the spring season. Assuming the bins have an average capacity of 175 tons, the fertilizer samples represent about 55,000 tons of material. The total tonnage sold in Alabama in 1989 was 638,503 tons (Hargett *et al.*, 1990). Assuming nearly all of the sampled material was sold in Alabama, these samples represented about 8.6 percent of the product sold in Alabama in 1989.

#### RESULTS AND DISCUSSION

Of the chemical analyses of the 313 unofficial fertilizers samples (Table 1), only 2 samples were found to be deficient by more than 5 percent of the guarantee, which is the investigational allowance in Alabama for a product with a single nutrient. Blends in Alabama are considered deficient if the analysis of any nutrient is more than 10 percent below the guarantee or if the commercial value of the blend is less than 95 percent of the guarantee. Of the official blend samples sold in bulk form in Alabama in the 1988-1989 season, 21 percent were found deficient. Packaged dry blends had a deficiency rate of 31 percent. Raw material deficiencies, therefore, were not considered a major contributor to deficiencies in blends in Alabama in 1989.

In (Table 2) is found the percent of each raw material sampled which had SGN values within the following ranges; less than 195, 195-215, 220-240, 245-265, and greater than 265. Since values were rounded to the nearest 5, the ranges were separated by 5. For each material, the total number of samples is also listed. For example, only 10 bins of urea were sampled, four of monoammonium phosphate (MAP), and six potassium magnesium sulfate (KMS). More than 20 samples were taken of all other materials.

Of the materials for which at least 10 samples were taken, urea and AN were the most consistently sized (had the smallest range of SGN values). Eighty percent of the urea had SGN values between 220 and 240. All other urea samples had SGN values between 195 and 215. Ninety-eight percent of AN samples had SGN values between 195 and 215. The other two percent had SGN values below 195. All other materials but DAP had samples in all five SGN ranges. There was no DAP with a SGN over 265. A ranking of the materials from most to least consistently sized, according to SGN values, is as follows: AN, urea, DAP TSP, 12-36-0, potash, limestone filler, and AS. The 12-36-0 is an ammoniated phosphate sulfate product. SGN values ranged from a high of 345 for a potash sample to a low of 60 for an AS sample.

Figures 2, 3, and 4 allow evaluation of the compatibility of each raw material with other materials. Figure 2 provides percentages of AN, DAP, and potash in the five SGN ranges listed in (Table 2). Because of AN's smaller particle size, there was a considerable amount of potash and DAP used in Alabama in 1989 that



had much larger SGN values. Blends of AN with these larger materials would tend to segregate during handling. Urea was better matched in size to potash than was AN but was larger than much of the DAP (Figure 3). TSP was similar to DAP in its SGN ranges, while much more of the 12-36-0 (Figure 4) had SGN values greater than 265. Limestone filler was by far the largest material with one third of its samples exceeding 265 in SGN. AS was by far the smallest (Figure 5). The chosen SGN ranges do not adequately describe the smallness of some of the AS particles. SGN values as low as 60 and 90 were found for AS. Most AS materials had SGN values below 150.

(Table 3) provides the percent of each raw material which had UI values in the following ranges; 10-20, 20-30, 30-40, 40-50, 50-60, and 60-70. Urea samples were most uniform in size. All of the urea UI values were greater than 50. AN was similar to urea. Ninety-six percent of its UI values were above 50. DAP products were less uniformly sized than urea and AN. Only 28.5 percent of the DAP samples had UI values above 50. However, only 10.1 percent of the DAP samples had UI values below 40. TSP was similar to DAP in particle size uniformity. Limestone filler had slightly less uniformly sized particles than DAP and TSP. Forty three percent of the limestone filler samples had UI values below 40. Potash, AS, and potassium magnesium sulfate (KMS) were the least uniformly sized materials. A ranking of the materials from most uniformly to least uniformly sized (highest to lowest UI values) would be as follows: urea, AN, DAP, TSP, limestone filler, potash, AS, and KMS. The UI values ranged from 17 for a potash sample to 66 for an AN sample.

The results of UI determinations indicate that particle size uniformity is related to the various fertilizer manufacturing processes. In urea and AN processes, granule size is achieved by a build-up of many thin layers or coatings. Thus, the processes produce granules within a narrow size range. Drum granulation of DAP and TSP produces granules in a broader range than urea and AN because of agglomeration of particles in the main granulation mechanism. The remaining products: potash, limestone filler, AS, and KMS- are not manufactured in a process where granules are built in layers but are crystallized or are crystalline materials crushed to a size for blending. Larger and more uniformly-sized AS can be made than that sampled in this survey. Its cost, however, is higher and its supply is limited by those industries which produce AS as a by-product. The crushing of crystalline materials produces particles in a range of sizes. Although fines can be removed from compacted potash and KMS, repeated handling of these products causes degradation, thus producing fines, and reducing UI values.

Degradation of granules during shipping and handling can increase the amount of fines in a material and, thus, reduces UI values. Without any information regarding the handling of materials in shipment, it is difficult to ascertain the effects of degradation on UI

values. AN and urea appear to have sustained little damage in shipping since they had high UI values (had few fines) and are easier to crush than some of the less uniformly sized materials in the study. According to Hoffmeister (1979), potash has a much higher crushing strength than either urea or AN. Potash, however, is typically handled much more than other products en route to Alabama. One possible explanation for the larger number of fines in crystalline products than in granulated products is that crystals tend to shatter into many small particles when broken than do granules. This is speculation since fracture tests were not included in this study.

One interesting observation from SGN and UI values is that the materials which were found to be most consistent in SGN values (urea, AN and DAP) also had the highest UI values. Conversely, the materials with lowest UI values (potash, AS, and limestone filler) varied most in SGN. One explanation for this is that materials may have segregated in storage at the production site. For example, materials having a broad particle size tend to segregate if allowed to cone when piled in storage. As the product is sold, the median particle size (SGN) varies with the location in the pile. High SGN product is taken from the outside of the pile, and low SGN product is taken from the center.

Further research is needed to verify this scenario. However, it is reasonable to expect a material manufactured with broad size range to contain individual lots of materials with more variation in SGN values than a material produced with a narrow size range. One basic producer has observed this phenomenon and has attempted to solve the problem by evenly distributing material while filling the warehouse at the production site. This practice, referred to as level filling, is recommended whenever materials having a tendency to segregate are delivered to storage.

(Table 4) provides SGN, UI values, and their coefficients of variation (CV) for unofficial samples taken from four dealerships. CV is the standard deviation of values in a set expressed as a percent of the mean or average value. Included in the listing is the deficiency rate of the dealerships. These dealers were selected since they were among the best and worst blenders in the state with regard to blend deficiencies. Blender A and B sold materials predominantly in bagged form; and dealers Y and Z sold material predominantly in bulk. The dealers with the lowest deficiency rate (dealers A and Y) used materials with similar SGN values. CVs of their SGN values were, respectively, 11.4 and 3.0 percent. Conversely, dealers B and Z with the highest deficiency rate used materials with a wide range of SGN values. The CV of their SGN values were 26.8 and 17.7 percent. Other management practices, details of which were beyond the scope of this study, probably contribute to these deficiency rates. One practice, however, deserves mentioning. Dealer A used anti-segregation baffles in the holding hopper above the bagging machine. These baffles, which reduce segregation by preventing coning,

were not used by dealer B.

Though the data in (Table 4) tend to support the practice of blending with materials having similar SGN values, the matching of UI values does not appear to be as essential for making quality blends. For example, dealer B (who had the highest deficiency rate of those listed: 54 percent) had raw materials with the best matched UI values among the four listed. The shortcomings of these data is that raw materials changed during the season and the physical properties of the materials used year round may have been different from those sampled in this study. Nevertheless, the trends reflected in the data support the use of the materials with similar SGN values.

### CONCLUSION

Conclusions which can be drawn from the data in this survey are as follows:

1. Materials are available to blenders which are compatible with regard to SGN.
2. AN and urea were most consistent with regard to SGN values followed by DAP, TSP, 12-36-0, potash, limestone filler, and AS.
3. Urea and AN had the highest UI values followed by DAP, TSP, limestone filler, potash, AS, and KMS.
4. Materials which varied in SGN values also had the lowest UI values, indicating that they segregated at the production site prior to being shipped.
5. UI values appear to be related to the manufacturing process for the material. For example, urea and AN (which are granulated by layering) were most uniformly sized; drum granulated phosphate materials were less uniformly sized; and crystalline materials were uniformly sized.
6. Dealers with the best record in terms of blend deficiencies used materials which matched SGN values. Conversely, dealers with the highest number of blend deficiencies used materials with poorly matched SGN values.
7. Unlike SGN values, there was no correlation between blend quality and the practice of matching UI values.

Several conclusions were made regarding the quality of materials sampled in 1989 in Alabama. Some of the trends in the data are perhaps universal. Others are perhaps unique to this study. Attempts to explain the reasons why the particle size characteristics were found in 1989 are, at best, speculative.

Further research is needed to determine acceptable ranges of particle size characteristics for producing high quality blends. Production of materials with desirable particle size characteristics should be a major goal of basic producers. A study of the effect of handling during transport on the particle size characteristics of fertilizers should be conducted. This should provide information which can be used to minimize adverse effects of handling on fertilizer physical properties. This information also may be useful for setting higher standards for

finished product to offset the degradation occurring during shipping.

Providing perfect fertilizer materials for the myriad of customers in the marketplace is perhaps an impossible task. By combining the efforts of the fertilizer industry, regulatory groups, and research institutions, the parties concerned should soon have a better idea of perhaps what perfect fertilizers should be.

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### APPENDIX

Calculation of SGN and UI by mathematical interpolation of cumulative sieve analyses data.\*

SIEVE SIZE (mm)	WEIGHT (gm)	PERCENT	CUMULATIVE %
3.35	1.9	0.5	0.5
2.36	48.0	13.7	14.2
1.70	277.3	78.9	93.1
1.18	20.8	5.9	99.0
0.85	1.9	0.5	99.5
0.60	1.5	0.5	100.0

### SGN CALCULATION:

Median particle size lies between 8- and 12-mesh, 2.36 and 1.70 mm

$$SGN = \text{Round} (20 * \text{Median Particle Size}) * 5$$

$$SGN = \text{Round} (20 * (1.70 + ((2.36 - 1.70) * (93.1 - 50) / (93.1 - 14.2)))) * 5$$

\* NOTE: Rounding of 20 times median particle size, then multiplying by 5, rounds SGN to the nearest 5.



*UI CALCULATION:*

10 percent retained lies between 6- and 8-mesh, 3.35 and 2.36 mm

95 percent retained lies between 12- and 16- mesh, 1.7 and 1.18 mm

$$UI = (\text{mm@ 95\%} / \text{mm @ 10\%}) * 100$$

$$95\% = 1.18 + ((1.7 - 1.18) * ((99.0 - 95) / (99.0 - 93.1))) = 1.53$$

$$10\% = 2.36 = ((3.35 - 2.36) * ((14.2 - 10) / (14.2 - 0.5))) = 2.66$$

$$UI = (1.53 / 2.66) * 100 = 57.4$$

**TABLE 1**  
**Unofficial Fertilizer Material Samples 1988-89**

<u>Fertilizer Material</u>	<u>Total Samples</u>	<u>Number Deficient</u> *	<u>Average Analysis</u>
Potash	71	1	60.7
Triple Super Phosphate	60	1	45.98
MAP	4	0	11.3-51.5
Urea	10	0	45.8
Ammonium Nitrate	54	0	33.9
Diammonium Phosphate	53	0	18.2-46
Ammonium Sulfate	33	0	21.5
0-0-22	5	0	22
12-36-0	23	0	12.9-36.6
TOTALS	313	2	

\* Sample was deemed deficient if the analysis was more than five percent below the guarantee.

**TABLE 2**

**Summary of SGN Values for Blend Materials  
(1989 Survey of Alabama Blend Materials)  
Percentage of Samples Within Specified SGN Ranges**

<u>SGN Range</u>	<u>AN</u>	<u>AS</u>	<u>DAP</u>	<u>KMS</u>	<u>Limestone</u>	<u>Potash</u>	<u>TSP</u>	<u>Urea</u>	<u>12-36-0</u>
< 195	2	72	10	33	12.5	10.0	8	0	4
195-215	98	13	47	67	9.0	18.5	38	20	9
220-240	0	9	28	0	8.0	33.0	32	80	17
245-265	0	3	15	0	37.5	21.5	15	0	44
> 265	0	3	0	0	33.0	17.0	7	0	26
Total # of Samples	55	32	53	6	64.0	70.0	60	10	23

**TABLE 3**

**Summary of UI Values for Blend Materials  
(1989 Survey of Alabama Blend Materials)  
Percentage of Raw Material Samples Within Specified UI Ranges**

<u>UI Range</u>	<u>AN</u>	<u>AS</u>	<u>DAP</u>	<u>KMS</u>	<u>Limestone</u>	<u>Potash</u>	<u>TSP</u>	<u>Urea</u>
10-20	0	0	0	0	15.0	7.5	0	0
20-30	0	22.0	6.1	83.3	15.0	28.7	3.9	0
30-40	4.0	55.5	4.0	0	13.3	24.2	15.4	0
40-50	0	18.5	61.2	16.6	30.0	34.8	48.0	0
50-60	57.1	3.7	28.5	0	26.6	4.5	32.7	90
60-70	38.7	0	0	0	0	0	0	10

\* Note: Percentages may not total 100 due to rounding

**TABLE 4**

**Comparison of SGN and UI Values for Four Blenders  
and Their Blend Deficiency Rates**

<u>Dealer</u>	<u>AN</u>	<u>AS</u>	<u>DAP</u>	<u>KMS</u>	<u>Limestone</u>	<u>Potash</u>	<u>TSP</u>	<u>Urea</u>	<u>Coeff of Variation %</u>	<u>Blender Deficiency Rate %</u>
<b>A - Bagged SGN</b>	200		225		190	250	200		11.4	4.5
<b>UI</b>	64		48		23	36	49		35.0	
<b>B - Bagged SGN</b>		115	255		175	265	215	225	26.8	54.0
<b>UI</b>		34	39		46	36	88	56	19.7	
<b>Y - Bulk SGN</b>	205	195	205	210		195		205	3.0	4.0
<b>UI</b>	58	37	47	25		23		65	40.5	
<b>Z - Bulk SGN</b>			225		290	275	185	225	17.7	38.0
<b>UI</b>			55		18	37	35	56	39.3	

FIGURE 1

Graphical Determination of SGN and UI

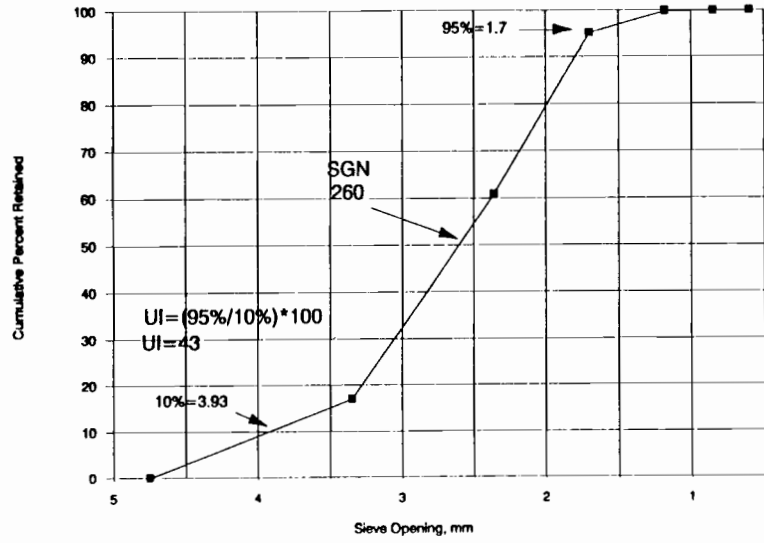


FIGURE 2

DAP, AN, Potash, and Limestone

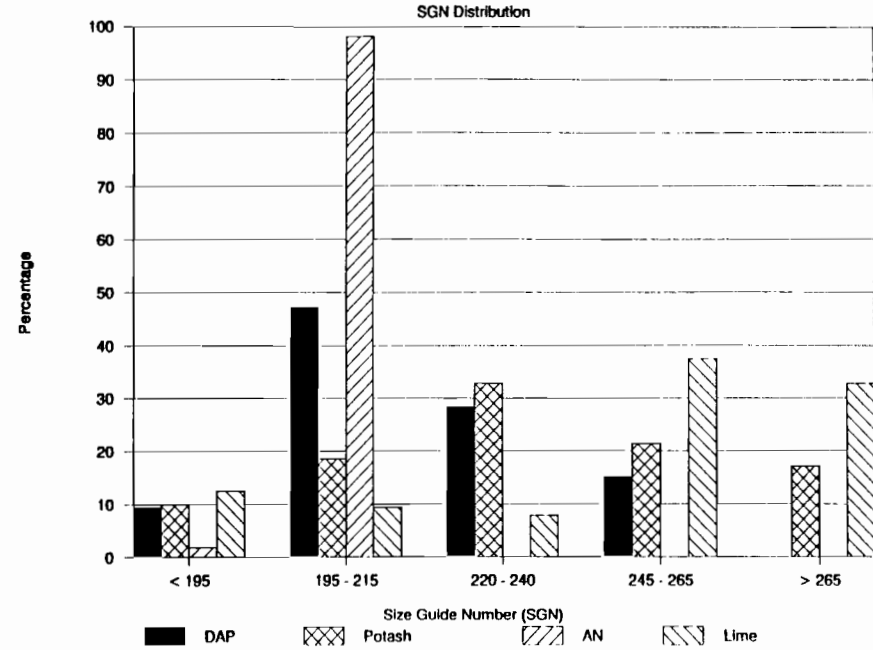
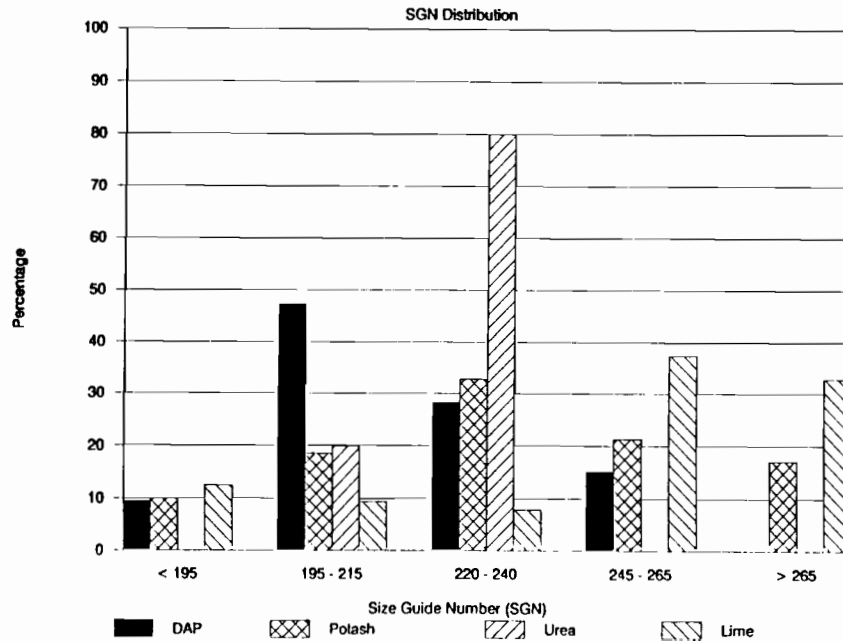
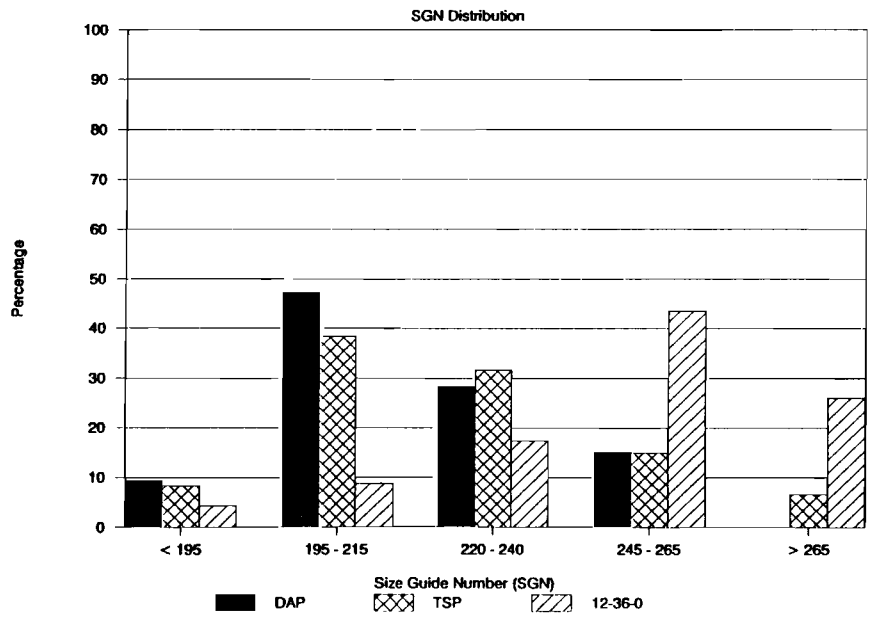


FIGURE 3

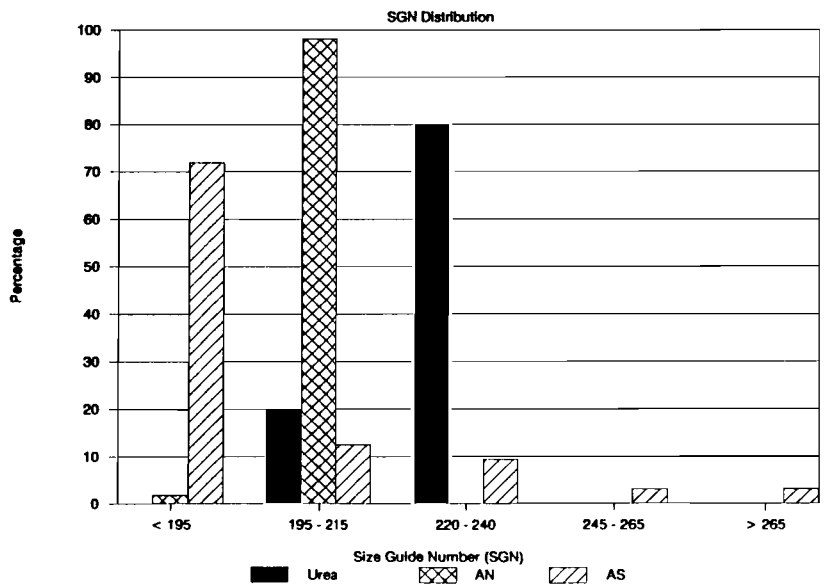
DAP, Urea, Potash, and Limestone Blend



**FIGURE 4**  
**Phosphate Materials**



**FIGURE 5**  
**Nitrogen Materials**



# Fluoride Stabilized Suspensions From Monoammonium Phosphate

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Suspension fertilizers such as 10-30-0 made from monoammonium phosphate (MAP) containing significant amounts of metallic impurities often exhibit poor storage properties. The addition of fluoride to bring the weight percentage cation ( $\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3 + \text{MgO}$ ): F ratio to 3 or less in the suspension has been shown to materially improve the physical properties of the suspension. Fluorosilicic acid was evaluated as a fluoride source and produced marked improvement in both viscosity and pourability of 10-30-0 and 11-33-0 grade suspensions made from impure 11-52-0 grade MAP, using as little as 0.6% fluorosilicic acid. A test of this process in the field using byproduct fluorosilicic acid demonstrated improvements in pourability, reduced diammonium phosphate (DAP) crystallite size, reduction of water-insoluble solids, and an increase in satisfactory storage time.

