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37th ANNUAL MEETING
FERTILIZER INDUSTRY
ROUND TABLE
1987

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Monday, November 2, 1987

Morning Session I
Moderator:

Thomas L. Howe

Opening Remarks

Chairman
Thomas L. Howe

I would like to welcome you to the 37th Annual Fertilizer Industry Round Table. It is pleasing to see so many friends, especially in these lean times, making this investment in education for yourself and your company. The Board of Directors of the Round Table have put together a quality program, covering many topics and touching on all areas of our fertilizer industry, and this year for the first time, includes a production facility tour on Tuesday afternoon.

I would also like to extend a warm welcome to our neighbors from other countries who have chosen to attend this year's Round Table. We hope your stay is rewarding and productive.

The Round Table has long been the forum for technology, fertilizer products and distribution in North America. This program will continue with that tradition as a source of pertinent and useful information.

The proceedings printed from these Round Table meetings is a living history book for our industry and has documented the many twists and turns our industry has seen. Tomorrow morning's panel will highlight the impact of the many changes affecting us today with their discussion of "The Role of The U.S. Fertilizer Industry in the World Fertilizer Market."

Who, even a few years ago, would have predicted the massive restructuring of American Industry? Not only in our fertilizer industry, but throughout the entire economic fabric of American and world businesses.

In the U.S., the agricultural market is shrinking from government acreage reduction programs as producers, suppliers and farmers scramble to become more efficient in order to compete in a market of declining consumption. It is clear that in this atmosphere the industry's strategy is one of consolidation, where sales of unused or unprofitable assets are an attempt to become leaner, stronger and more competitive by lowering the cost of supply and production. Some industry observers say the re-organizations and mergers we are seeing will strengthen our industry.

When a company is thinking of getting out of a business, it is not engaging in long-term planning. Those companies growing and investing in our industry are making a commitment for the long pull. It is necessary for us as an industry to invest not only in the long term, but in the future we want. Tomorrow's success depends, in part, upon the research and development we engage in today. Yet our struggle with the bottom line causes us to cut back on such investments. It is a challenge to all of us in the United States and other countries to step up the search for ways to economically manufacture, transport, handle, and apply fertilizers and still not detract from the environment.

We have a lot to be proud of and I believe we have a lot to look forward to. This industry, which is so basic and necessary to feeding the world, deserves a satisfactory return on its investment or profit. To accomplish this we all need to assess and re-assess what we are doing and how we are to do it, and then make the choice that makes sense for us and the industry. As an industry, we need better forecasting, more committed long range planning, a better understanding of world markets and the political environment upon which they work and a better dialogue between all interested parties.

This is the role the Fertilizer Industry Round Table has served for the last 37 years, bringing together our industry to discuss issues that focus on the future.

It is appropriate that today we meet in one of the world's greatest port cities, New Orleans. Located along the great Mississippi River, which opens up middle America to the rest of the world and is so important to the distribution of agricultural products, New Orleans is the home of a number of fertilizer companies and production facilities in this area. It is a privilege that the keynote speaker is the Commissioner of Agriculture and Forestry for the State of Louisiana.

Keynote Address

Bob Odom
Commissioner of Agriculture & Forestry
State of Louisiana

The production of fertilizer for many years has been a permanent and major part of Louisiana's industrial base along the Mississippi River. Situated at the terminus of the River, Louisiana has a number of geographic features that make it a prime location for the major bulk industries, such as the fertilizer industry.

The value of the dollar and the stagnant domestic farm economy have had a considerable adverse impact on fertilizer production. We think we are beginning to see signs of a turn-around in that situation and hopefully a corresponding pickup in the fortunes of our domestic fertilizer industry.

But the signs are only preliminary indications; so far the figures don't bear out the subjective indicators. In a six-month period in 1984 there were 133,000 tons of fertilizer sold in Louisiana; by 1986 that figure had fallen to 105,000 tons. The figures for the corresponding six months in 1987 are not in yet.

The decline in sales was caused by a farm economy stuck in neutral—some of the specific factors included set aside programs begun at the federal level in which considerable acreage was taken out of production, federal farm programs which led to some shift out of high-fertilizer using crops as well as a number of other less significant reasons.

This year in Louisiana agriculture we are going to see some of the better times than we've seen in several years. As usual, such a general overview won't apply to all crops equally, but virtually all our crops will yield above our annual averages and several will approach record levels.

In the cotton-growing area we've got some farmers making an unbelievable three-plus bales an acre. On most other farms they are in the two-bale category. Generally, we had the rain when we needed it during the growing season. And then, mercifully, and unlike the last couple of years, the rain held off at harvest. Farmers were able to be in the fields and go full-tilt during the harvest until it was all at the gin. Although we don't keep such records, this was one of the most trouble-free and earliest completed cotton harvests in recent memory. The no-rain harvest took what was already an excellent yield figure and gave us tremendous quality as well, giving our farmers a top dollar product to sell.

In the sugar cane area we are having another very good year with harvest underway. Yields and quality are expected to be good. Production is shaping up to be above last year—which was a good year in itself. Acreage is up to 285,000 acres, a six percent increase from last year. And up from around 200,000 acres in 1984, but still not equal to early 1970s figures around 350,000 acres.

Fertilizer Industry Round Table Award of Merit Presentation

Presented By
Thomas L. Howe

The early growth of our industry had its roots in the post-war years. It was an era of technological advances. Fertilizer Companies developed their work in an environment of secrecy and independence, which slowed the potential growth that was before the industry.

In 1951, a small group of engineers and production people gathered together at an informal meeting to exchange ideas, problems and information. This early beginning of the Round Table has matured into a dialogue between companies and countries.

Today's Round Table program continues its traditional focus on plant production, and also addresses a number of inter-related topics that together give us a global understanding of our industry.

The Fertilizer Industry Round Table has a great tradition within the fertilizer industry, and has prospered through these 37 years of our industry's development. The Board of Directors has decided that it was appropriate to honor those individuals who have advanced, promoted and contributed to our industry in a significant way, by awarding "The Fertilizer Industry Round Table Award of Merit".

I am proud to be able to make this presentation, but even more proud that our industry attracted, nurtured and developed such quality, contributing people as Travis Hignett, last years' recipient of this award and Frank Nielson, this year's award recipient.

Frank Nielson was born in 1914 in Syracuse, New York. He attended Syracuse University, graduating Magna Cum Laude with a B.S. in Chemical Engineering.

Frank began his career as an analytical chemist with Solvay Process Co. soon after his graduation in 1935. He moved on to work for the Tennessee Valley Authority in 1938 as a technical assistant in the phosphorous plant and later as a nitrate superintendent.

During the war years Frank worked as an operations manager in the Pantex Ordinance Plant.

After the war Frank worked again with TVA as a group leader of R & D.

For three years he was director of R & D for F.S. Royster Guano Company.

In 1956 Frank started his long association with International Mineral and Chemical Company which was only interrupted by a two year tour of duty with the United Nations in Vienna, Austria developing fertilizer aid programs for developing countries. With IMC, Frank was Manager of Fertilizer Technology and later as a Technical Service Consultant. Frank retired from IMC in 1982, but continued to work as a consultant to IMC and Phos Rock.

During Frank's thirty years of experience in production supervision, research and development and technical consulting, he had published many papers and recently was editor for the book "Manual of Fertilizer Processing." He was a member of the American Chemical Engineers and the Fertilizer Industry Round Table Board of Directors. In 1983 the Fertilizer and Soil Chemistry Group of the American Chemical Society presented him with a Merit award.

Frank is the inventor and holds two patents for the TVA ammoniator which has revolutionized compound fertilizer manufacture. TVA has 183 licenses for use of the process. He holds an additional four patents, concerning Nitric Phosphates, Slow Release Fertilizer and Feed Phosphates.

Frank, I would like you to come to the podium while I read the inscription on this "Fertilizer Industry Round Table Award of Merit. "In recognition of a lifetime of outstanding service and technical contributions to the Fertilizer Industry, Farmers and People of the World, awarded this 2nd day of November 1987 by the Fertilizer Industry Round Table to Frank T. Nielson."

World Outlook for Nitrogen Fertilizers

W. F. Sheldrick

The World Bank

INTRODUCTION

1. Before discussing the future for nitrogen fertilizers, I would like to spend a few minutes reviewing what has taken place in the industry over the last few years and the situation that prevails today.

2. A major growth in nitrogen fertilizer consumption and production took place in the 1960s and 1970s, particularly in developing countries. The "green revolution," with the increasing use of high-yield varieties of cereals, accelerated the consumption of nitrogen fertilizers, particularly urea. Between 1960 and 1970 worldwide growth rates for nitrogen fertilizer demand averaged 10% p.a. During this period there were also major changes in the structure of the industry as both consumption and production increased at a much higher rate in the developing market economies and centrally planned economies than in the developed market economies.

3. Before 1960, almost all ammonia capacity was in the USA, Western Europe and Japan, who together accounted for more than 90% of the 15 million tons of nitrogen produced at that time. Between 1960 and 1975 there was a rapid increase in nitrogen production in all parts of the world, but since that period the most rapid growth has been in the USSR, China and India. By 1985/86 total world ammonia capacity exceeded 110 million tons, of which only 35 million tons were in the developed market economies.

NITROGEN SUPPLY

4. The development in capacity of the world's major nitrogen producers is shown in Table 1.

5. In the last few years, both the USSR and China have overtaken the USA in ammonia capacity and production. Worldwide, there was a very large construction program in ammonia plants during the 1970s and in China and the USSR in particular, considerable new capacity came on stream. In the face of competition from overseas and a stagnant demand for nitrogen fertilizers, both the USA and several Western European countries have seen a decline in ammonia production during the 1980s and the largest increase in growth has been in the developing market economies, mainly, India. Following the major surplus of nitrogen that developed in the early 1980s, the construction rate for ammonia plants has declined considerably from its peak in the late 1970s, when more then 20 new plants were being built each year. Between 1985 and 1989 it is forecast that new capacity erected will be less than any other corresponding period since before 1965, and this may well have an important impact on the nitrogen situation after 1989. See Table 2.

TABLE 1:
MAJOR COUNTRY AMMONIA CAPACITIES
(million tons N per year)

Country	1975/76	1980/81	1985/86	1990/91 (estimated)
USSR	11.6	18.2	24.5	24.9
USA	14.2	15.6	13.6	13.7
China	6.0	16.0	16.9	18.3
India	2.6	4.8	7.0	9.8

Paper to be presented to the Fertilizer Industry Round Table, New Orleans, USA November 2-4, 1987.

The views expressed in this paper are the author's own and do not necessarily reflect those of the World Bank.

TABLE 2:
AMMONIA PLANTS COMMISSIONED WORLDWIDE, 1960-89

	1960-64	1965-69	1970-74	1975-79	1980-84	1985-89
New plants (number)	49	115	106	121	87	55
Capacity (mill tons)	5.0	18.2	21.2	27.6	18.4	14.2
Average size ('000 tons p.a.)	102	158	200	228	211	259

These figures which exclude the small Chinese plants constructed during this period also show how the average capacity of ammonia plants has increased since 1960 from about 100,000 t.p.a. to nearly 260,000 t.p.a. The average size in the period 1975–79 was greatly influenced by the fact that within this period about 30 new plants, many of them of 440,000 t.p.a. capacity were built in the USSR. The development of the large ammonia plant with centrifugal compressor has given benefits in economies of scale and energy efficiency and has played a major part in reducing ammonia production costs and prices.

NITROGEN CONSUMPTION

Fertilizer Nitrogen Consumption

6. World nitrogen consumption has increased about tenfold over the last three decades. There was a recession in demand in 1975 after a major price hike during the so-called "fertilizer crisis". In 1985/86 there was also a slight decline in demand as a result of the depressed agricultural situation in the developed market economies and particularly as a result of the US Farm Bill. Between 1955 and 1975, nitrogen fertilizer growth rates averaged about 10% p.a. but this rate has been falling steadily since, and between 1985/86 and 1995/96 the growth rate is expected to average about 2.7% p.a. Within this period, due to the depressed agricultural situation in the USA and Western Europe, demand increase in the developed market economies is expected to be no more than 0.5% p.a. The outlook for nitrogen demand in the developing market economies is more optimistic at about 4.9% p.a., and growth in the centrally planned economies is forecast at about 2.8% p.a.

Industrial Nitrogen Consumption

7. Industrial demand for ammonia for materials such as fibers, resins, plastics, explosives, livestock feeds and a variety of other products currently comprises about 13% of all nitrogen consumption. About 68% of this demand occurs in the developed market economies, 26% in the centrally planned economies, and only 6% in the developing market economies. For example, in Japan, a major user of industrial nitrogen, more than 60% of its nitrogen use is for industrial purposes. World industrial nitrogen consumption is projected to increase at about 2% p.a. over the next decade, and this must be taken into account when assessing the need for new ammonia capacity.

SUPPLY DEMAND BALANCES

8. Regional and world supply demand balances are based on those prepared by the World Bank/FAO/UNIDO and Industry Fertilizer Working Group in June 1987. This group maintains a comprehensive date base on fertilizer plant capacity and consumption and meets twice a year to update this information. Regional and world supply, demand and balances for nitrogen are given in Annex 1 and are summarized in Table 3.

9. Overall, these results indicate that a world surplus of nitrogen will continue through 1988/89, but thereafter the surplus will decline to reach a balanced situation in 1990. Generally, the developed market economies will have the potential to meet their own consumption needs and a balanced situation will prevail, although the region will continue to take full advantage of imports of cheap materials when available. The developing countries will continue to be major importers of nitrogen fertilizer and the centrally planned economies will maintain a large surplus in the foreseeable future.

10. Although many analysts including the Working Group have been projecting a tightening of the nitrogen situation in a few years' time, insufficient consideration has been made in demand figures for the depressed agricultural situation in many parts of the world, and so in the event, this balanced situation has not arisen as quickly as expected. This time the situation may be a little different for a number of reasons. First, as mentioned earlier, there is little new nitrogen capacity under construction, and the current low prices and expectations of low prices in the future are constraining new investment. Other constraints are the uncertainty of oil and energy prices and the difficulties for many developing countries to obtain the necessary financing for new projects.

11. Perhaps one of the most important reasons for expecting a sharp tightening of the nitrogen situation in about two years' time, lies in the relatively low forecasts that are now being made for nitrogen fertil-

izer consumption. Consideration of the relationship between fertilizer needs to increase food production and population growth rates indicate that we are now projecting nitrogen demand growth rates that may be less than adequate to meet future food needs unless there is some major revolution in the next decade or so that greatly improves the efficiency of fertilizer use. There is no doubt that the last few years have seen a major increase in food production during a period of favorable growing conditions, but there is already some evidence that we may be experiencing a check in this situation. FAO are projecting that next year after several years of steady increase, world cereal stocks will decline by almost 10%. When the full effects of the drought in India are available this decline could be even more. The International Wheat Council has also recently lowered its forecast of wheat production for the current year of 506 million tons, by 12 million tons. In the FAO publication "Food Outlook" of September 1987 it is stated that the aggregate use of cereals will exceed production for the first time in four years and that stocks held by developing countries will fall to their lowest level in a decade.

12. The major deficit regions for nitrogen fertilizers will continue to be the developing countries of the Far East, Africa and Socialist Asia, and all of these regions will continue as major net importers through the remainder of the decade and well into the 1990s. Most of the increased consumption of nitrogen in Socialist Asia will take place in China, where nitrogen consumption is expected to grow at about 3% p.a. China's new investment programs will be mainly directed to the development of the phosphate sector, with relatively little expansion in new nitrogen capacity, so that China seems likely to continue as a large importer of nitrogen fertilizers.

13. The major exporting region will be Eastern Europe and, to a much lesser extent, the Near East. The USSR will continue to dominate the export markets well into the 1990s, although its export capability is expected to decline gradually. It is difficult to obtain authoritative information on the USSR's nitrogen industry but it is believed that the emphasis of capacity development will be placed on existing plant improvement rather than new plants. Some new contracts have recently been announced between the USSR and Japanese engineering companies to upgrade some existing ammonia plants.

14. However, with an increasing domestic demand for nitrogen fertilizers and the possibility of some closures of older plants during the next five years, it seems likely that the export availability of nitrogen fertilizers from the USSR will decline. Nevertheless, with a balanced situation forecast at the end of the decade, the remainder of the world will become increasingly dependent on Eastern Europe for about five million tons of exports of nitrogen.

NITROGEN FERTILIZER TRADE

15. Trade in nitrogen fertilizer products and ammonia has grown steadily in all regions in recent years. In the last two decades, trade in nitrogen fertilizers has grown from about 3 million tons to more than 14 million tons, and about 21% of nitrogen fertilizer production is now exported. The USA is still the main importing and exporting country for nitrogen materials due to the fact that it imports large quantities of ammonia, most of which are processed and exported as diammonium phosphate. Other major exporters of nitrogen fertilizer are the USSR, Netherlands, Romania and Canada. The major importers are China, F. R. Germany, India and Iran.

16. The types of fertilizers traded have also changed considerably in the last two decades. For example, ammonium sulphate and ammonium nitrate trade, which comprised about 57% of the export trade in the mid-1960s, today accounts for only 13%. On the other hand, urea, which was near 20% in the mid 1960s, in 1986 was about 50% of total nitrogen fertilizer trade. Many of the major exporters of nitrogen fertilizers in the developed market economies are now being displaced by exporting countries elsewhere that have cheap natural gas. For example, in 1973 Japan had about 30% of the nitrogen fertilizer trade and dominated the Far East market. Today it has about 1% due to the fact that with expensive feedstocks such as naphtha and LPG it can no longer compete in the export markets.

17. Although it would seem a natural trend for new export capacity to go where gas is cheap, this trend may be rather slow because of the difficulties of financing and establishing export-based projects in developing countries where investment costs are high. Also, recent improvements in energy consumption in new ammonia plants, together with lower energy prices, have reduced the comparative advantage of export-based plants near cheap gas sources, particularly where high infrastructural investment is needed.

18. Another important development in nitrogen fertilizer trade is the increasing use of counter trade, particularly with Eastern European countries and about 25% of nitrogen fertilizer trade is conducted through various types of barter deals, counterpurchase or buy-back arrangements. Until there is a major structural change in the balance of trade and debt relationships, countertrade seems likely to stay as a significant component of overall nitrogen trade.

19. Increase in nitrogen fertilizer trade will take place mainly as urea, ammonia and as diammonium phosphate. In the short term, no major changes are expected in international trade patterns, due mainly to the depressed agricultural situation in the USA and Western Europe. In the longer term, there is likely to be some change in the structure of international fertil-

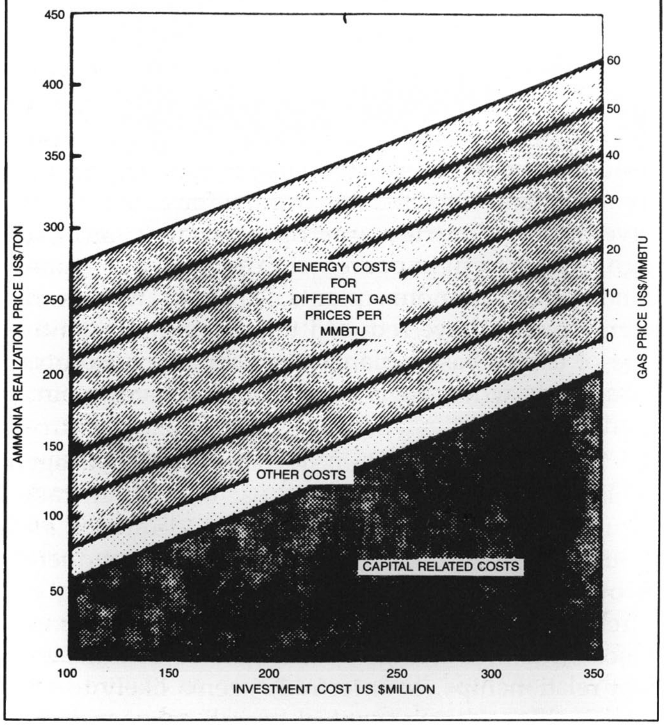
izer trade with the developed market economies increasing their dependence on imports from both the developing market economies and Eastern Europe. With several new plants coming on stream in the next few years, the Near East will strengthen its position as an exporter of urea and ammonia. Gas-rich countries in the Caribbean such as Trinidad and Venezuela and also Chile in South America are well placed to compete for growing market needs in North and South America. India is planning to reach self-sufficiency with several new plants coming onstream at the end of the decade. The needs for imports in Socialist Asia (including China) will continue to grow and will be the major markets for exports. Most of these needs will be satisfied from Eastern Europe.

THE EFFECT OF FUTURE ENERGY PRICES ON THE WORLD NITROGEN FERTILIZER INDUSTRY

20. Energy and investment costs are the two main factors that determine nitrogen fertilizer production costs, as indicated in Figure 1.

FIGURE 1

**AMMONIA PRODUCTION—1350 T.P.D.
REALIZATION PRICE TO GIVE 15% IRR FOR VARIOUS GAS PRICES
AND INVESTMENT COSTS**



For a new plant in a developed country where gas prices are likely to be related to other energy sources such as fuel oil, and hence are relatively high, energy costs can be more than 60% of the total cost of production. In the case where gas is cheap, usually in a developing country where all infrastructure has to be provided and hence the capital charges are relatively high, the cost of energy can be less than 10% of the total production cost. Figure 1 also shows clearly the major advantage that a plant with low gas price has in cash costs and why nitrogen fertilizer prices can fall to very low levels in periods of oversupply.

21. For the last decade there has been a strong move towards nitrogen fertilizer production in countries where the gas is very cheap, mainly in the Near East and the USSR. Today most trade in nitrogen products is based on cheap gas, and the experience of the last few years has indicated that only those companies which have very low cash costs can succeed in the longer term. The experience in the first half of the 1980s, which closed about 6 million tons of nitrogen capacity in the developed market economies, will continue to remain a major constraint to future building in this region even if there is a decrease in energy prices. Also, there is not at this stage sufficient confidence in either a sustained period of low energy prices or a growing domestic market that would justify new investment.

22. Although changes in oil prices in the future will obviously have an impact on energy prices to nitrogen plants in the developed market economies, it will have little impact on the opportunity cost of gas to those plants elsewhere which already dominate the export market and which have the capacity and willingness to sell ammonia and urea at prices well below US$100/ton for sustained periods.

23. It is generally expected therefore that the present trend of building export-based plants where the gas is cheap will continue, although if oil prices decline the trend will slow down, or accelerate if oil prices increase. The uncertainty of future energy prices, together with other constraining factors such as the world depressed agricultural situation, will have a delaying effect on new investments, and this could exacerbate a shortfall in supply in the early 1990s.

THE FUTURE OUTLOOK FOR THE WORLD NITROGEN INDUSTRY

24. Based on current projections for increased nitrogen demand and anticipate needs to replace existing plants, some rough projections have been made of new capacity needs for the period 1990/91–1995/96. In estimating demand, the increasing need for nitrogen of the industrial market has also been considered.

25. Demand for nitrogen worldwide is expected to increase by about 11.2 million tons between 1991 and 1996. Most of this will be produced in the form of ammonia and then converted either to urea or other nitrogen fertilizers. In calculating new capacity needs, allowance must be made for distribution and process losses and also for the fact that plants usually work at some level below their design capacity. Distribution and process losses are assumed to be 5% and an

overall utilization of 90% has been assumed for new ammonia plant capacity.

26. Although for project appraisal purposes ammonia and nitrogen fertilizer plants are assumed to have a life of about 15 years, in fact the actual average life is usually much longer. It is difficult to obtain statistical information on the average life of ammonia and downstream plants as there are plants still operating which are more than 30 years old and others which have closed with less than 15 years life. In this exercise it has been assumed that the average plant life will be 25 years and after that period a major refurbishing or replacement will be required. Other factors which would also force a plant to close would be the termination of a gas contract or unfavorable market or economic conditions. In Table 2 some information is given which shows new ammonia capacity construction since 1960. New capacity grew steadily during the 1960s and 1970s, peaking in 1975–79s when a major building program was implemented in Eastern Europe and Socialist Asia.

27. A survey was carried out by the World Bank at the end of 1985 to assess the age distribution of world ammonia capacity in order to assess replacement needs over the coming years. The survey excludes about 13 million tons of small and medium size plants in China for which specific start-up dates were not available. More than 90% of the remaining operating capacity could be accounted for by age and the age distribution of these plants is shown in Table 4. In considering these figures it is also important to take into account that the average total energy consumption per ton of ammonia has fallen from about 50 MMBTU for plants built before 1960 to less than 30 MMBTU for plants being built today.

28. The importance of Table 4 is that it illustrates the increasing amount of ammonia capacity which will have to be replaced in the period after 1990, when more than 25%, or more than 20 million tons of capacity in operation at the beginning of 1985, will be more than 20 years old. Already in the last 5 years we have seen about 4 million tons of ammonia capacity in the USA, about 2.0 million tons in Western Europe and about 1.5 million tons in Japan close permanently. Little information is available on Eastern European capacity closures, but an increasing number of older plants is expected to close in the next few years.

TABLE 4:
THE AGE OF WORLD AMMONIA CAPACITY[a]

Commissioned before	Cumulative capacity (mill. tons)	(%)	Age (years)
1960	1.4	1.6	>25
1965	6.0	6.8	>20
1970	21.9	25.6	>15
1975	41.2	47.0	>10
1980	68.8	78.8	>5
1985	87.1	100.0	

[a] Excludes small Chinese ammonia plants.

29. Closure rates are currently running at the rate of 1.5 million tons p.a. worldwide, and this is expected to increase significantly over the next decade as the average life of existing plants increases.