This presentation will discuss the background and basic research conducted over the last several years which lead to development of the fluorosilicic acid ( $\text{H}_2\text{SiF}_6$ ) process, laboratory tests of the new process, commercial tests of the process at the fertilizer dealer site, environmental considerations, economics, and conclusions.

## BACKGROUND AND BASIC RESEARCH STUDIES

The use of granular and powdered monoammonium phosphate (MAP) as intermediates in the production of suspension-type fluid fertilizers can lead to variable product quality, depending upon the impurity content of the starting MAP. In 1983 TVA research identified the compounds present in MAP that are responsible for sludge and gel formation when the MAP is ammoniated to make a suspension fertilizer (1). A typical distribution of impurity compounds present in a Florida MAP is shown in Table 1 (2). The ferric ammonium phosphate,  $\text{FeNH}_4(\text{HPO}_4)_2$ , in the MAP is the primary agent responsible for gelation or solidification problems in ammonium orthophosphate suspension fertilizers. The iron ammonium phosphate in the MAP dissolves in the suspension and forms an iron ammonium phosphate water gel. This gel entraps and retains a large amount of water causing high viscosity or solidification of the suspension during storage. Aluminum ammonium phosphate [ $\text{AlHN}_4(\text{HPO}_4)_2$ ], which is present in some

MAPs, produces effects in ammonium orthophosphate suspension fertilizers similar to those caused by iron ammonium orthophosphate. The aluminum ammonium orthophosphate is usually present in relatively low amounts in most MAPs. Aluminum combines readily with the fluoride present in ammoniated wet-process phosphoric acid to form aluminum ammonium phosphate difluoride [ $\text{AlNH}_4\text{HPO}_4\text{F}_2$ ], magnesium-aluminum-fluoride-water complexes (usually  $\text{MgAl}_2\text{F}_8 \cdot 2\text{H}_2\text{O}$ ), and magnesium ammonium phosphate difluoride [ $\text{MgAl}(\text{NH}_4)_2\text{H}(\text{PO}_4)_2\text{F}_2$ ] (3).

In the same study, a linear relationship (Figure 1) was discovered which indicated an 11-33-0 grade suspension made from MAP would remain stable for 10 weeks if the weight percent cation ( $\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3 + \text{CaO} + \text{MgO}$ ): F ratio is 3 or less in the suspension and the water-insoluble solids content is 14 weight percent or less (4). In this study, the fluoride ion was added as  $\text{NH}_4\text{F}$  at rates of 5-30 lb/ton to the 11-33-0 suspension fertilizer and was found to improve the suspension's viscosity and pourability. The results of this study indicate the need for a more systematic investigation of the solubility limits of metal impurities in fluid fertilizer formulations made from MAP.

A followup study was initiated that examined the solubility limits of Fe, Al, Mg, Ca, and F impurities in a 9-32-0 grade fluid fertilizer (5). It was found that addition of fluorine prevented precipitation of metal ammonium-phosphate-water compounds. For example, iron precipitated as crystalline  $\text{Fe}(\text{NH}_4)_2(\text{HPO}_4)_2\text{F}$  instead of the high water containing amorphous  $\text{FeNH}_4(\text{HPO}_4)_2 \cdot n\text{H}_2\text{O}$ . The crystalline iron ammonium phosphate fluoride causes less problems in a suspension than the amorphous iron ammonium phosphate because it contains less water and tends to form smaller crystals. Additional fluoride ion precipitated magnesium and aluminum as fluoride compounds which increased the solubility of nitrogen and phosphate yielding a higher quantity of solution phase and a higher citrate solubility.

The results from these research studies demonstrate that control of the fluoride ion concentration can prevent (or greatly reduce) the formation of sludges and gels in ammonium phosphate suspension fertilizer. However, many commercial MAP products do not have the desirable cation: F ratio of 3 or less and a water-insoluble solids content of 17% or less. An additional study was conducted to determine if fluorosilicic acid could be added in the formulation of the suspension made from these MAPs. Addition of ammonium bifluoride and hydrofluoric acid had already been proven to be technically feasible but these compounds are not economically viable. Fluorosilicic acid, a byproduct of the phosphate industry, is relatively inexpensive compared with bifluoride or hydrofluoric acid. However, as shown in the slide, the price of  $\text{H}_2\text{SiF}_6$  has increased since the research began in 1987.

## LABORATORY TESTS OF THE $H_2SiF_6$

The first objective of the present work was to determine the technical feasibility of adding fluorine as fluorosilicic acid *prior* to the ammoniation step in the production of stable suspension fertilizers from MAP. The fluorine would be released as  $NH_4F$  which would react with the metal impurities to form more desirable metal compounds, and the heat of reaction would dehydrate the silica gel, keeping it from gelling the suspension product. Previous research showed that only 0.7% by weight of 23% fluorosilicic acid could be added *after* ammoniation because it decomposed in the suspension to form ammonium fluoride, hydrated silica gel, and ammonium fluorosilicate. Upon storage, the silica gel hydrate further and caused the viscosity to rise above the satisfactory limit of 1000 centipoises (6).

Three commercial MAPs (designated as A, B, and C) (Table 2) were processed into ammonium orthophosphate suspension fertilizers. The MAPs A and B were similar in impurity levels while MAP C would be classified as a "sludge" MAP because of its extremely high Fe impurity level. The cation: F ratio varied from 3.4 to 4.0.

The laboratory procedure for making the suspensions consisted of adding the formulated amounts of water, fluorosilicic acid, and MAP to the reactor and ammoniating to a pH of about 6.5. After the mixing period, attapulgitic clay, 0.75 to 1.5% by weight, was added. Total batch time for all the tests was about 20 minutes. The temperature of the slurries during the ammoniation step ranged between 65 and 93°C and increased in each test as the fluorine addition increased. Extra ammonia was added in work with MAP C because of the high levels of fluorosilicic acid. The suspension fertilizer grades varied from 7-21-0 to 11-33-0 with fluorine levels of 0 to 1.2 weight percent for MAPs A and B and to 7% for MAP C. Fluorosilicic acid (23 weight percent aqueous) was the fluorine source. Aqua ammonia (23 weight percent N) and clay were the other raw materials used in the suspension production.

An initial test was conducted to determine the differences between using fluorosilicic acid prior to ammoniation and after ammoniation (Table 3). MAP A was processed into a 10-30-0 grade suspension fertilizer using the different orders of addition. Test samples 1 and 2 using fluorosilicic acid prior to ammoniation had excellent viscosity and pourability values after 14 days of storage at 38°C. Samples 3 and 4 were both totally unacceptable with high viscosities and low pourabilities, proving that this order of addition would not be acceptable.

An important aspect of this study was to determine if significant losses of fluorine would occur during the ammoniation and conversion of the MAP to the suspension fertilizer and, therefore, create an environmental problem. Four tests were conducted at different levels of fluorine addition, and analysis of the resulting suspensions indicated that in all three examples there

was no detectable loss of fluorine from the suspension during ammoniation.

The 10-30-0 grade suspensions made from MAPs A and B containing 0.6 to 1.2 weight percent fluorine added as fluorosilicic acid had lower viscosities and higher pourabilities after 90 days storage at 25°C when compared with the 10-30-0 grade control sample with no fluorine added. The pourability value is usually the determining value in judging the quality of a 10-30-0 suspension; that is, if the pourability is 98% or greater, then the product can be pumped. In these tests, the pourability of the 10-30-0 made from MAPs A and B with F were all 100% pourable; whereas, the controls without extra fluorine were only 75% pourable. Results with MAP C show that 7 weight percent F is required to produce a 9-21-0 grade suspension that can be stored satisfactorily for 30 days at 25°C without encountering complete solidification. Extra ammonia was added to this suspension because of the high levels of fluorosilicic acid added. The 7-21-0 grade product without extra fluorine had satisfactory storage for less than 30 days.

The improvement in viscosity and pourability was even more pronounced when the suspensions of grade 9-27-0, 10-30-0, and 11-33-0 were evaluated at 38°C. The highest satisfactory grade that remained 100% pourable without additional fluorine when stored at 38°C for 2 weeks was only 9-27-0. With addition of 1% by weight of fluorine as fluorosilicic acid, grades up to 11-33-0 had satisfactory viscosities and remained 100% pourable after 2 weeks.

An evaluation of the weight percent water-insoluble solids present in the suspension grades was made immediately after production and after storage for 60 days at 25°C. The addition of fluorine as fluorosilicic acid significantly reduces the water-insoluble solids content in both cases. For example, the water-insoluble solids content in the 10-30-0 suspension made from MAP A and with no F added was reduced initially from 17.4 to 7.1 wt. % with 1.2% F added. After 60 days, the water-insoluble solids content was reduced from 17.4 wt. % with no additional F to 2.4 wt. % with F added. The reduction of water-insoluble solids over the 60-day storage time is indicative of the time required for the residual fluorosilicate left after ammoniation to hydrolyze to the fluoride ion which reacts with the metal precipitates from the original MAP.

Since additional F increases water solubility of N and  $P_2O_5$ , tests were conducted on reduction of citrate-insoluble  $P_2O_5$  in the suspension fertilizer both initially and after storage. The citrate-insoluble  $P_2O_5$  level was determined initially in the starting MAP, in the suspension immediately after production, and after 60 days storage at 25°C. In these tests, MAP C was used because of its high citrate-insoluble  $P_2O_5$  level. Results show that fluoride added as fluorosilicic acid decreased the citrate-insoluble  $P_2O_5$  significantly in all cases.

Monoammonium phosphate is more readily available and at a cost less per unit  $P_2O_5$  than is wet-process orthophosphoric acid. In some areas of the coun-

try, waste materials such as spent phosphoric acid are readily available for disposal and utilization in fertilizer formulations as relatively inexpensive sources of phosphate. Since such spent acids contain high levels of aluminum (from pickling operations), it has been difficult to produce suspension fertilizers of high quality. Two experiments were performed using spent acid. In one test, one-third of the  $P_2O_5$  was supplied from spent acid (26%  $P_2O_5$ , 1.3% Al) and two-thirds were supplied from MAP A without F added. In the other test with the same mixture of spent acid and MAP A, 0.9% F was added. The spent acid suspension with fluorine added had an acceptable viscosity and was 100% pourable; whereas, the spent acid suspension without fluorine had a high viscosity and zero pourability. The incorporation of inexpensive spent acid into the formulation of 10-30-0 grade suspension allows the fluid dealer to increase their profit margin and provides a useful product from a waste material.

A method was developed to determine the fluorine requirement in different grade suspension fertilizers made from different impurity MAP and phosphoric acid products. The raw materials are processed in a Waring® blender at low speed with a retention time of 20 minutes and a minimum temperature of 60°C. The quantity of suspension produced for each test is approximately 12 ounces (500 g). The suspension is stored quiescently in a 16-ounce laboratory bottle (for evaluation) at a temperature of 49°C for 3 days. At the end of that time period the suspension is removed and allowed to cool to room temperature (25°C) and evaluated first for pourability. Pourability is measured by rotating the 16-ounce laboratory bottle end over end four times, and the percentage of total volume that pours at a 45-degree angle in one minute is recorded. At this time, the viscosity is checked using a Brookfield viscometer according to the procedure described in TVA Bulletin Y-185, *Fluid Fertilizers*. If the suspension has a pourability of 98% and a viscosity of <1000 cP at 25°C, then the suspension should store for 60 days.

#### DEALER TESTS OF THE $H_2SiF_6$ PROCESS

Scale-up tests of this process were carried out on a fluid fertilizer dealer site located in southern Alabama. This site was selected because (1) this dealer would benefit from being able to store the 10-30-0 grade suspension for periods of about 60 days and (2) this dealer's MAP was marginal for producing suspensions for storage. The nominal 11-52-0 grade MAP used in the tests had a water-insoluble solid content of 18.1% by weight and a total cation to fluorine ratio of 3.1. This was near the limits for producing satisfactory suspensions; however, this dealer had encountered problems with production and storage of 10-30-0 grade suspensions made from MAP in the past.

The field test involved producing one 5-ton batch of 10-30-0 grade suspension using fluorosilicic acid and producing a similar batch without the use of fluorosilicic

acid (Table 4). The dealer supplied the production facilities, MAP, ammonia, fluid clay, and storage facilities. The products were stored at the dealer location in 55-gallon polylined drums. During the storage period, no agitation of the suspensions by either mechanical means or by air sparging was conducted. Fluorosilicic acid, a 23% solution containing 18.2% F, was the fluorine source. Anhydrous ammonia and fluid clay were the other raw materials used in the production of the suspensions. The maximum temperature reached during the ammoniation step was 152°F for the batch with fluorosilicic acid and 147°F without fluorosilicic acid. Retention times were about the same for both batches and ranged from 41-43 minutes. No problems were encountered in the production of the suspensions with handling of the fluorosilicic acid or with strong odors over the reactor. The suspension fertilizer grades produced were 9.7-29.8-0 (F added) and 9.7-29.6-0 (no F Added). The pH, specific gravity, and N to  $P_2O_5$  weight ratios of these products were about the same for each batch and were in the range of 6.8 to 6.9, 1.372 to 1.378, and 0.325 to 0.328, respectively.

Results of the 60-day storage tests showed that the 10-30-0 grade suspension containing extra fluorine added as fluorosilicic acid had significantly improved storage properties over the 10-30-0 grade suspension without fluorine added (Table 5). The viscosity of the two suspensions were about the same and in the range of 420 to 460 centipoises with and without fluorine added, respectively. However, the product from the 55-gallon drums without fluorine added was only about 95% pourable because of the presence of about 5% by volume of packed crystals that had settled to the bottom of the drum. A clear layer of about 6.5 inches or 20% by volume was measured in the drum. The effective upper size limit on DAP crystals of the control sample, no F added, was in the range of 700 x 1000  $\mu$ m versus 200 x 200  $\mu$ m in the product containing the extra fluorine. Results of the 141-day storage tests showed that the control sample, no F added, had higher viscosity (960 versus 380 cP), lower pourability (75 versus 100 vol %), larger effective upper size limit on crystal size (800 x 1200  $\mu$ m vs. 200 x 200  $\mu$ m), higher settled solids (22 vs. 0 vol %), and a higher clear layer (39 vs. 0 vol %) than the sample containing extra fluorine. It is important to note that the 10-30-0 suspension with F added as fluorosilicic was homogeneous from top to bottom. The dealer was very impressed with the suspension because of the small crystals, homogeneity, and ease in handling.

#### ENVIRONMENTAL CONSIDERATIONS

Our test results clearly show that fluorosilicic acid addition to phosphate suspension fertilizers improves their physical properties (viscosity and pourability) during storage, thus increasing their storage life. Because of this, it was of great interest to determine if the levels of fluoride present in the suspension have any harmful effects on plant growth. Dr. Frank Sikora of TVA's



Agricultural Research Department carried out a greenhouse study (7) with corn as a test crop grown on a silt loam soil limed to pH 5.8. Results of the study indicated that there was no significant decrease in corn dry matter yield with suspension fertilizers containing up to 2.3% fluorine (32 mg/kg soil). Since the level necessary to improve fluidity of the suspension fertilizer is less than 2% fluorine (<25 mg/kg soil) for the 11-52-0 grade MAPs, no harmful effects on plant growth are envisioned from the fluorine. However, the production of suspension fertilizers with greater than this level of fluorine is not recommended because at higher F levels corn dry matter yields was significantly decreased. The reduction in dry matter yield at the higher fluoride concentrations was not due to fluoride toxicity as such but to high aluminum levels which were caused by the solubilizing effect of fluoride on aluminum containing minerals in the soil.

### ECONOMICS

The economics of using this process depends on several factors. The first is the cost of 23% fluorosilicic acid which varies widely and has increased significantly since this work was initiated. Last spring, fluorosilicic acid (23%) could be obtained at some normal superphosphate plants for approximately \$60/ton or 3 cents per pound. Approximately 10,000 tons of 23% fluorosilicic acid or 12.5% of total fluorosilicic acid production is produced at normal superphosphate plants. However, if purchased through a chemical wholesale supplier, the price of  $H_2SiF_6$  could be as high as \$200/ton or 10 cents per pound. The price of 23% fluorosilicic acid has fluctuated depending on market conditions in the phosphate industry; however, the price has remained relatively steady over the years at 3-5 cents per pound at the producer sites. Another factor that affects the economic viability of this technology is that 10-30-0 suspension fertilizers can be made from lower cost (poorer quality) phosphate raw materials (Table 6.) MAP of grade 10-50-0 has lower-per-unit  $P_2O_5$  cost than 11-52-0 grade MAP, which should help in lowering the cost of the 10-30-0 and lessen the effect of the cost of the fluorosilicic acid. For example, a 10-30-0 suspension made from 11-52-0 grade MAP + 1% F as fluorosilicic acid would have a raw material cost of \$113.58, as shown in formulation 1. When 30% of the phosphate comes from 10-50-0 and 70% from 11-52-0 and 1% as fluorosilicic is used in the formulation, the raw material cost of the 10-30-0 suspension is \$107.20, as shown in formulation 2. Formulation 2 lowers the cost of the 10-30-0 compared to using only 11-52-0 and F. The cost of the fluorosilicic acid is paid for by using lower grade MAP in this formulation. Also, the price of the 10-30-0 shown in formulation 2 is cheaper than a 10-30-0 suspension made from 11-52-0 MAP without fluorine which is \$108.58, as shown in formulation 3.

The 10-30-0 base suspension is very popular with dealers and in conjunction with potassium chloride and

UAN solution is used to prepare a variety of suspensions such as 3-9-30, 5-15-25, 4-12-12, 18-9-9 and 12-12-12 for their customers. Analysis for CaO, MgO,  $Al_2O_3$ ,  $Fe_2O_3$ , and F are not usually furnished with MAP; however, dealers can readily determine the water-insoluble solids content of the MAP and this value can be used to estimate the fluoride requirements. In general, MAPs with less than 13% water-insoluble solids will produce satisfactory suspensions without the use of added fluoride but the addition of fluorosilicic can improve storage life (Table 7). MAPs with 13-17%, 18-20%, and 20-23% water-insoluble solids require 0.6%, 1.0% and 3.0% respectively. In a recent evaluation a MAP with 19% water-insoluble solids was converted into 10-30-0. The 10-30-0 without fluorosilicate would not pour, while the 10-30-0 with fluorosilicate poured readily.

### CONCLUSIONS

In summary, the use of fluorosilicic acid in production of suspension fertilizers made from MAP offers the advantage of preventing gelation during storage, increasing water solubility of  $P_2O_5$  and associated N, and decreasing the citrate-insoluble  $P_2O_5$  content. The suspension produced is settling resistant with small crystals which offers ease in handling the material. This technology will allow a dealer to use cheaper phosphate raw materials such as spent phosphoric acid and high-impurity MAP to make stable 10-30-0 suspensions that are economically viable in the current market place.