30. Table 5 briefly outlines the new capacity to meet increased nitrogen demand in the period 1991–96 and also to replace or refurbish worn-out plants. This rough estimate indicates that about 11–12 new or refurbished large ammonia plants will be needed each year after 1990.

TABLE 5:
WORLD AMMONIA PLANT REQUIREMENTS, 1991-96

New nitrogen demand	Mill. tons	No. of plants
Nitrogen fertilizer	11.2	
Industrial nitrogen	1.1	
Subtotal	12.3	
New capacity required	14.5	39
Replacement capacity	7.5	20
Total new capacity	22.0	59

CONCLUSION

31. The world fertilizer industry has suffered what must be its worst recession ever, reflecting a depressed world agricultural industry which has lowered demand for and prices of nitrogen fertilizers. This situation will probably continue for another two years or so but, even assuming a relatively modest increase in world nitrogen fertilizer demand, a balanced situation will be reached by 1990. The rate of building new ammonia capacity has fallen off significantly in recent years in a situation of excess supply, and forecasts of additional new construction are also much reduced. To avoid a serious shortage of nitrogen fertilizer in the early 1990s, at least 11 large new or refurbished plants will need to come on stream each year after 1990/91. Some of these plants will be needed to replace old plants built during the 1960s and early 1970s.

32. The changing prospects for energy prices and nitrogen trading patterns will mean that greater care than ever will have to be taken to ensure that only those projects offering reasonable and worthwile returns to their owners are implemented.

NITROGEN

Introduction to the Tables

1. The FAO/UNIDO/World Bank Fertilizer Working Group has updated its forecasts of world and regional nitrogen supply, demand and balances.

2. The Group's objective has been to present world and regional balances indicating the future relationship between supply potentials and agricultural demand, thus providing guidance as to the necessity or otherwise of creating additional nitrogen capacity.

3. It should be pointed out that the Group does not endeavor to forecast future production, but rather the supply potential that could be available if the market so demanded. The Group's methodology for calculating supply potential is given below.

Notes on Terminology

4. *"NH_3 Capacity"* : refers to nominal or nameplate ammonia capacity.

5. *"NH_3 Supply Capability"* : refers to production capability of ammonia for 1985/86—1991/92. It is estimated by applying forecasts of country-specific operating rates, based on past performance and other factors, to existing capacity and phased-in new capacity. New capacities are phased-in as 80/90/100% for the first three *full* years of operations.

6. *"N Fertilizer Supply Potential"* : is derived from ammonia "supply capability" and non-ammonia sources of nitrogen. Industrial uses, and processing and distribution losses are subtracted from ammonia "supply capability" to derive 'ammonia available for fertilizers'. Production of nitrogen from non-ammonia sources is added to 'ammonia available for fertilizers' to estimate "N fertilizer supply potential". The assumed processing and distribution losses are:

Region	*Processing and Distribution Loss*
Developed Market Economies	7%
Developing Market Economies	10%
Centrally Planned Economies:	
Eastern Europe including USSR	10%
Socialist Asia	12%

7. *"N Fertilizer Consumption"* : refers to estimated use for 1985/86, and to forecast demand thereafter.

8. *"Surplus (Deficit)"* : refers to difference between "N fertilizer supply potential" and "consumption".

Table 3: SUMMARY OF REGIONAL AND WORLD NITROGEN BALANCES /a

	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
World total	3.31	3.01	2.42	2.40	1.39	0.07	-0.98
Developed ME	0.02	0.07	0.07	0.17	0.05	-0.17	-0.31
North America	0.43	0.75	0.87	0.88	0.74	0.58	0.40
Western Europe	-0.28	-0.46	-0.45	-0.34	-0.28	-0.29	-0.33
Oceania	-0.02	-0.03	-0.01	0.01	0.00	-0.01	0.10
Others	-0.10	-0.33	-0.35	-0.38	-0.41	-0.44	-0.47
Developing ME	-1.65	-1.58	-1.98	-1.82	-1.96	-2.34	-2.47
Africa	-0.65	-0.67	-0.63	-0.47	-0.42	-0.45	-0.49
Latin America	0.64	0.55	0.35	0.16	-0.01	-0.07	-0.01
Near East	0.21	0.51	0.60	0.63	0.64	0.71	0.74
Far East	-1.84	-1.96	-2.29	-2.13	-2.16	-2.54	-2.72
Centrally planned economies	4.94	4.67	4.34	4.04	3.30	2.58	1.80
Eastern Europe	6.72	6.71	6.64	6.36	5.94	5.56	5.20
Socialist Asia	-1.79	-2.04	-2.30	-2.32	-2.64	-2.98	-3.40

/a Figures may not add precisely due to rounding.

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ANNEX I

WORLD AND REGIONAL NITROGEN SUPPLY DEMAND BALANCES: 000 TONS N

DEVELOPED M.E.

North America

	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
NH3 Nominal Capacity	16,577	15,776	16,153	16,153	16,153	16,153	16,153
NH3 Supply Capability	14,869	14,552	14,713	14,912	14,957	14,973	14,973
NH3 Industrial Use	3,010	3,040	3,070	3,100	3,130	3,160	3,190
Losses	830	806	815	827	828	827	825
NH3 Available for Fert.	11,029	10,706	10,828	10,985	10,999	10,986	10,958
Non-NH3 Nitrogen	90	90	90	90	90	90	90
N Fert. Supply Potential	11,119	10,796	10,918	11,075	11,089	11,076	11,048
N Fert. Consumption	10,690	10,050	10,050	10,200	10,350	10,500	10,650
Surplus (-Deficit)	429	746	868	875	739	576	398

Western Europe

	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
NH3 Nominal Capacity	15,388	15,067	14,909	15,234	15,234	15,234	15,234
NH3 Supply Capability	13,553	13,403	13,481	13,616	13,749	13,803	13,824
NH3 Industrial Use	2,457	2,466	2,479	2,443	2,457	2,468	2,480
Losses	777	766	770	782	790	793	794
NH3 Available for Fert.	10,319	10,171	10,232	10,391	10,502	10,542	10,550
Non-NH3 Nitrogen	120	120	120	120	120	120	120
N Fert. Supply Potential	10,439	10,291	10,352	10,511	10,622	10,662	10,670
N Fert. Consumption	10,720	10,750	10,800	10,850	10,900	10,950	11,000
Surplus (-Deficit)	(281)	(459)	(448)	(339)	(278)	(288)	(330)

Oceania

	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
NH3 Nominal Capacity	525	525	606	606	606	606	971
NH3 Supply Capability	476	476	513	549	549	549	680
NH3 Industrial Use	121	124	128	131	134	138	141
Losses	25	25	27	29	29	29	38
NH3 Available for Fert.	330	327	358	389	386	382	501
Non-NH3 Nitrogen	5	5	5	5	5	5	5
N Fert. Supply Potential	335	332	363	394	391	387	506
N Fert. Consumption	360	360	370	380	390	400	410
Surplus (-Deficit)	(25)	(28)	(7)	14	1	(13)	96

Other Developed M.E.

	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
NH3 Nominal Capacity	2,480	2,480	2,480	2,480	2,480	2,480	2,480
NH3 Supply Capability	2,403	2,186	2,198	2,198	2,198	2,198	2,198
NH3 Industrial Use	1,413	1,438	1,459	1,484	1,505	1,530	1,551
Losses	69	52	52	50	49	47	45
NH3 Available for Fert.	921	696	687	664	644	621	602
Non-NH3 Nitrogen	105	105	105	105	105	105	105
N Fert. Supply Potential	1,026	801	792	769	749	726	707
N Fert. Consumption	1,130	1,130	1,140	1,150	1,160	1,170	1,180
Surplus (-Deficit)	(104)	(329)	(348)	(381)	(411)	(444)	(473)

WORLD AND REGIONAL NITROGEN SUPPLY DEMAND BALANCES: 000 TONS N

DEVELOPING M.E.

Africa

	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
NH3 Nominal Capacity	701	429	973	1,291	1,291	1,291	1,291
NH3 Supply Capability	251	241	340	557	655	673	674
NH3 Industrial Use	20	21	22	24	25	26	28
Losses	23	22	32	53	63	65	65
NH3 Available for Fert.	208	198	286	480	567	582	581
Non-NH3 Nitrogen	0	0	0	0	0	0	0
N Fert. Supply Potential	208	198	286	480	567	582	581
N Fert. Consumption	860	870	920	950	990	1,030	1,070
Surplus (-Deficit)	(652)	(672)	(634)	(470)	(423)	(448)	(489)

Latin America

	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
NH3 Nominal Capacity	5,829	5,829	5,829	6,199	6,199	6,989	7,359
NH3 Supply Capability	4,721	4,733	4,733	4,866	5,016	5,304	5,715
NH3 Industrial Use	231	241	251	262	272	282	293
Losses	449	449	448	460	474	502	542
NH3 Available for Fert.	4,041	4,043	4,034	4,144	4,270	4,520	4,880
Non-NH3 Nitrogen	5	5	5	5	5	5	5
N Fert. Supply Potential	4,046	4,048	4,039	4,149	4,275	4,525	4,885
N Fert. Consumption	3,410	3,500	3,690	3,990	4,290	4,590	4,890
Surplus (-Deficit)	636	548	349	159	(15)	(65)	(5)

Near East

	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
NH3 Nominal Capacity	4,558	4,884	5,302	5,284	5,828	5,937	6,209
NH3 Supply Capability	3,307	3,662	3,923	4,123	4,304	4,508	4,662
NH3 Industrial Use	56	57	59	60	62	63	65
Losses	325	361	386	406	424	445	460
NH3 Available for Fert.	2,926	3,245	3,478	3,657	3,818	4,001	4,137
Non-NH3 Nitrogen	0	0	0	0	0	0	0
N Fert. Supply Potential	2,926	3,245	3,478	3,657	3,818	4,001	4,137
N Fert. Consumption	2,720	2,740	2,880	3,030	3,180	3,290	3,400
Surplus (-Deficit)	206	505	598	627	638	711	737

Far East

	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
NH3 Nominal Capacity	12,492	12,753	13,188	14,799	14,799	15,164	16,166
NH3 Supply Capability	9,099	9,793	10,139	11,073	11,677	11,929	12,414
NH3 Industrial Use	299	309	320	330	342	353	365
Losses	880	948	982	1,074	1,134	1,158	1,205
NH3 Available for Fert.	7,920	8,536	8,837	9,669	10,202	10,418	10,844
Non-NH3 Nitrogen	40	40	40	40	40	40	40
N Fert. Supply Potential	7,960	8,576	8,877	9,709	10,242	10,458	10,884
N Fert. Consumption	9,800	10,540	11,170	11,840	12,400	13,000	13,600
Surplus (-Deficit)	(1,840)	(1,964)	(2,293)	(2,131)	(2,159)	(2,542)	(2,716)

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WORLD AND REGIONAL NITROGEN SUPPLY DEMAND BALANCES '000 TONS N

	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
ALL DEVELOPED M.E.							
NH3 Nominal Capacity	34,970	33,848	34,148	34,473	34,473	34,473	34,838
NH3 Supply Capability	31,301	30,617	30,905	31,275	31,453	31,523	31,675
NH3 Industrial Use	7,001	7,068	7,136	7,158	7,226	7,296	7,362
Losres	1,701	1,648	1,664	1,688	1,696	1,696	1,702
NH3 Available for Fert.	22,599	21,901	22,105	22,429	22,531	22,531	22,611
Non-NH3 Nitrogen	320	320	320	320	320	320	320
N Fert. Supply Potential	22,919	22,221	22,425	22,749	22,851	22,851	22,931
N Fert. Consumption	22,900	22,290	22,360	22,580	22,800	23,020	23,240
Surplus (-Deficit)	19	(69)	65	169	51	(169)	(309)
ALL DEVELOPING M.E.							
NH3 Nominal Capacity	23,580	23,895	25,292	27,573	28,117	29,381	31,025
NH3 Supply Capability	17,378	18,429	19,135	20,619	21,652	22,414	23,465
NH3 Industrial Use	606	628	652	676	701	724	751
Losses	1,677	1,780	1,848	1,994	2,095	2,169	2,271
NH3 Available for Fert.	15,095	16,021	16,635	17,949	18,856	19,521	20,443
Non-NH3 Nitrogen	45	45	45	45	45	45	45
N Fert. Supply Potential	15,140	16,066	16,680	17,994	18,901	19,566	20,488
N Fert. Consumption	16,790	17,650	18,660	19,810	20,860	21,910	22,960
Surplus (-Deficit)	(1,650)	(1,584)	(1,980)	(1,816)	(1,959)	(2,344)	(2,472)
ALL CENT. PLANNED EC.							
NH3 Nominal Capacity	52,299	53,543	54,707	54,707	54,872	55,327	55,382
NH3 Supply Capability	41,918	42,734	43,756	44,498	44,733	45,005	45,215
NH3 Industrial Use	2,671	2,716	2,766	2,811	2,861	2,911	2,961
Losses	4,215	4,298	4,406	4,486	4,507	4,531	4,548
NH3 Available for Fert.	35,032	35,720	36,584	37,201	37,365	37,563	37,706
Non-NH3 Nitrogen	195	195	195	195	195	195	195
N Fert. Supply Potential	35,227	35,915	36,779	37,396	37,560	37,758	37,901
N Fert. Consumption	30,290	31,250	32,440	33,350	34,260	35,180	36,100
Surplus (-Deficit)	4,937	4,665	4,339	4,046	3,300	2,578	1,801
WORLD TOTAL							
NH3 Nominal Capacity	110,849	111,286	114,147	116,753	117,462	119,181	121,245
NH3 Supply Capability	90,597	91,780	93,796	96,392	97,838	98,942	100,355
NH3 Industrial Use	10,278	10,412	10,554	10,645	10,788	10,931	11,074
Losses	7,593	7,727	7,918	8,168	8,298	8,396	8,521
NH3 Available for Fert.	72,726	73,641	75,324	77,579	78,752	79,615	80,760
Non-NH3 Nitrogen	560	560	560	560	560	560	560
N Fert. Supply Potential	73,286	74,201	75,884	78,139	79,312	80,175	81,320
N Fert. Consumption	69,980	71,190	73,460	75,740	77,920	80,110	82,300
Surplus (-Deficit)	3,306	3,011	2,424	2,399	1,392	65	(980)

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June 8, 1987

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WORLD AND REGIONAL NITROGEN SUPPLY DEMAND BALANCES: 000 TONS N

CENT.PLANNED EC.	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
Eastern Europe							
NH3 Nominal Capacity	34,147	35,091	35,091	35,091	35,091	35,461	35,516
NH3 Supply Capability	26,780	27,286	27,751	27,999	28,083	28,231	28,400
NH3 Industrial Use	2,056	2,091	2,126	2,161	2,196	2,231	2,266
Losses	2,472	2,520	2,563	2,584	2,589	2,600	2,613
NH3 Available for Fert.	22,252	22,676	23,063	23,254	23,298	23,400	23,521
Non-NH3 Nitrogen	180	180	180	180	180	180	180
N Fert. Supply Potential	22,432	22,856	23,243	23,434	23,478	23,580	23,701
N Fert. Consumption	15,710	16,150	16,600	17,070	17,540	18,020	18,500
Surplus (-Deficit)	6,722	6,706	6,643	6,364	5,938	5,560	5,201
Socialist Asia							
NH3 Nominal Capacity	18,152	18,452	19,616	19,616	19,781	19,866	19,866
NH3 Supply Capability	15,138	15,448	16,005	16,499	16,650	16,774	16,815
NH3 Industrial Use	615	625	640	650	665	680	695
Losses	1,743	1,779	1,844	1,902	1,918	1,931	1,934
NH3 Available for Fert.	12,780	13,044	13,521	13,947	14,067	14,163	14,186
Non-NH3 Nitrogen	15	15	15	15	15	15	15
N Fert. Supply Potential	12,795	13,059	13,536	13,962	14,082	14,178	14,201
N Fert. Consumption	14,580	15,100	15,840	16,280	16,720	17,160	17,600
Surplus (-Deficit)	(1,785)	(2,041)	(2,304)	(2,318)	(2,638)	(2,982)	(3,399)

Outlook for Phosphates

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SUMMARY

The outlook for fertilizer phosphates worldwide, and especially in the United States, is for significant change through the 1990's. (Fig. 1)

Looking at a typical life cycle of a product, we see the progression from an embryonic stage through growth into a mature stage and then into aging. (Fig. 2)

Using this description, we can see that the U.S. phosphate industry has evolved from the status of a growth industry in the 60's and 70's, to a mature industry beginning in the 80's, and in the 90's and beyond to possibly an aging industry.

The United States, the leading producer of both phosphate rock and upgraded P_2O_5, will feel the most pronounced impact as the annual growth rates for domestic consumption drop to zero or turn negative. Also international market shares will shift to offshore suppliers, principally Africa and the Mideast.

SUPPLY SIDE PRESSURES

Let's first examine the supply side of the U. S. phosphate industry over the past four decades. (Fig. 3)

Since World War II, the phosphate rock industry, particularly in the United States, has been expanding rapidly, from only 12.0 million tons per year of rock in the 1950's, to 25.0 million tons per year in the mid-1960's, to 45.0 million tons per year in the mid-1970's, and now in the 1980's to over 60.0 million tons per year of rock capacity. (Fig. 4)

In the case of P_2O_5, the industry has expanded from 500,000 tons per year of P_2O_5 capacity in the

1950's, to 3.0 million tons per year in the mid-1960's, to 8.0 million tons per year in the mid-1970's, and now in the 1980's to nearly 12.0 million tons per year of P_2O_5.

Now and into the 1990's and beyond, what is happening to U.S. rock and P_2O_5 production? What factors are affecting the slowdown from the supply side? (Fig. 5)

—Low prices for both upgraded phosphate products and rock concentrate are commonplace—crop/fertilizer price ratios are low. Peter Drucker, often called "father of American management", says, "The collapse of non-oil commodity prices began in 1977, and by early 1986 were at the lowest levels in recorded history."

—Dismal returns on investment in an increasingly capital-intensive industry are sharply limiting U.S. mine and P_2O_5 expansions.

—No significant or radical technology or process developments have occurred in this industry in over four decades. Perhaps an exception may be made of cogeneration, which was brought about primarily by factors related to energy demand.

—No new phosphate product innovations of significance have occurred during the growth period.

—There are more intense environmental responsibilities for the industry, with an ongoing requirement for greater improvement that is anticipated to increase through the year 2000, particularly in the United States and other developed countries.

—In most instances in this country, there are diminishing quantities and quality of reserves. (Fig. 6)

As we examine U.S. acid P_2O_5 production from 1950 through the present and project it through the year 1993, it clearly represents an industry that left it's embryonic stage in the early 1950's and entered a growth period, which seemed to end in 1980 when the industry began to mature. Many factors suggest that our industry, particularly in the United States, has changed from a growth industry to at least a mature industry, and may, before the end of the century, become an aging industry. (Fig. 7)

Still examining the situation from the supply side, it is interesting to see what has been happening outside the United States during the period since World War II.

The developing countries, particularly Africa and the Mideast, have shown the most significant growth as suppliers. The world has been growing in rock production. In 1950, U.S. rock production was at 50.0 percent of world. Today, U.S. rock production is only 30.0 percent. (Fig. 8) And while the world was growing in wet acid production, acid P_2O_5 production in the United States was 20.0 percent of world in 1950, increasing to 47.0 percent in 1966, and now is only 35.0 percent of world P_2O_5 production.

What are the factors that have impacted the development of rock and P_2O_5 production outside the United States? (Fig. 9)

—The desire by most developing countries to be self-sufficient in essential raw materials. A few examples are Brazil and Russia in rock and China and India in wet acid and DAP production.

—The abundance of sufficient quantities of high-quality rock reserves—as in Morocco, Tunisia, Syria, Jordan, Israel and Senegal—has precipitated major industry growth in these countries.

—The vital need for developing countries to produce hard currencies to buy essential products and foodstuffs not produced within the country causes phosphate industry growth.

—Abundance of available capital for development from the World Bank and other developed country institutions has been a factor.

—Availability of technology and engineering at bargain prices from firms seeking new business as the U.S. industry ceased its expansion phase has been taken advantage of by Third World countries.

—There is the basic drive of developing countries to improve their economic well-being through development of internal industry.

DEMAND SIDE PRESSURES

Now, let's examine how the demand side has changed over this same period of time since World War II. (Fig. 10)

In the United States, the factors that appear to be limiting demand are:

—Shifts in U.S. dietary habits from less beef and subsequently less grain and phosphorus

—High inventories, at the PIK year levels or higher, resulting in low grain prices caused by overproduction

—U.S. becoming a residual grain supplier starting with the trade embargo imposed against the USSR in 1980

—U.S. farmers—most productive in the world—going bankrupt at rates not seen since the Great Depression

—Grain shortages of the 70's becoming grain surpluses in the 80's

—Third World improvements in diets have not materialized—per capita food production is actually falling

—Irrigated lands in the U.S. are declining—Ogallala aquifer in the Plains states may itself be in jeopardy

—Surviving farmers in the 1990's will be more sophisticated

- Increasing testing of soils for phosphorus content and making greater utilization of the nutrient soil bank, resulting in lower application rates
- Selected and banded application allowing more efficient placement and lower use of phosphate
- Time and amount of application, applied more scientifically, also resulting in reduced phosphate consumption.

—Environmental pressures

- Soil erosion—more emphasis will be placed on tilling methods to prevent soil erosion
- Marginal lands more vulnerable to erosion will be left idle or converted to grazing lands
- Nutrient runoff will become more limiting as the Clean Water Act is implemented
- Ground and surface water protection will place further pressures to limit the use of fertilizers and organic fertilizer substitution will increase as municipalities are compelled to clean up their effluent discharges.

(Fig. 11) Clearly, the United States fertilizer consumption peaked in 1981, if not earlier, and is now leveling or declining. And, of course, phosphate as a major component of fertilizer is tracking this same pattern. This graph is typical of an industry market segment that has passed from the growth phase into the mature phase and is heading for an aging market. Note the increasing volatility in nutrient demand since the mid-to-late 70's. This same volatility is also reflected in pricing and is characteristic of a maturing market.

Western Europe, like the United States, finds itself in a similar position, if not more so, with respect to the market phase, i.e., it is into a mature to aging period. But Europe has restructured its industry much more than the United States. (Fig. 12)

In viewing the total global grain production, we find a situation which is still exhibiting some growth, but showing evidence of a slowing of the annual growth rate. (Fig. 13)

When one reviews the world's harvested area of grain, a leveling which suggests an oversupply condition can be seen. Since 1980 the trend is downward, with many factors affecting a reduction or at least stopping the increase in cultivated acres. (Fig. 14)

As total fertilizer use exhibits a leveling in growth since 1980, grain acres per capita continue to decline. The pattern is clear that the number of acres under cultivation is decreasing, and increases in actual grain production will come from existing acreage.

While a number of factors limiting global growth are the same as those affecting U.S. growth, I believe it is important to recognize another major factor frequently credited with influencing global or world demand for phosphate fertilizer—population. (Fig. 15)

All too often one hears the argument that the ever-expanding population, compounded with the per capita increase in grain consumption, will continue to cause an increase in grain and subsequently in phosphate fertilizer demand.

For the moment, let's examine the projected size of populations of the major countries in the world at their stabilization size, as reported by the World Bank in the 1987 world development report.

If one accepts the projected rates and potential growth to stabilization, it can be seen that most of the rapid growth countries may lack the economic strength to pay for the grain or the fertilizer to feed their expanding populations. "For example, even if Nigeria's population, now just over 100 million, reached 532 million by the middle of the twenty-first century, one must question their capability to provide for their basic needs with such a tremendous increase." The same holds true for most of the other rapidly growing countries. "The variations in projected population growth suggest that a demographically divided world is likely to become divided along economic lines as well." (Fig. 16)

To further illustrate the point, let's examine the per capita income in the 1980's versus population growth of these countries.

One can see that where population growth rates are generally below 2.0 percent, the per capita income is rising. Note that India, the large fertilizer consumer with an annual growth rate of 2.1 percent, is an exception. Admittedly there are other factors that come into play, such as the current relative standards of living; however, when one examines countries where population growth rates generally exceed 2.0 percent, it can be seen that the per capita income is declining. Thus, it appears that only through subsidies can countries with these rapidly expanding populations afford the grain and fertilizer required to meet their needs. Subsidies in any situation can only be for interim relief and not a permanent solution. (Fig. 17)

This chart shows the population growth rates of the developing, centrally planned, and developed countries. I do not believe that the high growth rates in the developing countries can be maintained and that they will begin to approach those of the developed and centrally planned countries, who in turn will decline even further. (Fig. 18)

World consumption of P_2O_5 through the year 1993 appears more likely to be on the path indicated, rather than the continued growth that has occurred since the 1960's and as suggested by some of the current industry forecasters. (Fig. 19)

Growing populations of the world landless are invariably exhibiting far higher levels of malnutrition as a segment of the population. In India, the number of landless rural households is predicted to increase from 15.0 million to 44.0 million by the year 2000, as is the case in much of the subcontinent of Asia.

"In Bangladesh, for example, those in rural households who own no land consume on average 1,924 calories per day. Those who own 1.2 hectares or more consume 2,375 calories per day, or 23.0 percent more calories. Consumption of protein is even higher—on the order of 40.0 percent more for the land holders." (Fig. 20)

As can be seen here, per capita grain production in Africa shows the lack of productivity typical of developing countries versus developed countries such as Western Europe.