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### 11-33-0 Suspension Data

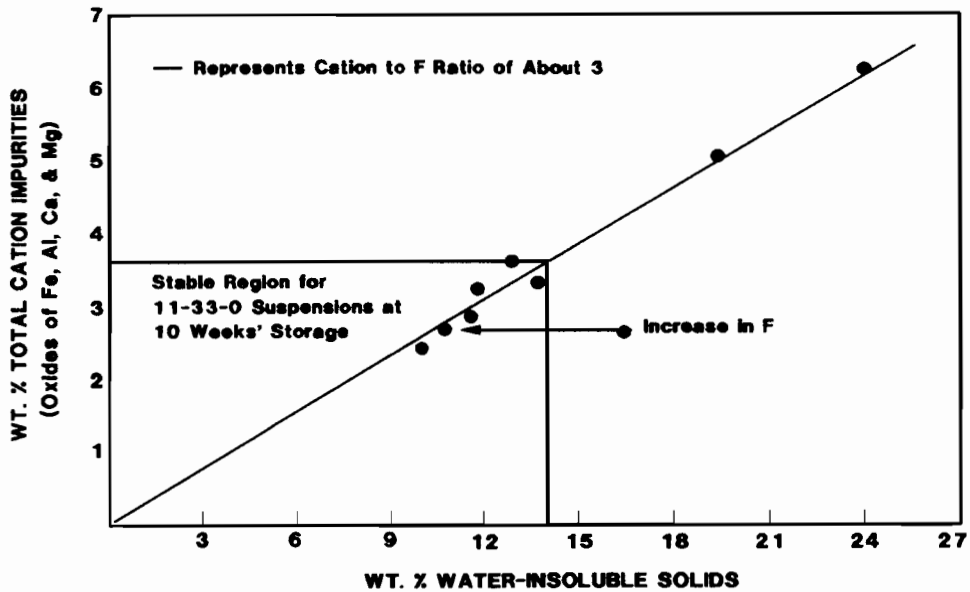


TABLE 1

### Calculated Percentages of Compounds in Florida MAP Fertilizer

<u>Compound</u>	<u>WtX</u>	<u>Compound</u>	<u>WtX</u>
MgAl(NH <sub>4</sub> ) <sub>2</sub> H(PO <sub>4</sub> ) <sub>2</sub> F <sub>2</sub>	4.2	Ca(NH <sub>4</sub> ) <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub>	0.8
FeNH <sub>4</sub> (HPO <sub>4</sub> ) <sub>2</sub>	7.2	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	6.1
AlNH <sub>4</sub> HPO <sub>4</sub> F <sub>2</sub>	0.9	(NH <sub>4</sub> ) <sub>2</sub> SIF <sub>6</sub>	0.2
Mg-Al-F-XH <sub>2</sub> O (as MgAl <sub>2</sub> F <sub>6</sub> ·2H <sub>2</sub> O)	1.4	(NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub>	1.0
CaSO <sub>4</sub>	0.4	NH <sub>4</sub> H <sub>2</sub> PO <sub>4</sub>	73.8
SiO <sub>2</sub>	0.1	H <sub>2</sub> O	1.7
		<b>Total</b>	<b>97.8</b>

TABLE 2

### Chemical Analysis of Granular MAPs

Sample	Weight Percent									Ratio Cation:F
	Total N	Total P <sub>2</sub> O <sub>5</sub>	Ortho P <sub>2</sub> O <sub>5</sub>	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	MgO	CaO	F	SO <sub>4</sub> -S	
A	11.2	51.7	51.3	2.4	2.6	0.6	0.6	1.8	1.6	3.4
B	11.2	51.9	51.6	2.1	2.6	1.0	0.5	1.6	1.6	3.9
C	10.0	49.2	49.0	5.3	2.3	1.2	0.8	2.4	1.7	4.0

TABLE 3

### Effects of Order of Addition on Viscosity and Pourability of 10-30-0 Suspension Fertilizer Using H<sub>2</sub>SiF<sub>6</sub>

Test No.	H <sub>2</sub> SiF <sub>6</sub> Added <sup>a</sup>		After Quiescent Storage for 14 Days at 38°C	
	Wt%	%F	Viscosity, cP, 38°C <sup>a</sup>	Pourability, % of Total Volume
<b>Added Prior to Ammoniation Step</b>				
1	0.8	0.6	200	100
2	1.2	0.9	180	100
<b>Added After Ammoniation Step</b>				
3	0.8	0.6	>1000	0
4	1.2	0.9	>1000	0

<sup>a</sup> Added as 23% solution and contains about 18 to 20% fluorine

TABLE 6

### Raw Material Costs for 10-30-0 Formulations (\$/Ton)

Raw Material Cost	Formulation #1 (11-52-0 + F)		Formulation #2 (11-52-0 + 10-50-0 + F)		Formulation #3 (11-52-0)		
	Lbs	Cost, \$	Lbs	Cost, \$	Lbs	Cost, \$	
Ammonia:	150.00	89	6.68	91	6.83	89	6.68
MAP 10-50-0:	131.00	-	-	360	23.58	-	-
MAP 11-52-0:	174.00	1,154	100.40	808	70.30	-	100.40
H <sub>2</sub> SiF <sub>6</sub> , 23%:	100.00	100	5.00	100	5.00	-	-
Water:	0.00	627	0.00	621	0.00	727	0.00
Clay:	100.00	30	1.50	30	1.50	30	1.50
<b>Total Cost</b>			<b>113.58</b>		<b>107.20</b>		<b>108.58</b>
<b>Total Cost Per Unit Plant Food</b>			<b>2.84</b>		<b>2.68</b>		<b>2.71</b>

TABLE 7

### Fluoride Dosing Based on Water-Insoluble Solids in MAP

% Water-Insoluble Solids	% Fluoride Dosage
Less than 13	0.0 <sup>a</sup>
13-17	0.6
18-20	1.0
20-23	3.0 <sup>b</sup>

<sup>a</sup> Fluoride not needed for pourability but it may improve long-term storage

<sup>b</sup> Fluoride dosages greater than 2.3 are not recommended for field application

TABLE 4

### Formulations and Batch Operating Conditions for Dealer Test

Formulation (5-ton batch)	With F Added,	% of	Without F Added,	% of
	Lb	Total	Lb	Total
H <sub>2</sub> O	2637	26.4	3187	31.9
MAP	5769	57.7	5769	57.7
H <sub>2</sub> SiF <sub>6</sub> (23% basis)	550	5.5	0	0
NH <sub>3</sub>	444	4.4	444	4.4
Fluid clay (1.5 wt.%)	600	6.0	600	6.0
<b>Batch Operating Conditions</b>				
Temperature, °F	152		147	
Time, min	43		41	
<b>Grade</b>				
	9.7-29.8-0		9.7-29.6-0	
pH	6.8		6.9	
Sp Gr	1.378		1.372	
N : P <sub>2</sub> O <sub>5</sub> wt. ratio	0.325		0.328	

TABLE 5

### Results from Dealer Test

	60 Days		141 Days	
	10-30-0, No F	10-30-0, 1% F	10-30-0, No F	10-30-0, 1% F
Viscosity, cP	460	420	960	380
Pourability, Vol.%	95	100	75	100
Crystal Size, Microns	700x1000	200x200	800x1200	200x200
Settled Solids, Vol.%	5	0	22	0
Clear Layer, Vol.%	20	0	39	0

## Design Criteria For Blend Plants

Larry Taylor

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I would like to emphasize a point. That is "*ALL BLEND PLANTS ARE NOT CREATED EQUAL*". Blend plants vary tremendously in terms of size, capability and sophistication depending on the market they are serving. Blending plants can be as simple as mixing materials together on a concrete pad or as sophisticated as a highly automated plant capable of producing well over 100,000 tons per year of blended product.

In order to put blend plants in perspective, I would like to discuss the nature of blending and its function. Fertilizer blending is the deliberate and careful mixing of two or more dry fertilizer materials to obtain a mixture (blend) of the desired nutrients in a predetermined ratio and concentration. The process of blending does not involve chemical reactions between the materials and each material maintains its own identity.

It is normally assumed that blends are prepared using granular materials of similar size. However, in practice, the particle size often falls outside of the generally accepted granular range of 1-4mm.

It should be emphasized here that blending is a marketing tool that provides a convenient method to apply more than one nutrient at the same time. This convenience is usually cost effective if the crop requires the application of more than one nutrient during the same general time period. Keep in mind that blending is merely a distribution method for granular materials. It in no way replaces chemical granulation, and in fact, the success of blending is totally dependent upon the production and availability of good granular single and multi-nutrient products.

What is meant by "bulk-blending" which is heard so often? The term bulk blending originated in the United States presumably because most fertilizer blends were sold in bulk and applied directly to the field without an intermediate step, such as bagging. I will refer to blending rather than bulk blending in order to go beyond the borders of the U.S.

In order to get a better perspective on the importance of blending, let's examine the question of how much of the world's fertilizer is actually blended. The answer is "not much". Of the approximate 400 million tons of fertilizer consumed worldwide, only about 20 million tons (about 5%) is in the form of blends. Of this, the United States and Canada account for about 12 million tons. Another 60 million tons (15%) is in the form of compounds, while about 30 million tons (7%) is in fluid form (mostly nitrogen solutions and anhydrous ammonia). The remainder (nearly 300 million tons or 75% is used as straight materials, such as, urea, ammonium nitrate, ammonium sulfate, ammonium phosphate, su-

perphosphate and potash).<sup>1</sup>

The estimated world production of blended fertilizer by country is as follows:

Country	Estimated Annual Production Million Tons
<b>United States</b>	<b>9.0</b>
<b>Canada</b>	<b>3.0</b>
<b>Brazil</b>	<b>2.8</b>
<b>Ireland</b>	<b>1.0</b>
<b>United Kingdom</b>	<b>1.0</b>
<b>Central America/Caribbean</b>	<b>0.6</b>
<b>Japan</b>	<b>0.6</b>
<b>Others</b>	<b>2.0</b>
<b>Total</b>	<b>20.0</b>

Although, this is a relatively small percentage of the fertilizer market, there has been steady growth over the past ten years and the trend seems to be continuing. The reasons for the growth in bulk blending worldwide are fairly obvious, although they vary somewhat depending on geographical location. They can be summarized as follows:

1. *Availability of consistent quality granular materials for blending* - The world production of granular products which are suitable for blending, such as urea, ammonium phosphates, nitro phosphates, and potash has increased significantly over the last ten years. These products are essential in order to produce acceptable blends.

2. *Cost* - Blend plants are relatively inexpensive to build and operate. They offer the advantage that they can be located almost anywhere as long as granular materials can be transported to their location.

3. *Flexibility and simplicity* - Blending fertilizer has virtually no process restrictions and allows the production of numerous ratios in almost any quantity. Blending provides the means by which a local plant can provide varying fertilizer grades to satisfy the specific crop requirements of local farmers.

4. *Quality* - It has been widely shown through test plots and other methods that blends made with compatible sized granular materials and blended and handled by efficient methods produce similar results to compound fertilizers.

Thus, the question becomes, "What is the most economical method to get the required nutrients to the plant?"

Now that we have decided that blending makes sense, what do we need to know to design our blend plant? Let's start with this question, "What is the function of a blend plant?"

1. To receive raw materials either by ship, rail, truck or combination of the three.
2. To store these materials for some period of time while maintaining their quality.
3. To accurately produce a quality finished product containing two or more materials for delivery to the farms in bulk or bag.

Remember that any plant design is determined by its function. Blend plant designs vary dramatically depending upon the market that they serve. The major determining factors in the design of a blend plant are as follows:

#### A. *Know Your Market.*

- Are the farms large or small?
- Do they require blends in bulk, bags, or both?
- How long is the application season?
- What crops are being produced and how wide a variety of formulas are required?
- What soil types are there, and what are their requirements?
- Who will determine formulas required for your market?
- Are secondary and micronutrients required?
- Method of application (machine, hand, etc.)

**B. *Location and size of the plant or plants*** - In the United States, blend plants are located throughout the country; in fact, there are somewhere around 5,000 of them. In some countries like Guatemala, three or four blend plants serve the whole country. This is an important question and should be based on considerable market research. Generally, if the infrastructure for transporting fertilizer is good and the fertilizer is distributed in bulk, smaller and more numerous plants are feasible.

**C. *Reliability of raw material supply*** - How often can you get raw materials and what quantities are economical? This will determine type and capacity of material inloading systems as well as storage capacity of building.

Once these general criteria are determined, it is time to ask some more specific questions?

- How often will materials be received - ship, truck or rail, or some combination of these?
- How many tons per hour do you need to inload, and what logistics problems does this cause?

- How much storage capacity is required?
- What materials of construction are available and economical to use? Generally, plants are constructed of wood, concrete or steel.
- How many different materials will be stored?
- How will bins be partitioned?
- How many tons per hour do you need to blend, and what do you need to blend, and what is your annual throughput expected to be?
- Will materials be delivered in bulk, bag, or both?
- Will finished product be stored or will it be delivered immediately?
- How much bag storage capacity do you need?
- What special precautions must be taken in handling, storing, blending, and bagging of fertilizers?

It seems that fertilizer blend plants can be divided into three general categories. Each one of these categories has its own requirements for design. Broadly these are:

- A. Small Blend Plants that produce 10,000 tons per year or less and deliver blends in bulk.
- B. Moderate Size Blend Plants producing 10,000 tons per year or more and delivery blends in bulk.
- C. Large Blend Plants producing 25,000 tons per year and delivering blends in bags.

**A. *Small Blend Plants (Bulk)*** - Small blend plants are very common in the United States. Their average storage capacity is about 1,500 tons. Generally, raw materials are delivered by rail and their availability is very reliable. Materials can be obtained on short notice and in relatively small quantities. Virtually all materials are delivered in bulk and the seasons are very short, usually less than eight weeks.

These plants generally use an undertrack conveying system for rail car unloading and a belt conveyor for distribution in the plant. Typically, these plants will use a floor mounted blending system, such as, a cement mixer style, paddle mixer, rotary mixer, or vertical screw mixer. The blended fertilizer is delivered to trucks and taken directly to the field for application. These plants generally offer limited services and serve a geographical area of about 25 kilometers radius. Since these plants have a fairly low annual throughput, design criteria are fairly simple. Building construction is usually wood and inloading is accomplished by rail and/or truck. Blending is usually accomplished by batch mix-

ing systems with the front end loader operator weighing directly into a weigh hopper or a mixer mounted on a scale system. Accuracy and speed is a function of the front end loader operator's skills. In the United States, blend quality have not been a major consideration in the past due to the fact that it is generally delivered in bulk. Quality of the blend delivered and applied in bulk is not nearly as critical as blends that are put in bags. Recently, more concern has been shown for blend accuracy and indications are that this will be a major area of concentration in the future.

**B. Moderate Size Plants** with annual throughput of 10,000 tons per year are fairly common and increasing in number for economic reasons. These plants also have short seasons and therefore must have a greater hourly output to accommodate their market. These larger plants will have at least 5,000 tons of storage and hourly production rates in excess of 60 tons per hour. Often, they will receive materials in multi-carload shipments and unload from rail or truck at rates of 120 tons per hour or more.

These plants will serve a larger geographical area and can offer more services to their customers. Most of the plants of this size have tower blending systems. This plant size is popular in the mid-west of the United States. The raw materials are retrieved from storage by front end loader, and are blended through a tower blending systems with capacities up to 100 tons per hour. These larger plants have some major advantages and appear to be growing in popularity in the United States. Obviously, they have better buying power and can better meet the environmental concerns required in today's market. They have a larger customer base and can offer better services to the farmer.

A tower blending system can be computerized and weight accuracies and speed are not determined by the front end loader operator. Inventory throughput can easily be automated for control. All of the materials passing through the system are recorded and matched against what was purchased. Formulas can be predetermined and stored in the computer so that the number of batches and formula are determined by pushing a few buttons. The control system can be located in a remote location, if necessary.

**C. Large Blend Plants (Bulk)** - There is a recent trend toward extremely large blend plants. These plants receive large quantities of material by barge or rail and distribute materials as straights or blends. These plants have unique design criteria as their input and output requirements are very high. They require large storage capacity and are quite sophisticated in terms of function and design.

A recent plant built by The Andersons in Webberville, Michigan, U.S.A. demonstrates this type of operation. This blend facility is a unique combination of high speed rail or truck inloading air shell formed insulated con-

crete dome structures in conjunction with conventional pole buildings and a high speed computerized blending system. This facility offers product as a single material or a custom blend. The 65,000 ton storage capacity operation incorporates a number of features to conserve space, lighting, and labor while ensuring quality service to the customer. Materials are received by unit trains which share trackage with the owner's grain operation.

**Receiving System** - Railcars or trucks are spotted over the undertrack conveyor and unloaded at approximately 400 tons per hour. This conveyor is a chain conveyor which incorporates stainless steel chain pins and urethane conveying flights. It changes directions from horizontal and elevates product at approximately 45 degrees. This type of system requires less space due to the steep angle of incline and also requires a relatively shallow pit under the track. The railcar gates are opened using a monorail supported pneumatic gate opener. This system allows for the gates to be opened quickly and efficiently. There is also a system for cleaning out the cars after they have been emptied. The undertrack conveyor elevates materials up to a 30 inch belt conveyor at the rate of 400 tons per hour. The belt conveyor delivers materials to storage across one or more of the dome fill conveyors.

**Storage** - The insulated concrete domes are 140 ft. in diameter x 70 ft. high. Each 718,000 cubic ft. dome stores 18,500 tons of 60 lb. per cubic foot material. The strength of these rebar reinforced high test concrete structures allows product to be stored up on the sidewalls (limited only by the angle of repose of the material) thus minimizing the required floor area. The design provides an economical water-tight structure of incredible strength.

The exterior of each dome is P.V.C. coated polyester membrane which initially acts as the air shell form. Inside the airform is a layer of seamless insulating foam (2 or 3 inches thick) followed by reinforcing bar and 6 to 12 inches of high strength concrete. The result is a clearspan structure impervious to thermal shock, high wind, and interior and exterior loading; able to be sealed air tight and dehumidified, if required. A 14 ft. high x 18 ft. wide entry with bulkhead allows access by the front end loader. Skylights located near the top of the dome, in conjunction with the front end loader lights, preclude the need for artificial lighting inside the structures.

The flat storage areas, located between the domes, consist of clearspan pole buildings with tongue and groove treated lumber walls up to the load line height, translucent fiberglass reinforced corrugated roofing, and 14 ft high by 20 ft wide sliding door entries. Each 9,000 square ft. flat storage building can be divided off by movable concrete block walls to allow for storage of two minor products per flat storage building. These movable walls allow for flexibility in products and tonnage stored.

**Reclaim** - Loading out of the products can be a single bulk materials delivered to trucks by front end loader, or as a blended product produced by a blend tower at 120 tons per hour and discharged directly into truck. These operations take place under the 14,400 square ft. canopy area. The use of translucent roofing in this canopy area provides natural light.

Within the canopy area, overhead clearance is a minimum of 22 ft. to provide for loading over the sides of semi-trailers with front end loaders. The rebar reinforced concrete floor tolerates the many turning actions of both end-loader and truck.

**Blend Tower** - The front end loader reclaims materials (ex. DAP, KCL, Urea) from storage and feeds into an elevator through a material delumper (conditioner). This removes lumps caused by pile set and ensures a more uniformly sized product prior to blending, without creating an excess of fines. Materials are elevated at 200 tons per hour into a 200 ton overhead bin system that is divided into 10 compartments (6 compartments for major nutrients and 4 compartments for micronutrients). Products are discharged through a motorized, totally enclosed distributor into any one of the 10 compartments. The front end loader operator selects the bin that requires charging by watching a light system which indicates which compartments are full and which are empty. The 10 compartments discharge through hydraulically controlled slide gates into a 5 ton weigh hopper. This system is controlled by computer. Various formulas are stored in the computer and designated by number. The operator designates a formula and the number of tons he wants to mix. The computer then controls the opening and closing of gates. This ensures that accurate weights are weighed into the weight hopper. The computer is relatively flexible and adjustments can be made easily. Tolerances are set and can be changed by key access. Approximately 60 formulas can be stored in memory and formula changes can be made by the operator to add or delete. Weighed products are then fed into a stainless steel paddle mixer and mixed for various lengths of time depending on the grades being produced. While the batch is being mixed a second batch is being weighed into the weigh hopper. The system is sequenced so that time lags should not occur. The system is also electrically interlocked to minimize problems. The mixer then discharges by gravity through three slide gates located in the bottom of the mixer. This allows for quick discharge and good clean out. The total discharge time is approximately 30 seconds. The blended product is then held in a 5 ton surge hopper or loaded directly into truck. The system is capable of blending throughout in excess of 120 tons per hour.

*Major Benefits include:*

1. Increased throughput capacity.
2. Maximum use of 304 stainless steel in system design.

3. Improved mixing efficiency.

4. Fully automated scale system to minimize chance of human error and for inventory control.

**C. Large Blend Plants (Bag)** - There have been many extremely large blend plants built worldwide over the past five to ten years, which produce most or all of their blends in bags. These plants often produce in excess of 100,000 tons per year. Generally, they are in developing countries and two or more of these plants may meet the fertilizer requirements of an entire country.

These plants often take the place of granulation plants or restrict imports of multi-nutrient fertilizers from other countries. They offer the following advantages:

1. Use of local labor for bagging
2. Low consumption of energy
3. Good buying opportunities for raw materials in bulk
4. Flexibility in grades produced to meet local market requirements
5. Relatively low capital investment

Most of the plants of this size received raw materials from ship. Due to this, their storage capacity must be large, often exceeding 20,000 tons and their loading capacity must be fairly high (150 tons per hour or more).

Many of this type of plants are in the tropics or subtropics and are required to blend and bag most of the year. The annual throughput is high and equipment must be extremely heavy duty and designed to operate in humid environments. Also, due to the fact that most of the product is delivered in bags, the weighing and blending system must be extremely accurate. Most of these plants have computerized scale systems to ensure weighing accuracy even when located in remote locations. Blending accuracy is much more important when materials will be delivered in bags rather than in bulk. Each bag must contain the exact formula which is printed on the bag. Often a farmer will buy only a few bags for his complete crop.

This type of blend plant requires special design features due to environment and market. The hygroscopic nature of fertilizers in humid climates is a recipe for disaster if the plant is not designed properly.

**Inloading** - Generally, these plants will be located near a port and all materials will be imported. These materials will usually be received by ship and transported to the plant by truck. The inloading system must be fast and reliable. Equipment only breaks down when it is being used and usually at the worst possible time. Back-up systems are important as ship demurrage is costly.

**Storage** - Capacity is normally a minimum of 20,000 tons and should be maximized. The economics of receiving large shipments is very important to a plant's



success. Plants may be built of wood, concrete, or steel. Non-corrosive material of construction are preferable where available and economical.

**Blending and Bagging** - A delumping system is required as materials cake in humid climates. Chain elevators are essential as belts tend to slip and can cause continuous maintenance problems. Spouts and chutes should be on steep angles of at least 50 degrees in order to avoid buildup and plugging. As blend accuracy is extremely important, a proven mixer and scale system are essential. Weighing by computer will decrease the chances of human error. The bagging system will be determined by the local market requirements. Most use open mouth baggers with polypropylene woven bags and polyethylene liners. They may be sewn or heat sealed or both. Manual tying and then sewing is also popular. These bagging systems must be reliable and designed to operate in corrosive and humid environments.