The problem for the U.S. phosphate producer is that his expanding or potential growth markets are in the Third World countries where:

—Overcrowding is causing increasing political unrest and violence

—Forty percent of the population oftentimes is under the age of fifteen

—Rapid population growth is leading to a steady decline in living standards and educational systems are becoming overcrowded and ineffective. (Fig. 21)

Now, let's examine another factor in fertilizer use—accepting for the moment that grain consumption may not be directly linked to population growth, and, even if it were, population growth may be brought into check by factors beyond the phosphate producers' control. When we look at the response ratio of grain production to fertilizer use over the past three decades, we see that grain production has increased significantly while the ratio of fertilizer use to grain has decreased and become level, as expressed by the response ratio. In 1950, for example, the ratio of a million tons of grain production to a ton of fertilizer use was forty-six to thirteen to one. It decreased thirteen to one in 1980 and has remained constant since. (Fig. 22)

Fertilizer use per capita has leveled since 1980. While the increase from five kilograms per capita in 1950 to twenty-six kilograms per capita in 1980 is significant, it now remains constant. (Fig. 23)

One sign of encouragement is the rapid increase since 1960 of chemical fertilizer in countries such as China to supplement the already high use of organic fertilizer or nite soil. China is a bright spot because it has stabilized its population, has significant room to grow by improving its living standards, and leads the world in improving per capita income, improving 58.0 percent from 1980 to 1986.

However, more use of organic fertilizer should be anticipated in other regions, particularly developed countries and urban regions as environmentalists put pressure on communities to clean up their municipal discharges.

Also, as pointed out by Edwin Harre at the recent TFI meeting in New York, phosphate's share of total nutrient use has dropped from 35.0 percent in 1961 to 25.0 and 23.0 percent in the World and the U.S. respectively in 1986.

FORECAST FOR THE 1990'S

As you might expect, from the tone of my presentation to this point, I am forecasting a maturing market, both in the U.S. and somewhat later worldwide. The finite resources of the world will require a more disciplined and planned economic growth, which will eventually bring into check worldwide the demand for phosphate fertilizer. Expanding populations in Third World countries will be brought under control as they have in many of the developed civilizations, such as the United States and Europe and in China, Japan, and South Korea. How traumatic these adjustments will be depends on how successfully the transition can be managed.

I am not a professional forecaster, but my guess is that it may be a rough and difficult road for the phosphate producer through this transition period into a more stable, mature and disciplined market, especially if he does not make adjustments to recognize the maturing market. (Fig. 24)

Let's take a moment to look at what some of those who spend more time researching the problem than I do are forecasting. In North America—with some limited exceptions—many forecasters associated with the industry are predicting a return of growth, as can be seen in this chart. The spread in forecasts is not significant. I suggest to you that we may actually be in a decline mode as indicated by my forecast at the present time, certainly facing zero growth. (Fig. 25)

What factors suggest slower or negative U.S. consumption?

—Lower global annual growth rates will directly impact U.S. exports.

—Stronger competition from abroad, particularly Africa and the Mideast, will increase.

—Environmental concerns and pressures about nutrient runoff and groundwater contamination at home will intensify.

—Significant consolidation and reduction in number of plants by the U.S. fertilizer industry demonstrates pressures already at play to bring producer behavior in line.

—Frequency of bankruptcies and significant income losses demonstrated by the industry during the 80's may continue.

—Lack of expansions currently on the near-term horizon illustrate that management and the financial communities have no economic justification to consider such actions.

—Low grain prices and high grain stocks continue for the foreseeable future.

When one looks at the existing P_2O_5 overcapacity in the United States, one must recognize that oversupply seriously threatens the viability of the U.S. industry. (Fig. 26)

The world consumption, correlated with increasing population, shows continued growth, and many industry forecasters suggest varying degrees of annual average worldwide growth—from 1.0 to 5.0 percent, varying of course by region and country. (Fig. 27)

In this case, one can accept the fact that world growth will continue, but at a much slower rate than many forecasters suggest. Annual world growth rates will be much closer to 1.0 than to 5.0 percent. The Texasgulf prediction plotted is a 2.0 percent growth.

Many countries and regions whose populations suggest a greater demand for fertilizer will be thwarted by the slower increases in population than projected and/or by the countries' economic inability to purchase the required raw materials, including phosphate fertilizer.

Now, if you assume for the moment that my somewhat pessimistic future scenario relative to the growth period of the 60's and 70's for world and U.S. phosphate fertilizer growth is valid, we must answer the question as to what share of the world market the U.S. will have in the future relative to the past and the present. (Fig. 28)

In 1970, total world exports of P_2O_5 were 1.7 million metric tons and the U.S. had a 47.0 percent share, followed by West Europe with 24.0 percent and North Africa with only 16.0 percent.

By the end of the decade in 1980, export trade has increased more than fourfold to 7.1 million metric tons, with every supplier experiencing increased volume. U.S. share increased to 56.0 percent at the expense of Western Europe, whose share dropped to 13.0 percent, while North Africa held share at 16.0 percent. (Fig. 29)

During the next six years, world P_2O_5 exports increased by 27.0 percent to 9.0 million tons per year, but market shares were changing. The U.S. had suffered a drop in market share to 44.0 percent, but was still in first place. Western Europe dropped 2.0 percent to a 10.0 percent market share, with North Africa increasing 118.0 percent to a 27.0 percent market share. Other suppliers slightly gained market share. (Fig. 29)

If world P_2O_5 exports grow by 2.0 percent per year to 10.8 million tons, rather than the continued growth that has occurred since the 1960's and as suggested by some of the current industry forecasters, North Africa will increase 67.0 percent to 38.0 percent market share and the U.S. will increase 4.0 percent, falling to 38.0 percent market share. (Fig. 30)

So, now let us return to the question of the factors which I believe favor the U.S. loss of market share in the world markets. (Fig. 31)

—Newer, larger and more modern competitive plants are now located offshore and are equipped with the latest technology.

—The competitors are now better trained and motivated, particularly in Africa, and they can achieve operating rates equal to those of the United States.

—In many instances, the foreign competitors have higher quality and more extensive phosphate reserves.

—Foreign competitor's current governments, most of which own the phosphate-producing entities, have a strong and urgent need for hard currency, making intense their need to compete at low prices.

—Foreign producers have improved their competitive cost position.

—Third World competitors lack the environmental constraints and requirements faced by the more developed countries of the U.S. and Western Europe.

If one accepts the U.S. position of diminishing markets at home and abroad in the face of stronger and more efficient foreign competition, one then recognizes the nature of the challenges facing the U.S. phosphate industry in the future. (Fig. 32)

At least some of the steps required for the U.S. phosphate industry to survive, and hopefully prosper, are: (Fig. 32)

—Radical process improvements

—Product innovations

—Continued efficiency improvements in labor, energy, fuel and supplies

—Abandonment of the concept of oversupplying the market to minimize unit costs through volume effect

—Recognition that oversupplying a market is not a key to survival and that different rationales are required to manage and profitably survive in a mature and aging industry.

While no one can accurately forecast the future, even with the sophisticated computer models of today, I believe significant growth will not be a factor occurring in the phosphate industry; and to properly and profitably manage our phosphate companies in the future, we must search for solutions other than increasing the phosphate supply.

SOURCES

1. "The Changed World Economy", Peter F. Drucker
2. "Living on a Lifeboat", Garrett Harden
3. "State of World" 1987, Lester R. Brown and Staff
4. "FAO", Fertilizer Yearbooks
5. "USDA", Agricultural Statistics
6. World Fertilizer Conference, "Emerging Trends in the World Phosphate Market", Edwin M. Harre
7. Texasgulf Market Research

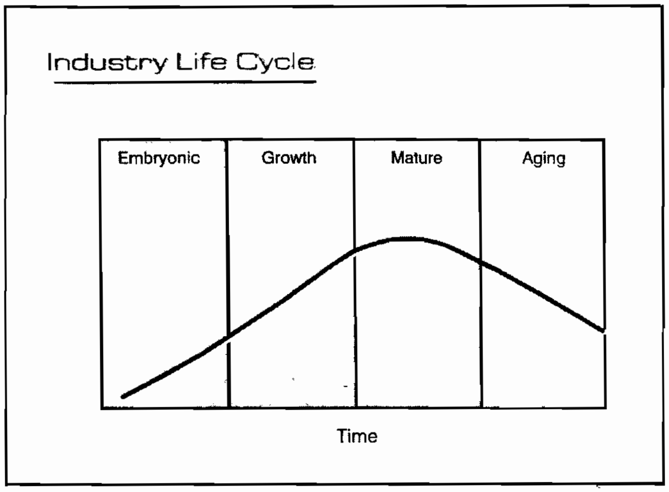

Industry Life Cycle

Figure 1

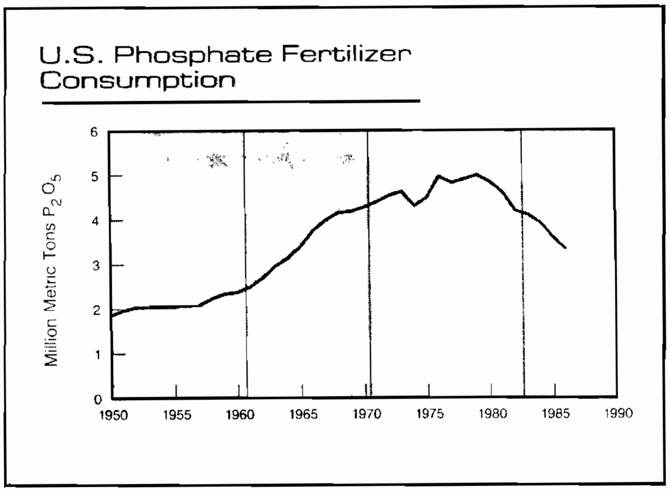
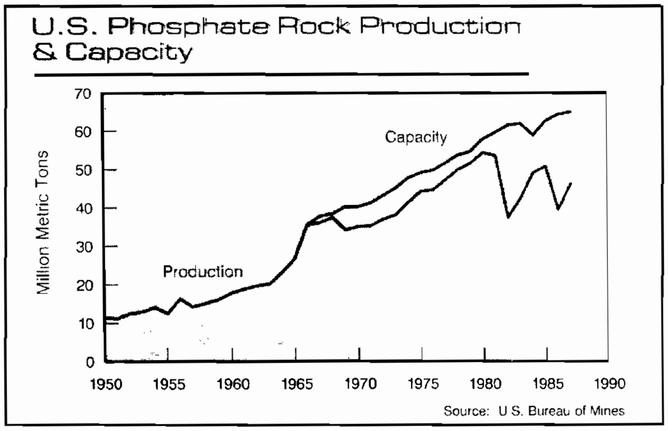
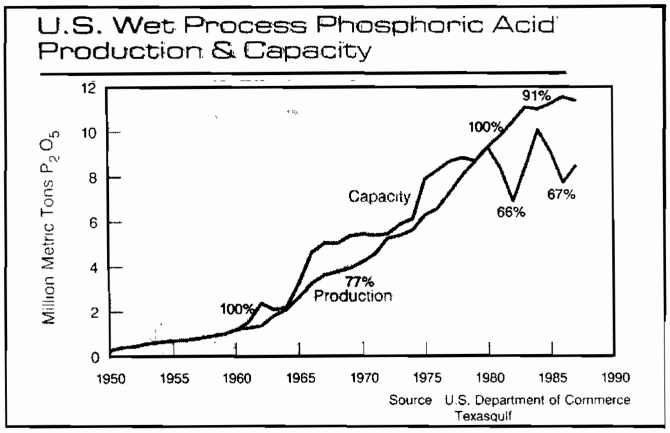

U.S. Phosphate Fertilizer Consumption

Figure 2


U.S. Phosphate Rock Production & Capacity

Source: U.S. Bureau of Mines

Figure 3


U.S. Wet Process Phosphoric Acid Production & Capacity

Source U.S. Department of Commerce
Texasgulf

Figure 4

Factors Affecting Phosphate Supply Side

- Low Prices
- Poor Returns
- No Process Developments
- No New Products
- Environmental Pressures
- Diminishing Reserves

Figure 5

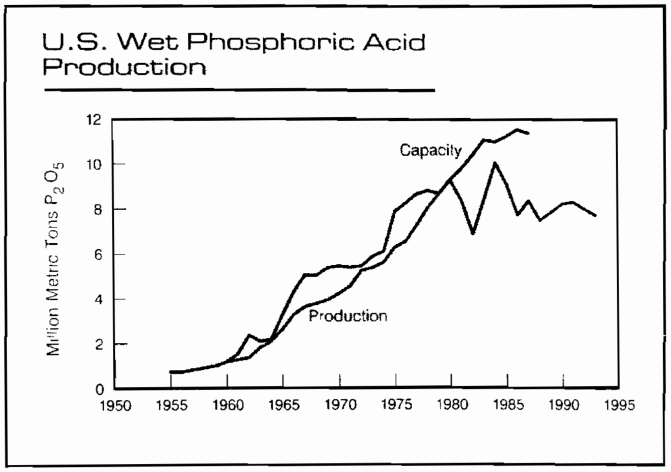
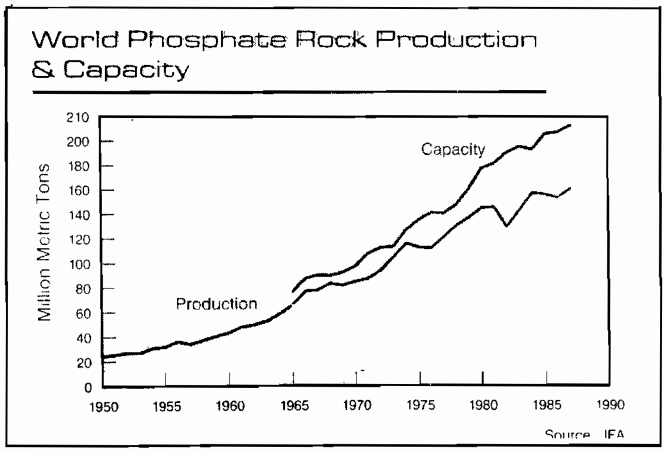
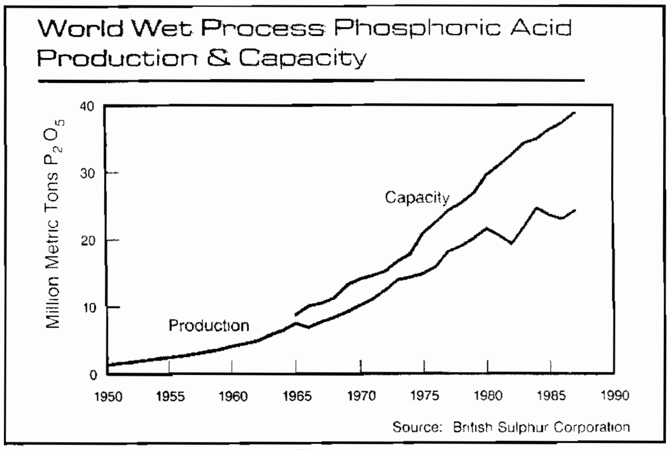

U.S. Wet Phosphoric Acid Production

Figure 6


World Phosphate Rock Production & Capacity

Source IFA

Figure 7


World Wet Process Phosphoric Acid Production & Capacity

Source: British Sulphur Corporation

Figure 8

Factors Affecting Phosphate Production Outside U.S.

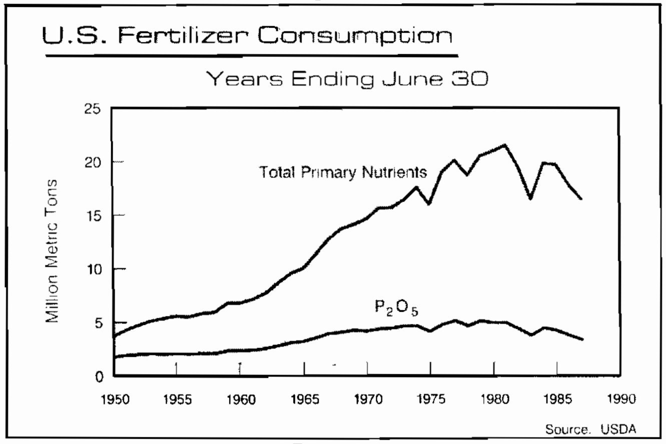
- Self-Sufficiency in Raw Materials
- High Quality Reserves
- Need for Hard Currencies
- Available Capital
- Inexpensive Technology
- Drive for Economic Improvement

Figure 9

Factors Limiting Phosphate Demand in U.S.

- Dietary Habits
- Low Grain Prices
- Residual Export Supplier
- Farmer's Economic Plight
- Grain Surplus
- Third World Diets Unimproved
- Irrigation Declining
- More Sophisticated Farming
- Environmental Pressures

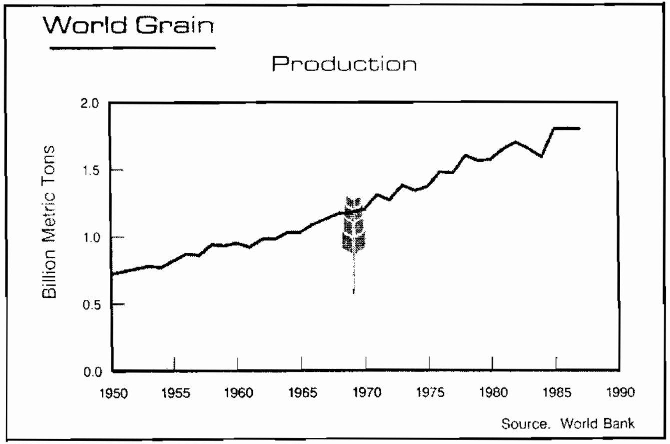
Figure 10


U.S. Fertilizer Consumption

Years Ending June 30

Source. USDA

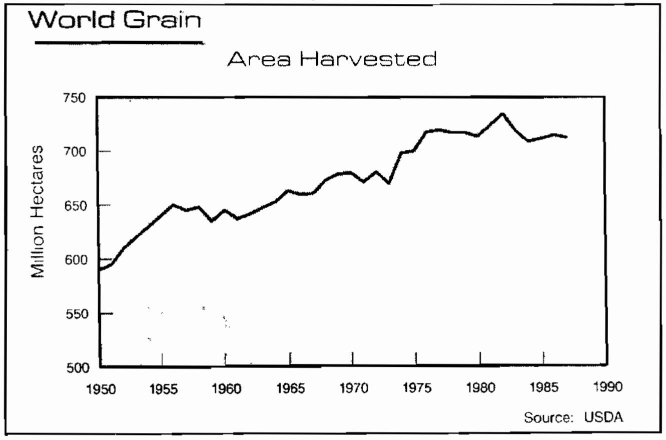
Figure 11


World Grain

Production

Source. World Bank

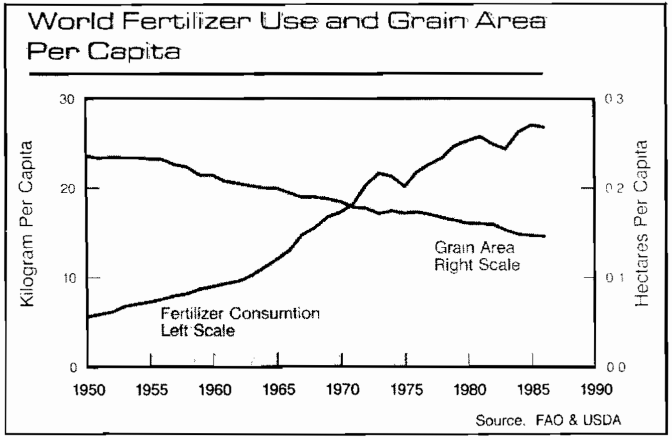
Figure 12


World Grain

Area Harvested

Source: USDA

Figure 13


World Fertilizer Use and Grain Area Per Capita

Source. FAO & USDA

Figure 14

Projected Population Size at Stabilization

Country	Population in 1986	Annual Rate of Population Growth	Size of Popultion at Stabilization	Change from 1986
	(million)	(percent)	(million)	(percent)
Slow Growth Countries				
China	1.050	1.0	1,571	+ 50
Soviet Union	280	0.9	377	+ 35
United States	241	0.7	289	+ 20
Japan	121	0.7	128	+ 6
United Kingdom	56	0.2	59	+ 5
West Germany	61	-0.2	52	-15
Rapid Growth Countries				
Nigeria	105	3.0	532	+ 406
Pakistan	102	2.8	330	+ 223
Bangladesh	104	2.7	310	+ 198
Mexico	82	2.6	199	+ 143
Indonesia	168	2.1	368	+ 119
India	785	2.3	1,700	+ 116
Brazil	143	2.3	298	+ 108

Sources World Bank *World Development Report* 1985

Figure 15

Changes in Population and Per Capita Income

1980-86

Country	Rate of Population Growth	Cumulative Change in Per Capita Income
	(percent)	
Rising Incomes		
China	1.0	+ 58
South Korea	1.6	+ 34
Japan	0.7	+ 21
India	2.1	+ 14
West Germany	-0.2	+ 10
United States	0.7	+ 10
United Kingdom	0.2	+ 12
France	0.4	+ 3
Declining Incomes		
Nigeria	3.0	-28
Argentina	1.6	-21
Philippines	2.5	-16
Kenya	4.2	- 8
Mexico	2.6	- 7
Brazil	2.3	6

Sources Population Reference Bureau World Bank

Figure 16

World Population

Showing Annual Growth Rates

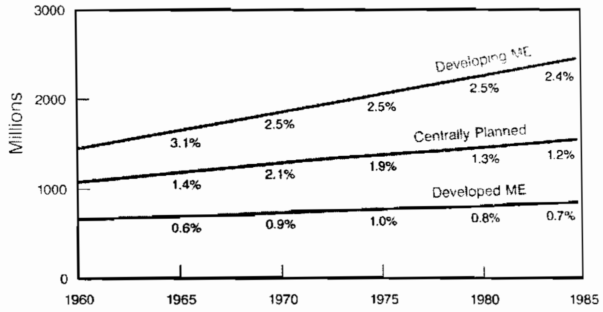


Figure 17

World Phosphate Fertilizer Consumption

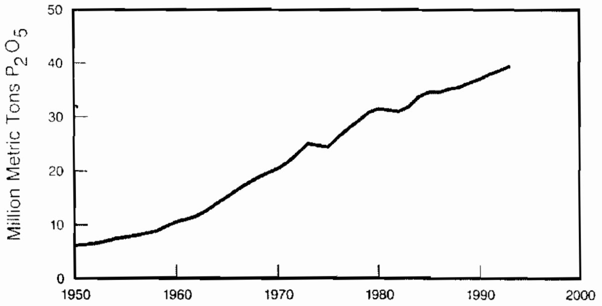


Figure 18

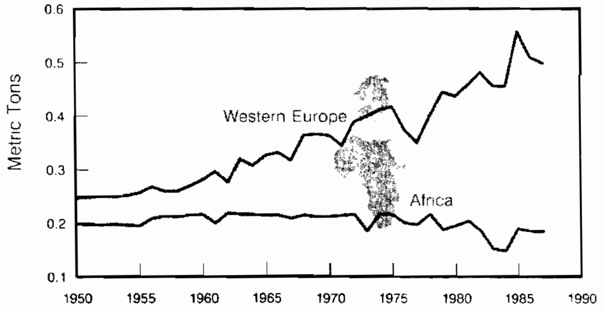
Landless Rural Households - India

Year	Landless Households (millions)
1961	15
1981	26
2000	44

Source FAO

Figure 19

Grain Production Per Capita



Source U.S Department of Agriculture

Figure 20

Ratios of World Grain Production to Fertilizer Use

Year	Grain Production	Fertilizer Use	Response Ratio
	(million metric tons)		
1950	624	14	46
1955	790	18	43
1960	812	27	30
1965	1,002	40	25
1970	1,197	63	19
1975	1,354	82	16
1980	1,509	112	13
1985	1,674	130	13
1986	1,661	131	13

Source FAO USDA

Figure 21

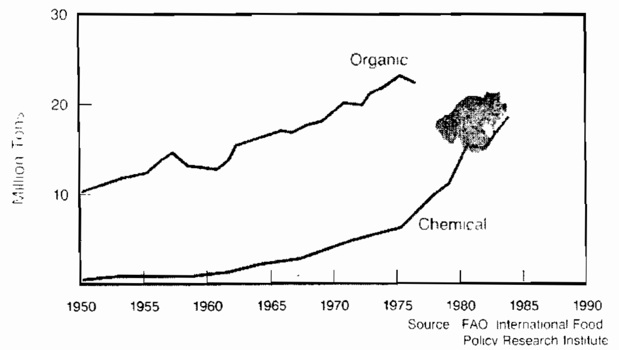
World Fertilizer Use

Year	Total	Per Capita
	(million metric tons)	(kilograms)
1950	14	5
1955	18	7
1960	27	9
1965	40	12
1970	63	17
1975	82	21
1980	112	26
1985	130	26
1986	131	26

Source FAO USDA

Figure 22

Fertilizer Use in China



Source FAO International Food Policy Research Institute

Figure 23

Annual Phosphate Fertilizer Consumption

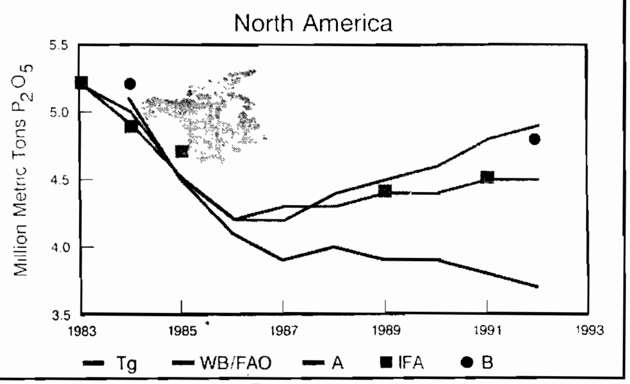


Figure 24

Factors Suggesting Reduced U.S. Phosphate Consumption

- Lower Global Growth Rates
- Stronger Competition from Abroad
- Environmental Pressures
- Industry Consolidation
- Industry Bankruptcies
- Lack of Major Expansions
- Low Grain Prices
- High Grain Stocks