All equipment should be relatively simple, heavy duty and repairable in remote locations. These plants are major production facilities and must produce large annual volumes. Their design requirements are quite different from a blender producing 5,000 tons in the U.S.A.

In summary, criteria for blend plant design is highly dependent on the plant location and the market that is being served.

Generally, blend plant design falls into three categories:

- A. Building design
- B. Inloading equipment
- C. Blending or blending and bagging equipment

There are some general guidelines that strongly influence all of these areas. Use materials of construction that are local and economical. However, pay attention to such factors as corrosion resistance, strength, and durability. Plant location and size is extremely important, and depends on source and reliability of raw materials and how you will deliver finished product. Inloading equipment is determined by how raw materials will be received, building layout, and local conditions. Simplicity, reliability, and speed are high priorities. Keep pits to a minimum and use as little equipment as possible to accomplish what you need. Pay attention to details, such as, chain, versus belts in humid climates. Chain mechanisms in elevators and conveyors are positive and can prevent the slippage problem often encountered with belts.

Blending systems cover a multitude of opportunities. Buy from a reliable and experienced manufacturer and require that they have had tests performed from a recognized organization to prove the efficiency of their blender. Make sure that the blending system you buy is designed to meet your requirements.

Ask these questions:

- Is it 304 stainless steel?
- Have other people used it in similar applications?
- Is a front end loader fed system fast and accurate enough or is a tower system required?
- Is delumping required in the systems?
- Is it heavy duty enough to hold up to my market demand?
- How will material be delivered and applied?  
Application method can have a big influence on system design.
- Work with someone who can give you assistance with system design, engineering, installation, and startup.
- Is the system flexible enough to meet my requirements for the next ten years? Design for growth and change.

System design for blending and bagging offers a special challenge.

If materials are to be delivered in bags, make sure you choose the right bagging system.

- What type of bags will be used, plastic, polypropylene, paper or other?
- How will bags be sealed?
- What size bags are required? Is lawn and garden a possibility?
- Blends must be very precise and system must be designed so that segregation does not occur. Have you had your system designed with this in mind?
- How automated should bagging system be?
- Will bags be palletized or loaded directly on truck?
- Are baggers stainless steel?
- How long will bags be stored before use and what problems might this cause?

Trend is toward blend plants that are larger in scope, serve a bigger market, and are more sophisticated in technology and services. In conclusion, I would like to emphasize what I believe are the most important criteria to consider in designing your blending plant:

1. Maximize storage capacity and efficiency.
2. Use non-corrosive materials wherever possible - wood or concrete in building and 304 stainless steel equipment.
3. Keep equipment systems simple, heavy duty, and designed to meet *your* market requirements.

4. Do it right the first time. A little extra spent up front will save you much time, money, and aggravation long term.
5. Work with a company who has experience in blending and get their assistance in plant design.

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# Wednesday, November 14, 1990

Session V

Moderator:

Robert E. Robinson

## U.S. Fertilizer Consumption and Reporting Methodology

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Tennessee Valley Authority

### U.S. Fertilizer Consumption

For more than 30 years, until 1981, annual report of fertilizer consumption reflected positive growth rates, and market expansion was almost uninterrupted. After peaking at 54 million tons in 1981, fertilizer consumption has fluctuated downward, reaching 43 million tons in 1987 and recovering to an estimated 48 million tons in 1990. Acreage reduction programs designed to control supplies of agricultural commodities have been largely responsible for this general decline in fertilizer use.

The estimated 1989-90 consumption total of about 48 million tons is 8 percent greater than the 1989 total and has significantly exceeded most predictions. Estimated use of primary plant nutrients (N-P-K) totaled 21 million tons, a 7 percent increase over the previous year. Nitrogen use was approximately 11.4 million tons, 54 percent of total nutrient use; phosphate use was 4.4 million tons of  $P_2O_5$ , 21 percent of the total nutrient use; and potash use was 5.2 million tons of  $K_2O$ , 25 percent of the total plant nutrient market. The 48 million tons of fertilizer was sold to about 2.2 million farmers at an approximate cost of \$8 billion and was applied to about 320 million acres. Fertilizers are still an important industry and have significant impact on national and world economies.

Corn, cotton, wheat, soybeans, and sorghum accounted for approximately 69 % of the nation's total crop acreage. These crops receive more than half of all fertilizers used.

Nitrogen markets are dominated by fluid-nutrient materials. Anhydrous ammonia and nitrogen solutions account for more than half of all nitrogen consumption. Solid materials including urea, ammonium nitrate, and ammonium sulfate, make up 22 percent; diammonium phosphate accounts for 6 percent; and multi-nutrient grades account for the remaining 15 percent.

More than half of all phosphate consumed is in multi-nutrient grades with diammonium phosphate accounting for 38 percent of the market. Other sources of phosphate play only a minor role in U.S. phosphate consumption.

Potash markets are dominated by potassium chloride. Reported consumption before blending shows that its market share is more than 60 percent. Mixtures containing potassium chloride account for 36 percent. Other potassium products, such as potassium and potas-

sium magnesium sulfate, make up the remainder of the potash materials used in the United States.

### Regional Consumption Patterns

Fertilizer use varies according to geography. For purposes of this analysis, the United States has been divided into five major regions.

*New England and Middle Atlantic.* Agriculture in the Northeast has been steadily declining. Land use for agricultural crops has decreased 43 percent since 1940, and fertilizer use has decreased accordingly. Total fertilizer used in 1989 was 2.1 million tons or 5 percent of all fertilizer used in the United States. Total planted crop acreage was 12 million acres, about one half of which was hay crops and 45.0 percent was corn, soybean, and wheat.

Fertilizer use as dry bulk multiple-nutrient grades was 481,324 tons or 23 percent of the total fertilizer used. Dry bagged multiple-nutrients (46 percent of all mixtures) continue to be important. This reflects the regions relatively large nonfarm market. Fluid multiple-nutrient grades at 148,432 tons, account for 12 percent of total mixtures.

*South Atlantic States.* The five states in this region used 6.2 million tons of fertilizer in 1989 or 14% of total U.S. consumption. This regions market share of total national fertilizer consumption has steadily declined over the last 20 years. Plant nutrient use has decreased 2.4 percent per year since 1981. In 1990, this region had 15 million acres of planted cropland. Corn, cotton, soybean, and wheat accounted for 64 percent of the acreage. Most of the remaining acreage was planted in hay, tobacco, and peanuts.

Multiple-nutrient fertilizers accounted for 67 percent of all fertilizer used in 1989, with 42 percent in dry bulk form, 17 percent bagged, and 13 percent fluid. Fluid single-nutrient fertilizers, primarily nitrogen solutions, comprise 17 percent of the total.

*East North Central and North Central States.* In 1989, 46 percent of total fertilizer consumption and 56 percent of nitrogen, phosphate, and potash used in the United States was applied in the Midwest. Fertilizers were used on 196 million acres, or 61 percent of the total planted acreage in the United States. Corn, wheat, and soybeans accounted for 74 percent of the total planted acreage.

Single-nutrient fertilizers accounted for 68 percent of the fertilizer used. From this group, dry materials comprised 26 percent and fluids comprised 34 percent. The fluids consisted primarily of anhydrous ammonia and nitrogen solutions. Both materials have had tremendous growth rates since 1965. About 23 percent of all fertilizer used in this region in 1989 was bulk multiple-

nutrients. Fluid multiple-nutrients made up about 8 percent of the fertilizer consumed.

*East South Central and West South Central States.* Fertilizer used in these states represent 19 percent of all fertilizers used in the United States (both fertilizer and plant nutrients). Total planted crop acreage in 1990 was 61 million acres, with 71 percent being in corn, cotton, wheat, and soybean.

Multiple-nutrient fertilizers accounted for 45 percent of the total fertilizers used, with 28 percent being dry bulk, 10 percent fluid, and 7 percent bagged. Dry bulk single-nutrient fertilizers were 30 percent of the total.

*Mountain and Pacific States.* This region has high-value crops grown under irrigation and special cropping conditions; it also has most of the nation's rangelands. More than 200 commercial crops can be produced because of the favorable climate in much of the regions southern portion. About 11 percent of all harvested cropland in the United States is here. Leading crops are wheat and cotton. This region used 16 percent of all fertilizer and 11 percent of all plant nutrients consumed in the United States in 1989. Almost 69 percent of the fertilizer applied was single-nutrient—40 percent fluid and 7 percent dry. Dry multiple-nutrients accounted for more more than 8 percent of fertilizers used.

Of the 3.5 million tons of fertilizers used in California during 1989, almost 1 million tons consisted of secondary and micronutrients, mostly gypsum.

#### *Reporting Methodology*

Based on past fertilizer tonnage reporting procedures, how valid are the numbers just presented? Through programs developed at the NFERC, significant progress has been made in improving the fertilizer consumption data. Currently, 37 states are using a microcomputer program, Uniform Fertilizer Tonnage Reporting System (UFTRS), developed at the NFERC in cooperation with the Association of American Plant Food Control Officials (AAPFCO). The remaining states are using the uniform codes and procedures recommended by the Uniform Fertilizer Tonnage Reporting Committee of AAPFCO.

Since the USDA discontinued publication of the "Commercial Fertilizers" report in 1985 due to budget problems, the NFERC has increased its involvement in the fertilizer tonnage reporting process. At that time, NFERC began collecting the data and distributed its first report in 1986. The UFTRS microcomputer program promotes uniformity, reliability, timeliness, and availability of the data.

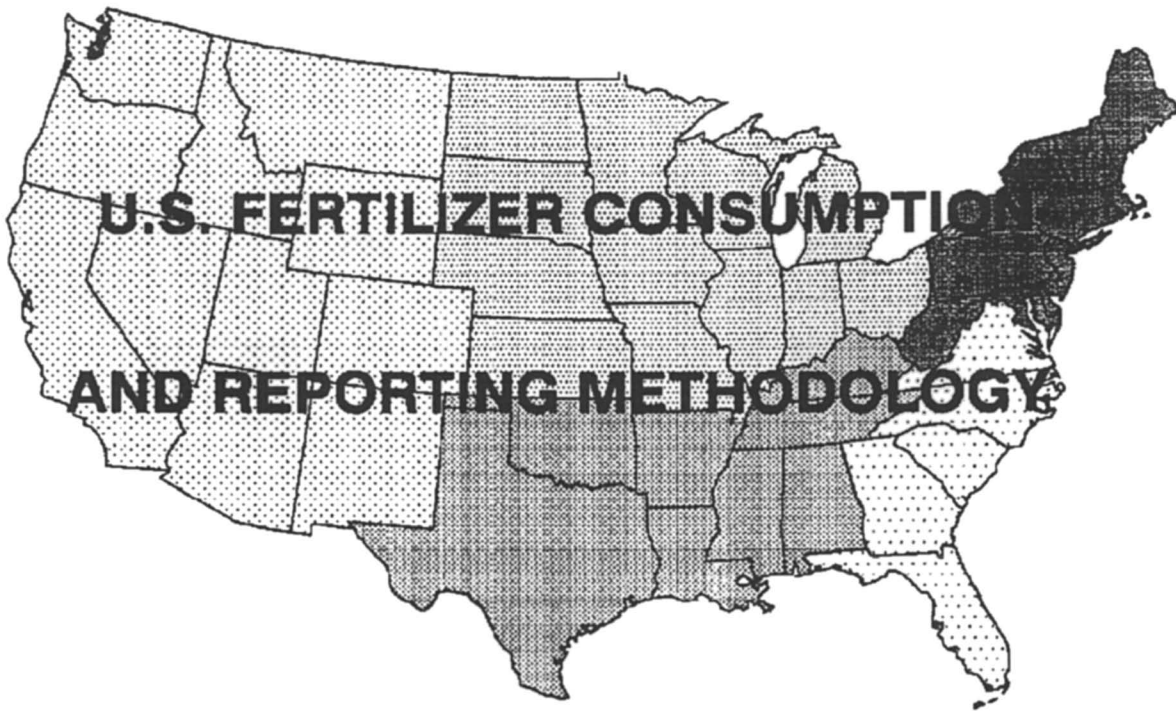
All states, except Alaska and Hawaii, require various levels of the industry to report fertilizer tonnage consumption to the state fertilizer regulatory office. The control officials primary responsibility is to assure compliance with the state's fertilizer laws and regulations. Published fertilizer consumption data reflects tonnages moving through the supply chains from basic manufacturing to retailers to consumers as reported by the state regulatory agencies.

The annual "Commercial Fertilizers" report is based on fertilizer year (July 1- June 30) and is published by NFERC from tonnage reports supplied by each state. The report provides details on single-nutrient and multi-nutrient fertilizers. It has also proven to be an effective and inexpensive means of maintaining fertilizer use by county. Currently, 32 states, compared with 23 states in 1985, provide detailed county information. Fertilizer use information is often studied during investigations of surface and groundwater quality and particularly in investigations of variability of surface and groundwater nutrient concentrations over time and space.

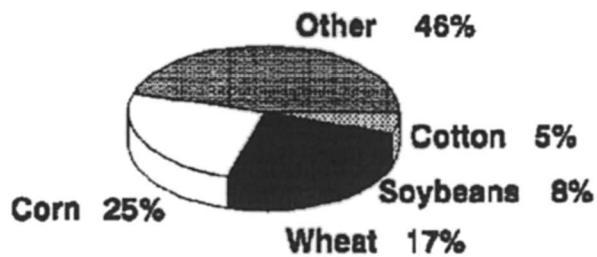
The latest NFERC-AAPFCO project to facilitate fertilizer tonnage reporting is the Fertilizer Tonnage Reporting Program (FTRP) which allows dealers/manufacturers to submit their data electronically to state regulatory offices. A file import program, called Uniform File Import Utility (UFILE), edits the data, provides modifications, and writes the data to an appropriate data base or to an ASCII (text) file. The FTRP will simplify reporting for dealers/manufacturers and state offices by cutting down on paperwork and clerical time and enhancing accuracy. Assistance in testing has come from Mississippi. Bill Michaels, Market Analyst, and Benton Hayman, Data Processing Manager, at Mississippi Chemical Company in Yazoo City, developed their company's capability to submit data in the desired format and are now sending diskettes to three states. Mark Hannaford and Phyllis Floyd of Panola Farm Center in Batesville have also developed capability for sending the data electronically. Alabama Farmers Co-Op, Decatur, Alabama, has cooperated in the initial testing and is now submitting their data to Alabama on diskettes. Several other companies are presently developing the capability.

Reliable fertilizer consumption data is crucial to those who study the fertilizer industry. It is used in planning ahead. Should a retailer expand a blending facility? Where should a new plant be located? Is a large plant needed or a small one? Which materials and how much are going to be needed to meet the demand of a certain area? Are new transportation and storage terminals justified? Without accurate information, those serving agriculture can only guess at fertilizer use as they try to develop programs. County data is valuable to market analysis, agronomists, and county extension agents in evaluating crops and potential fertilizer demand by product. Also, fertilizer dealers, basic manufacturers, farmers, regulatory agencies, and other environmentally concerned persons are increasingly concerned about how fertilizers are impacting the environment. County fertilizer consumption data helps identify possible sources of nonpoint pollution reaching rivers, streams, and underground water tables.

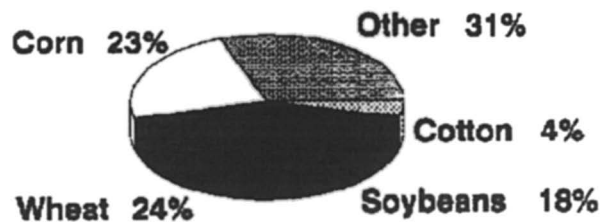
Excellent cooperation from each state has enabled NFERC, with help from AAPFCO, NFSA, TFI and the fertilizer industry, to publish more reliable fertilizer use statistics. Our goal is to continue to improve the timeliness and accuracy of this data.



**TOTAL PLANTED CROP ACREAGE**

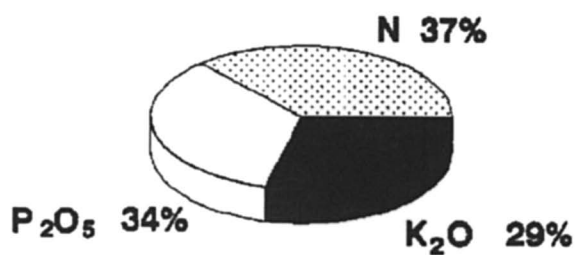


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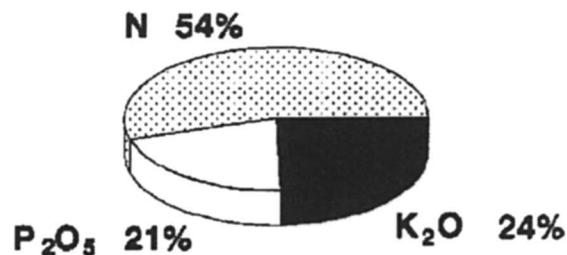


**1990**

# NUTRIENT USE

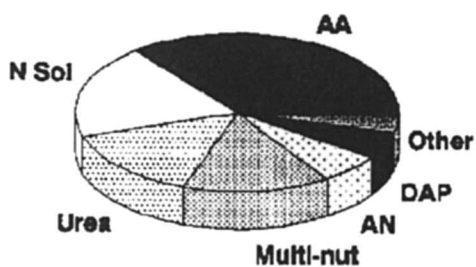


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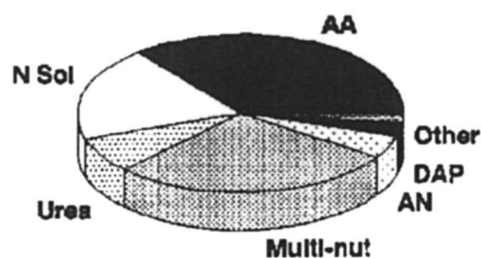


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# NITROGEN USE

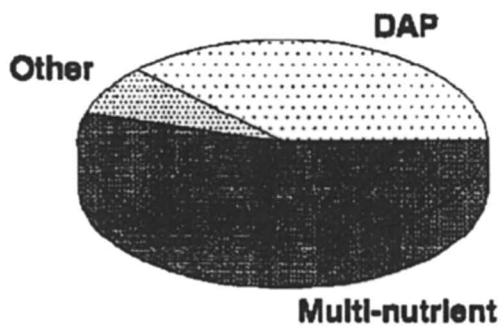


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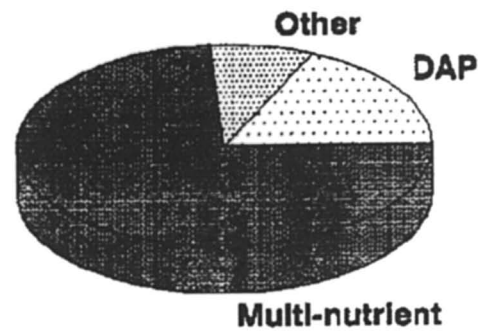


**ACTUAL**

# PHOSPHATE USE

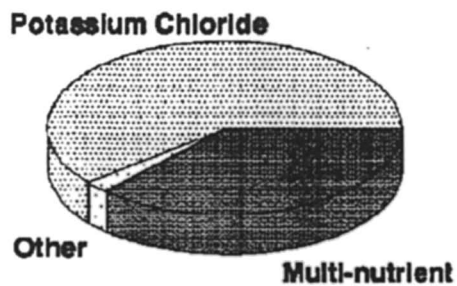


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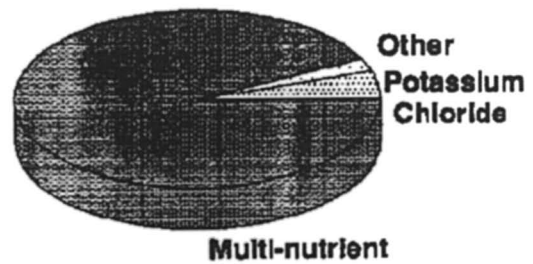