Figure 25

U.S. Wet Phosphoric Acid Production

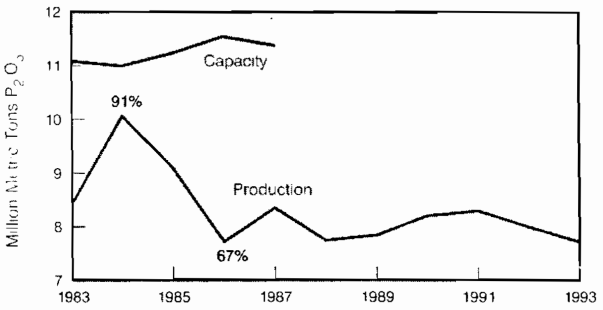


Figure 26

Annual Phosphate Fertilizer Consumption

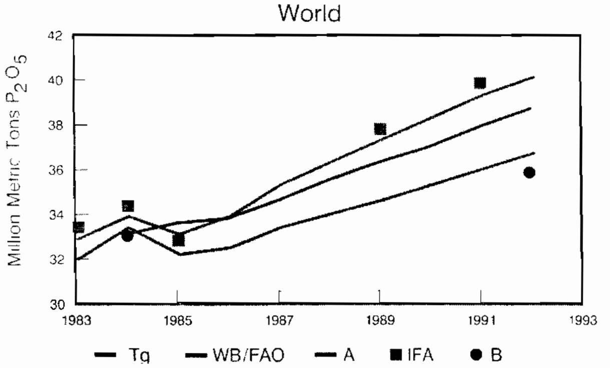


Figure 27

World P_2O_5 Exports

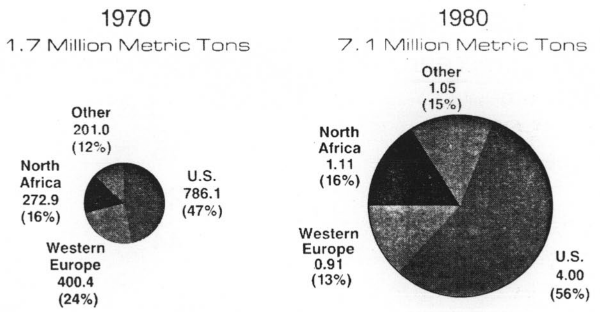


Figure 28

World P_2O_5 Exports

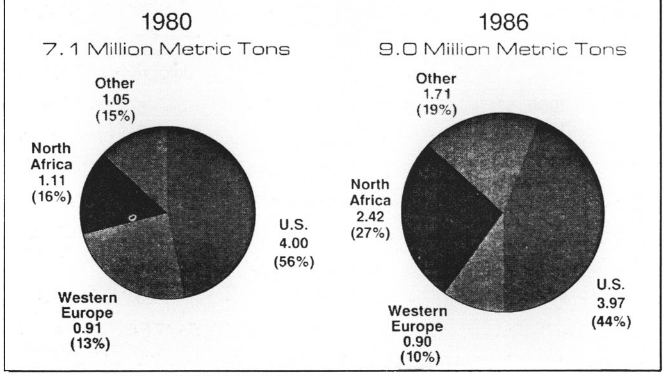


Figure 29

World P_2O_5 Exports

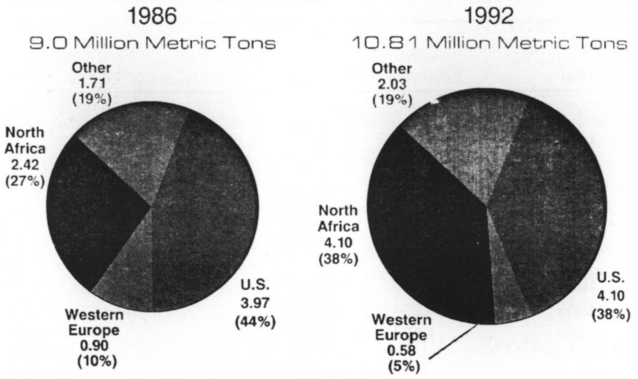


Figure 30

Factors Favoring Foreign Competitors

- Newer, Larger Plants
- Training and Motivation
- High Quality, Extensive Reserves
- Government Support
- Competitive Cost
- Lack of Environmental Constraints

Figure 31

Steps for Survival

- Process Improvements
- Product Innovations
- Efficiency Improvements
- Avoid Oversupplying to Minimize Costs
- Manage More Astutely

Figure 32

The Outlook for Potash

Dr. Raymond W. Payne
Manitoba Energy and Mines

INTRODUCTION

Ever since the introduction of major new production from Saskatchewan during the 1960's the fortunes of the industry have been subject to large cyclical fluctuations.

Occasionally, supply-demand imbalances have generated shortages and very high prices for consumers. Such periods however, have been followed by the emergence of surplus capacity and very low prices. The importance of potash to the Saskatchewan economy has led the provincial government to intervene to support price levels during market downturns. Saskatchewan's role as the largest potash producer in the non-communist world has allowed it to influence price by restricting output.

The period since the 1982 recession has been a trying one for the world's potash producers. Supply capacity committed during the period of relatively high prices came onstream to coincide with a sharp drop in agricultural fertilizer demand and created a prolonged period of excess capacity, low prices, and low industry profitability. These conditions have in turn reduced industry expectations and created a pervasive attitude of pessimism concerning the outlook for potash.

There are, however, indications that the trend of the last five years is in the process of reversing itself. In the short term, a combination of producer restraint and strengthening offshore demand has led to better market conditions in 1987. The recent potash anti-dumping duties assessed by the U.S. Department of Commerce have resulted in the imposition of legislation in Saskatchewan allowing government production controls. Whatever the eventual outcome of the anti-dumping action, the result is likely to be greater production restraint and higher prices.

Over the longer term, the fundamental relationship between potash demand and effective supply capability is expected to narrow considerably by the mid 1990's. On the one hand, while world demand growth is expected to be slower than that experienced over the last 20 years, it is generally expected to average over 2 percent per year through the mid 1990's. On the other hand, the period of rapid potash capacity expansions is now over with relatively few additions planned over the next 5–10 years.

This paper focuses first on the shorter term developments and then reviews the longer term outlook in more detail.

CURRENT SITUATION AND SHORT TERM OUTLOOK

Indications are that the period of severely depressed potash prices which began in 1982 is in the process of reversing itself. During the first half of 1987, the North American price for coarse grade material (f.o.b. Saskatchewan) rose from the $40 per ton range to the high $50 range. With the impact of the preliminary anti-dumping duties prices have risen sharply to $88 per ton. The offshore price for standard grade material, f.o.b. Vancouver has risen from the low $60 per tonne range to the low $80 per tonne range.

This price increase has been the result of a number of demand and supply related factors. On the demand side there has been a recovery of consumption in offshore markets. During the first six months of 1987, Canadian offshore exports increased 24 per cent to 1.6 million tonnes K_2O. This rapid growth was due primarily to increases in Asian demand. It is estimated that potash consumption in Asia grew by 15 percent during the 1986/87 fertilizer year and is expected to grow by a further 9 per cent in 1987/88. After a sharp drop in purchases in 1985/86, China returned to the international potash market in 1986/87 with its consumption increasing from 600,000 to 850,000 tonnes K_2O.

Rapid demand growth in offshore markets was offset, to some extent, by continued weak demand in North America and Europe, a result of the continued global oversupply of agricultural products. North American potash consumption declined by 5 per cent in 1986/87 to some 4.7 million tonnes and is expected to increase only marginally in 1987/88. Western European consumption was basically unchanged at 5.3 million tonnes and is expected to remain at that level through 1987/88.

Overall, world potash demand was up 1.9 per cent in 1986/87 and is expected to be up by another 2.3% in 1987/88. As a result, North American production was up 6% (16% for Canada) in July 1987 compared to July 1986, while inventories were drawn down by 34%.

There are preliminary indications that the world wide agricultural oversupply which has severely affected European and North American producers may be coming to an end. World inventories of most agricultural products have stopped growing, and in some commodities they have started to decline. U.S. corn stocks, for example, fell at the start of the 1987/88 crop year for the first time since 1983.

Two important developments on the supply side have occurred over the past year. First, world potash capacity has been significantly reduced by the sudden loss of 2 million tonnes K_2O of capacity at Berezniki III in the USSR and the PCA mine in Saskatchewan. In addition the Soviet Union has reportedly experienced problems with its new Berezniki IV mine and IMC has been coping with water inflows at its large K2 mine in Saskatchewan. Therefore, in addition to production already lost, 2.4 million tonnes K_2O of world capacity should be considered at risk (7 per cent of world production capability).

The second major development is the anti-dumping case launched against Canadian potash producers and the subsequent introduction of legislation allowing production controls by the government of Saskatchewan. In early 1987, two U.S. potash producers launched an anti-dumping action against Canadian producers alleging that they had been injured by the sale of Canadian potash at less than fair market value. In August, 1987 the U.S. Department of Commerce released a preliminary ruling imposing duties ranging from 9 to 85 per cent on Canadian producers.

Since 80 per cent of U.S. potash is imported from Canada, the major impact of the ruling has been to raise prices for coarse grade product from around $55 per tonne (f.o.b. Saskatchewan) to around $88 per tonne. If these prices hold, it will be the U.S. farmer rather than the Canadian potash producer who will pay most of the cost of the countervailing duties.

A final determination on dumping margins is due on January 8th with a final injury due February 21, 1988. Considerable efforts are being made by Canadian producers and U.S. agricultural groups to reverse the decision. First, as already indicated, most of the cost is being borne by the U.S. farmer. Second, prices in the U.S. market were significantly above the price levels of September 1986 - January 1987, the levels used in the assessment of dumping duties.

However, the reaction of the government of Saskatchewan to the anti-dumping action could prove to be of more lasting significance. In September 1987 legislation was passed allowing the Saskatchewan government to set overall provincial output levels and to allocate production among existing mines. This legislation is similar in concept to that utilized by Saskatchewan in the late 1960's to restrict its potash output. It is not yet clear how Saskatchewan will use its new powers, but it clearly has the capability of maintaining much higher potash prices by restricting production and shipments.

LONG TERM OUTLOOK THROUGH 1996

The longer term outlook over the next decade also points to a significant improvement over the downturn of the last four years. Potash demand is expected to grow steadily at a rate of 2 to 2.5% through the mid 1990's. The projections contained in Table 1 show an average annual growth of 2.3 percent, significantly lower than the 5 percent historical growth in world potash consumption which occurred between 1960 and 1984.

The current shift in demand growth away from the traditional consuming regions of Western Europe and North America is also expected to continue. At an overall growth rate of 2.3 percent, there will be 6.5 million tonnes K_2O of new agricultural demand by 1996. Of this total 3.5 million tonnes, just over half, is expected to occur in the USSR, and another 2 million tonnes in Asia and Latin America.

In Asia, China has enormous underlying potential since its fertilizer application practices are severely potash deficient. China's current nitrogen/phosphate/potassium rate is 1.0:.27:.06 compared to a balanced ratio of 1.0:.55:.4. In other words, China should be using seven times as much potash for each unit of nitrogen.

India also has ambitious plans for increased fertilizer use by the end of the decade. That country's seventh and eighth plan targets saw potash consumption doubling from 1.1 to 2.1 million tonnes K_2O by 1996, although recent agricultural setbacks have revised the 1996 target down to 1.5 million tonnes. In summary, there is potential in Asia for consumption increases well above those projected in Table 2, although these could be offset by slow demand growth in North America.

Table 2 projects the growth in world potash supply capability through 1996. This table is based on committed and announced expansion plans of major producers as of mid 1987. A total decline in capacity of some 1.4 million tonnes K_2O is expected to occur in the United States and Western Europe as older, higher cost mines gradually close.

This loss will be partially offset by 1.1 million tonnes of new capacity in Canada, including the Lanigan and Kalium expansion in Saskatchewan and the achievement of full capacity at the Denison/Potacan mine in New Brunswick.

In addition, 2.2 million tonnes of new or expanded capacity are expected in the USSR and .2 million tonnes in Jordan.

However, there are a large number of projects in various stages of study from preliminary exploration to completed feasibility studies. These total some 13 million tonnes K_2O and can be divided into two categories: those most likely to proceed by the mid 1990's and those least likely to proceed.

As shown in Table 3, the projects most likely to proceed total some 5 million tonnes. They include the rehabilitation of flooded mines in Saskatchewan and the USSR as well as some expansion of existing facilities in the Middle East. Three new mines are at a stage where they could be brought on stream by the mid 1990's. The Manitoba Potash Project is a major high grade deposit located on the same ore body as that being mined by the IMC and PCS mines in Southeast Saskatchewan. Mines in this region have operating costs which are the lowest in the world. A full scale feasibility study was completed in August 1987, and negotiations with potential purchasers and equity participants are now underway.

The other two prospective new mines have higher operating costs but enjoy locational benefits. A solution mine in Michigan would be highly energy intensive but would be located close to the region of highest US potash consumption. A third New Brunswick mine, planned by BP but postponed indefinitely, would be located relatively close to tidewater, thereby enjoying favourable access to Europe and the Eastern United States

Most of the projects considered least likely to proceed by the mid 1990's are in the early exploration stage, lack the required infrastructure, or are in remote deposits for which there is very little mining experience. An exception is the Bredenbury deposit in Saskatchewan which was brought to the feasibility stage but postponed indefinitely and written off by the Potash Corporation of Saskatchewan (PCS) after the downturn in potash markets. However, this project is unlikely to be brought into production by the mid 1990's partly because of the government of Saskatchewan's concern with restraining production to maintain higher prices and partly because of that government's re-evaluation of the status of the Crown-owned PCS.

However, as mentioned above, there is also about 2.4 million tonnes of capacity in Canada and the USSR which is threatened by flooding, as well as the possibility that older mines may deplete at a faster rate than that projected in Table 3.

Figure 2 presents a world potash demand projection of 2.3 percent per annum plotted against three supply scenarios. One supply projection is based only on the committed or announced expansion shown in Table 2. A second, enhanced supply scenario is based on 30 percent of the most likely projects listed in Table 4 coming on stream by 1990 and 60 percent by 1996. It is now extremely unlikely that this enhanced scenario could occur by 1990 given that no firm decisions have been made for the projects listed. However, the addition of 3 million tonnes of announced capacity by the mid 1990's is feasible given a continuation of higher price levels. A third, restricted supply scenario is based on the loss of 2 million tonnes K_2O of capacity, from flooding or other causes, relative to scenario one.

Figure 2 shows a considerable narrowing of the current gap between potash supply and demand through the 1990's. Table 4 shows this narrowing in terms of the ratio between demand and effective production capacity. Historical experience has shown that when this ratio exceeds 90% over an extended period (as was the case during the latter part of the 1970's) supply becomes tight and prices are high.

On the basis of announced expansions only, a period of tighter supply emerges by the mid 1990's with a severe shortage occurring by the middle of the decade. If additional flooding results in the emergence of more restrictive supply, this shortage could emerge by the early 1990's. While enhanced supply would ease the situation, the ratio of supply capacity to demand will be well in excess of 90 percent by the mid 1990's.

CONCLUDING SUMMARY

There is clear evidence that the recent prolonged period of excess potash capacity and depressed prices is coming to an end. Demand is increasing, particularly in Asia, while a combination of flooding and voluntary production restraint is restricting supply. Given the lead time required to bring new projects into production, it is unlikely that new, unannounced capacity can be brought on stream in time to avoid a tightening of the market by the early 1990's. By the mid 1990's at least one major new mine as well as expansions to existing operations will be required to avoid the emergence of a supply shortage.

The most favourable scenario for the longer term future of the world potash industry would see the announcement of these new projects within the next 12 to 24 months. The least favourable scenario would see the emergence of a supply shortage by the mid 1990's with sharply higher prices. While these price levels would benefit producers in the short run, they would create market disruptions and risk setting off another round of capacity over expansion, resulting in lower prices over the longer term.

TABLE 1

WORLD POTASH CONSUMPTION FORECAST

(Tonnes K_2O x 1,000)

	1986	1990	1996
Western Europe	5,094	5,177	5,283
Eastern Europe	9,872	11,115	13,345
North America	4,892	5,320	5,625
Central America	408	463	560
South America	1,542	1,560	1,805
Africa	498	567	675
Asia	3,067	3,757	4,596
Oceania	251	244	274
Agricultural Consumption Subtotal*	25,624	28,203	32,163
Industrial Consumption	745	825	945
Losses	1,388	1,528	1,743
TOTAL DELIVERIES	**27,757**	**30,556**	**34,851**

* This represents an average annual rate increase in agricultural consumption of 2.3 percent from 1986 to 1996.

TABLE 2

WORLD POTASH CAPACITY-BASE CASE

(Tonnes K_2O x 1,000)

	1986	1990	1996
North America			
Canada	9,225	10,365	10,365
United States	1,428	958	658
Total	10,653	11,323	11,023
Western Europe			
France	1,700	1,700	1,200
Federal Republic of Germany	2,275	2,275	2,275
Spain	800	800	600
Italy	200	200	200
United Kingdom	400	400	400
Total	5,375	5,375	4,675
Eastern Europe			
German Democratic Republic	3,450	3,450	3,450
Soviet Union	10,000	11,000	12,200
Total	13,450	14,450	15,650
Asia			
Israel	1,390	1,390	1,390
Jordan	650	840	840
China, Peoples Republic	50	80	120
Total	2,090	2,310	2,350
Latin America			
Brazil	30	150	300
Total	30	150	300
TOTAL WORLD	31,598	33,608	33,998

Note: Potash capacity is the maximum annual production capability that each mine or region could achieve under the most favourable circumstances. It corresponds to supply capability as defined by the FAO/UNIDO/World Bank Fertilizer Working Group.

TABLE 3

POTASH PROJECTS MOST LIKELY TO PROCEED IN FORECAST PERIOD

PROJECT	000 K_2O TONNES
Rehabilitation of PCA Saskatchewan	600
Rehabilitation of Berezniki III - U.S.S.R.	1,460
Expansion - Arab Potash Company	360
Expansion - Dead Sea Works	310
New Mine - PPG Inc. - United States	425
New Mine - Manitoba Potash Corporation	1,200
New Mine - British Petroleum - New Brunswick	700
Subtotal	5,055

PROJECTS LEAST LIKELY TO PROCEED IN FORECAST PERIOD

New Mines - U.S.S. R. - Turkemania & Urals	2,000
New Mine - Fazendhina - Brazil	900
New Mine - Argentina	600
New Mine - Salar de Atacama - Chile	400
New Mine - Ethiopia	900
New Mine - Thailand	600
New Mine - Bredenbury, Saskatchewan	1,800
New Complex - China Lake Qarhan	480
Rehabilitation - Congo Mine	500
Subtotal	8,180
TOTAL	13,235

TABLE 4

WORLD POTASH INDUSTRY PROJECTED CAPACITY UTILIZATION DEMAND AS A PERCENTAGE OF SUPPLY CAPABILITY

	1986	1990	1996
Enhanced Supply	88	87	94
Base Case	88	91	103
Restricted Supply	88	97	109

Sulphur: An Endangered Element?

Paul S. Murphy

Freeport Sulphur Company

The title of my presentation may leave many with the first impression, "here is another sulphur company telling us what we've heard before . . . the world is running out of sulphur." Well, . . . almost.

Quite to the contrary, there are sulphur reserves beyond man's wildest imaginations. Hundreds of millions of tons in sedimentary formations and salt domes, sour gas fields, heavy sulphur crudes, tar sands, volcanic deposits, non-elemental sources from metal smelters and pyrites, etcetera, etcetera. And let's not forget, the phosphogypsum stacks which also contain trapped sulphur. These readily available sulphur resources (with a big question mark on the phosphogypsum) have provided, and will continue to provide consumers with more than enough sulphur in the future . . . for hundreds or possible thousands of years.

You may not have expected a sulphur company to forecast that there will be enough sulphur for everybody . . . that we will not run out! Believe it or not, it's been done with quite regularity for most of the past century. These facts we will discover together.

Let me take you back through history, examine the development of the world sulphur industry we have today, who were and are the players, and what lies ahead. Of course, I won't disappoint you completely, since you know what the climax of my message will reveal.

But first, I feel compelled to point out a message from 50 years ago . . . its point all too clear. The source, a 1938 annual report from the Jefferson Lake Sulphur Company. It reads:

> "It is to be remembered that sulphur is a basic material. The volume of consumption in any country, or in the world, depends upon the general industrial activity . . . The situation means that our sales effort must be in competition with other producers for the patronage of manufacturers of other products and goods who need sulphur for their processes. We cannot stimulate sulphur consumption by any mass appeal of advertising; we can only struggle for our share of a total consumption over which we can exercise, no control, and in these days of troubled economics the purchasers of raw sulphur are seeking their material at the lowest possible prices."

As I said, that was 1938. One of our last outlook assessments was presented in early 1985. The year before, world sulphur demand increased by 3.5 million metric tons. Stock reductions, most notably in Canada, reached their highest level ever. Prices had rebounded by nearly two-thirds and there appeared to be no end in sight. The world was running out of sulphur was the hit song of the day. And then one day it ended.

Today, the situation has changed markedly from 1985. The struggle for a share of the pie has resulted in intense competition. Buyer's became more patient buyers. Sellers became more accommodating, all-the-while insisting things will be improving soon. The somber mood has tempered our once rosey forecasts and just as in 1938, companies are searching for the sign that better times lie just ahead.

The evolution and change in the sulphur business goes beyond the past three, or even the past 50 years. I'd like to take you back even further.

The Date: 1867.

The Place: Calcasieu Parish, Louisiana.

The Event: drilling for oil, the Louisiana Petroleum & Coal Oil Company drilled a 1,200 foot dry hole that was going to ultimately prove a young German engineer's theories. What was discovered in Calcasieu was a gypsum deposit containing sulphur. Early efforts to mine this sulphur proved futile. Trying in vain twice to push cast iron rings through 400 feet of quicksand to forge a shaft to the underground sulphur deposit, the effort proved fatal when deadly hydrogen sulphide gas was encountered. Lives were lost and the project was abandoned.

But on Christmas Day, 1894, to a chorus of oohs and ahhs, Dr. Herman Frasch's theories proved correct. Out of this same salt dome, Frasch and his crew poured hot water into the formation, melted the sulphur and pumped it to the surface. The Union Sulphur Company and the Frasch process were born. For the next several years, Frasch and his company improved the process, increased production and developed markets at home and abroad. The Sicilian native sulphur industry, the largest player in the business at that time, closed its eyes to the events occurring in Louisiana. They were certain the Frasch process was only a short-term phenomena.

Another important event in the sulphur business, and I underscore important, came in Texas on November 12, 1912, when, out of the Bryanmound salt dome, the newly formed Freeport Sulphur Company began producing sulphur using Herman Frasch's hot water process. With a new production source from Freeport, a supply side competitive battle was not far off. The experts reasoned the price of sulphur would soon be depressed beyond belief.

Even Herman Frasch, somewhat myopicly stated that he had all the sulphur he would ever need, and declined to participate in any new sulphur ventures.

On August 4th, 1914, Germany invaded Belgium and the world was at war. The demand for sulphur soared and available stocks were strained.

Between 1914 and 1938, more new sulphur sources were brought on-stream in Texas and Louisiana. The pendulum swayed back and forth, as did prognostications of the future. As with the events of 1912 and the start of Freeport's mine that had led to the foreboding predictions of long-term oversupply, Jefferson Lake's 1938 vision of sulphur being long proved wrong. On December 7th, 1941, Japan bombed Pearl Harbor and the world was at war again; and soon sulphur was in short supply as well.

I'm not going to stand before this assembly and predict Armageddon is coming soon, and that the demand for sulphur is going to double. Today, the world sulphur situation has never seemed more uncertain. Some of the world's sulphur industry sage's believe we're on the threshold of disaster, if not prolonged weakness in prices due to oversupply. "The Russians are coming" is the topic in vogue. Some are uncertain and the others see an apparent deficit just over the next hill, or should I say through the current valley. This last group sees a slightly tempered prospect for Russian sour gas development during the next few years. I'd like to explore the factors at play in brief detail and let you form your own conclusions.

DEMAND

The cornerstone of future sulphur demand is rooted in the demand for fertilizers, notably phosphate fertilizer demand. Industrial—or non fertilizer—uses of sulphur have waned somewhat in highly developed countries in the past two years. However, worldwide uses of sulphur for industrial purposes continues to rise. I should point out that the biggest markets for expected growth in the use of sulphur for industrial purposes, are large unknowns—namely the Soviet Union and China. In the absence of information, we can all be experts, but on balance, the trend of increasing demand for nonfertilizer purposes does appear sound.

Anyone present can throw out a number that may be more correct, but we use a figure of around +200,000 metric tons per year for industrial purposes. Most of this will be used in metal ore leaching and petroleum refining.

When we look at the sulphur demand for agricultural purposes, we have to focus on the world's population which is expanding by about 1.7% per year. Today we have 5 billion people in the world. By the year 2000, over a billion new mouths to feed. I needn't point out that if we are to make any in-roads in improving the dietary standards, agricultural productivity must outpace the increase in population. But by how much seems to be another one of those elusive statistics on which the experts cannot seem to agree.

We estimate world phosphate demand will trend upward at +2.3% per year. When it will deviate from that upward trend line is anybody's guess; but it will. Two years of successive droughts, even moderate ones, would send the demand for phosphate fertilizers spiraling upwards. The excellent weather we have had over the past four years contributed to higher yields and cannot continue—historical averages on this subject tell us so. When it comes to weather, short-term trends mean little.

Our phosphate forecast of +2.3% growth per year translates into a modest increase in annual sulphur consumption, on the order of +1.7% per year, basically because our estimate for industrial demand is lower than that for P_2O_5 growth. Also, sulphur consumption starts from a higher base.

SUPPLY

Now I'd like to turn to the area of supply. I've divided my talk into the four principal components of supply:

Frasch
Recovered
Pyrites
Sulphur in Other Forms

Elemental sulphur, in simple terms, the yellow kind of sulphur we all visualize, the sources include Frasch or native sulphur and that which is recovered in processing petroleum products. *Frasch* sulphur is mined using water or steam, whereas, *native* sulphur mining can be as simple as picks and shovels or as complex as utilizing large excavation and dragline equipment. The latter usually requires a flotation plant to remove the sulphur from clays, limestone or gypsum.

Recovered elemental sulphur comes from natural gas processing or high sulphur crudes which are removed in refineries. Sulphur from this source represents the largest single component of production in the world today.

Next we will focus on the use of non-elemental sources such as *pyrites* which are high sulphur containing metallic ores such as iron, copper, lead or zinc sulphides. This material is roasted in a furnace where the SO_2 gases are then converted into sulphuric acid.

The last form of material we will put in a category called *sulphur-in-other-forms* (SOF). SOF comes principally from metal smeltering operations as a by-product. In the past, smelters did not have adjacent recovery systems to capture the sulphurous gases emitted during the process. However, today many governments are requiring these operations to reduce acid-rain emissions. In the future, flue or stack gas emissions from coal burning units could yield significant volumes of sulphur.

FRASCH/NATIVE

Focusing on Frasch sulphur and native sulphur, the major sources include the United States, Poland, Mexico, the USSR and Iraq. Although exploration efforts have identified other sulphur bearing structures, one in Poland (Osiek) and other structures in

Iraq (near Mishraq) which could be mined using the Frasch process, no specific construction plans are in process to bring these deposits into production.

The only known deposit which we know will be brought into production in the forecast period, is called Otapan and is located in the Isthmus of Tehauntepec in Mexico. Although production at this mine could increase to between 300,000 to 600,000 tons per year, production at Jaltipan and Texistepec, two of Mexico's older mines, is expected to decline and offset the increase in latter forecast years.

In Poland, the status quo is expected. In spite of the aging mines at Grzybow, Jeziorko and Machow have large reserves; over 100 million tons. The Osiek mine is not under construction as many "experts" had insisted and could take longer than expected.

I can not intelligently assess the Soviet Frasch and native mines but will only mention them in passing. Let's be generous and assume things won't change.

The last area for known or existing Frasch(able) deposits are located in the United States. The three existing producers include Freeport, Texasgulf and Pennzoil. Pennzoil has the largest reserves, followed by Freeport and then Texasgulf. Our position on reserves is quite public and could be termed critical in the latter years of this forecast. Without a new discovery, neither Texasgulf nor Freeport will play a major role, if any, in the 21st century, from U.S. production sources.

I should note that as Frasch mines near their exhaustion, recovery rates go down and the "nameplate" capacity means nothing. Without a near-term start-up in Tg's Commanche Creek, or our own idled Caminada mine, annual U.S. Frasch production capability is below 4 million tons. Allowing for depletion of Boling Dome (Tg), Garden Island Bay (Freeport) and Grand Isle (Freeport), the capability will decline to less than 2.5 million tons.

All together, annual world Frasch production capability should decline by a total of 2.5 million tons by 1995.

RECOVERED—SOUR GAS PROCESSING

Turning to recovered elemental sources of sulphur, I'm going to briefly mention the major changes in the outlook from sour gas processing.

France—a continual drop from Lacq.

Iran and Kuwait—slightly higher.

Canada—no real increase until the Caroline field is brought into production, and then a net decline towards the latter end of the horizon.

U.S.—a conservative forecast would show no change, but realistically we can see a net trend downward.

Saudi Arabia—a slight upward trend is probable.

All totaled and, for the time being, excluding the Soviet Union, a net increase of less than 100,000 tons per year from sour gas.

I'm purposely going to save the Soviet Union details for last.

RECOVERED—REFINERIES

In world refinery sulphur production, only minor increases in output are expected. On the order of 200,000 tons per year or less. A sharp upward change in real energy prices could push this forecast off course, however. Also, crude oil suppliers pricing terms have a bearing as well.

At the first of this year, Middle Eastern suppliers eliminated the use of netback pricing arrangements. We feel this produced a significant downturn in U.S. refinery sulphur production through the first nine months of 1987. In the absence of these arrangements, U.S. refiners switched back to sweeter crudes from closer sources.

PYRITES

Switching to pyrites, one of the oldest sources of sulphur, we find an increasing likelihood that environmental pressures of cinder disposal may limit further development within this sector. Pyrites, or iron sulphides, come in basically crude or complex ores and are crushed and burned in roasters to capture the sulphurous gases. Although the process yields sulphuric acid for use in local industries, it ranks as one of the highest cost sources from voluntary sulphur sources. At today's brimstone prices, no investment in such a venture would prove feasible. In our opinion, an optimistic forecast for pyrites as a sulphur source would be for no change from current production. We believe that any increase in state run enterprises, in say China or the USSR, will be met with matching decreases in Europe, where ecological concerns are gaining importance.

SOF

The last category of sulphur is the "all-other" or sulphur-in-other-forms (SOF). The bulk of production in this category comes from adjacent sulphuric acid units in metal smelting operations. In copper, zinc, nickel, lead and gold production, most smelting operations end up producing SO_2 gases which were vented off into the atmosphere. As governments became more conscious about acid-rain issues, smelting operations were required to install sulphuric acid units to reduce or eliminate such practices.

The difficult aspect of forecasting changes in the output of sulphur from this source, is that it presupposes one knows about the future of the metals markets. I assure you, we don't know any better than the next "expert" the vagaries of this highly complex sector. What we can examine, however, is the current or plausible projects to construct sulphur recovery systems at metals smelters.

The major changes are all copper based smelters located in Canada (Noranda), Chile (Codelco) and Mexico (Mexicana de Cobre). Together with other small additions, a total increase of a million tons of non-elemental sulphur can be expected from this source before the mid 1990's. We do not expect a major contribution from utility flue gas desulphurization to take place in the period in question. For simplicity, an average increase of 100,000 tons per year for the next ten years.

SOVIET UNION

I would like to concentrate on the future production source which will have the single greatest bearing on the world supply/demand picture. This being the new massive Soviet sour gas projects, most prominently—Astrakhan.

Located just East of the Volga River on the Northwestern perimeter of the Caspian Sea, this major development is expected by many to be producing more sulphur by 1991 than is produced by the 50 or so sour gas processing plants presently operating in Canada.

One of the critical elements surrounding the Soviet plants' production capability involves the content of the H_2S contained in the Astrakhan gas. The average range has been quoted from 9% up to 29% H_2S.

"Glasnost", the new Soviet openness policy, doesn't include details about this project.

Again, as it was in the case of native mined sulphur in the Soviet Union, we don't know. Nor does anyone else, as you can see by this slide. The range between high and low forecast for new Soviet sour gas production is around 4 million tones by 1990.

SUPPLY/DEMAND BALANCE

So in arriving at the world supply/demand outlook for sulphur, we see a picture such as this. A decline in Frasch and native sulphur. An increasing contribution from the petroleum processing sector, principally the USSR. A slight increase from by-product smelters and a constant level of sulphur from pyrites.

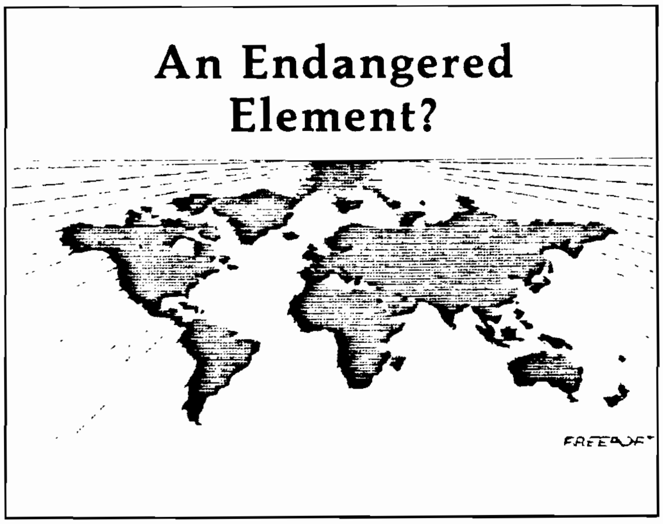
If we lay our demand and stock change figures on top of this, you now see how we view the world. We recognize just as unpredictable events occur on the demand side, so too in supply. The deficit will not occur. We will not consume more than does not exist. The gap will be filled.

Today there are increasing exploration efforts by companies who must hold the same view as we. Had Herman Frasch recognized Calcasieu did not contain all the sulphur his company would ever need, the Union Sulphur Company might still be in business today. Unlike their fate, Freeport plans to be producing from new resources well into the 21st century.

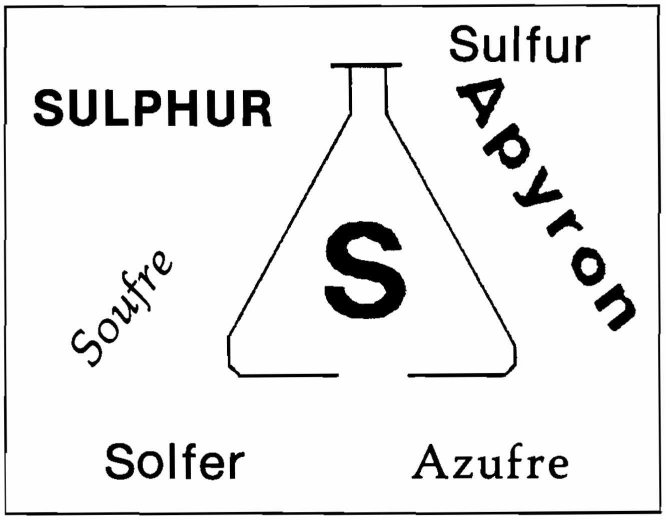
Worldwide, exploration and development projects by several companies are underway in Chile, Bolivia, the Philippines, Canada, The Mediterranean, and the Middle East. In Egypt, we will begin drilling in the Sinai this month. The conditions appear right, but there are no guarantees.

Closer to home, the three existing U.S. Frasch suppliers have all maintained a presence in West Texas exploring for sulphur. And an offshore lease sale for the privilege to probe the salt domes located off the Louisiana and Texas coasts is slated for January. Interests appear high.

Will there be too much, or not quite enough? The controversy has been debated for a long while. The debate continues.



An Endangered Element?



Sulfur

SULPHUR

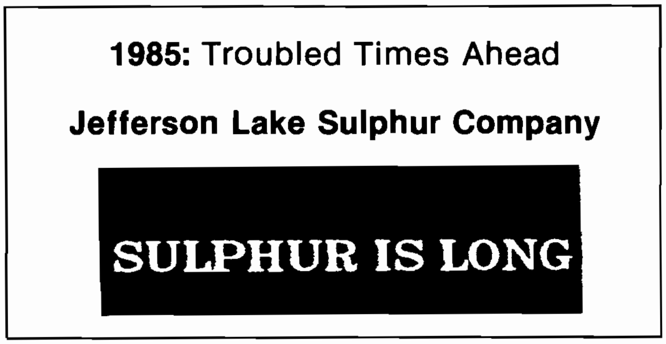
Apyron

S

Soufre

Solfer

Azufre



1985: Troubled Times Ahead

Jefferson Lake Sulphur Company

SULPHUR IS LONG

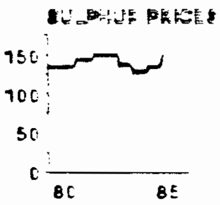
1985: The Future Looks Bright

1984 WORLD DEMAND CHANGE

+3.5 MM

CANADIAN STOCKS CHANGE

-2.8 MM

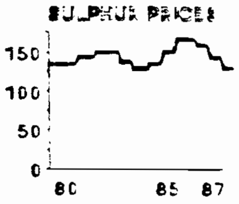


SULPHUR IS SHORT

1987: The Situation Worsens

1986 WORLD DEMAND CHANGE

-1.2 MM



SULPHUR IS LONG

1887: Calcasien Parish, Louisiana

1894: Dr. Herman Frasch

"IT WORKS"

Union Sulphur Company

1912: Bryanmound (Texas)

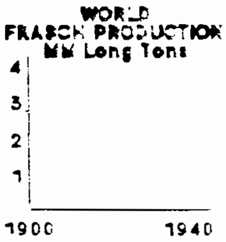
FREEPORT

Sulphur Company

SULPHUR IS LONG

1914-85: New Frasch Mines

Big Hill
Long Point
Hoskins Mound
Jefferson Island
Big Creek
Grande Ecaille
Palangana
Clemens Dome
Boling Dome
Orchard Dome

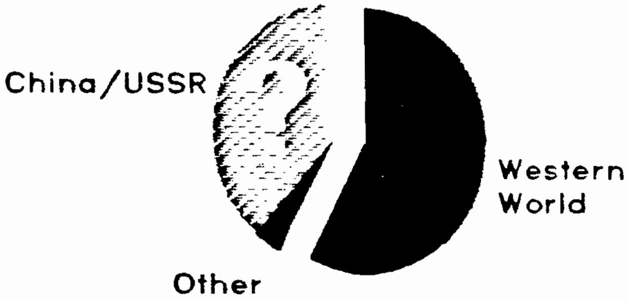


Tomorrow: The "Experts" Opinions

Sulphur Is Long	Somewhere In Between	Sulphur Is Short
FERTECON	PETROMIN	CANSULEX
		INTCAN
BSC		
	ICI	IMIC
SNEA		
		WORLD BANK
TEXASGULF	IFA	PENNZOIL

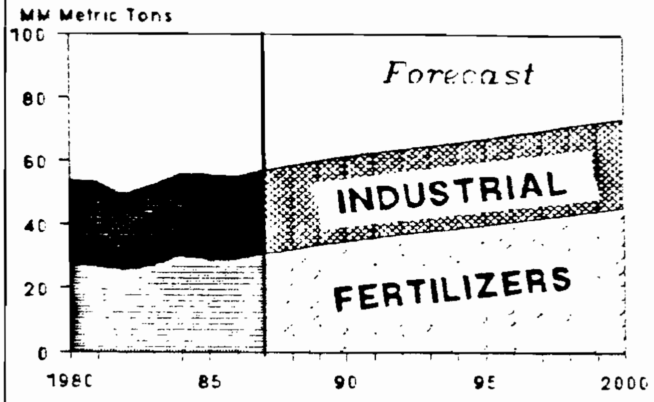
- Fertilizers
- Industrial

SULPHUR DEMAND FOR INDUSTRIAL PURPOSES

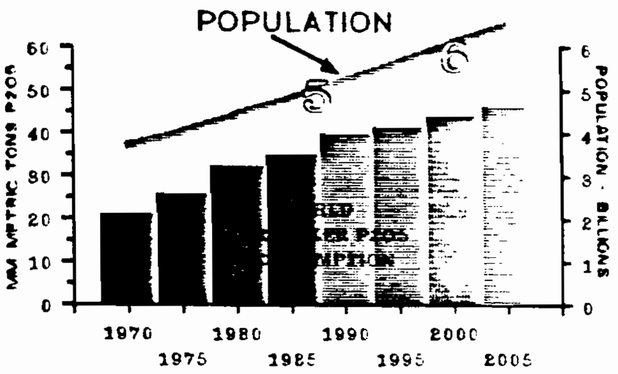


WORLD SULPHUR DEMAND

Components of Demand

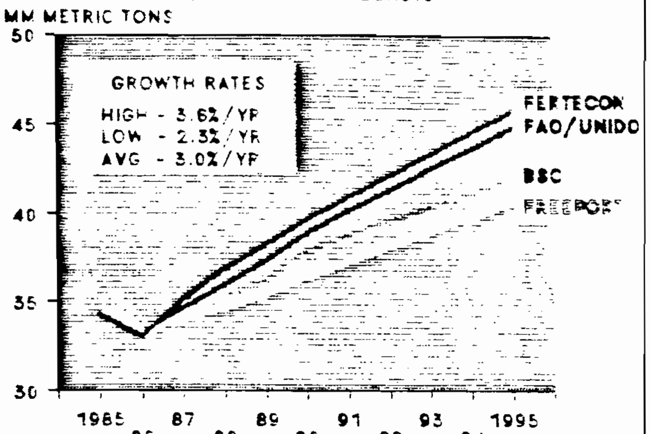


2:6 NEW PEOPLE ARE ADDED EVERY SECOND



WORLD PHOSPRATE DEMAND

COMPARATIVE FORECASTS



- Elemental
- Non-Elemental

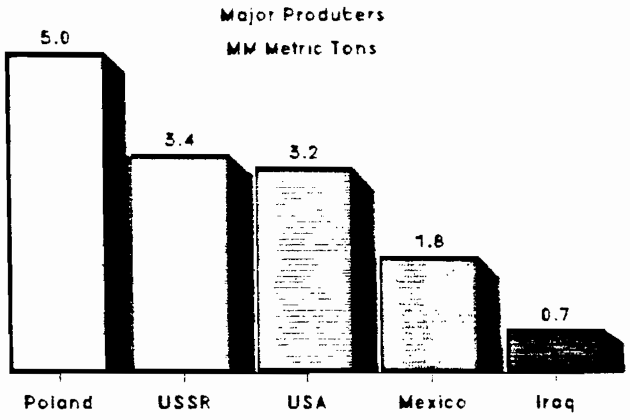
SUPPLY SOURCES

(A) Frasch/Native
(B) Recovered Petroleum

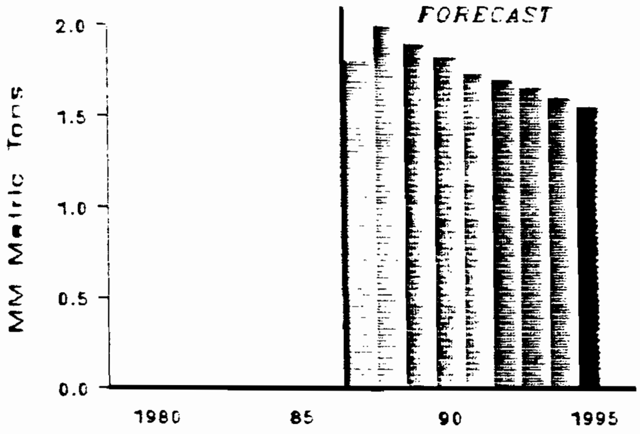
NON-ELEMENTAL

(C) Pyrites
(D) Sulphur-in-Other-Forms

Estimated 1987
FRASCE/NATIVE SULPHUS PRODUCTION



MEXICAN FRASCE SULPHUR PRODUCTION



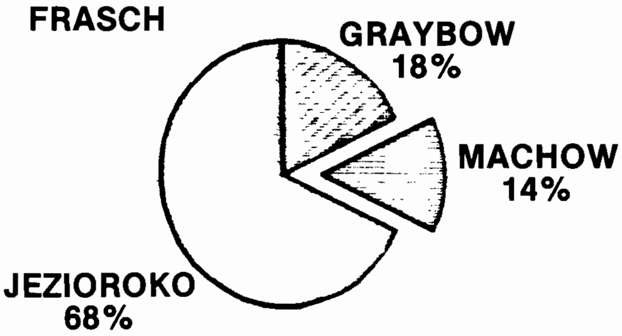
FRASCH/NATIVE SULPHUR PRODUCTION IN THE USSR

?

ASSUME NO CHANGES

SULPHUR PRODUCTION IN POLAND

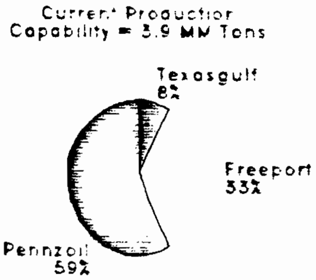
Operating Mines

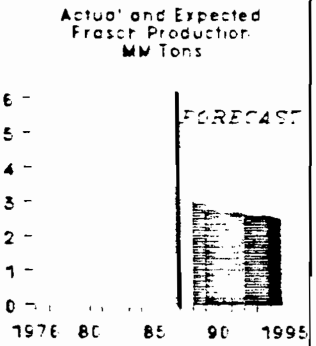


OPEN-PIT

Oslek - In Planning Stages

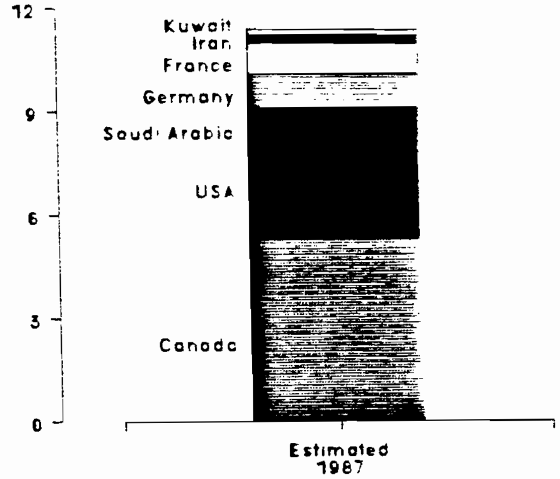
U.S. FRASCH SULPHUR SITUATION AND OUTLOOK





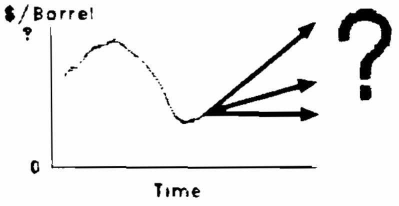
Gas-Recovered Sulphur Production

Major Producers, Excluding The Soviet Union



Oil-Recovered Sulphur Production

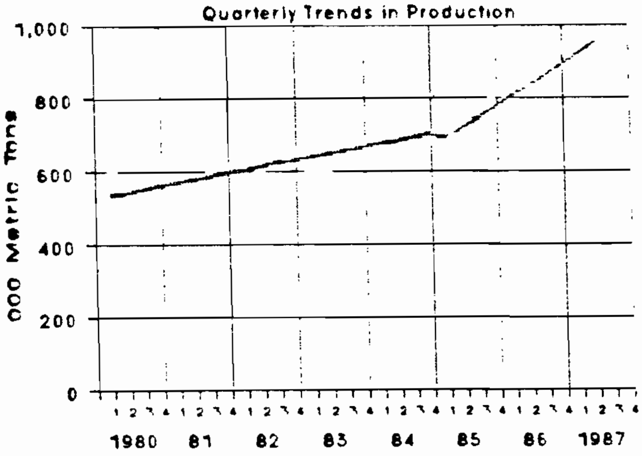
Heavily Dependent On
Energy Price Forecast



+200,000 TPY "S"

U.S. REFINERY-RECOVERED SULPHUR PRODUCTION

Quarterly Trends in Production



PYRITES

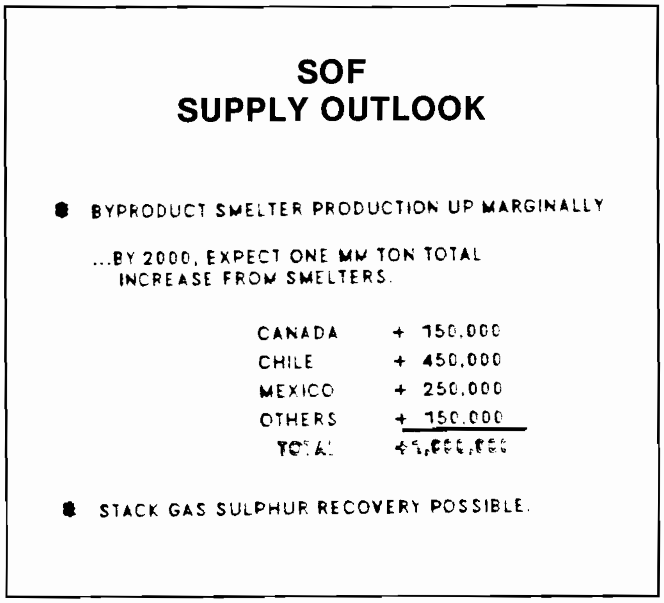
Issues Surrounding Future

- New Projects Uneconomic Today
- Transportation Disadvantage
- Environmental Concerns High

SOF

(Sulphur-In-Other-Form)

- By Product of Metal Processing
- Market factors complex
- Economics not tied to merchant sulphur market



SOF
SUPPLY OUTLOOK

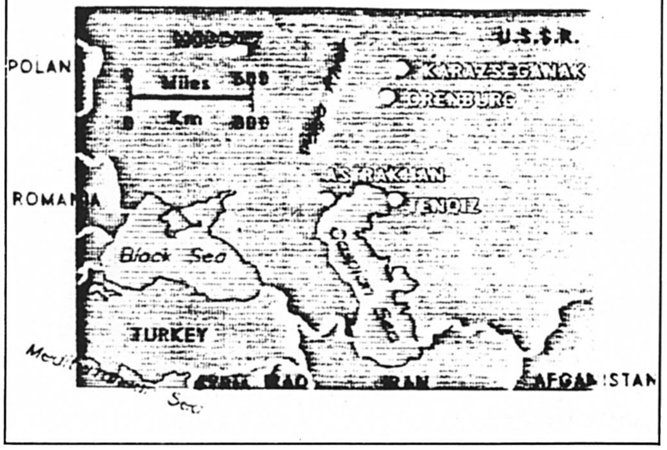
- BYPRODUCT SMELTER PRODUCTION UP MARGINALLY

...BY 2000, EXPECT ONE MM TON TOTAL INCREASE FROM SMELTERS.