**ACTUAL**

# POTASH USE



**REPORTED**

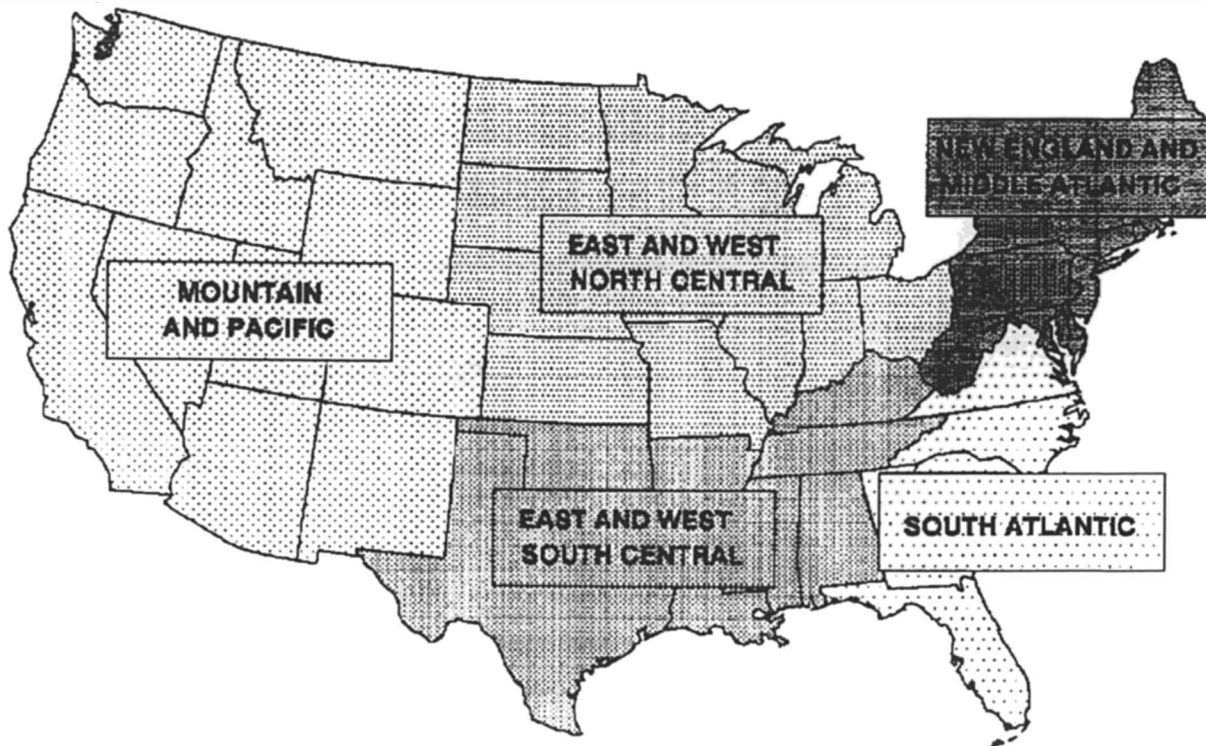


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# U.S. FERTILIZER MARKET

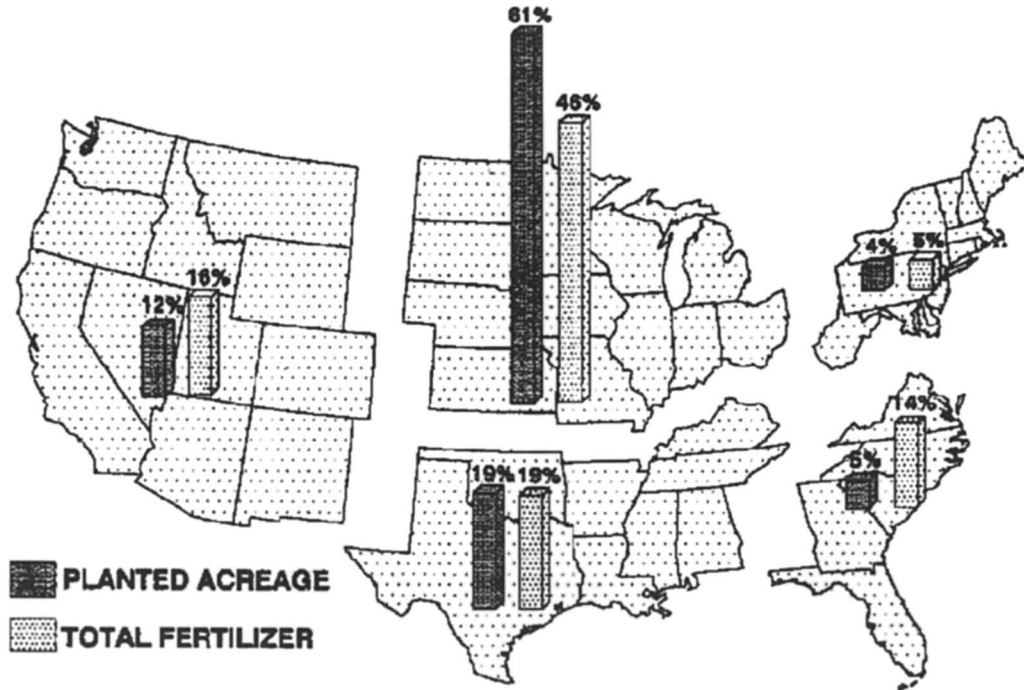
- **\$8.0 BILLION**
- **2.2 MILLION FARMERS**
- **47 MILLION TONS**

## REGIONAL CONSUMPTION PATTERNS

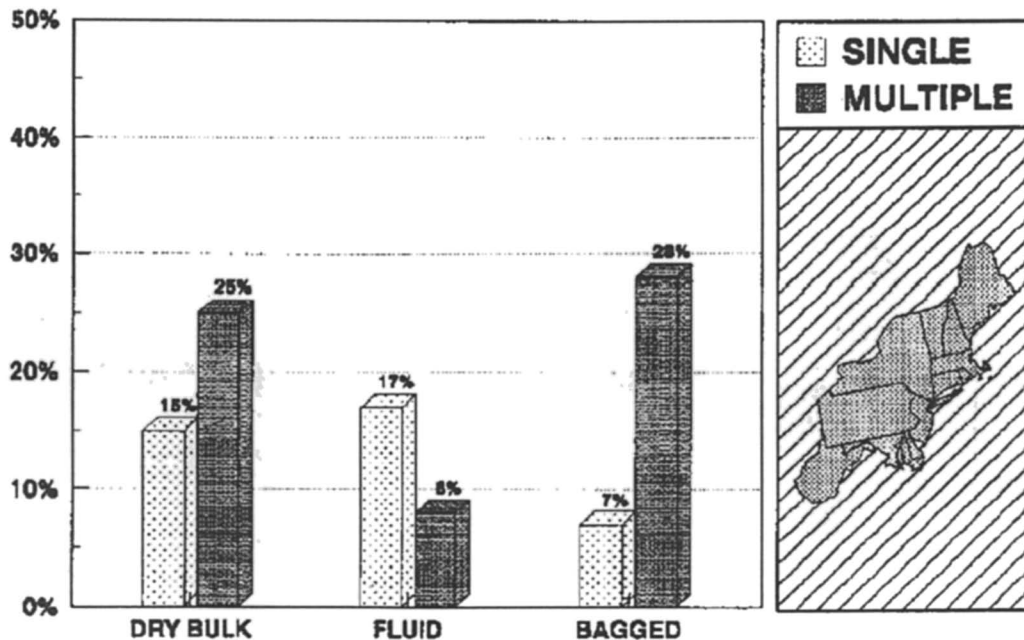




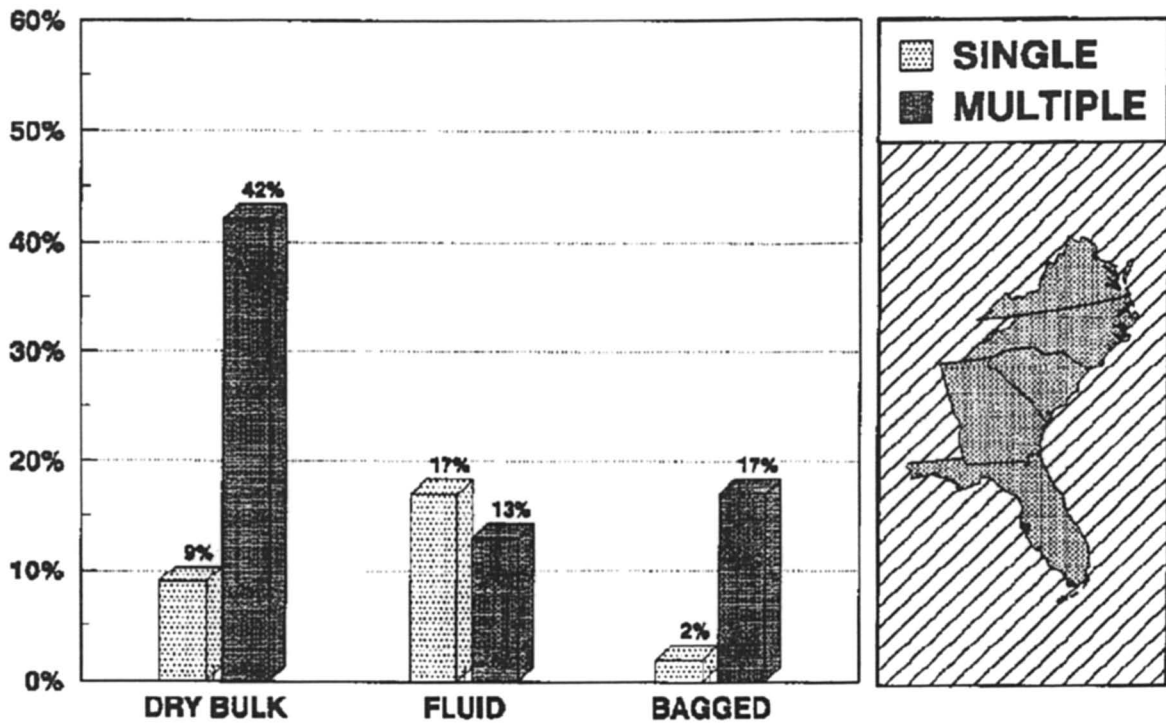
## REGIONAL DISTRIBUTION OF CROP ACREAGE AND FERTILIZER CONSUMPTION (1989)



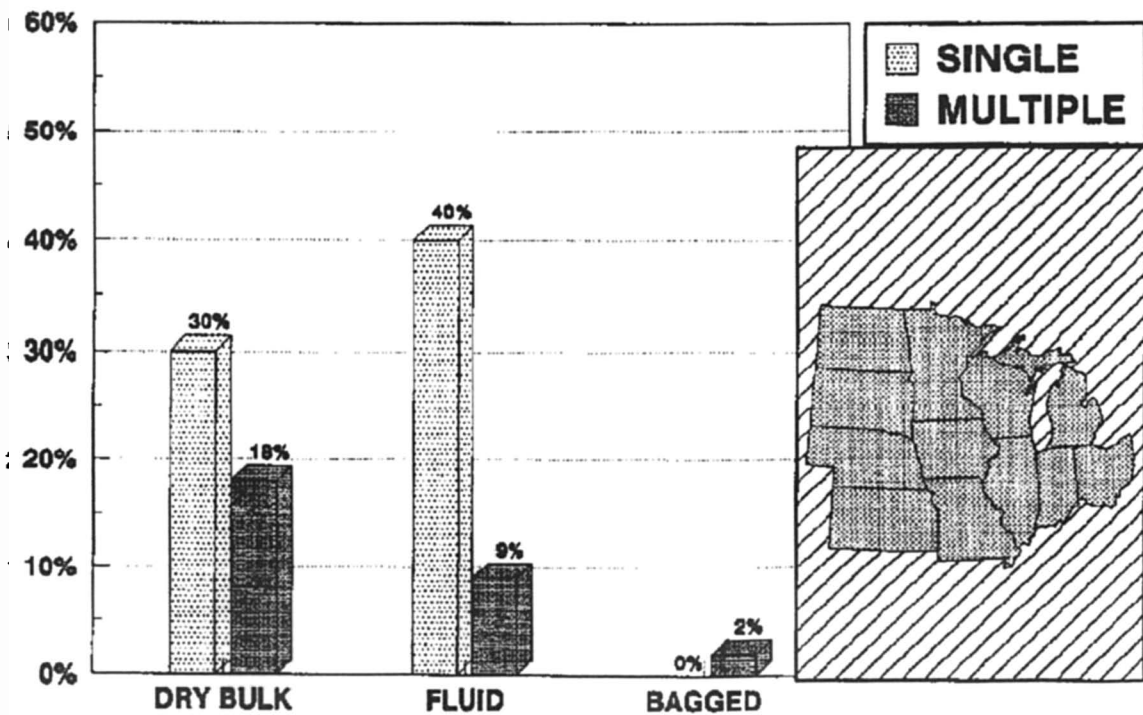
## NEW ENGLAND AND MIDDLE ATLANTIC



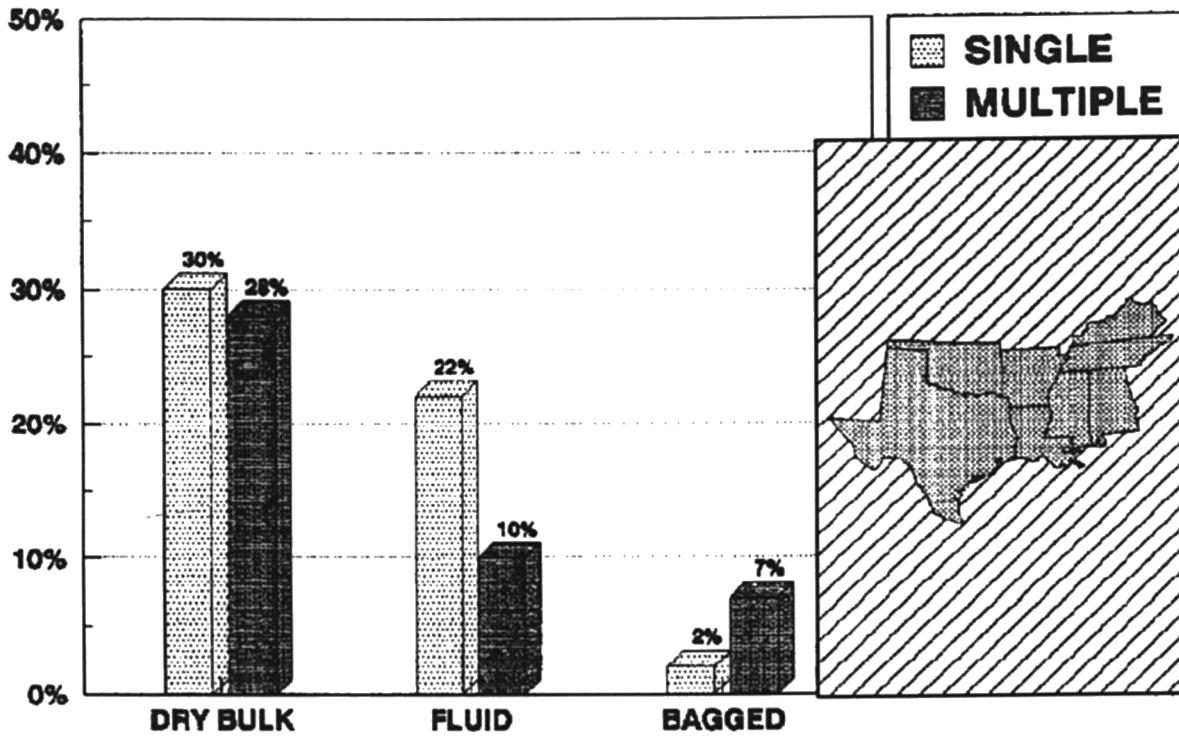
## SOUTH ATLANTIC



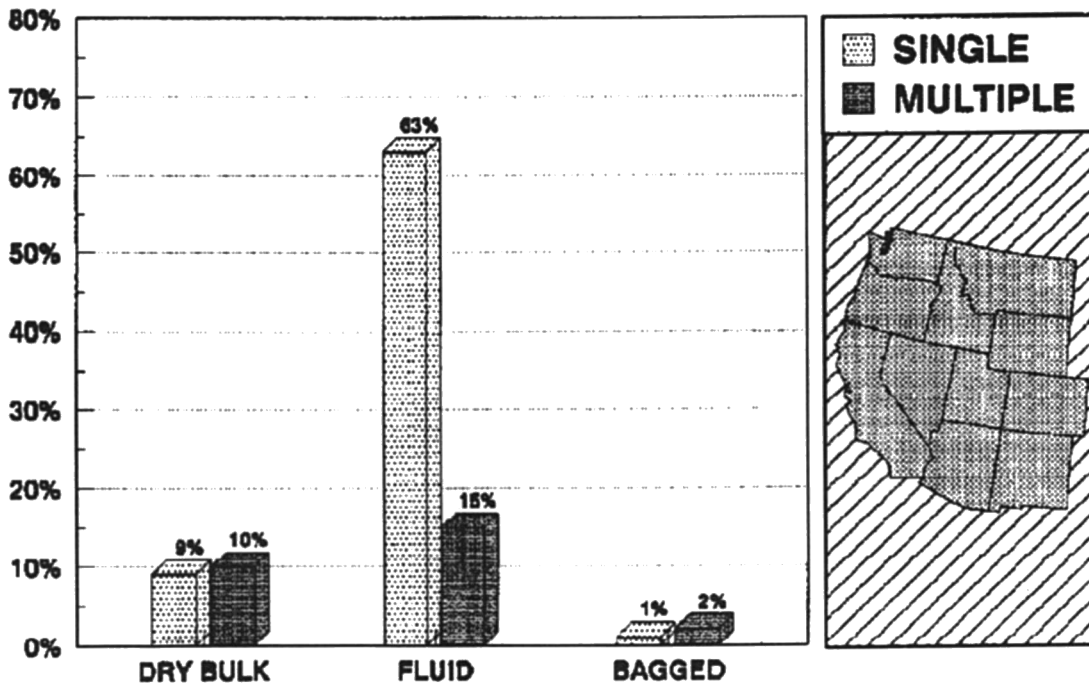
## EAST AND WEST NORTH CENTRAL



## EAST AND WEST SOUTH CENTRAL



## MOUNTAIN AND PACIFIC



# Natural Nitrates Their Production & Uses

James C. Wilson  
Chilean Nitrate Corporation

## INTRODUCTION

The Sociedad Quimica y Minera de Chile S.A., (Soquimich) is a company devoted to the recovery of salts contained in the ores formed in the Chilean Nitrate Desert and to the sale of the products obtained in the domestic and overseas markets. After being subject to a series of mining operations and chemical recovery, the nitrate ore or caliche yields several products, such as natural sodium nitrate, potassium sodium nitrate, iodine and sodium sulphate, all used in agriculture and industry. Through additional chemical processing, potassium nitrate fertilizer is also produced.

## HISTORY OF SODIUM NITRATE

Sodium nitrate is probably the oldest known inorganic fertilizer. Prior to 1800 the extraction of saltpeter from caliche was performed by leaching ore in animal skins with cold water. The resultant solution was run into copper pots and concentrated by boiling until the nitrate crystallized out.

By the end of the 18th century, commercial exploitation of sodium nitrate was beginning in Northern Chile. The product was used mainly for the production of explosives and gunpowder. When the Europeans began to conquer the Americas and dominate it, South American sodium nitrate was as valuable as gold. It was used for blasting powder for work in the mines and gunpowder for weapons. The Indians from the Atacama desert were the first to discover and use the fertilizing qualities of sodium nitrate. Undoubtedly, this new peaceful property of this product was the great "explosion" of sodium nitrate use throughout the world.

In 1831 the first shipment of sodium nitrate landed in the United States at Norfolk, Virginia. It was a small parcel of 830 tons used for explosives. Subsequent deliveries were slow and sporadic because the use of Chilean Nitrate had not been clearly established for agricultural purposes.

By 1869 Chile was producing 100,000 tons of nitrate to meet the increasing world demand. Some 8-10,000 tons of the material was used annually in North America. Thereafter, the industry grew steadily for more than 30 years culminating at the end of WWI with 3.3 million tons of Nitrate exported from Chile in 1918. Chilean production statistics show worldwide (not only in U.S. market) that 67.3% of total world nitrogen production between 1900 and 1905 came from Chilean Nitrate. During this period the United States annual consumption was some 82,000 tons N as  $\text{NaNO}_3$  and represented almost 70% of total U.S. nitrogen usage.

With the introduction of synthetic ammonia by the Haber-Bosch process the demand for natural nitrates in the U.S. began to decline. The world depression of the early 1930's also burdened the Chilean exports, but recovered much of its earlier position in the years leading up to the second world war. During the war years the U.S. government bought large quantities of Chilean Nitrate as strategic reserves not only for explosives but for food production for the Allied powers. After World War II the industry was in deep decline due to competitive synthetic products and was nearly abandoned. This decline proved to be the lengthiest period of all.

Twenty-two years ago a new beginning was made by creating a new corporation, Sociedad Quimica y Minera de Chile, S.A. or SQM. In 1971 the company was 100% state owned. This company did not have a positive performance and up until 1980 was losing closed to 20 million dollars annually. Privatization of the company was started in 1983 by transferring shares to the private sector. In 1986, 51% was sold to private investors and by 1988, 100% of the stock was privately owned. SQM currently has a total of over 5000 employees with commercial subsidiaries in selected locations throughout the world. Each subsidiary has its own staff, which includes agronomists, sales and marketing personnel. The actual situation in each market is different, requiring unique knowledge and approaches. The agronomists and sales force are responsible for maintaining the products competitiveness within their local markets. Using this marketing strategy sales have increased systematically in the last years from 143 million tons in 1984 to 244 million in 1989. These dollars represent 18.3 million tons of minerals processed producing 920,000 tons of final products.

## NITRATE DEPOSITS

### Location

The nitrate deposits are located on a plateau lying between the coastal ranges and the Andes, principally in the Atacama Desert, the driest in the world. Most of the commercial deposits are located at altitudes of less than 2000 meters although some are higher. The richest nitrate ore in Northern Chile occurs in the provinces of Tarapaca and Antofagasta along the eastern side of the coastal range. The deposits form a discontinuous belt ranging in width from a few kilometers to 30 km and extend between latitudes 19°S to 26°S for a distance of some 700 km. Although large accumulations of naturally occurring nitrate minerals have been reported in Egypt, China, India, Argentina, Peru and in Death Valley California, the only commercial source remains in Chile. Today, about 100,000 tpa of nitrogen equivalent (N) are derived from natural Chilean Nitrate, representing a small fraction of world N production. However, there is a steady demand for the natural product and nitrate production is a significant part of the Chilean economy.

## STRUCTURAL FEATURES

The deposits are in all types of rocks and unconsolidated sediments in the Coastal Range and Central Valley without showing any systematic variation in content of the saline components or of trace elements in those components.

Two major types of nitrate ore (caliche) can be recognized, alluvial caliche where the saline minerals occur chiefly as a cement in regolith and bedrock caliche in which the minerals form impregnations, veins, and irregular masses in porous or fractured bedrock. The typical alluvial type nitrate deposit is considered to be made up of several layers i.e. chuca, costra, caliche, conjelo, and coba, each having characteristic chemical and physical features. Alluvial type caliche is generally 1-3m thick but material as thin as 50cm and as thick as 5m has been mined locally. The chemical composition of the caliche ore is varied.