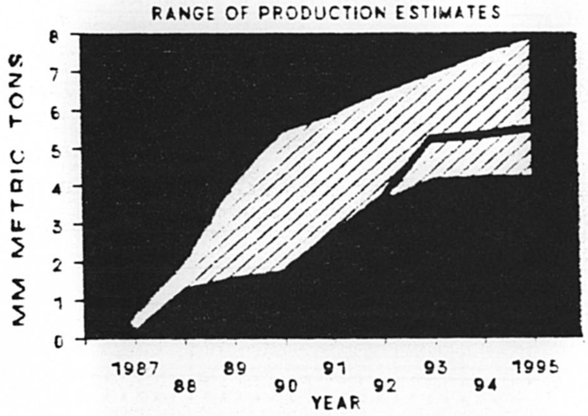
CANADA	+ 150,000
CHILE	+ 450,000
MEXICO	+ 250,000
OTHERS	+ 150,000
TOTAL	+1,000,000

- STACK GAS SULPHUR RECOVERY POSSIBLE.

MAJOR U.S.S.R. SOUR GAS PROJECTS

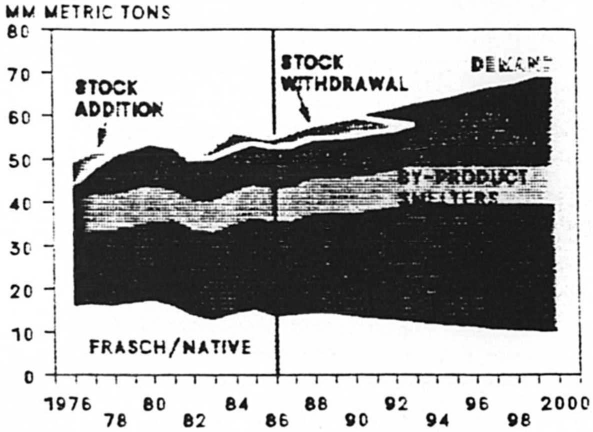


WORLD SULPHUR SUPPLY / DEMAND



SOURCES: BSC,FERTECON,INTCAN,U.S. GOVERNMENT

U.S.S.R. INCREMENTAL SOUR GAS SULPHUR PRODUCTION FORCAST



Phosphate Fertilizers: The Costs of Production of Major Manufacturers; Do Production Costs Matter?

Ken Gilbert and Terry Phillips
The British Sulphur Corporation, Ltd.

Over the last 6 months my colleagues have been studying the costs of making fertilizer phosphates and the results of their endeavors will appear as a multiclient study in a few days time. As a group we have a great deal of experience in the field. About 18 months ago we completed an ammonia costs multiclient study which was very well received and over the years we have carried out many ad-hoc studies on the costs of specific processes, specific mines and plants, groups of plants and whole industries. It has always helped in these studies that in the normal course of our work we follow, on a day-to-day basis, raw materials and finished products prices and freight costs and handling and storage costs.

For our present work on phosphate fertilizer production costs we have looked at major plants throughout the world on a 1986 timebase. We will also present estimates for 1987 and we will examine trends for the future. We will present costs for the manufacture of sulphuric acid, phosphoric acid, DAP and TSP on specified sites. Our objective has been to provide an up-to-date study in which the U.S. and the rest of the World are dealt with on a truly comparative basis. We also consider that the competitive position between U.S. plants is very important, particularly in the light of recent changes of ownership.

Although there are some people in the industry who say "Why should we be concerned by the costs of our overseas competitors when these competitors are ignoring cost when deciding on their selling prices", we believe that an understanding of these matters is vital to any business, private or state-owned, that wants to operate in the most effective and "profitable" way in the long run. Of course production cost is not the only thing to be considered but it is, we believe, a very important element in the overall picture. It was Maynard Keynes the economist who is supposed to have remarked "in the long run we are all dead" but the long run does matter, particularly to an industry based on mining operations and where cost differences are important in determining the future shape of the industry.

Another factor which influenced our decision to proceed with the study was that there is little information about costs of production for large parts of the world's phosphate fertilizer industry. The U.S.A. is quite well provided with indicative costs by way of the excellent Fertilizer Institute analyses and from other sources but much less is known about producers outside North America from where the main competitive pressures are coming. Myth and supposition abound. We hope to throw light on these less well known areas and compare them with our own assessments of Western producers.

Our costs will be presented for 1986 and 1987 for individual plants operating at capacity and at their actual 1986 onstream factors and estimated 1987 onstream factors. We have used the convention that the product of one stage is transferred to the next stage at variable cost so that we can give total variable cost as well as total fixed cost, total operating cost and total production cost. The layout of the production cost summary sheet is given in the appendix.

For this presentation we concentrate on phosphoric acid and DAP. All the phosphoric acid plants covered in this paper are di-hydrate although we will include some semi-hydrate plants in the final report.

From our preliminary work we have costings of 20 phosphoric acid plants on 13 sites. The total capacity of these plants amounts to about 9.24 million t/a and unit size varies from 380–1815 t/d. They are situated in West Europe, North Africa, Northwest Africa, Middle East and U.S.A. The U.S. plants are in Florida, North Carolina and on the Mississippi. There are integrated and non-integrated (with respect to phosphate rock) plants. Some are inland and some at deep water sites. Some are privately owned and some are state owned.

A point on units. We use tonnes (t) and calculate on the basis of 54% P205 phosphoric acid. Costs in local currencies are converted to US dollars at the published annual average rates. Changes in relative exchange rates can have a profound effect on competitive costs and as exchange rates fluctuate rather quickly and widely at present, these effects have to be watched carefully.

If we examine raw material input costs first (Fig. 1), we find that the average variable cost for phosphate rock was $82/t phosphoric acid P205. The range of phosphate rock cost was wide—$31–135/t phosphoric acid P205. Phosphate rock accounts for 5–48% of total cost for the producers examined. The companies with well below average phosphate rock costs are OCP, IMCC, TGC and SOM. The companies with the highest costs of phosphate rock are the European importers (where variable cost does not come into it), the Mississippi River plants and Jordan Fertilizer Industries (JFIC) which, although a rock producer, has poor rock production economics. JFIC's position should improve when the mine at Shidiya is brought into production.

The 2 European plants in the 20 examined are able to take phosphate rock in substantial shipments directly into plant. There are some European phosphoric acid plants which are sited inland and which take rock by barge. Unless these plants make industrial phosphates or have some other differentiating or compensating feature they would appear to be in a very uncompetitive cost position. Although not in the 20 plants considered here (they will be in the final report) the 2 Prayon-Rupel plants in Belgium are interesting in this regard. They have a good cost position despite being inland as they are able to use low cost smelter sulphuric acid or their own sulphuric acid made from pyrites. This advantage alone would not secure their survival but they also have a product mix advantage in that they convert a high proportion of their phosphoric acid to high quality, non-fertilizer, phosphates.

The TFI cost analysis for 1986 gave an average cost of phosphate rock to large plants (400,000 st/a) of $20.79/t rock which at a utilization of 3.5t rock/t P205 is a cost of about $73/t P205 as phosphoric acid. The US plants in our sample of 20 are in this size category. Our average is also $73/t P205 but the range is wide at $47–116/t P205.

The range of variable input cost for sulphuric acid is narrower than that for phosphate rock but significantly higher (Fig. 2) at $73–148/t phosphoric acid P205 with an average of $110/t. Sulphuric acid accounts for 41–61% of total costs of production of the 20 plants examined. The variable cost of sulphuric acid charged to the phosphoric acid plant already has energy credit for both co-generation and process steam taken into account. Where co-generation plants exist they are taken to be part of the sulphuric acid plant and therefore all credits for power and low-pressure steam acrue to the sulphuric acid plant.

All the 20 phosphoric acid plants costed are on sites on which sulphuric acid is also produced but 2, in Florida, also buy sulphuric acid to meet part of their needs. In 1986 these purchases cost fractionally more than variable cost of production.

The companies with well below average costs of sulphuric acid in 1986 were SOM, ICS (Senegal), the

Mississippi River plants and TGC. The companies with above average costs were in North Africa and Europe.

When the 2 main raw materials, phosphate rock and sulphuric acid, are taken together there are compensations for some producers (Fig. 3). The range of total raw material cost is $151–256/t phosphoric acid P205 with an average of $192. The range of 1.70 (highest as a multiple of lowest) is less than those for phosphate rock (4.35) and sulphuric acid (2.03). It is interesting to note that the US plants costed, all fall below the average, as do OCP (Jorf Lasfar), SOM and ICS. Significantly higher than average are the European plants, JFIC, and the Tunisian plants.

Of concern to some producers should be the fact that their costs of raw materials alone exceeds the total manufacturing costs of others.

Raw materials account for 61–96% of total costs at the operating level.

Although cost of raw materials is of crucial importance, costs other than raw materials (utilities, process chemicals, gypsum disposal, operating labor, maintenance materials and contract labor, overheads, the fixed element of sulphuric acid and phosphate rock costs and capital charges less credits for uranium and fluorine compounds) are found to vary from plant to plant to a much greater extent (Fig. 4).

At 100% capacity utilization these costs range over a factor of 8.14 from $22–179/t phosphoric acid P205 with an average of $72/t. At the operating level they range over a factor of 15.25 fro$28–427/t with an average of $98/t. It is salutary to remember that anything over about $280/t for 1986 would mean that raw materials would have to be available at nil cost for the operation to break even.

The plants at the bottom end of the range are those that are fully written off with some credit for by-products. An example is Freeport at Uncle Sam. A new plant such as that at Jorf Lasfar has very high capital charges and thus pays an enormous penalty for operating at a low capacity utilization. The capital cost of Jorf Lasfar amounted to about $374/t P205 capacity whereas a plant built in the mid-1970s in the US would have had a capital cost of about $42/t P205 capacity.

Of the 20 plants costed in this preliminary exercise, 13 have by product credits. The value of these credits range from about $1–25/t phosphoric acid P205. The highest credits arise from uranium recovery and depend on advantageous contracts which probably could not be negotiated today at anything like the same price.

At the total operating cost level (total variable cost + total fixed cost) for 1986 at the operating level, costs ranged from $181–335/t phosphoric acid P205 with an average of $258/t (Fig. 5). Significantly below the average level were IMCC, TGC, the Mississippi River plants and SOM. Significantly above the average were the European and North African plants.

Finally at the total production cost level (total operating cost + capital charges) at 1986 operating rates, the range is $216–593/t phosphoric acid P205 with an average of $290/t P205 (Fig. 6). The capital charges consist of depreciation (15 years linear), finance charges, and the capital costs contributions of gypsum disposal and sulphuric acid. Calculated on a 100% capacity utilization basis total production costs range from $210–344/t P205 with an average of $264/t.

All the US plants in the 20 covered in this preliminary exercise operated at a cost well below the average in 1986 but as the average cost, at $290/t P205, was above the average selling price for phosphoric acid for 1986 of $280/t P205 fob US Gulf, the overall position of the industry is far from satisfactory.

The Moroccan plant included in this analysis is that at Jorf Lasfar, the most recent and, therefore, the complex with the highest burden of fixed costs. Also to be included in the final report will be the other major phosphoric acid plants in Morocco. These should have significantly lower total production costs. The present indication is that their total production costs will have averaged $260/t at 100% capacity and something like $310/t P205 at the actual operating rate for 1986.

The average selling price for phosphoric acid in 1986 were about $280/t P205 fob US Gulf and $286/t fob North Africa. The net-backs to manufacturing plant would obviously be a little less than these figures on average with Central Florida plants being at a disadvantage to plants at deep sea locations. The comparison of this level of selling price with the elements of cost is shown in the figure (Fig. 7).

The DAP costings available for this paper were somewhat restricted in number. They cover 8 companies, 5 of which are in the US and a total capacity of about 10.3 million t. The range of (calculated) cost at 100% capacity utilization for this rather small sample is (Fig. 8):

Raw materials	$ 98-147/t
Total Variable	$101-148/t
Total Fixed	$ 16- 37/t
Total Production Cost	$140-233/t product

The ranges for the 5 US companies are:

Raw Materials	$ 98-121/t
Total Variable	$101-124/t
Total Fixed	$ 16- 23/t
Total Production Cost	$140-152/t

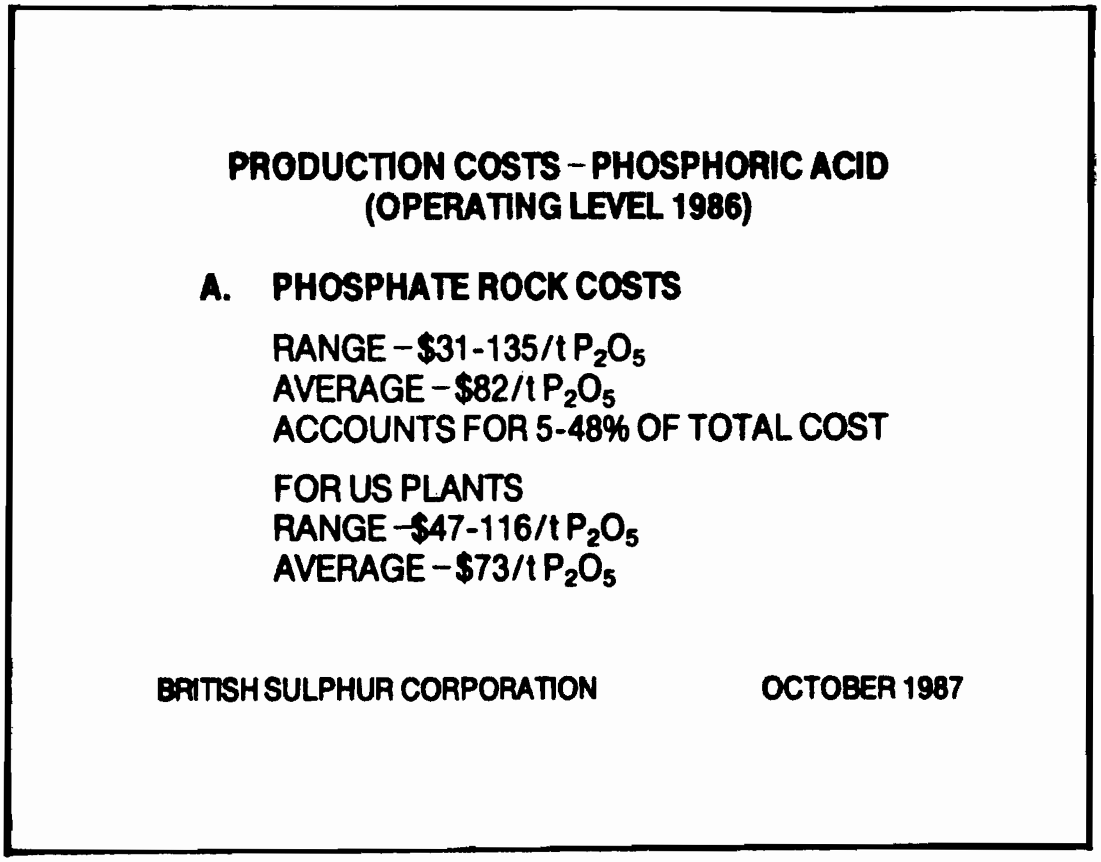
The figures for costs at the 1986 operating rate are not strictly comparable as Moroc Phosphore 3&4 is included in the 8 and this plant did not operate in 1986. The range of total production cost for the other 7 is $149–244/t product with the range for the 5 US companies being $149–179/t product.

The average selling prices for DAP in 1986 was about $154/t product. The comparison of this level of selling price with the elements of cost of production is shown in the figure (Fig. 9).

The largest element of cost for DAP is phosphoric acid cost. This varied over the range 66–76% of total production cost at the 1986 operating rate. Phosphoric acid at Moroc Phosphore 3&4, at 100% capacity utilization, would have accounted for about 69% of total production cost. Ammonia cost varied over the range 9–17% of total production cost at the 1986 operating rate.

These production cost analyses suggest that the existing major producers in the U.S.A. were competitive with other major World producers in 1986 despite not having the lowest phosphate rock costs. As far as raw materials are concerned, sulphuric acid is the great leveller as none of the major producers outside the U.S. have its own sulphur. Sulphur cost more per unit of P205 produced than did phosphate rock for most manufacturers in 1986. 1986 was a year of low average oil prices and so the energy credit from sulphuric acid manufacture was depressed. The 1987 situation will be somewhat different as sulphur prices are lower and energy prices higher. Despite these fluctuations it seems likely that the sulphur suppliers are still going to take a large slice of the turnover of the phosphate fertilizer industry in future years. The competitive position of the major U.S. producers in costs of production terms also depends in part on low capital costs per unit of P205. This advantage would not apply to a new plant in the U.S. where the incidence of capital charges would be much higher.

The cost analyses presented in this paper (which are to be considerably extended and more thoroughly discussed in the published multiclient report) show clear differences between producers and provide a measuring stick for competitor analysis and suggest possible avenues for cost reduction. They do not, of course, provide a "survival index" of the plants covered. Costs of production do have a bearing on survival but there are other factors such as ownership, the provision of employment, location, delivery logistics and environmental restrictions which are also important. We will address some of these, including the very important matter of delivery costs, in the final report. We are providing some pieces of a jigsaw puzzle. You will have others. None of us have them all. And what is more—the picture, full of holes as it is—will have changed when we next sit down at the table. That is what makes it so interesting.



PRODUCTION COSTS – PHOSPHORIC ACID (OPERATING LEVEL 1986)

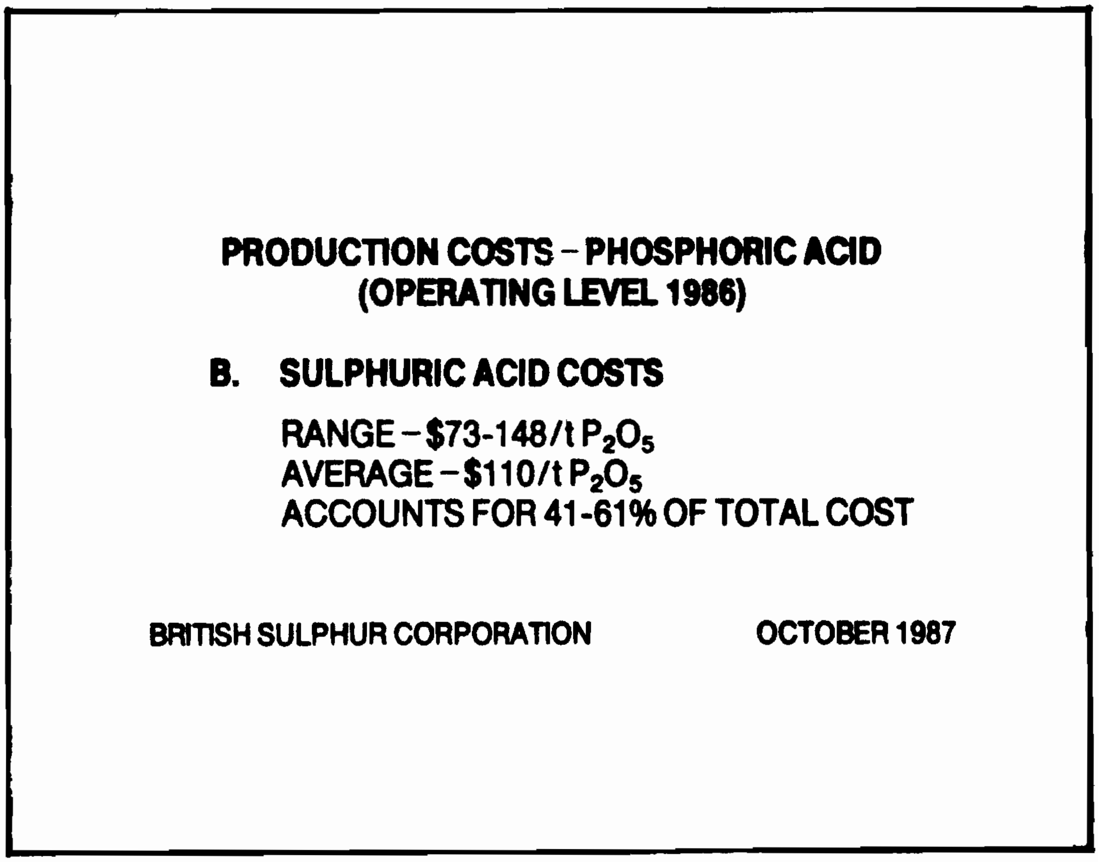
A. PHOSPHATE ROCK COSTS

RANGE – \$31-135/t P_2O_5
AVERAGE – \$82/t P_2O_5
ACCOUNTS FOR 5-48% OF TOTAL COST

FOR US PLANTS
RANGE – \$47-116/t P_2O_5
AVERAGE – \$73/t P_2O_5

BRITISH SULPHUR CORPORATION OCTOBER 1987

Figure 1



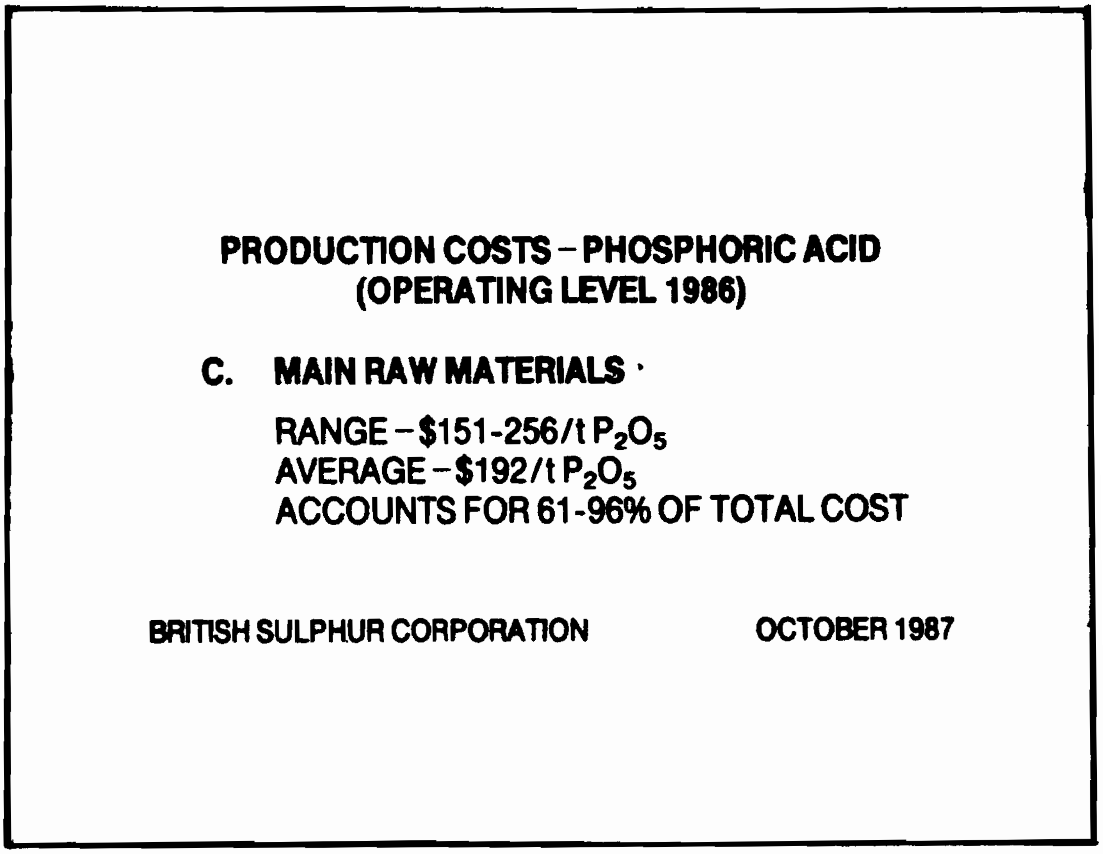
PRODUCTION COSTS – PHOSPHORIC ACID (OPERATING LEVEL 1986)

B. SULPHURIC ACID COSTS

RANGE – \$73-148/t P_2O_5
AVERAGE – \$110/t P_2O_5
ACCOUNTS FOR 41-61% OF TOTAL COST

BRITISH SULPHUR CORPORATION OCTOBER 1987

Figure 2



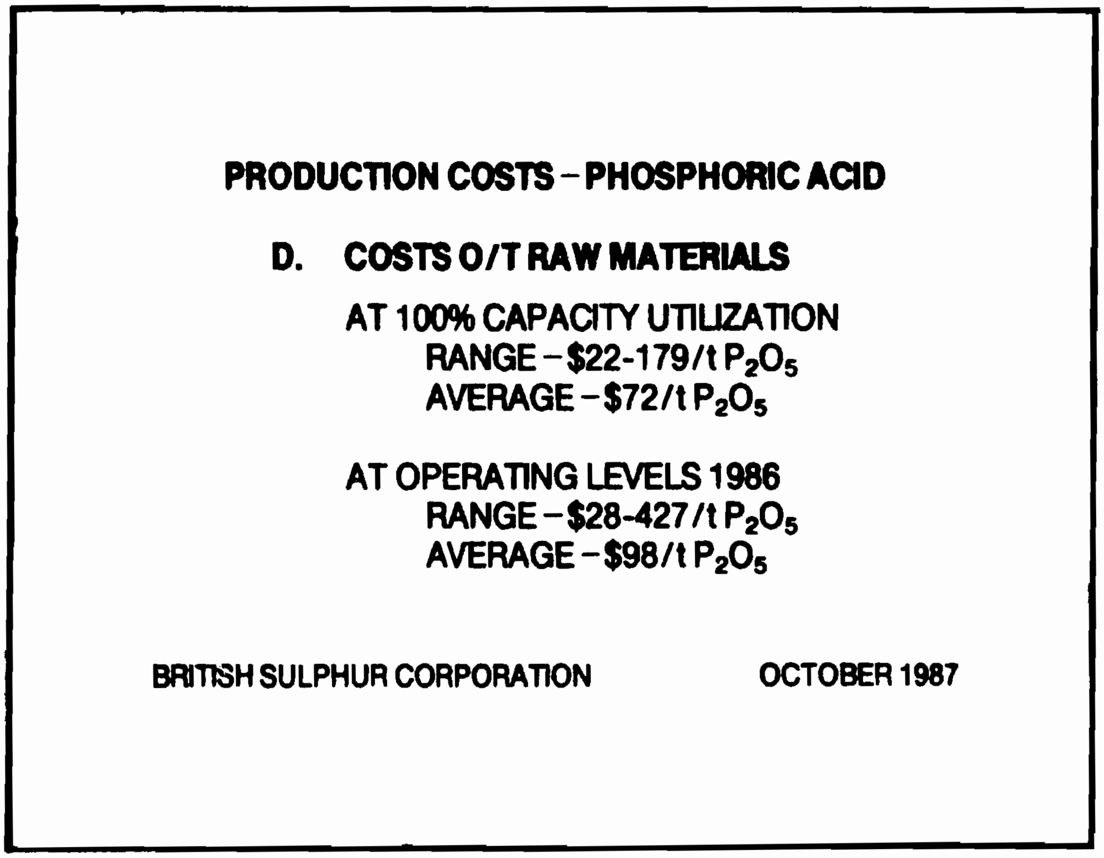
PRODUCTION COSTS – PHOSPHORIC ACID
(OPERATING LEVEL 1986)

C. MAIN RAW MATERIALS

RANGE – \$151-256/t P_2O_5
AVERAGE – \$192/t P_2O_5
ACCOUNTS FOR 61-96% OF TOTAL COST

BRITISH SULPHUR CORPORATION OCTOBER 1987

Figure 3



PRODUCTION COSTS – PHOSPHORIC ACID

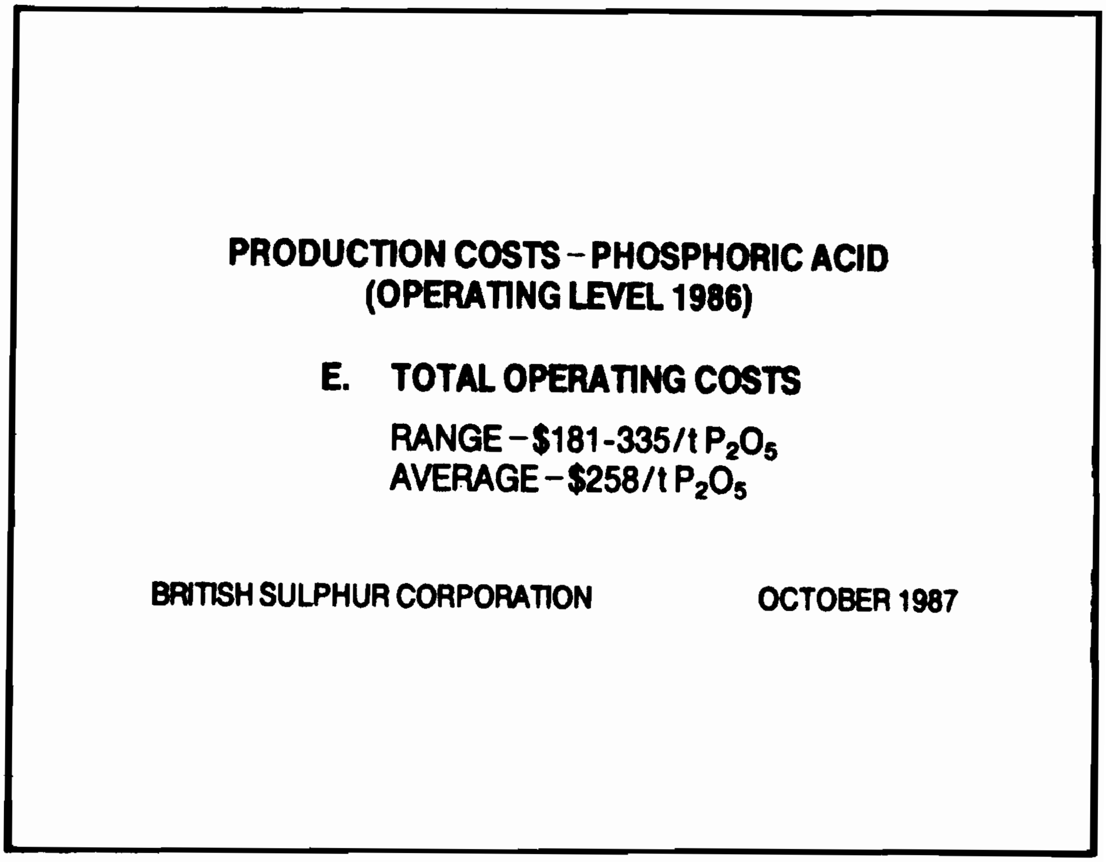
D. COSTS O/T RAW MATERIALS

AT 100% CAPACITY UTILIZATION
RANGE – \$22-179/t P_2O_5
AVERAGE – \$72/t P_2O_5

AT OPERATING LEVELS 1986
RANGE – \$28-427/t P_2O_5
AVERAGE – \$98/t P_2O_5

BRITISH SULPHUR CORPORATION OCTOBER 1987

Figure 4



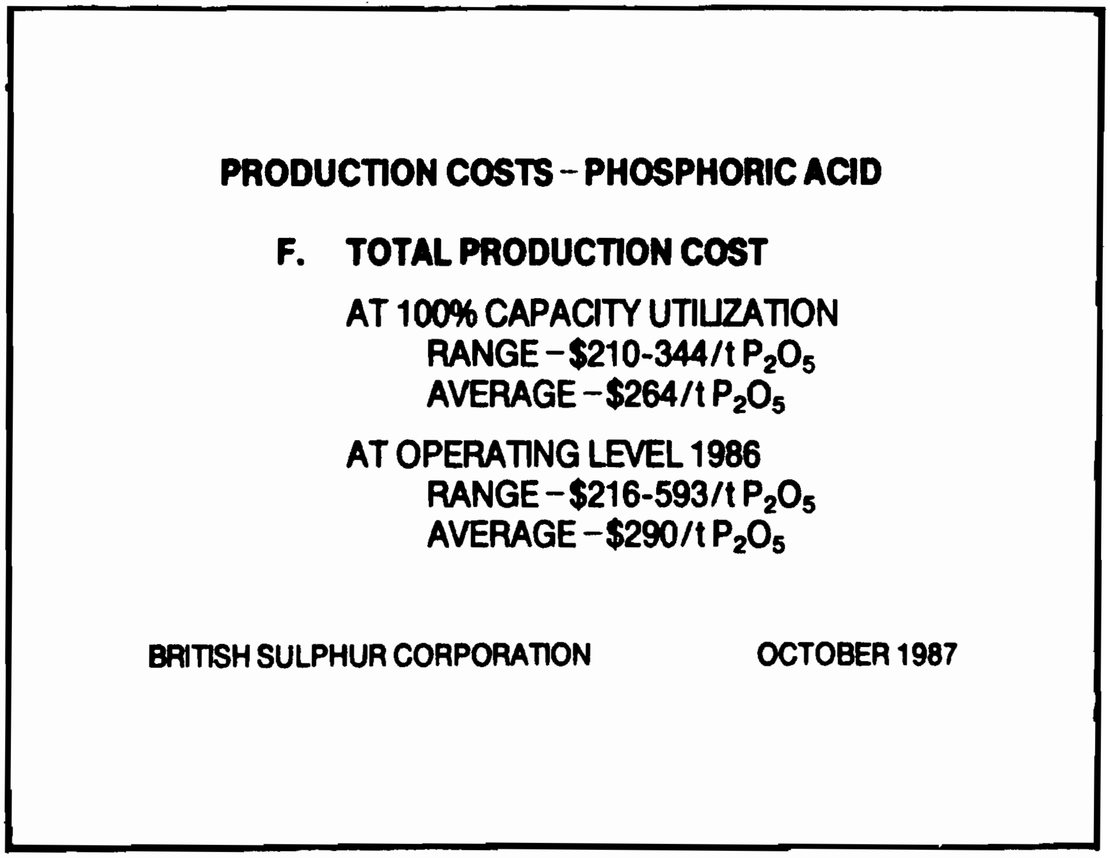
PRODUCTION COSTS – PHOSPHORIC ACID
(OPERATING LEVEL 1986)

E. TOTAL OPERATING COSTS

RANGE – \$181-335/t P_2O_5
AVERAGE – \$258/t P_2O_5

BRITISH SULPHUR CORPORATION OCTOBER 1987

Figure 5



PRODUCTION COSTS – PHOSPHORIC ACID

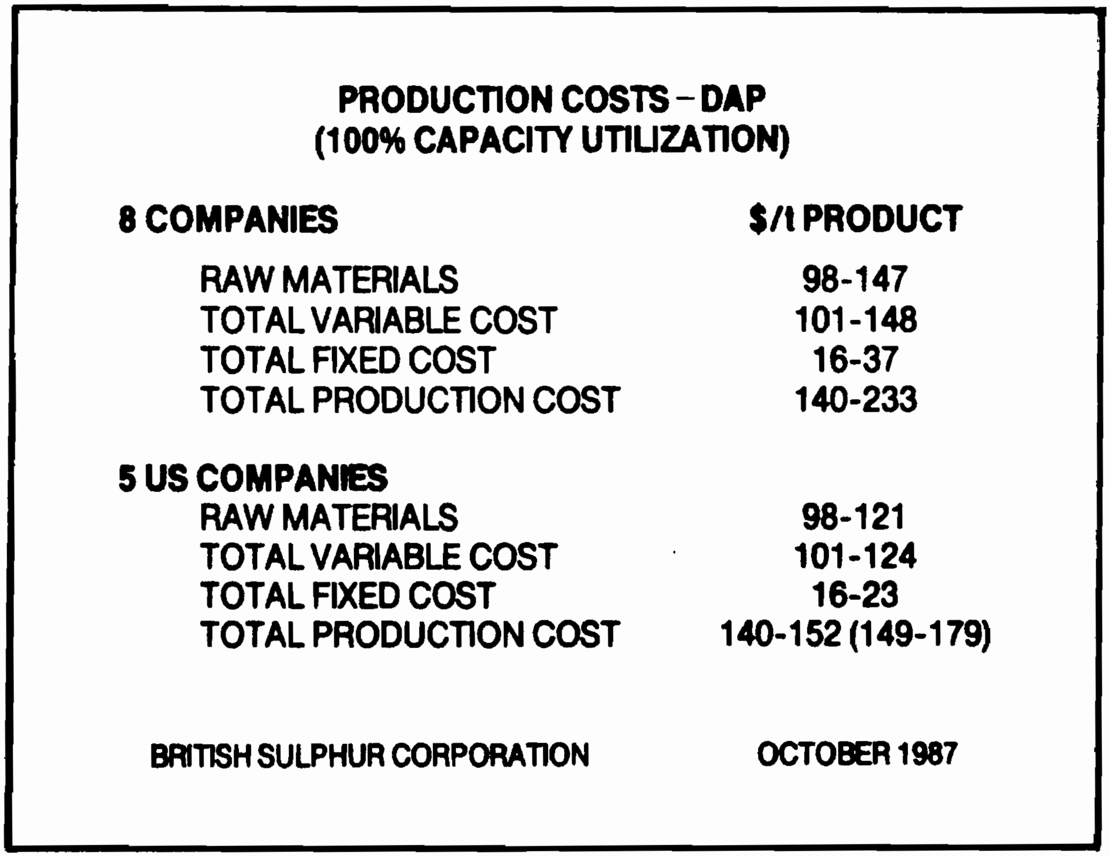
F. TOTAL PRODUCTION COST

AT 100% CAPACITY UTILIZATION
RANGE – \$210-344/t P_2O_5
AVERAGE – \$264/t P_2O_5

AT OPERATING LEVEL 1986
RANGE – \$216-593/t P_2O_5
AVERAGE – \$290/t P_2O_5

BRITISH SULPHUR CORPORATION OCTOBER 1987

Figure 6



PRODUCTION COSTS – DAP
(100% CAPACITY UTILIZATION)

8 COMPANIES	$/t PRODUCT
RAW MATERIALS	98-147
TOTAL VARIABLE COST	101-148
TOTAL FIXED COST	16-37
TOTAL PRODUCTION COST	140-233
5 US COMPANIES	
RAW MATERIALS	98-121
TOTAL VARIABLE COST	101-124
TOTAL FIXED COST	16-23
TOTAL PRODUCTION COST	140-152 (149-179)

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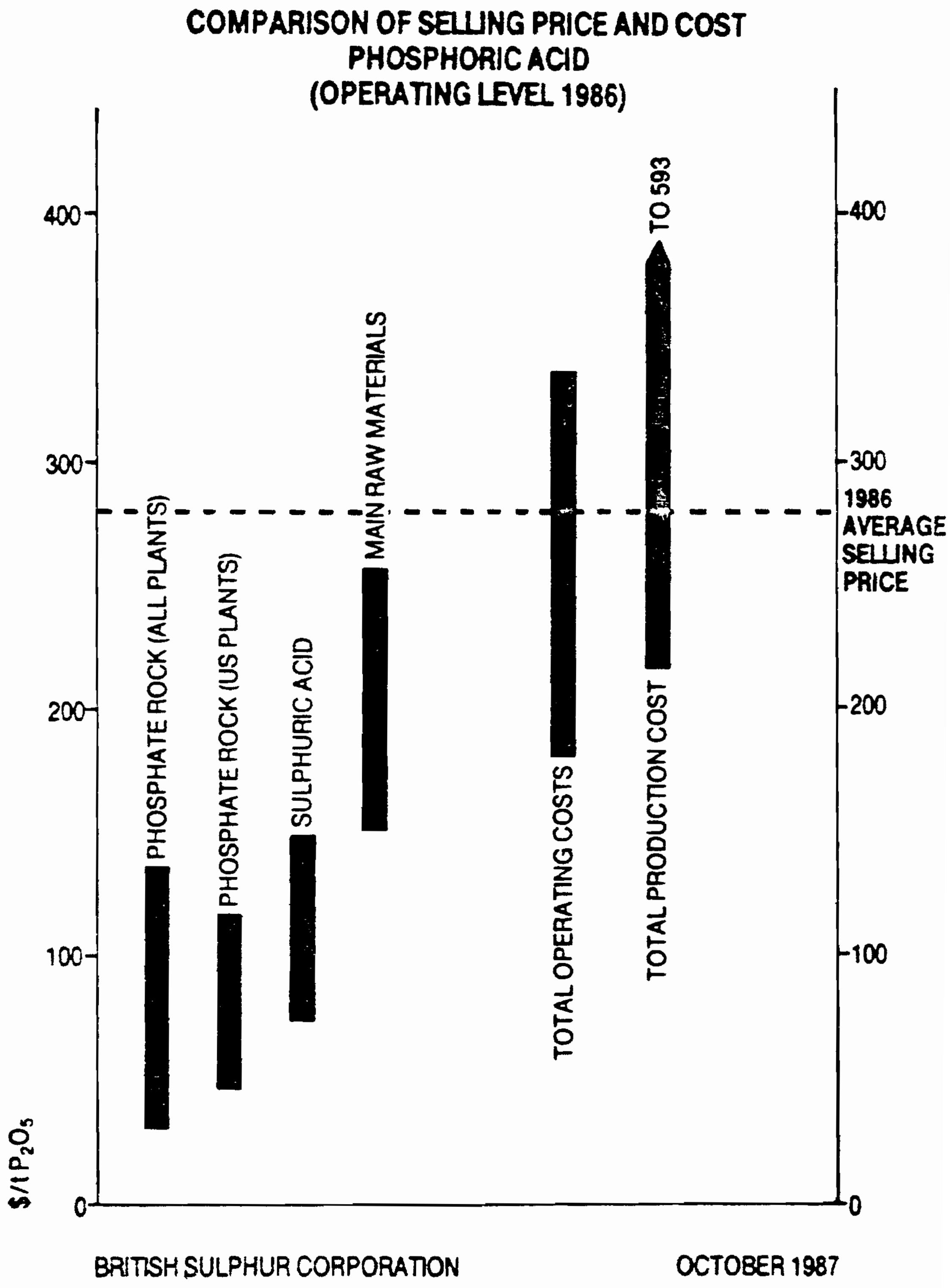
Figure 8



COMPARISON OF SELLING PRICE AND COST
PHOSPHORIC ACID
(OPERATING LEVEL 1986)

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Figure 7

PHOSPHORIC ACID PRODUCTION COST SUMMARY

COMPANY :

TIME BASE : 1986

LOCATION :
COUNTRY :

ON-STREAM DATE:

CAPACITY : Tonnes per day P205

ACHIEVABLE ON-STREAM FACTOR (O.F) : Days per year

ACTUAL 1986 ON-STREAM FACTOR : Percent
(Based on achievable O.F.)

CAPITAL COST : (In Million $ U.S.)
Original :
Present Day (P.D.) :
(Including offsites associated with the phos acid plant)

EXCHANGE RATE:$1.00 U.S. =
Present :
At start-up :

INTEREST RATE :

ITEM		UNIT CONSUMPTION	UNIT COST Local Currency	UNIT COST U.S. $	COST Per Tonne P205 @Capacity	@1986 Prod.Level
RAW MATERIALS						
Phosphate Rock	Tonne					
Sulphuric Acid (Variable cost)	Tonne					
UTILITIES						
Steam	Tonne					
Electricity	kWh					
Water	Tonne					
GYPSUM DISPOSAL	Cost per Tonne P205					
TOTAL VARIABLE COST						
Labour	Total on Site					
Maintenance	Per Annum					
Overheads	Cost per Tonne P205					
Fixed Cost - Sulphuric Acid	Cost Per Tonne P205					
TOTAL FIXED COST						
TOTAL OPERATING COST						
CAPITAL CHARGES						
Depreciation	15 Years Linear	Per Annum				
Finance Charges	On outstanding loan	Per Annum				
Sulphuric acid	Cost Per Tonne P205					
TOTAL PRODUCTION COST						

Phosphate Rock Cost - Percent of 1986 Production Cost :
Sulphuric Acid Cost - Percent of 1986 Production Cost :

British Sulphur Consultancy Services - Confidential

Figure 9

Monday, November 2, 1987

Afternoon Session II
Moderator:

Harold Blenkhorn

TVA's Experience in Producing and Marketing Urea LS™

By L. M. Nunnelly and W. C. Brummitt
National Fertilizer Development Center
Tennessee Valley Authority

Since the mid 1970's, formaldehyde has been used industry-wide as a conditioning-hardening agent in urea finishing processes. Conditioning agents are used to harden the product, reduce dust generation during handling, and to provide anticaking properties for storage. Formaldehyde, however, has been found to cause nasal cancer in laboratory animals and is listed by the Environmental Protection Agency as a hazardous material. Because of the concern for environmental health and safety and the possible implications to urea producers, TVA, at the request of The Fertilizer Institute, began a search for suitable replacements for formaldehyde in urea finishing processes. Details on the procedures and compounds tested in this study were presented at the 190th ACS meeting in September 1985 and are given in TVA Circular Z-190 (*1*). Of the many compounds tested, thus far the most promising are the group of metal and ammonium lignosulfonates. Calcium lignosulfonate (CaLS), in particular, has proved to be a very good conditioning-hardening agent for urea. As a result, TVA has patented the use of metallic and ammonium lignosulfonates as a conditioning agent for urea (*2*). Urea LS™ is the TVA trademark for urea produced with lignosulfonate conditioner.

CALS CONDITIONER FOR UREA

CaLS, a by-product of the paper manufacturing industry, is a soluble derivative of lignin formed in the sulfite wood pulping process as wood chips react with bisulfite and sulfur dioxide. CaLS is readily available as a powder or as a fluid containing 50 or 58% by weight CaLS. It is a stable compound that does not require expensive storage and handling facilities, and compared with formaldehyde, it is usually less expensive to use as a conditioning-hardening agent for urea when added in the recommended amount (0.5-0.7% by wt).

TVA studies show that lignosulfonates modify the crystal structure of urea the same way that formaldehyde does. Figure 1-A shows the crystal structure of a urea granule without a conditioning agent. The crystals in this granule are large and loosely bonded with many voids or holes. Because of this structure, the crushing strength of this granule is low. Figure 1-B shows the crystalline structure of a urea granule conditioned with formaldehyde. The crystals in this granule are small (modified) and well bonded with few voids. The crushing strength is moderately high. Figure 1-C shows the crystal structure of a urea granule that was conditioned with CaLS. The crystals are small (modified), strong, and well bonded. There are essentially no voids in the structure and the crushing strength is high.

PRODUCTION OF UREA LS™

TVA began full-scale production of Urea LS™, the TVA trademark for urea produced with CaLS, in a 330-ton/day prototype plant by the falling-curtain evaporative-cooling process in October 1986. Since that time, more than 40,000 tons of Urea LS™ has been produced for demonstration programs and industry. Dealer responses and customer evaluations of the product have been generally favorable. However, because urea traditionally has been supplied as a pure white granule or prill, or as a clear liquid, customers and dealers have had some questions and concerns about the color (tan to brown) of Urea LS™. This coloration, which is caused by the CaLS, should not be a disadvantage and may prove to be an advantage. Product specifications are listed in Table I. Some advantages of Urea LS™ are as follows:

1. The conditioning-hardening additive, CaLS, is environmentally safe and nontoxic when added in the recommended amount.
2. The conditioning-hardening additive, CaLS, is cost effective. Depending on plant location and shipping costs, use of CaLS instead of urea-formaldehyde concentrate will usually result in a raw material savings of $0.50 to $1.00 per ton of product.
3. Urea LS™ has very good chemical, physical,

and storage properties, as good or better than granular urea produced by this process with formaldehyde additive.

4. Use of CaLS produces a more stable granule and thus reduces dust formation.
5. Cost of plant changeover from urea-formaldehyde concentrate to CaLS is minimal. In most cases, the equipment used to store and meter urea-formaldehyde concentrate can be adapted to store and meter CaLS as is or with only minor modifications. Also, CaLS can be added upstream of the urea concentrator.
6. Urea LS™, because of its tan-to-brown color, looks more like other fertilizer materials and reduces the salt-and-pepper look when it is used in bulk blends.

PROCESS DESCRIPTION

Figure 2 is a basic flow diagram of the TVA falling-curtain urea-granulation process for producing Urea LS™. CaLS fluid containing 58% by weight CaLS is metered into the weak urea solution feed stream to the evaporator. Scrubber liquor also is returned to the system at or near this point. The concentrated solution (⩾99%) from the evaporator flows by gravity to a small surge vessel. The level in the surge vessel is controlled by an instrument loop that includes a level-sensing device in the vessel, a flowmeter and control valve located downstream of the concentrated solution pump, and a controller-recorder located in the control room. Addition of CaLS is ratio-controlled by an instrument loop using a signal from the concentrated urea solution control loop. This system has given very accurate and reliable control of the CaLS additive.

The concentrated solution is pumped to the granulation drum which is the heart of the process (Fig 3). As the drum rotates, seed particles and undersize granules are elevated from the rolling bed by lifting flights and discharged onto the inclined collecting pans. Material sliding from the pans form two curtains of falling granules. Cooling air is blown into the top curtain, and the concentrated urea solution containing CaLS is sprayed onto the lower curtain. As the concentrated urea solution spreads over the surface of the seed particles and undersize granules, it quickly solidifies forming a thin coating. Granules of the desired size are produced by the successive layering of urea over the smaller granules. Cooling inside the drum is provided by a combination of

1. Heat transfer to air flowing through the drum
2. Evaporation of atomized water into the hot airstream
3. Introduction of cool recycle
4. Heat losses through the shell of the drum.

An energy-saving feature of the falling-curtain evaporative-cooling process is the cooling provided by the evaporation of water inside the granulation drum. Water sprayed as a fine mist into the open area of the granulation drum (Fig 3) quickly evaporates, cooling the heated air in this area. The fans blow the cooled air through the upper curtain of falling granules to provide efficient, low-cost cooling. In most cases, evaporative cooling will only be needed when ambient temperatures reach 85°F or higher. Care must be taken to prevent water from coming in contact with the urea granules and drum shell or buildup on the shell will result.

Granules discharge from the drum to the front half of a fluid-bed cooler which provides further cooling which is necessary to harden the granules so they do not break during screening and form dust. Undersize from the screens is conveyed and fed back to the granulation drum as recycle. Oversize is crushed, passed through an air classifier to remove dust, and then metered to the granulation drum at the required rate to replace the product granules taken out of the system (one seed particle for each product granule removed). Usually there is not enough oversize produced in the process to generate the seed needed, so some product also must be crushed. Dust from the crusher/air classifier is scrubbed from the exhaust airstream in a spray chamber immediately downstream of the air classifier. Product from the screens is further cooled in the product side of a fluid-bed cooler before it is transferred to storage.