## ORIGIN

The origin of the nitrate deposits is controversial and several theories of formations have been proposed since the 1960's; (1) decay of seaweed and other marine vegetation in waters and marshes of inland areas of the sea, or of vegetation in saline lakes of continental origin; (2) nitrification and leaching of seabird guano at the margins of saline lakes, inland arms of the sea, or salars, or accumulation of windblown ammoniacal matter and gas from guano deposits that were presumed to have existed along the coast; (3) bacterial decay of plant and animal remains, during Tertiary and Quaternary time, when a less arid climate supported abundant vegetation; (4) nitrification and fixation of atmospheric nitrogen by bacteria in soil; (5) reaction of atmospheric nitric acid with feldspathic igneous rocks of the nitrate fields; or by reaction of atmospheric nitrogen with ozone; (6) accumulation of nitrogen compounds of volcanic origin (ammonia, nitrogen oxides, or nitric acid) in gases associated with intense volcanism in the Andes, and nitrate salts leached either from volcanic rocks of Jurassic age or from rhyolitic ash-flow tuffs of late Tertiary and Quaternary age; (7) nitrate from diverse sources accumulated in the subsurface saline waters and brines of salars or in the soils of the nitrate fields.

According to these theories, the saline constituents of the deposits were supplied by: (1) evaporation of saline waters at the margins of inland areas of the sea or saline lakes, or within such bodies of water or marshes that subsequently evaporated to dryness; (2) capillary migration of subsurface saline water and brine from salars into soils and fractured rock of nearby hillsides, where the saline materials were deposited by capillary evaporation; (3) accumulation in the nitrate fields by fallout or washout from the atmosphere, and by reactions or atmospheric constituents with these soils; (4) accumulation of saline-rich mudflows.

It has been suggested that an atmospheric course of the saline components was the only way the geographic and topographic distribution of the deposits could be adequately explained. These arguments are as valid today as they were a century ago. The evidence for an atmospheric source was chiefly the presence of nitrate deposits on hills; the existence of these deposits presented insurmountable difficulties to any mode of accumulation of the saline material other than deposition from the atmosphere. The most important factor in the accumulation of nitrate deposits in the Atacama Desert has been the extreme aridity of the region which has existed for some 19 million years. Nitrate deposits may have formed in other deserts but have been destroyed during intervals of increased rainfall.

## PRODUCTION

### Mining and Processing

In the Guggenheim Process used at Maria Elena and Pedro de Valdivia plants, the overburden covering the nitrate deposits is first loosened by drilling and blasting and the barren material then removed or stripped by mechanical draglines to expose the actual ore body. After further drilling and blasting, the broken ore is loaded by shovel, dragline, or both into cars of 30 to 35 tons capacity which are hauled to plant by electric or diesel powered locomotives.

At the plant the ore cars pass through a rotary-car dumper, and the ore is dumped into the primary crushing units which are of the jaw or gyratory type. Crushing is carried out in three stages with smaller gyrators serving as secondary and cone crushers as the tertiary units. The ore is screened following each crushing stage, and the clean crushed product constituting about 80 percent of the input tonnage ranges between 3/8 and 3/4 in. in size.

Since the coarse ore fraction is to be treated in leaching vats and the nitrate extricated by downward percolation of the leach liquors, the removal of the fine undersize by screening is essential to permit the free flow of solutions and to give reasonably fast percolation rates. The fine ore removed in screening operations is processed by filtration.

The leaching vats are about 160 ft. in length, 110 ft. in width and 20 ft. in height. These vats each have an ore capacity of about 10,000 metric tons of crushed caliche. The vat bottoms are provided with a filter bed of crushed stone and coco matting to insure the discharge of a clear solution.

The vat leaching cycle consists in the downward percolation of solutions successively advanced through a series of four vats. Mother liquor applied to the surface of the first vat percolates downward by gravity through the ore charge and the vat underflow is pumped on top of the second vat in the series. The leach solutions are thus advanced through the four vats in series successively increasing in concentration as they advance from vat to vat. The dissolving action of nitrate causes a



cooling effect and the leach solutions are passed through heat interchangers between stages to maintain a fairly constant leaching temperature.

The average leaching temperature in the Guggenheim Process is about 40°C and the nitrate pick up from another liquor to final strong solution stage is from an initial 350 to a final 450 gr/l nitrate concentration. The cycle time is about 10 hours, a newly charged vat entering the cycle every 10 hours and a leached vat dropping out.

After a vat has been in the four-stage leaching cycle for a total of about 40 hours, it is removed from the series and allowed to drain. The vat tailings are next washed with a series of graduated washed and finally with water. The residue is then underloaded from the vat with clam-shell grab buckets, suspended from a moveable gantry crane structure which serves all ten vats, and is dumped into trucks to be moved to the tailing disposal area.

### *CRYSTALLIZATION*

In the crystallizing plant, there are shell and tube type crystallizing tanks arranged in series. The strong nitrate solution to be cooled is circulated rapidly through the tubes, the cooling medium circulating through the shells. This results in a gradual cooling from 40°C inlet temperature to about 10°C. The first 14 tanks of the 20 tanks series serve as heat recuperators where the cooling medium is the 10°C countercurrent returning mother liquor. The last six tanks are refrigerators, and the cooling medium is liquid ammonia.

While the mother liquor is heated in its flow through the crystallizing plant and emerges at about 35°C, leaching temperatures in the vat cycle must be maintained at about 40°C. The heat required to achieve this rise in temperature as well as to overcome radiation heat losses from large open vats is obtained in the form of "waste heat" from the diesel power plants and ammonia compressors.

The sludge of nitrate crystals produced in the crystallizing plant is dewatered and given a short water displacement wash in a battery of 48 in. diameter by 24 in. basket-type centrifuges. The centrifuge product is pure white, about 48 mesh in crystal size, of 95 to 96 percent nitrate purity, 16 percent of nitrogen equivalent (16-0-0), and between 3.0 and 3.5 percent moisture.

### *NITRATE GRANULATION*

After centrifuging operations, the nitrate is carried by conveyor belt to the granulation plant where it is charged into large oil-fired reverberatory type furnaces. At a temperature of about 350°C, the nitrate changes from solid to liquid form. Molten nitrate withdrawn from the furnace flows by gravity through inclined canals into holding pots from which it is pumped by vertical submerged pumps to the top of a large spray chamber about 100 ft. in height. The molten nitrate is pumped through spray nozzles 5/8 in. in diameter and the

droplets produced solidify in their fall into small solid pellets.

The product from the spray chamber is carried by conveyor belt to a screening plant where the oversize and any undersize product is returned to the furnaces for remelting. The screened product passes next by gravity through ten shell and tube type coolers about 6 ft. in diameter by 10 ft. high. Mother liquid is circulated on the outside of the tubes through the shell jacket thus recuperating additional heat for the main leaching circuit. The grained product consists of pellets ranging from about 20 to 8 mesh and has a purity in excess of 97.14 percent sodium nitrate. Moisture content is about 0.20 percent with valuable traces of magnesium, potassium, boron, and other elements which have proven beneficial to plant life. Grained Chilean Nitrate is guaranteed to contain 16 percent nitrogen (16-0-0).

After the normal nitrate leaching operation, at the Maria Elena plant, the vat residues are being given a secondary leach with raw water which serves not only to dissolve additional sodium nitrate but also to extract potassium nitrate and the sulfates, chlorides, borates, and iodates which are insoluble in the main plant leach solutions. The weak brine containing these added chemical values is now collected and pumped to ten evaporating ponds arranged in series having a total area of approximately 100 acres at the Coya Sur plant. Under the hot desert sun these values concentrate to form a strong solution. Refrigeration of this strong pond solution produces potash nitrate of variable  $K_2O$  grade as well as substantial quantities of additional sodium nitrate not recovered from in the main plant extraction operations. From this same solution, boric acid and additional quantities of iodine are likewise being recovered. The potash nitrate is present in two final fertilizer formulations, potassium sodium nitrate with 14 per cent (15-0-14) and potassium nitrate with 44 per cent  $K_2O$  (13-0-44). The guarantee  $K_2O$  concentration in the final products is controlled by the addition of  $KCl$  to the concentrate solution before crystallization.

### *STORAGE AND SHIPMENT*

The finished products are removed from the processing plants on the nitrate pampa in rail cars of approximately 22 tons capacity down to the port of Tocopilla where large storage facilities are provided. At the port it is dumped from the cars by means of a revolving railroad-car dumper from which the nitrate moves on belt conveyors to the top of six storage silos, each having a storage capacity of 10,000 metric tons. The nitrate is distributed into the silos by means of a moveable belt tripper.

Discharge from the silos is accomplished by a series of belt feeders operating underneath the bin discharge gates. These feeders discharge their load onto the main out-loading conveyor leading to a uniquely designed ship loader bridge. The bridge is mounted on a pivot pier and extends as a cantilever 225 ft. from the

center of the pier and serves to transport the nitrate to the several hatches of a ship moored in deep water offshore. Within the main bridge structure there is a shuttle conveyor which extends the discharge point of the loading tower and permits the bridge to reach and discharge through a vertical telescopic chute to all hatches of the cargo vessel without the necessity for moving the ship from its moored position. An operator's cab mounted on the outboard end of the shuttle truss contains the controls for all conveyor movements from the silo-discharge feeders to the final shuttle conveyor on the loading bridge. The capacity of this modern shiploading installation is such that a vessel carrying 10,000 m/t of nitrate can be loaded in less than 10 hours.

### *CNC AG PRODUCTS*

#### The role of Nitrate Nitrogen

Generally it may be said that lack of nitrogen is the first limiting factor in the growth of crops. The effect of nitrogen applications is more striking than of other plant food elements, especially of the nitrate form of nitrogen, because of the ease with which plants are able to assimilate it. Although nitrogen makes up about four-fifths of the volume of ordinary air, nonlegume plants cannot use it and in intense production systems, nitrogen fertilization is essential.

The free movement of nitrate nitrogen in the soil moisture make it particularly desirable for use whenever immediate action is required. It promotes rapid early growth and aids in the production of increased yields. Nitrate nitrogen applied to the surface of a dry soil will dissolve in the moisture it attracts from the air. Ammonia, on the other hand is fixed at the point of contact with the soil and stays there until the soil is moistened and soil microbes have time to change it to nitrate. Because of its unique ability to meet the requirements of these and other adverse conditions, nitrate nitrogen is favored over other sources especially where top dressing and sidedressing are widely practiced. Nitrate nitrogen is non-acid forming whereas ammonia nitrogen has an acid reaction usually requiring corrective applicators of lime to maintain soil productivity.

Soil reaction is one of the most important factors in soil productivity. It has a direct influence on the efficiency of fertilizers. In a large measure, it determines how much plant food will be maintained in the available form for use by the plant and how much of it will be lost through conversion into unavailable forms. Ammonium forms of nitrogen have an acidulating affect on the soil. Thus it would require 5.2 lbs. of limestone to neutralize the acidity produced by each pound of nitrogen applied to the soil in the form of ammonium sulfate. On the other hand, each pound of nitrogen applied in the form of sodium nitrate has an alkaline value equivalent to 1.8 lbs. of limestone. It is this alkaline effect that explains the tendency of Chilean Nitrate fertilizers to increase the availability of soil phosphate, particularly in acid soils.

The ability of sodium to substitute in part for potassium in plants is a matter of economic as well as agronomic importance. The sodium has value in itself, as a partial substitute for potassium. Natural sodium nitrate and soda/potash also possess a series of valuable side effects rising largely from the sodium and minor elements it contains.

### *CHLORINE-FREE K<sub>2</sub>O*

Soquimich produces two N-K product combinations to meet the need of crops requiring both nitrate nitrogen and Cl-free K<sub>2</sub>O. Freedom from chlorine is an important advantage in many high value crops such as tobacco, vegetables, fruit, and citrus where excess Cl can adversely affect plant growth yield and quality.

Potassium sodium nitrate (15-0-14) is a fertilizer similar to sodium nitrate where potassium has practically substituted the sodium content. Most properties of potassium sodium nitrate are similar to sodium nitrate with their main difference being the content of K<sub>2</sub>O. Soda-potash is used extensively on tobacco, vegetables, melons, and citrus. The requirements for nitrogen and potassium in these crops is similar and the near 1:1 ratio of N to K makes it ideal for straight application as well as a component of blended fertilizer grades.

Potassium nitrate was first produced by Soquimich in 1987 and introduced to the U.S. market in 1988. Potassium nitrate contains 13% nitrogen (N) in the nitrate form and 44% of Potassium (K<sub>2</sub>O). It has a very low content of elements such as Cl, SO<sub>4</sub> or others which could lead to salt accumulation near the roots. Therefore, it does not affect soil structure, or plant development. The salt index of KNO<sub>3</sub> is among the lowest in relation to other fertilizers, especially when the concentration of nutrient units is considered. Agronomically, it is an excellent source of fertilizer nitrogen and potassium.

KNO<sub>3</sub> finds its greatest use in fertilizers for intensively grown crops such as tomatoes, potatoes, tobacco, leafy vegetables, citrus, peaches and other crops. The properties of potassium nitrate that make it attractive for these crops include moderate salt index, nitrogen present as nitrate, favorable N/K<sub>2</sub>O ratio, negligible Cl content, alkaline soil reaction and high solubility. Its low hygroscopicity allows for considerable flexibility in its use for direct application and in bulk blends mixtures or ammoniation.

Because of its high solubility in water and its high nutrient concentration, potassium nitrate is a fertilizer very well adapted to be applied through the irrigation system. Its solubility is 31.6 g/100g H<sub>2</sub>O which is three times higher than the figure of 11.1 g/100g H<sub>2</sub>O corresponding to potassium sulphate. Potassium nitrate has also shown significant results as a foliar spray on citrus and other tree fruits to supply critical K<sub>2</sub>O on alkaline soils where K<sup>+</sup> uptake is inhibited by high pH.

Many areas of intense agricultural production are coming under massive environmental pressure. Urban-

ization of farm land, pressures of water supply and concerns about ground water contamination are pushing growers to rethink their fertility and irrigation practices. The advent of low volume irrigation systems has brought out the need for high quality, highly soluble fertilizer materials to be applied through irrigation water. This practice of fertigation will further expand the role of Chilean Nitrate fertilizers, particularly potassium nitrate and soda/potash.

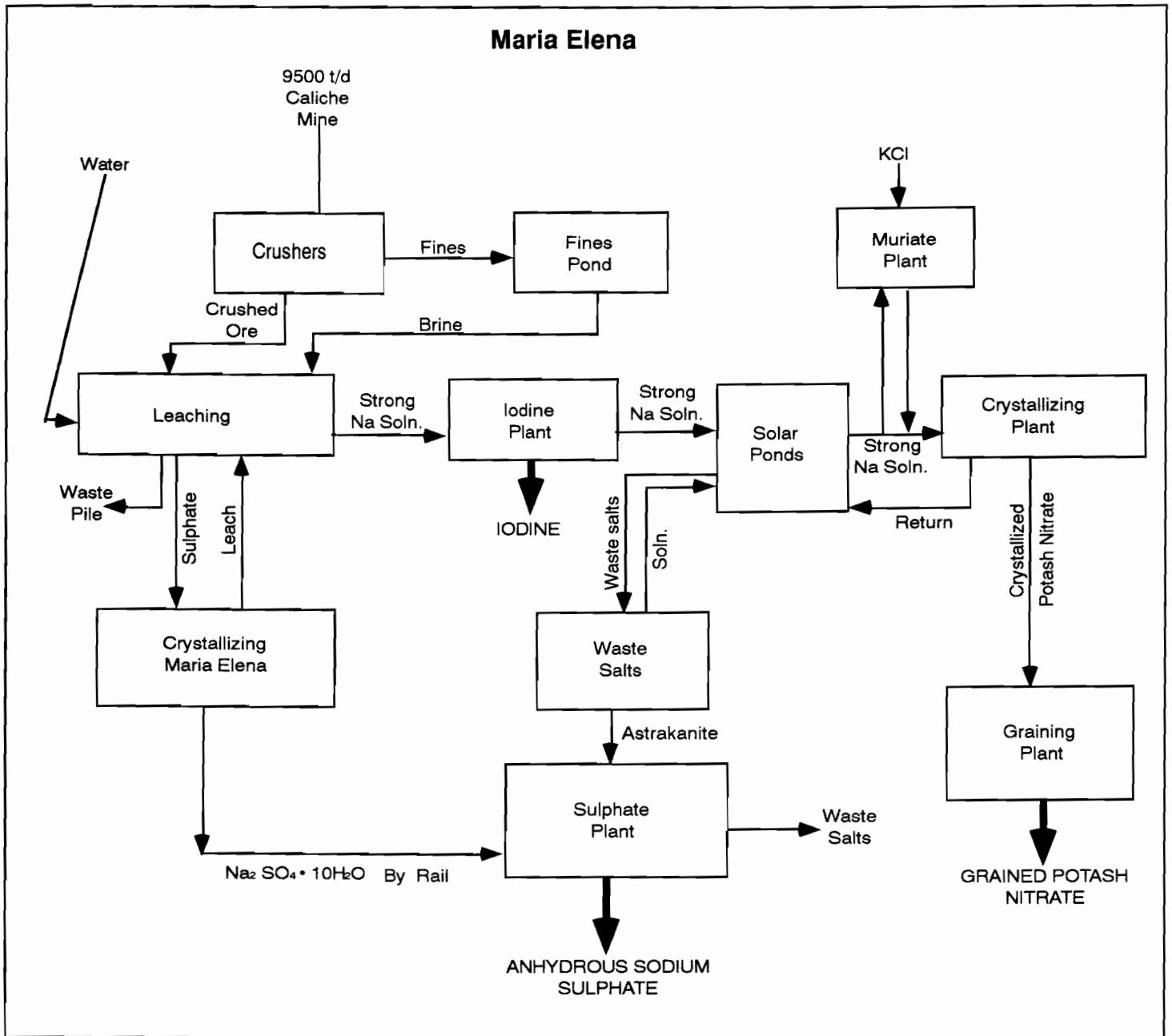
Farm economy, as any other enterprise, is driven by the need to make a profit. If any input of production cannot show an increase in bottom line profit it should be discarded and an alternate input employed. Chilean Nitrate products are not the "lowest cost" inputs, but in many situations they may be the "highest profit" inputs. The 100% nitrate nitrogen forms insures immediate availability and controlled plant response. Nitrogen utilization can be maximized by using source material that is an available form and can be controlled to coincide with times of maximum crop uptake. By timing application appropriately, nitrogen levels can be maintained at optimum levels with minimum loss to non-target areas such as ground or surface water. Nitrogen concentration is critical for maximum crop yields and quality during initial fruiting stages of selected crops. Chilean Nitrate products, appropriately times, fill this need as no other product can.

#### *CONCLUSION*

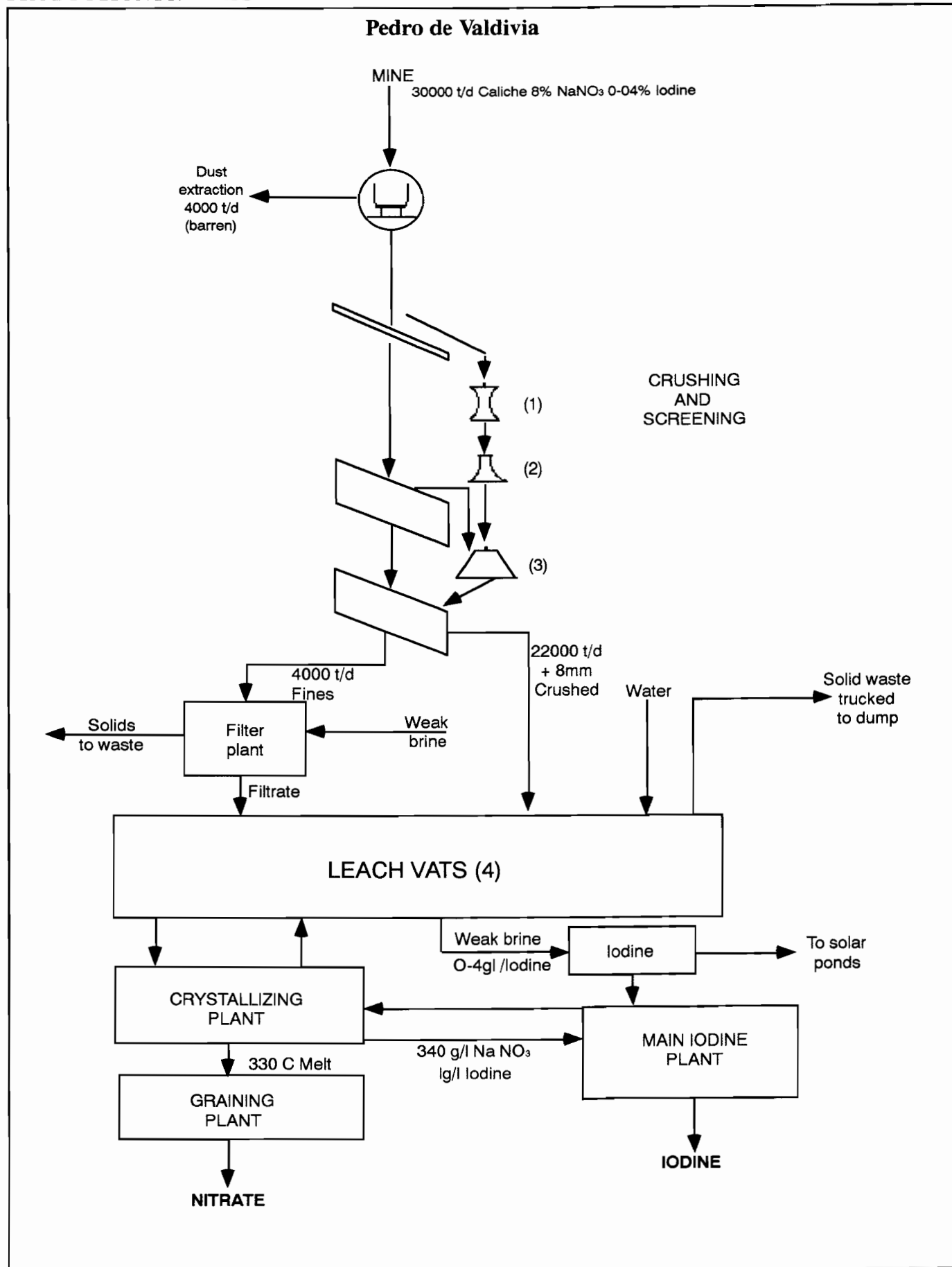
In conclusion, we see a company that has been in existence for over 150 years but has adapted to modern business and is ready to enter the 21st century as a competitive enterprise. The use of a natural mineral to produce materials used throughout the world for agricultural production as well as industrial application is testimony to the ingenuity and expertise of the Chilean operation. Unique resources and innovative use of those resources assures Chilean Nitrate of a productive future in the fertilizer market.



**PRODUCTION PROCESS**



**PRODUCTION PROCESS**



# Recognizing the Agronomic Benefits of Sulphur and Ways to Meet These Needs Through Fertilizers

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## INTRODUCTION

The term "essential nutrient" can have a different meaning to different people. For instance, an agronomist might say that an essential nutrient is one that the plant needs to grow. A farmer who is required to spend money for fertilizers might argue that an essential plant nutrient is one that he needs to add in order to increase production. Regardless of one's position, agronomists have identified sulphur as essential for plant growth. Farmers and others in agribusiness are now realizing the essential role that sulphur plays in a farming operation where a productive and profitable crop is desired.

This paper will examine the transformation of sulphur from a relatively unknown nutrient to one of international importance. What is an agronomist considering when he refers to the role of sulphur in crop development? Why are more and more farmers considering sulphur a key component to a profitable farming operation? This paper shows what the transformation has meant to their fertilizer industry in the past, and projects its future impact.

## SULPHUR - ESSENTIAL FOR PLANT GROWTH

Scientists have identified 16 nutrients which are essential for plant growth. No nutrient is more important than another, but each has a role in the development of the plant that makes it essential.

These 16 nutrients are needed in varying amounts for optimal growth. Sulphur ranks third or fourth in terms of amount needed for optimal plant growth, behind nitrogen, phosphorus, and sometimes potassium. Sulphur is necessary to form specific amino acids which are components of proteins. Further, the nutrient is involved in the formation of vitamins and enzymes which are required for the plant to conduct its biochemical processes. Without sulphur, grains, oils, fruits, or vegetables cannot be produced. The questions that have challenged researchers for many years and will be more frequently asked in this decade are: How much sulphur can the plant obtain from its environment, such as the soil or the atmosphere? and, How much must be added through the use of commercial fertilizers?

## CHANGE IN AGRICULTURE AND SULPHUR USE

Agricultural practices have changed considerably over the years and many of these changes have led to an increased frequency of sulphur deficiencies. Fertilizer preference has changed and contributed to the need for sulphur additions. When single superphosphate and

ammonium sulphate were more prominent in the phosphorus and nitrogen fertilizer markets, farmers were applying a significant amount of sulphur, in many cases without realizing it. Single superphosphate contains 12% sulphur and ammonium sulphate contains 24% sulphur. But now, urea represents a more significant proportion of nitrogen fertilizer use, in comparison to ammonium sulphate. Accordingly, worldwide agriculture has witnessed a drastic reduction in sulphur additions.

Changes in agricultural practices have brought about a dramatic increase in crop production, resulting in a greater demand for required plant nutrients including sulphur. For example, the U.S. had a national corn yield average of about 3400 kg/ha (60 bushels/acre) in 1960. Thirty years later, this number is nearly 7500 kg/ha (120 bushels/acre), or almost double the yield (USDA, 1989). With this increase in yield, the demand for sulphur has increased proportionately.

Other unrelated international events have affected the demand for sulphur fertilizer consumption and will become of greater importance. Increased environmental concern has prompted reductions in sulphur dioxide emissions. The government of Ontario, Canada's most industrialized province, has directed its four major sulphur dioxide emitting industries to reduce their sulphur dioxide output by one-third before 1994 (ACS, 1985). These four companies account for 80% of the sulphur dioxide emissions in the province. The Environmental Law Institute (1990) reports that Canada is not the only country making dramatic reductions in their sulphur dioxide emissions (Table 1). France, West Germany, the U.K., and Japan have all reduced their contribution of sulphur dioxide by greater than 30% from 1970 to 1985. Sweden has reduced its sulphur dioxide emissions substantially by 70% since 1970. This trend is expected to continue into the next century. For example, the U.S. government is currently considering clean air legislation which would reduce sulphur dioxide levels by one-half at the end of the decade.

Sulphur dioxide from the atmosphere is important to the sulphur cycle because it often finds its way to the soil through precipitation or dry deposition. A portion of this becomes available for plant growth. The reduction in this source of sulphur, combined with raised yield levels and decreased popularity of incidental applications of sulphur, have led to increased frequency of sulphur deficiencies. In some areas, visual responses to sulphur additions have recently been observed while in other areas, it has become necessary to increase existing rates of application for sulphur fertilizer to prevent serious yield reductions.

## INCREASING SULPHUR DEFICIENCIES WORLDWIDE

These mentioned changes have significantly increased the worldwide interest in sulphur as a plant nutrient in the last two decades. Less than 20 years ago,

only 36 countries reported sulphur deficiencies, while today more than 70 countries have found the need to apply sulphur (Morris 1988). Some countries are aware that deficiencies exist but are still in the process of quantifying the need. Other countries have seen such remarkable production increases from sulphur that they have pursued research with a high priority. This research has produced valuable information which is bringing about changes in fertilization practices and increasing the demand for sulphur fertilizers. In certain parts of the U.S. and Canada, applications of sulphur are now as common as nitrogen applications. Research conducted in the last decade in North America indicated that a US\$1 investment by a farmer for sulphur fertilizer commonly resulted in a US \$9 or US \$10 return.

Regions in Asia and Latin America have also illustrated the agronomic value of plant nutrient sulphur. In 1970, only four Asian countries had reported sulphur deficiencies. Currently, 12 Asian countries and two countries in the Pacific have identified sulphur deficiencies. Especially noteworthy is the vast amount of research that has been conducted in this 20 year span.

In Latin America, 12 countries have now reported sulphur deficiencies and 55% of the cultivated land is estimated to be deficient (Malavolta, 1984). Sulphur responses in this region have been impressive. Malavolta (1987) documented responses in Latin America ranging from 10 to 67% in research with various crops including cereals, grain, legumes, coffee, pastures, sugar and fiber crops, and fruit and vegetable crops. One cotton research study in Brazil reported nearly double the yield obtained by adding about 30 kg/ha (27 lbs/acre) of sulphur (McClung et. al., 1961).

The International Maize and Wheat Improvement Center (CIMMYT) is active in sulphur research in Latin America. Researchers involved with CIMMYT have established phosphorus and sulphur studies on corn at nine different locations in four different Central American countries: Guatemala, Costa Rica, Panama, and Honduras.

Preliminary results from the studies suggest that sulphur can substantially benefit farmers in this region.

In Europe, sulphur deficiencies have been found in 18 countries. Increased cropping intensity, greater production of oilseeds and small grains, and reduced atmospheric levels of sulphur have led to more frequent crop responses to sulphur. Responses have been reported in areas of the U.K., Italy, Spain, France, and Ireland. In Ireland, research conducted from 1974 to 1984 on grassland swards have shown significant responses to sulphur at 71 out of 139 locations in 15 counties (Murphy and Boggan, 1988). At some of the sites, the responses resulted in a doubling of herbage.

France and Germany may be the next European countries to report dramatic yield benefits from sulphur additions. In many regions of France, sulphur is now being applied routinely. Responses have recently been reported in Germany and France on wheat and rapeseed. Continued reductions in sulphur dioxide inputs are

expected to exacerbate the problem.

Results of research being conducted in Eastern Europe and the Soviet Union have not been reported in much detail until recently. Golov (1989) wrote a review regarding sulphur fertilization research in the Soviet Union for *Sulphur In Agriculture*. Many of the same factors which have led to increased deficiencies in other parts of the world also contribute to increased deficiencies in the Soviet Union. Responses have been documented in a variety of regions of the country including the Ukraine, Byelorussia, Pribaltic, Bashkiria, Moscow, Saratov, Vogograd, Amursk, Krasnoyarsk, and Ptimoyre. Considering the size of the U.S.S.R. and the preliminary work that has been conducted regarding sulphur, this country represents a significant market potential for sulphur fertilizers.

## WORLD PLANT NUTRIENT SULPHUR NEEDS

### *A Prediction Equation*

The requirement for additional sulphur fertilizer to maintain current agricultural production levels and predicted increases in crop yields is a function of several parameters. These include the balance between the addition and removal of sulphur from the soil system and the ability of the soil to supply sulphur, a condition which is dependent upon the type of soil and environmental conditions. Crop removal and leaching losses represent the major losses to the system while sulphur fertilizer, the soil, rain, irrigation water, decomposing crop residues, and manure represent additions to the system.

To predict world and regional requirements for plant nutrient sulphur, an empirical model can be employed based on crop production or crop removals and fertilizer inputs. Available data limit the precision of the prediction, but the model permits a relative indication of need, both qualitatively and quantitatively for sulphur fertilizers.

### *Sulphur Requirements*

The Sulphur Institute (Morris, 1988) estimated 1985 world sulphur requirement to be 16.5 Mt based on FAO production statistics, average crop sulphur contents, and sulphur fertilizer efficiency factors of 33% for the tropics and 50% for temperate climates. Total world production of food has increased 23% according to FAO data for the period 1976 through 1988 (FAO, 1982). However, since production between 1985 and 1988 has varied between 0.5% and 3.2%, little change would occur today from the predicted removal rate of 16.5 Mt for 1985.

### *Sulphur Additions*

To calculate the additional market for plant nutrient sulphur, or the deficit in application of sulphur fertilizer materials, the additions of currently applied commercial sulphur containing fertilizers must be considered in the equation. With known values and assumptions related to

the amount of sulphur contained in specific materials, a reasonable estimate can be made for this input for the world and by region using International Fertilizer Association (IFA) and TSI fertilizer statistics. However, these statistics include multiple nutrient materials such as ammonium sulphate or single superphosphate that may have been used primarily as nitrogen or phosphorus fertilizers. Since this situation exists for a variety of fertilizer materials, the determined deficit may be understated with certain areas within a region receiving a "luxury dose" of sulphur and other areas requiring sulphur, receiving none.

#### *Current and Future Requirements*

With the use of TSI and IFA's fertilizer consumption figures, and TSI's crop removal estimates, the market potential for plant nutrient sulphur can be estimated as of 1988 and predicted for the future. Using TSI's figure of 16.5 Mt of sulphur removed with crop production and applications of sulphur fertilizers totaling 10.8 Mt in 1988, this leaves a deficit of 5.7 Mt for plant nutrient sulphur worldwide.

Looking forward to the year 2000, regression analyses can be used with the production data from FAO over the last 20 years (FAO, 1982; FAO, 1989). Total world crop production will increase to 129% of its 1985 value. To achieve this increase level of production, an estimated 21.3 Mt of plant nutrient sulphur will be needed worldwide.

Using the trends derived from IFA's fertilizer consumption data from 1978 to 1987, 11.1 Mt of sulphur will be applied in the year 2000 if the trends in fertilizer mix continue (IFA, 1989). According to this prediction, the world deficit for plant nutrient sulphur is 10.2 Mt, an 80% increase from 1988. This will be less if deliberate application of plant nutrient sulphur increases during the period.

By taking a closer look at the IFA and TSI figures, one can determine what areas represent the greatest potential for the expanding market in 2000. Although Asia has shown a fairly consistent linear increase in consumption of sulphur containing fertilizers since 1973, the requirement is increasing at an even greater rate. With current trends, Asia will have a deficit of 6.9 Mt in the year 2000. Latin America will also experience a dramatic rate of increase in requirement. The model predicts that Latin America will require 2.2 Mt of sulphur in the year 2000, more than double the 1988 requirement of 0.9 Mt. With consumption predicted to be 1.5 Mt, this would result in an additional market of 0.7 Mt.

North America is also expected to show an increasing sulphur deficit from 1.3 Mt in 1988 to 1.7 Mt in 2000. During the same time period, Western Europe is expected to increase its sulphur fertilizer deficit from 0.6 Mt to 0.9 Mt. While their deficit is increasing, the increase is not as large as seen for the other regions. Changing fertilizer practices may accelerate the demand in Western Europe.

The data sources illustrate an interesting trend regarding Africa. Crop production is increasing rapidly, climbing 118% from 1983 to 1988 for the continent. At the same time, consumption of sulphur containing fertilizers has not increased. Given this trend, Africa represents a growing potential market for sulphur fertilizers and is estimated to have a deficit of 1.2 Mt at the end of the decade.

Eastern Europe and the U.S.S.R. have been static in both crop production and the level of sulphur fertilizer consumption for the period considered. However, yields in this region are not as high as Western Europe and North America. As the recent political changes become more apparent and technology is imported, production may increase significantly as would demand for sulphur fertilization. Evidence that sulphur deficiencies exist in the region add support to this claim.

#### *FERTILIZERS TO MEET THE GROWING DEMAND*

Nitrogen, phosphorus, and potassium fertilizers have shown little or no annual growth over the past decade, but deliberately applied sulphur has increased by 10% per year (Morris, 1990). This application of sulphur as a nutrient and not as an incidental nutrient contained in a fertilizer product, totaled 0.45 Mt in 1975 and expanded by 0.75 Mt to total 1.2 Mt in 1985. By 1988, it had nearly doubled to reach 2.2 Mt. If this growth continues at the same rate, deliberately applied sulphur fertilization will reach 9 Mt worldwide by 2000, considerably less than the anticipated requirement.

There are a variety of sulphur fertilizers available to suit various methods of application. Some of the more commonly mentioned sources include ammonium sulphate, single superphosphate, ammonium phosphates, potassium magnesium sulphate, and potassium sulphate. Sulphur is also contained in varying amounts in mixed grades and directly applied materials such as ammonium trisulphate and sulphur bentonite.

With the market expanding, companies are introducing new products to meet the requirements. Hi-Fert Pty. Ltd. in Australia has developed a sulphur-coated triple superphosphate, called Gold-Phos, which Hi-Fert promotes for pastures. In its second year of availability, this product has been well-received by farmers. Two grades of the product are available: Gold-Phos 10 (0-41-0-10S) and Gold-Phos 20 (0-36-0-20S). The manufacturer anticipates the combined production of the grades to increase from 10,000 t in the first year to 30,000 t this year.

Sulchem Products Ltd. of Canada has recently released two new products to the sulphur market. Sulchem SUPER SULF-8 (7-0-0-68S) is a granular product suitable for use in a suspension or as the sulphur component of a dry bulk blend. The product contains both sulphate sulphur and elemental sulphur and is designed to give the farmer both immediate and reserve availability of sulphur. Eight percent of the material's sulphur is in the immediately available sulphate form. The other portion,

due to its small particle size, is expected to oxidize and become available after the initially available sulphate portion is depleted.

The company's other new product will be marketed under the trade name SULCHEM 95 (0-0-0-95S). This product is a granular elemental source which can be used in suspension or dry blends. Since the product is rapidly dispersed into fine particle sizes regardless of its application method, it is expected to convert to sulphate rapidly and become plant available.

### *MARKETING SULPHUR FERTILIZERS*

Opportunities are still available for manufacturers to improve the marketing of sulphur products. Although deficiencies are known to exist, there is still a need in many areas to delineate where these deficiencies exist and under what conditions. For a given soil, a response and the degree of the response will depend on upon the crop grown and the other inputs made to the crop. Canola is expected to need more sulphur than a wheat crop of average production. However, if a wheat producer is in an intensively managed program, his crop may require as much sulphur as the canola crop. A competent and credible researcher, whether employed by a government institution or a fertilizer retailer, can determine these evaluations through additional research. With the availability of reliable recommendations, farmer acceptance for sulphur will rise.

While it is important that the research be conducted, it is also important that the findings be disseminated. Many individuals are not aware of the entire benefit of the products which they use or that are available to them. This is especially true with sulphur materials. In some areas, many people still think of ammonium sulphate and single superphosphate as single nutrient fertilizers, when, in fact, they are multiple nutrient fertilizers.

The Sulphur Institute devotes much of its resources to the educational process; now, several producers have accepted the challenge of educating their product distributors and farmers. One North American producer of ammonium sulphate has supported research, predominantly with agricultural universities in North and Latin America, demonstrating the benefits of both the nitrogen and the sulphur contained in their product. The producer also has developed a variety of programs to disseminate the findings from the research. Some of the programs include newsletters, preparing articles for the trade press, advertising, and producing slide sets and videotapes for their customers to use. These efforts can be promoted to either the manufacturers' potential customer or the end user, the farmer, and are directed to major markets in several regions of the world.

Other producers have also started to educate their customers about the full benefit of their products. Single superphosphate producers in Oceania have contributed by marketing this product for both its phosphorus and sulphur content. Companies marketing potassium magnesium sulphate have also addressed the value of the

sulphur in their marketing campaigns. European producers of potassium sulphate have likewise produced marketing materials illustrating the benefits of the sulphur in their product.

Worldwide recognition of the value of sulphur in crop production will be a benefit to everyone involved. The industry will benefit by selling more product and the farmer will benefit with more efficient utilization from his other agricultural inputs, a higher yield, and a more profitable farming operation.

### *SUMMARY*

The market for sulphur, the essential plant nutrient, is growing rapidly. An increasing number of farmers are recognizing the need for sulphur as essential to their fertilization programs to ensure efficiency of other system inputs, to obtain maximum economic yield and optimal quality of their crops, and to improve the profitability of their farming operation.

The recognized need for sulphur has become more apparent worldwide in the last two decades. The causes for the increased level of deficiencies include: reductions in the overall use of fertilizer materials which contain sulphur but were traditionally used as other nutrient sources; an increased level of crop production; and, a dramatic reduction in sulphur dioxide emissions. These factors have not only caused deficiencies to be reported in new areas but have also made it necessary for some sulphur recommendations to be revised upward to maintain or increase levels of production.

The amount of sulphur research has increased dramatically with the increased frequency of deficiencies. Certain countries have been especially expeditious in conducting the research. While there is still much to be learned about the role of sulphur in increasing the profitability of agricultural systems, countries such as India with sulphur recommendations for 30 crop, have a considerably advanced data base.

Looking to the future, sulphur consumption is expected to rise. Worldwide demand is expected to exceed 20 Mt by the year 2000. Only about half of the requirement is expected to be met, representing a favorable situation for sulphur fertilizers. Asia, Latin America, and North America will represent significant market opportunities for manufacturers of sulphur fertilizers. Africa is expected to increase its food production significantly in the next decade and will increase its need for sulphur fertilizers several fold. However, in terms of total market potential, it will continue to trail Asia, Latin America, and North America. Western Europe will need additional sulphur fertilizers but the additional quantity required in 2000 is only estimated at 0.9 Mt.

Several manufacturers have taken great strides to educate their customers and others concerning the benefit of sulphur in modern crop production. Farmers need to understand the entire benefit of the material which they apply. Some of the fertilizers which have traditionally been known as single nutrient fertilizers can actu-

ally be a benefit by supplying more than one needed nutrient.

Fertilizer companies are introducing new products to meet specific needs of the sulphur fertilizer market. These materials include elemental sources that oxidize rapidly to be available in one growing season, and a versatile product which can be used in suspensions or dry blends and offers immediate and reserve availability of sulphur. The need for sulphur fertilizers is expected to provide significant benefits to manufacturers and farmers through the next decade and beyond.

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**Table 1. Sulphur Dioxide Emissions and Trends**

Country	Total SO <sub>2</sub> Emissions 1985 (Mt)	% Change SO <sub>2</sub> Emissions 1980-1985	% Change SO <sub>2</sub> Emissions 1970-85
USA	20.7	-11	-27
France	1.8	-48	-38
West Germany	2.4	-25	-34
U.K.	3.6	-23	-42 (1975-85)
Japan	1.1 (1983)	-12	-36 (1970-83)
Canada	3.6 (1983)	-22	-46 (1970-83)
Sweden	0.3	-44	-70

Source: Environmental Law Institute. Washington, D.C. 1990.



## Hazard Management

*Dan Paradiso, Jr.*

*and*

*Stacy Schmidt*

**The Andersons**

*Presented by Dan Paradiso, Jr.*

We'd like to describe for you The Anderson Ag and Lawn Products Group approach to hazard management. We will share the "tools" we use to effectively manage safety and health concerns at our facilities. Perhaps they'll be useful to you and others as well.

### **"AWARENESS"**

Hopefully, the discussion will heighten our collective awareness on these issues and will serve to improve safety compliance and hazard management within the industry.

Most important in any hazard management program is support from top management. Without it you're in for a difficult time. At the Andersons we're grateful to have a solid commitment from our CEO right on down. Now, let's talk about how our program works.

We will focus on five major points: risk surveys, loss prevention planning, employee safety incentives, recordkeeping and hazard communication/medical surveillance programs.

### **"RISK SURVEY"**

What is a risk survey? We think it is a primary hazard management tool that should be performed on an annual basis. The goal of a risk survey is to identify, evaluate and control hazards that may exist at all levels of the operation.

Our risk survey utilizes a two-tiered approach, focusing on physical hazards as well as the procedures and human elements that promote safety and health. Specifically, the physical audit checks for compliance with OSHA's safety regulations, such as machine guarding, work platforms, mobile equipment, emergency equipment, and in-house company standards. On the other hand, the procedural audit checks for compliance with people-oriented standards including safety committee activities, housekeeping documentation, confined space entry permits, hot work permits, etc. The surveys require an immediate response from site managers as well as quarterly updates as to the progress made on the recommended action items.

What are the benefits? First, they help to prioritize areas needing attention on an annual basis. Second, the survey helps management maintain physical assets. Third, they help continued compliance with appropriate regulations and standards. Fourth, the Risk Survey helps promote the safety and health of employees and other constituents. Fifth, such audits are considered a real plus by regulators and insurance companies.

### **"LOSS PREVENTION PLANNING"**

What is loss prevention planning? We feel it is another primary hazard management tool that is performed on an annual basis.

The goal of loss prevention planning is to focus on training and site-specific hazard management activities. Site managers have the responsibility to assign accountabilities for a variety of activities along with a target date for completion.

The activities include:

- 1) Administration/Organization
- 2) Loss Prevention Inspections
- 3) Security Systems
- 4) Quality Control
- 5) Hazard Communications
- 6) Employee Safety Committee
- 7) Employee Safety Incentives
- 8) Environmental Protection
- 9) Plant Emergency Organizations
- 10) Health Maintenance
- 11) Employee Loss Prevention Training

Each of our facilities is required to file a loss prevention plan at corporate headquarters in January and provide quarterly updates as to the progress made.

What are the benefits? First, the plans serve as a strategic focus to control and/or eliminate loss exposures at each company location by providing a detailed work schedule by month. Second, they ensure continued compliance with regulations and standards. Third, the plans help ensure employee involvement in the hazard management process. Fourth, they help give a positive perception of our operations that can result in more productive relationships with regulators and insurance companies. Fifth, loss prevention planning allows for across-the-board evaluation of the effectiveness of our program and assists us in setting priorities and identifying problem areas.

### **"INCENTIVES"**

Results of the annual risk surveys and loss prevention plans form the primary basis for determining the winner of our annual "Excellence in Safety" award presented to the facility which best represents concern for hazard management. On an individual level, the employee who works safely is also rewarded.

The general eligibility requirement for our individual awards is the absence of a recordable accident on a calendar year basis. The program is longevity based with award value increasing with length of accident-free service. Awards range from a golf shirt to a weekend trip for two to Toronto or Chicago. The program also consists of monthly safety incentive award drawings to promote continued awareness by the workforce. These awards generally consist of \$50 gift certificates to local



restaurants or our General Stores.

What are the benefits? The most important benefit is increased safety attitude and awareness. Incentives also provide an opportunity to reward employees for a job well done. And, incentives help to motivate all employees to work safely.

#### **“RECORDKEEPING”**

Unfortunately, sometimes accidents do happen and when they do, you must be prepared to handle the situation appropriately.

Complete accident investigation and reporting is critical for three reasons: 1) to resolve the particular incident, 2) to aid in preventing this type of accident from occurring again, and 3) for OSHA compliance purposes. A computerized database may be useful to assist in the recordkeeping task and makes reporting and research much easier.

Of course, compliance with government regulations is very important and solid accident reporting and recordkeeping helps ensure compliance with OSHA requirements. The OSHA 200 log, the company's official record of injuries and illnesses, must be conspicuously posted for the preceding calendar year between February 1 and March 1 of each year.

Participation in industry-wide accident reporting programs, such as TFI's Accident Facts, helps keep management informed of accident trends and lets them know how their operations compare to others in the industry.

Recordkeeping and trend analysis are important, but, supervisory personnel must understand their critical role in keeping their workforce safe. Accidents mean lost productivity. Therefore, we must be proactive in preventing accidents and getting injured workers back to work as soon as they are able.

#### **“HAZARD COMMUNICATION/MEDICAL SURVEILLANCE”**

Another important role of the supervisor is to provide their employees with the information they need to work safely and healthfully. A primary tool in this effort is the Material Safety Data Sheet of MSDS. Of course, all employees should be well trained in the use of MSDS's and they must be readily available for employee use.

As a supplement to the MSDS, we have prepared safety and health summary documents that we refer to as Material Safety Sheets. These sheets focus on personal protective equipment requirements and fire/spill control procedures.

Before we introduce any new raw material of toxicological concern into any of our facilities, we perform a New Chemical Evaluation. This process involves reviewing all pertinent references on the material, including a computerized scientific literature database search of all health-related information, govern-

ment-funded research, technical data supplied by the manufacturer, among others. The material cannot be accepted for use until the New Chemical Review committee members sign off on the formal review.

Other important activities performed to assure employee health and safety include: 1) a comprehensive health testing program, 2) routine blood cholinesterase testing and physical exams for “at risk” employees, and 3) regular consultation with occupational physicians and toxicologists who are familiar with the chemical hazards of our operations.

We've briefly outlined five hazard management programs in place at The Andersons. We firmly believe these programs are at least partly responsible for keeping our workforce healthy and happy. I welcome the opportunity to discuss the details of our Hazard Management Program with any of you.

### **Genetic Engineering of Endophytic Bacteria: A Novel Approach for Producing Pest-Resistant Corn**

*Peter S. Carlson, M.B. Dimock & S.F. Tomasino*

**Crop Genetics International**

*Presented by Peter S. Carlson*

Genetic engineering techniques currently permit several approaches to produce crop plants with enhanced resistance to pests. Many groups are directly introducing genes which encode for pest resistance into the plant's genome. Crop Genetics International is developing an endophyte based technology for systemic delivery of biopesticides to corn and other crops.

Defined broadly, an endophyte is a plant dependent microorganism that lives protected within the tissues of its host. Among endophytic bacteria, those associated with plant disease have been the past object of study. However, nonpathogenic bacterial endophytes present an opportunity for systemic delivery of genetically-engineered biopesticides and plant growth regulators. Crop Genetics has chosen a xylem-limited endophytic bacterium, *Clavibacter xyli* subsp. *cynodontis* (Cxc) which occurs naturally in bermudagrass and is distributed throughout the southern two-thirds of the U.S. as well as Europe and Asia. Cxc is a fastidious microorganism with precise nutritional and environmental requirements. Cxc survival is brief outside the host plant in plant debris, soil, air or water, and the endophyte is not seed transmitted. Cxc, when modified with recombinant DNA techniques, provides a systemic delivery system for biopesticides within plants.

The first product under development involves Cxc producing the delta-endotoxin of *Bacillus thuringiensis* toxic to European corn borer (*Ostrina Nubilalis*). Follow-on products will deliver other insecticides, fungicides, and plant growth enhancers.

Crop Genetics has developed an inoculation technology to introduce the bacterium into seeds. The protocol includes imbibition followed by pressure treatment in a buffered solution containing the bacterium. Seeds are removed from the solution, dried, and coated with conventional seed coatings. This inoculation technology does not alter seed vigor or germination and provides a satisfactory shelf life of the product.

### Introduction

The application of recombinant DNA technology to the field of crop protection against insect pests has followed two principal routes. Entomopathogens, particularly the bacterium *Bacillus thuringiensis* (Bt), have been the subject of many attempts (some of them successful) to overcome the problems of poor persistence, slow action, and narrow spectrum of activity that, paradoxically, are the principal environmental advantages of microbial insecticides as well as the major factors that have hindered their commercial success. The other principal approach has been to insert genes coding for insecticidal proteins (such as Bt delta-endotoxins and proteinase inhibitors from various plants) directly into the DNA of plant cells, so that the resulting transgenic plant produces these compounds for its own defense.

Another approach that has received attention takes advantage of our increasing awareness of the diversity of relationships between plants and microorganisms, particularly bacteria. For example, root-colonizing bacterial epiphytes such as *Pseudomonas fluorescens* have been engineered to produce Bt endotoxin. Among endophytic bacteria (those that live within the host plant, rather than upon it), there are some species which are pathogenic to plants and other species which are nonpathogenic. Genetic engineering of nonpathogenic endophytic bacteria presents an opportunity for the systemic delivery of biopesticides within host plant tissues without direct genetic manipulation of the host plant. Such a systemic microbial pesticide should exhibit sustained and protected biopesticidal activity.

### InCide Biopesticides

Crop Genetics International (CGI) is currently developing such an endophytic delivery system under the trade name InCide.

CGI's InCide technology utilizes genetically engineered endophytic microbes to produce biological plant protectants. One such microbe is *Clavibacter xyli* subsp. *cyndontis* (Cxc), a fastidious, gram positive, coryneform bacterium, that occurs naturally in the xylem of bermudagrass (*Cynodon dactylon*). The first product involves a genetically-engineered Cxc capable of producing the delta-endotoxin of *Bacillus thuringiensis* subsp. *kurstaki* (Cxc/Bt) that is toxic to European corn borer (*Ostrinia nubilalis*) larvae.

Species of bacteria that are presently classified as belonging to the genus *Clavibacter* were previously listed as species of the genus *Corynebacterium* (Davis et

al. 1984). Due to the lack of literature references for the subspecies *cyndontis* of *Clavibacter xyli*, CGI has generated extensive biological and environmental fate data to aid in product development and registration.

Extensive sampling of bermudagrass has shown that Cxc is distributed widely within the geographical range of its natural host. Currently, Cxc has been isolated from bermudagrass in 26 states in the U.S. including important corn producing states such as Nebraska, Iowa, Illinois, and Indiana.

Once introduced into seedling corn by wound or seed inoculation, Cxc rapidly colonizes the xylem of roots, stems, leaves, and husk. Cxc population levels up to  $1 \times 10^9$  bacteria per gram fresh weight tissue is achieved. Since it is xylem limited, Cxc is not present in or transmitted via seed. Host range studies have shown Cxc is capable of colonizing primarily grass species. Recombinant strains of Cxc have patterns of host colonization similar to patterns of the wild type.

Extensive laboratory, greenhouse, and field studies were conducted from 1987 through 1989 to determine the ability of Cxc and/or Cxc/Bt to persist in the environment and disperse beyond the point of introduction. Since Cxc is dependant on live plants for replication, and does not produce spores, persistence in soil, water, and on plant surfaces is brief. In the field, Cxc was undetectable after 2 weeks in soil, 3 weeks in soil-incorporated green residue of colonized corn plants, 5 weeks in buried sections of cornstalks, and 7 weeks in cornstalks standing in the field after harvest. Cxc could not be detected at any time in corn plants grown in inoculated soil, even when the roots were injured deliberately by passing knives through the soil to stimulate cultivation damage. Volunteer seedlings originating from colonized parents in the field also were not colonized. Likewise, Cxc was never detected in irrigation run-off from plots of colonized corn. These results indicate that soil, water, or plant debris are unlikely to serve as sources of inoculum for neighboring fields or subsequent crops or weeds in the same field. Dispersal of Cxc from inoculum foci was rarely observed. Mechanical transmission in the field was very limited.

Field studies conducted with a prototype recombinant Cxc (Cxc/Bt) in 1988 again demonstrated poor persistence in soil, incorporated plant material, and cornstalks remaining after harvest. Cxc/Bt populations were undetectable very soon after inoculation of soil in July and August, but persisted somewhat longer when the test was repeated under cooler conditions in October. Cxc/Bt was not detected at all in soil around inoculated plants, even after incorporation of the plant material into the soil. As in 1987, the endophyte was not detected in runoff water, even after colonized plant debris was chopped and incorporated, providing additional evidence that a colonized crop is not likely to provide a source of soil inoculum for subsequent crops.

Field trials in 1988 demonstrated that Cxc/Bt was not naturally dispersed from corn to other corn plants or weeds and that, under normal agricultural conditions,

Cxc/Bt was not spread mechanically from corn to other corn plants or weeds. In an attempt to induce artificial transmission, colonized corn plants were repeatedly cut with shears until the shears were wet with sap, and the shears were then used to trim uncolonized weeds; only in this case was any mechanical transmission observed and even then the frequency of transmission was quite low. Cxc/Bt did not colonize any of the trap plants (corn and bermudagrass) planted around the perimeter of the test sites to monitor for the dispersal of the organism. Field trials conducted in Maryland, Illinois, Minnesota and Nebraska (involving plants from seed inoculated with Cxc and Cxc/Bt).

### Genetic Engineering of Cxc

Recombinant DNA techniques have been used to modify wild-type Cxc to produce delta-endotoxin proteins of *Bacillus thuringiensis* subsp. *kurstaki* strain HD-73. Different Cxc/Bt recombinant strains contain the intact protoxin gene (coding for the 130 kilodalton protein that is broken down by proteolysis in the alkaline gut of the corn borer to form the activated toxin), gene fusions combining the toxic domain of HD-73 with various marker genes, and the toxic domain itself (coding just for the active endotoxin). Molecular geneticists at CGI construct plasmids that comprise the toxin coding region, regulatory sequences that control transcription of the genetic code to messenger RNA (promoters) and the translation of the message into amino acid sequences (ribosome binding sites), marker genes that confer selectable traits (such as resistance to antibiotics) for detection of transformants, and a DNA sequence (replicon) that is capable of initiating replication of the entire plasmid. The common enteric bacterium *Escherichia coli* is used as a host for transformation with these cloning vectors for the initial construction of these expression cassettes. Successful cassettes are then cloned into an integration vector which contains a segment of DNA homologous to a segment of the chromosomal DNA of Cxc, which (unlike *E. coli*), has no plasmids. When the integration vector is inserted into the Cxc cell, crossing-over occurs between the homologous regions of the vector and the host chromosome, resulting in the stable insertion of the engineered DNA sequence into the Cxc chromosome. The resulting Cxc/Bt recombinant produces HD-73 toxin proteins that can be identified electrophoretically by reaction with radioactive antibodies against purified HD-73 crystal protein (Western blotting). Because Cxc has no detectable plasmids of prophage (which could mobilize recombinant genes in nature), and because Cxc isolates have proven unable to transmit or exchange integrated DNA sequences with other bacteria, there is minimal risk of genetic exchange of recombinant toxin genes between Cxc and other microorganisms. Cxc/Bt recombinant strains have also been shown to revert spontaneously, losing the engineered gene sequences at a low frequency. Revertants are able to divide more rapidly and hence outcompete

recombinants. Consequently the recombinant genes are eventually lost from the Cxc population in the host plant. This phenomenon (i.e. sufficient Cxc/Bt populations) within a growing season, but rapidly enough that toxin genes would not persist in the environment in the unlikely event that Cxc/Bt was transmitted by mechanical means to a noncrop host plant.

### Effects of Cxc/Bt on European Corn Borer

Unlike Bt, Cxc/Bt does not sporulate and release crystal toxins into the environment, which are then ingested by caterpillars. Cxc/Bt does not secrete its toxin, and must therefore be digested by the insect in order to release its active ingredient. However, once this is accomplished, the symptoms are similar to those observed in larvae ingesting Bt: feeding slows and eventually stops, and larvae die from starvation or from invasion of the hemocoel by opportunistic microorganisms.

Experiments have demonstrated that Cxc/Bt can prevent or reduce borer damage to inoculated field corn under conditions of artificial infestation in the greenhouse. In four separate trials, test plants were inoculated with a strain of Cxc/Bt approximately 2 weeks after planting (about 6 to 8 leaf stage) by injection approx. 10 cm above the soil line with 7 to 8 log CFU per plant from a suspension of recombinant cells in phosphate buffered saline. Endophyte control plants were inoculated in similar fashion with wild-type Cxc. A sham-inoculated group were injected with sterile buffer only.

Plants confirmed as colonized systemically by Cxc or Cxc/Bt (except for the sham-inoculated group) were infested with neonate ECB larvae 5 or 6 weeks after inoculation. Incidence of colonization was determined by phase contrast microscopy (1000x) of a drop of sap expressed from a leaf taken from each plant. In the first three experiments, each plant was infested with 15 larvae divided equally among 5 holes (6 mm dia.) drilled into the stalk at 5 internodes, a method first used by Chiang (1959) in field experiments with ECB. The holes were sealed with nonabsorbant cotton plugs to prevent escape. Plants were dissected 3 or 4 weeks later to assess tunnelling damage as well as the numbers and condition of surviving insects. In the fourth experiment, plants were infested at or near tasseling with 50 larvae each, distributed among 5 upper leaf axil with a camel hair brush. The first three trials were designed to detect any activity of Cxc/Bt *in planta* against ECB larvae feeding on a more natural substrate than a laboratory diet, and was not a true simulation of a natural infestation. Normally, ECB larvae are physically unable to penetrate the stalk until third instar, about halfway through their larval development. The axil-infestation technique of the fourth trial was used to simulate more realistically a heavy natural infestation by second brood ECB, in which eggs are laid on plants during anthesis and larvae on leaf tissues (particularly sheath and collar) and pollen in the

axils prior to entering the stalks at third or fourth instar (Showers et al. 1989).

In the first three trials, plants colonized by Cxc/Bt contained, on average, one third to one half as many tunnels and one quarter to one third as many live insects than control plants at the end of the 3 to 4 week infestation period (Table 1). Results of the axil-infested trial were less dramatic, possibly due to the opportunity afforded to the larvae to feed and grow on external tissues before tunneling into the stalk (where Cxc/Bt concentrations tend to be 5 to 10 times higher than in the leaves) as third or fourth instars, which may be less sensitive to the effects of the Bt toxin (McGaughey 1978, Dimock, unpublished observations). Nevertheless, even in the fourth trial, Cxc/Bt-colonized plants contained about half as many borer tunnels and live insects per plant as did the controls, and total tunnel damage was also reduced by about 40% (Table 1).

These results demonstrate that sufficient amounts of a microbial insecticide can be delivered by genetically engineered endophytes to reduce the numbers of corn borers and their tunneling damage to inoculated plants. Field tests are planned for 1990 and 1991 to determine how the effects of Cxc/Bt on artificial infestations in the greenhouse are manifest in the field. Under field conditions, activity levels similar to those present in Table 1 should prevent or lessen yield losses due to corn borer infestations, since yield loss is closely related to the number of borers per plant and the tunneling damage they inflict (Showers et al. 1989).

#### Seed Inoculation Technology

CGI has developed proprietary methods for inoculation of Cxc/Bt into corn seeds for delivery to growers via seed company licensees. Crop Genetics International initiated its seed inoculation program in 1986. Early efforts focused on existing seed delivery systems. Various methods for external seed application were examined, including seed pelleting and coating with Cxc contained in a variety of polymers, oils, and powders. Both needleless injectors and microparticle guns were examined for direct injection into the seed. None of these methods appeared to be commercially useful for producing colonized plants. However, they demonstrated that penetration of the seed embryo was requisite for successful seed inoculation.

The use of a pressure differential to force Cxc-containing suspensions into dry seeds was successful, although this method produce only low percentages of colonized plants and resulted in a precipitous drop in germination and seedling vigor. However, if seeds are subject to a period of imbibition in water prior to pressure inoculation with Cxc, up to 100% of the seeds treated can produce vigorous, endophyte-colonized plants.

The current inoculation protocol calls for imbibition

followed by placement of seeds in a pressure vessel containing a suspension of Cxc cells in a buffer solution. Seeds are then removed from the inoculation suspension and dried on a forced air dryer. Conventional seed coatings can then be applied.

Seed treatment with Captan appears to have no adverse impact on bacterial survival or efficacy of inoculation. Storage of inoculated seeds for longer than a year is possible, with only a gradual reduction in bacterial titer and no significant effect on seed germination. Shelf life for crops will vary. One year of shelf life is expected for the first InCide product for corn. Controlled environment and warehouse storage experiments are in progress.

Seed inoculation will be performed by machinery built specifically for that purpose, that will fit into the lines of current seed conditioning plants with little or no need for redesign of existing facilities. CGI is currently working with four seed companies on the development and field testing of InCide technology. These cooperators are DeKalb-Pfizer Genetics (DeKalb, IL), NC+ Hybrids and Hoegemeyer Hybrids of Nebraska, and Rogers Brothers Seed Co. of Idaho.

Crop Genetics has targeted 1993 for the market introduction of its first InCide product.

#### Literature Cited

Chiang, H.C. 1959. Survival of European corn borer larvae, *Pyrausta nubilalis* (Hubn.) in artificial tunnels in stalks of field corn, *Zea mays* L. *Ann. Entomol. Soc. Amer.* 52: 631-632.

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McGaughey, W.H. 1978. The effects of larval age on the susceptibility of almond moths and India meal moths to *Bacillus thuringiensis*. *J. Econ. Entomol.* 71: 923-925.

Showers, W.B., J.F. Witkowski, C.E. Mason, D.D. Calvin, R.A. Higgins, and G.P. Dively. 1989. European corn borer: development and management. N. Central Regional Ext. Publ. 327.

**Table 1. Stalk-tunneling damage to inoculated field corn and borer populations in greenhouse test of Cxc/Bt against European corn borer.**

a Trial	b n	c Treatment	No Tunnels Per Plant	Total cm Tunneling Per Plant	No. Live Borers Per Plant
1	21	Control	3.7	15.0	4.3
		Wild-type Cxc	3.6	13.1	3.9
		Cxc/Bt Recombinant	1.2	3.7	1.2
2	30	Control	2.5	7.1	2.8
		Wild-type Cxc	2.7	8.6	3.2
		Cxc/Bt Recombinant	0.8	1.2	1.5
3	24	Control	6.7	20.4	3.7
		Wild-type Cxc	5.2	15.5	2.8
		Cxc/Bt Recombinant	3.6	9.3	1.2
4	24	Control	10.9	34.9	8.6
		Wild-type Cxc	10.4	34.8	8.0
		Cxc/Bt Recombinant	6.7	18.4	4.4

a Plants in Trial were infested by placing neonate larvae in leaf axils. Other trials infested by drilling holes in stems.

b n=number of corn plants tested per trial.

c control plants were inoculated with sterile buffer.

**FINANCIAL STATEMENT**  
 October 25, 1989 to November 12, 1990

Cash Balance October 25, 1989 \$20,533.49

**Income October 25, 1989 to November 12, 1990**

Registration Fees - 1989 Meeting & Cocktail	
Party Receipts	\$ 6,195.00
Sale of Proceedings	2,199.59
Registration Fees - 1990 Meeting & Cocktail	
Party Receipts	<u>13,995.19</u>

Total Receipts October 25, 1989 to November 12, 1990	<u>\$22,389.78</u>
Total Funds Available October 25, 1989 to November 12, 1990	<u>\$42,923.27</u>

**Disbursements October 25, 1989 to November 12, 1990**

1989 Meeting Expenses (Incl. Cocktail Party)	\$ 4,167.77
Misc. Expenses Incl. Postage, Stationery, etc.	593.18
Directors Meetings	1,400.03
1989 Proceedings, Incl. Postage, etc.	12,116.11
Advertising	987.50
1990 Meeting - Prel. Expenses	<u>3,210.71</u>

Total Disbursements October 25, 1989 to November 12, 1990	<u>\$22,475.30</u>
<b>CASH BALANCE - November 12, 1990</b>	<u>\$20,447.97</u>

Respectfully submitted,

PAUL J. PROSSER, JR.  
 Secretary/Treasurer

Meeting Attendance: 147