Overall, the falling-curtain evaporative-cooling process is easily controlled and only two operators are required to run the plant. The falling curtain-evaporative cooling urea-granulation process is a TVA patented process (*3, 4, 5, 6, 7*) and detailed descriptions of the plant and process are available in TVA Bulletin Y-181 (*8*) and TVA Circular Z-194 (*9*). Typical operating conditions for the TVA prototype plant are given in Table II.

TVA conducts a national fertilizer research and development program and sells its experimental products to members of the U.S. fertilizer industry. These firms pay prevailing market prices for TVA fertilizers and provide feedback on experiences with these products.

Through September 1987, over 40,000 tons of Urea LS™ was shipped to 27 cooperators; the material was used by about 75 dealers, and by one university in 13 states. Urea LS™ has been used for direct application, for bulk blending, and as substrate for producing sulfur-coated urea. The material appears to be particularly well suited for producing sulfur-coated urea (i.e., less sulfur is required for a given dissolution rate) and TVA was recently granted a patent for this particular use (*10*). The material has been shipped by barge, truck, and rail.

The most severe storage test (an unplanned test) involved a barge which was loaded in January, and unloaded four months later in Shawneetown, Illinois. The material had a one-half to three-quarter inch crust, and a few lumps, but was in satisfactory condition. Reports by dealers confirm that Urea LS™ has excellent storage and handling properties. A few cooperators have commented that the material is more spherical than other urea products, and several report that the material is more dust free than urea from other sources.

TVA recently changed its patent policy regarding its new technology and will charge U.S. producers and importers a small royalty (5 cents per ton during the first year of production and 10 cents per ton thereafter) for use of its Urea LS™ patent. Efforts are underway to achieve commercial production. We feel that several United States and Canadian urea producers are taking a serious look at the process. We are aware of eight urea producers in the United States and Canada which have made trial production runs of Urea LS™, but we are unaware of any firm which is firmly committed to produce the material.

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3. Blouin, G. M., U.S. Patent 3,877,415, "Apparatus for Applying Coatings to Solid Particles," April 15, 1975.
4. Blouin, G. M., U.S. Patent 3,991,225, "Method for Applying Coatings to Solid Particles," November 9, 1976.
5. Shirley, Jr., A. R., U.S. Patent 4,213,924, "Granulation and Coating by Improved Method of Heat Removal," July 22, 1980.
6. Shirley, Jr., A. R., and F. T. Carney, Jr., U.S. Patent 4,424,176, "Process for Granulation of Molten Materials," January 3, 1984.
7. Shirley Jr., A. R., and F. T. Carney, Jr., U.S. Patent 4,506,453, "Enhanced Heat Transfer Process by Forced Gas Recirculation," March 26, 1985.
8. "New Developments in Fertilizer Technology," Tennessee Valley Authority, 14th Demonstration, October 5-6, 1983, Muscle Shoals, Alabama (TVA Bulletin Y-181).
9. Nunnelly, L. M., R. C. Finch, F. T. Carney, and D. A. Kelly, "Computer Modeling of the TVA Falling Curtain Process for Granulation of Urea," September 1985, Tennessee Valley Authority, NFDC, Muscle Shoals, Alabama 35660 (TVA Circular Z-194).
10. Gullett, L. L., and C. L. Simmons, U.S. Patent 4,676,821, "Sulfur-Coated Urea," June 30, 1987.

TABLE I

Specifications of Granular Urea LS™ Made by TVA's Falling-Curtain Evaporative-Cooling Process

Physical properties	
Nominal size, Tyler mesh	-6 +10
Bulk density, lb/ft^3	48
Specific density	1.3
Sphericity, %	85
Crushing strength, lb	
-6 +7 Tyler mesh	10
-7 +8 Tyler mesh	7
-8 +9 Tyler mesh	4
Angle of repose, degrees[a]	26
Abrasion resistance, % degradation[a]	0.2
Typical screen (Tyler) analysis, wt %	
+6 mesh	0
-6 +7 mesh	1
-7 +8 mesh	35
-8 +9 mesh	48
-9 +10 mesh	14
-10 mesh	2
Size guide number	225
Chemical analysis, wt %	
Nitrogen content	46.2
Urea nitrogen content	100
Biuret content	1.0
Calcium lignosulfonate, %[b]	0.6
Moisture	0.1

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[a] "Physical Properties of Fertilizers and Methods For Measuring Them," TVA Bulletin Y-147, October 1979.

[b] Calcium lignosulfonate, 58% solution.

TABLE II

Typical Operating Conditions for Production of Granular Urea LS™ by the Falling-Curtain Evaporative-Cooling Process

Granulation drum conditions	
Drum size, diameter x length, ft	11 x 29
Rotation speed, r/min	4
Urea melt concentration, %	99
Feed rates	
Urea melt, tons/h	13.8
Recycle, tons/h	12.4
Recycle-to-melt ratio	0.9
Seed, lb/h	600
Seed-to-melt ratio	0.02
Calcium lignosulfonate, gal/h[a]	27.6
Airflow through drum	
Rate, ft^3/min	17,000
Relative humidity, est %[b]	40
Cooling water (spray), lb/h[c]	1,000
Operating temperature, °F	
Urea melt	290
Recycle/seed	140
Ventilating air inlet	85
Granules leaving drum	225
Drum exhaust air	175
Pressure, lb/in^{2}g	
Urea melt spraying pressure	150
Air to water spray nozzles	48
Water to water spray nozzles	40
Urea spray nozzles[d]	
Type	Hydraulic
Pattern	Flat, wide
Number	62
Distance from curtain, in	6-8
Water spray nozzles[e]	
Type	Air atomizing
Pattern	Full cone
Number	37

TABLE II (CONTINUED)

Fluid-bed cooler conditions	
Effective screen area, ft^2	100
Retaining dam height, in	8.0
Fluidizing airflow, ft^3/min	35,000
Cooler operating temp, °F	
Urea granules entering	
Process side	225
Product side	145
Urea granules leaving	
Process side	150
Product side	105
Fluidizing airflow	90
Exhaust airflow	160
Process screen	
Type	Gyrating
Effective screen area, ft^2	78.5
Oversize screen cloth	
Weave type	Square
Mesh, Tyler equivalent	6
Open area, %	62.7
Product screen cloth	
Weave type	Square
Mesh, Tyler equivalent	8-1/2
Open area, %	53.4

---

[a] Calcium lignosulfonate liquid, 58% by weight CaLS.

[b] The relative humidity of ventilating air entering the granulation drum depends on atmospheric conditions. Relative humidity of air exiting the drum depends on atmospheric conditions as well as the amount of cooling water sprayed in the drum.

[c] Cooling water used only as needed for temperature control. Usually not needed unless ambient temperature of ventilating air exceeds 85°F.

[d] Unijet nozzles with 65-degree, flat-spray patterns, manufactured by Spraying Systems Co., Wheaton, Illinois.

[e] Air-atomizing 1/4 JH-29 water spray nozzles with wide-angle round-spray patterns, manufactured by Spraying Systems Co., Wheaton, Illinois.

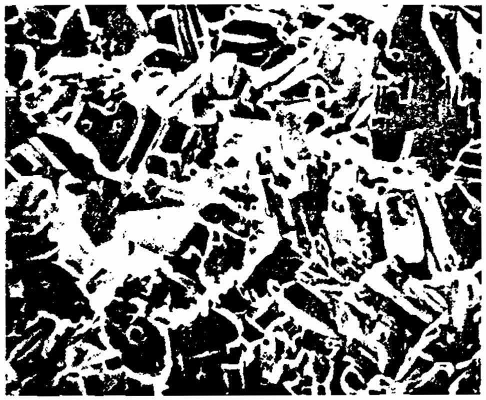

FIGURE 1-A
Urea Granule (200X)
Without Conditioner

FIGURE 1-B
Urea Granule (200X)
With HCHO

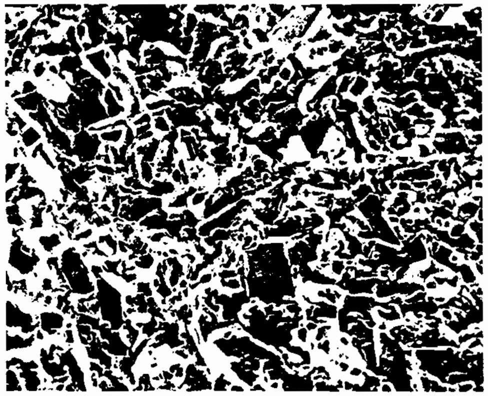

FIGURE 1-C
Urea Granule (200X)
With CaLS

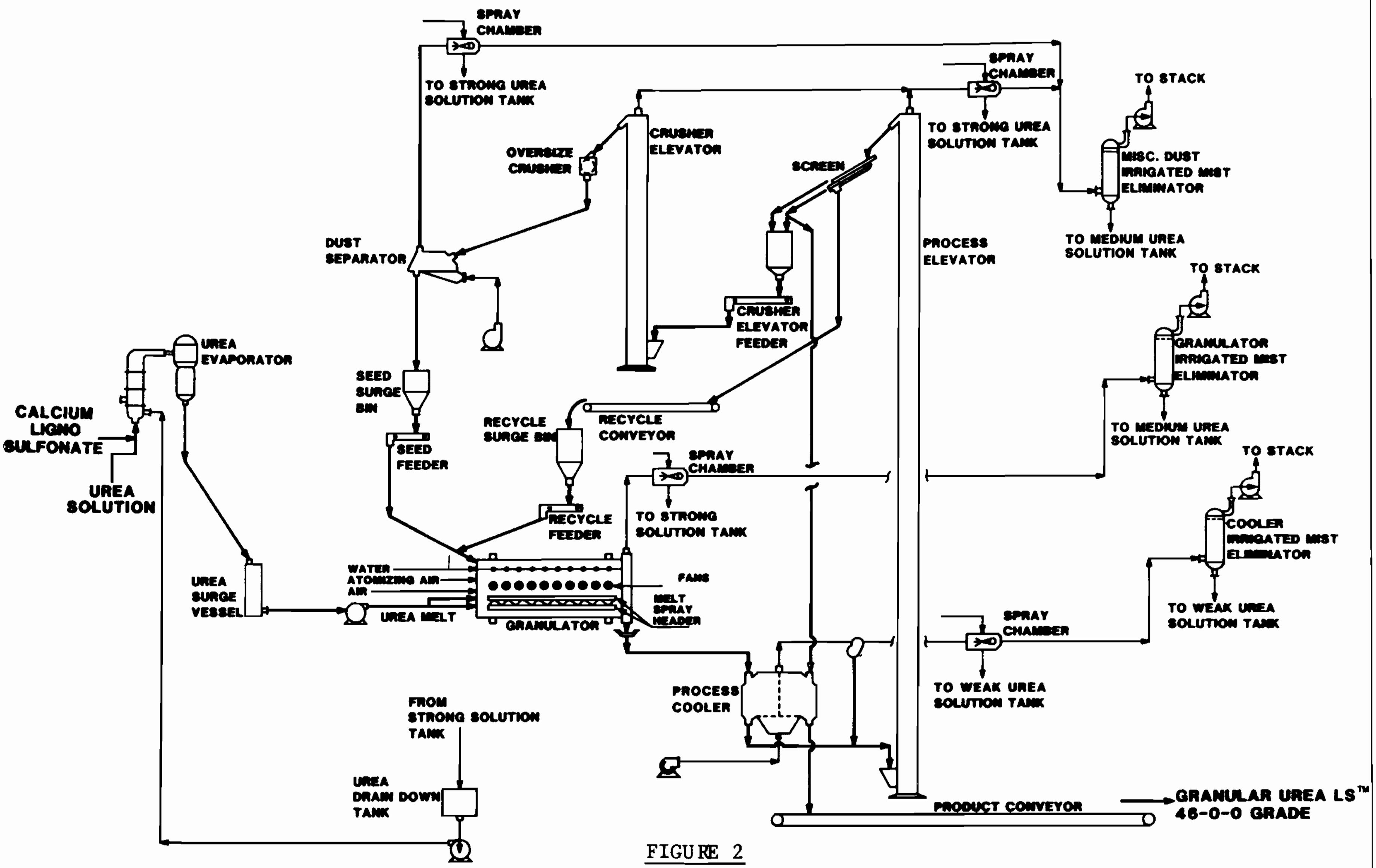

FIGURE 2

Basic Flow Diagram for Production of Urea LS™ by the Falling Curtain-Evaporative Cooling Process

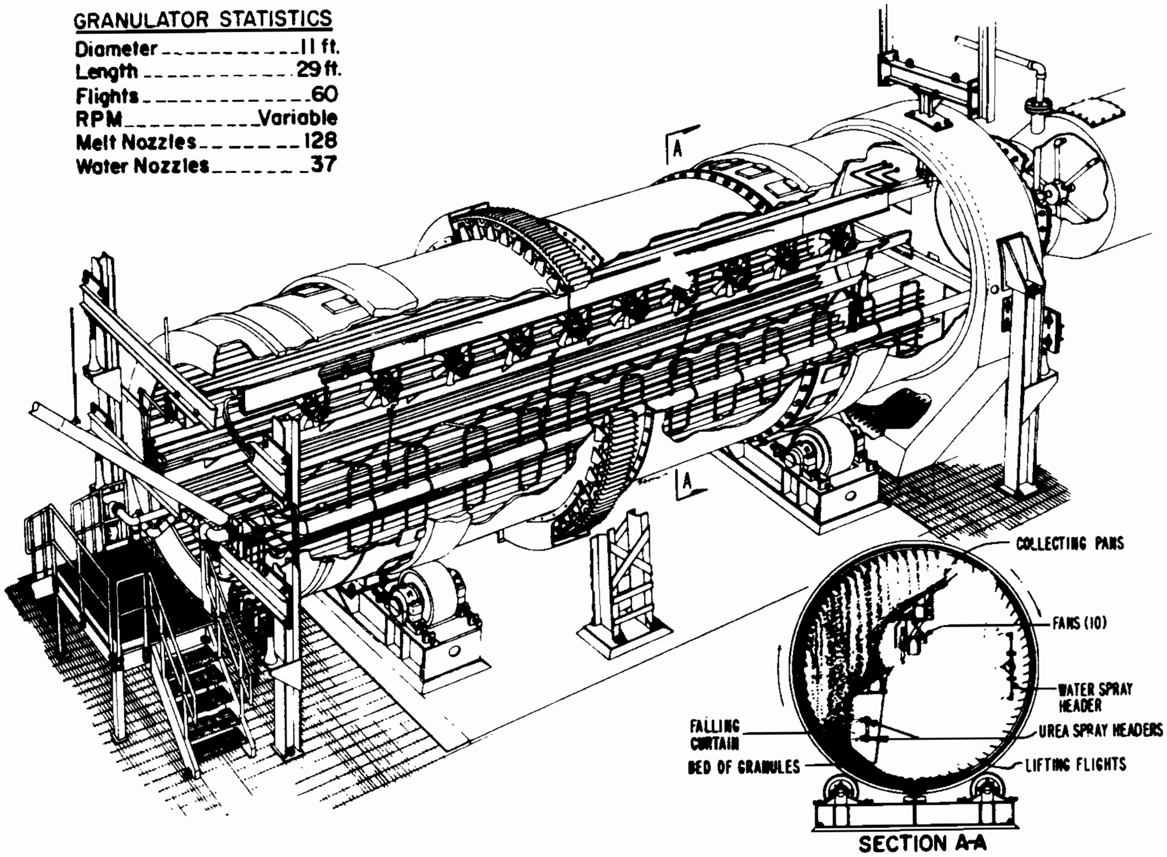

FIGURE 3

Schematic Diagram of Urea LS^{TM} Granulation Drum in Falling Curtain-Evaporative Cooling Demonstration Plant

Retrofitting Fertilizer Mix Plants to Improve Their Profit or Operations

Frank P. Achorn
David G. Salladay
Tennessee Valley Authority

This paper suggests retrofitted processes which could be installed in existing plants. The result could be improved operations and lower operating costs. The discussion is divided into three parts: granulation of NPK mixtures, bulk blends, and fluid fertilizers.

HOMOGENEOUS GRANULAR MIXTURES

Although the number of granulation plants producing NPK mixtures has decreased, the demand for these products is still significant. An increasing amount of bagged fertilizer is being sold in the turf, garden, and ornamental type fertilizer market. In fact, this market now accounts for about 3.5 million tons of fertilizer in the United States. Also, many states are encountering difficulty with plant nutrient deficiencies of grades sold in their states. Homogeneous mixtures are a way to avoid penalties for off-grade products. Therefore, although production of granular homogeneous mixtures in the United States is at an all-time low, we expect no further decreases in their total production during the next few years.

Companies with regional granulation plants have recently encountered two supply problems:

1. Supply of run-of-pile triple superphosphate.
2. Limited supply of ammoniating solutions. These solutions usually contain free ammonia and ammonium nitrate. A typical ammoniating solution contains 25 percent free ammonia and 65 percent ammonium nitrate (44.8% N).

One solution to the triple superphosphate problem is to produce a slurry of TSP by installing a tank at the granulation plant and reacting the phosphoric acid and phosphate rock before it is added to the ammoniator-granulator. Figure 1 shows a sketch of a typical granulation plant with a mix tank of this type. At the 1981 Fertilizer Industry Round Table meeting, John Rednour of the Mississippi Chemical Corporation explained how his company had used such a slurry to produce such O-X-X grades as 0-17-34 and 0-24-24 (1). Some equipment corrosion occurs but operators say it isn't unreasonable. We have conducted plant tests in which slurries of this type were ammoniated to produce products with a higher pH (pH between 3 and 7). It should be possible to produce an NPK mixture using such slurries to supply phosphate. When this is done, the triple superphosphate generated usually can be ammoniated at a rate of 3 lbs of ammonia per unit of P_2O_5 supplied by the slurry. Plant tests indicate that grades such as 13-13-13 and 6-24-24 can be produced using this slurry as part of the P_2O_5 of the grade.

Some have suggested that another approach is to install a mini-sized triple superphosphate plant at the granulation plant. Figure 2 shows a sketch of a typical run-of-pile triple superphosphate plant that uses a TVA cone mixer and a belt conveyor. The belt conveyor is used to den the triple superphosphate for about 8 minutes before the run-of-pile material is discharged into a storage building (2). Suitable scrubbing systems should be installed to scrub the exit gas streams from the cone mixer and belt den. Usually, venturi type scrubbers are required.

The problem large primary producers have encountered in storing run-of-pile triple superphosphate is that fluorine emissions from the storage buildings exceed the legal limit. That problem can be eliminated by installing smaller plants at several locations. The storage buildings do not have to be very large since the triple superphosphate is only stored for about six weeks. Also, because the cone mixer type operation is a simple operation with low maintenance and operating costs, it can be operated for short periods of time and on an intermittent basis to produce triple superphosphate as needed.

Regional granulation plants have had to substitute other nitrogen materials for nitrogen solutions. One effective solid product is ammonium sulfate. There has been some shortage of this material, but production of chemicals and associated production of ammonium sulfate is increasing. Much of this ammonium sulfate is too small for use in bulk blending. Some companies are considering using TVA's process for granulating ammonium sulfate to get a product of suitable size for good quality bulk blends.

In this process the small crystals are granulated with sulfuric acid, water, and ammonia. Countercurrent drying is required. An alternative is to use larger quantities of the small crystals to produce ammonium phosphate sulfate or granular NPK mixtures. Ammonium sulfate crystals are fed to the dry recycle system while sulfuric acid and ammonia are added beneath the bed of material in the granulator. The heat of reaction between the sulfuric acid and ammonia causes the ammonium sulfate, ammonium phosphates, and potash to be granulated.

Considerable difficulty has been encountered with maintenance of the sparging system for adding the sulfuric acid. Frequently, loss of ammonium chloride fumes due to the reaction of sulfuric acid with the potassium chloride causes scrubbing difficulties. We have recommended that the sulfuric acid be premixed with ammonium sulfate crystals to form an ammonium bisulfate solution. Figure 3 shows the solubility of ammonium sulfate in a solution of sulfuric acid. The final mixture of sulfuric acid and ammonium sulfate is 35 percent. These data show that about 50 lbs of ammonium sulfate can be dissolved in about 100 lbs of the total final solution. The solution contains 35 percent sulfuric acid. At this composition the sulfuric acid and ammonia are combined as ammonium bisulfate. This ammonium bisulfate solution has a reaction rate with potash that is only half of the reaction rate that occurs between potassium chloride and sulfuric acid. Because of this lower reaction rate, we believe the ammonium bisulfate solution can be sprayed above the bed in the granulator to eliminate problems with the acid sparger and the scrubbing system. This should significantly decrease maintenance and operating costs of the plant when ammonium sulfate crystals are used.

We are developing processes for using ammonium bisulfate melt in TVA's pipe-cross reactor (PCR). Operators of regional granulation plants should consider installing a PCR so they can use more phosphoric acid and sulfuric acid in formulations. In this way they can use more anhydrous ammonia which should reduce formulation costs and partially satisfy the need for larger quantities of nitrogen other than nitrogen solutions. Figure 4 shows a sketch of a typical PCR. This reactor is being used in many regional ammoniation-granulation plants throughout the United States. Figure 5 is a sketch of the PCR installed inside the TVA-type rotary ammoniator-granulator (3). In this process the sulfuric acid and phosphoric acid are reacted with anhydrous ammonia to produce an ammonium phosphate sulfate melt used to granulate potash and other solid raw materials. Product from the ammoniator-granulator contains a low moisture and does not need to be dried with the use of fossil fuel. Usually, it is passed through the existing dryer. The dryer serves as a cooler and removes some additional moisture. The resulting product is dry and hard, and resists degradation. Design criteria for the PCR is as follows:

Design Criteria to Produce MAP and NPKS

1. Minimum length, 10 feet.
2. Materials of construction are Hastelloy C-276.
3. Cross section heat flux 600 × 10^3 Btu/hr/in^2.
4. Ammoniation volume 2 lbs NH_3/hr/in^3.
5. Heat flux in slot discharge 600 × 10^3 Btu/hr/in^2.

The advantages of using the PCR to produce granular homogeneous mixtures are:

1. No fuel required.
2. Use larger quantities of acids.
3. Product is harder and less dusty.
4. Higher analysis mixtures.
5. Homogeneous product which will not segregate.
6. Uniform application

This same PCR can be used to produce MAP and granular ammonium polyphosphate (GAPP) which is a special product for producing high quality suspension fertilizers (4). To produce granular ammonium polyphosphate with this PCR, the acid must be preheated to 250°F. An alternative is to use a higher strength acid rather than the conventional merchant-grade phosphoric acid which contains 54 percent P_2O_5. One of the largest phosphoric acid producers now produces an acid with a P_2O_5 concentration of about 58 percent. When this acid is used, probably no external heating of the acid would be required. Thermodynamic calculations show that at this acid strength, enough ammonium polyphosphate would be generated in the PCR to result in a granular product with sufficient polyphosphate. The polyphosphate content usually should exceed 10 percent to produce good quality suspensions. During the production of GAPP, the temperature of the melt is 450°F.

Another excellent source of nitrogen for ammoniation-granulation plants is urea, but caution is advised in selecting materials to combine with the urea. We have considerable data which show that using combinations of ammonia, phosphoric acid, urea, potash, and sulfuric acid to produce a granular urea-ammonium phosphate sulfate-potash mixture results in a product with poor bulk storage characteristics. It will store satisfactorily if conditioned and bagged immediately, but this isn't always practical.

Therefore, we recommend producing X-X-O grades which have good bulk storage characteristics (5). Three grades of this type are a 28-28-0, a 32-16-0, and 35-17-0. After these materials are stored in bulk, they can then be conveniently mixed in a small concrete mixer to produce NPK mixtures. However, the NPK mixtures should be bagged or applied soon after they are mixed.

Table 1 shows some bag storage tests of NPK mixtures that contain urea. The 15-15-15 grade is a homogeneous mixture produced from phosphoric acid, sulfuric acid, anhydrous ammonia, urea, and potash. Although it contained only 10 percent urea, the product did not store satisfactorily unless conditioned with 1-percent-by-weight finely-ground kaolin type clay. With the conditioning agent, the 15-15-15 stored quite well in bags for 9 months. The storage data also showed that an unconditioned 19-19-19 grade produced by blending a granular homogeneous 28-28-0 with granular potash stored well in bags for about nine months.

These bag storage tests indicate that combinations of urea, ammonium phosphate, potash, and ammonium sulfate require conditioning for good storage characteristics, but mixtures of ammonium phosphate, potash, and urea do not require a conditioning agent. Other bulk storage data indicate that neither of the mixtures stores well in bulk. Both products have critical humidities (relative humidity at which product accumulates water from atmosphere) of less than 50 percent. Storing product in bulk at these low critical humidities is impractical. TVA bulk storage data show that X-X-O grades store well in bulk. Therefore, when potash is required, it should be blended with the urea-ammonium phosphate just before bagging or direct application. We recommend that X-X-O grades be produced using the PCR previously described.

Table 2 shows formulations and some operating data from a conventional granulation plant using a TVA rotary ammoniator-granulator. Figure 6 shows a flow diagram of a typical plant that uses this type of process. It has a rotary ammoniator-granulator, dryer, cooler, and associated screens and dust collecting system. The PCR is installed inside the ammoniator-granulator. Test data for the 28-28-0 and 32-16-0-4S grades are shown.

These data show that the recycle rate for the 28-28-0 grade is 1.5 tons of recycle per ton of product; the rate for the 32-16-0-4S grade is 4.5 tons of recycle per ton of product. If we assume the average regional granulation plant has a throughput capacity of about 100 tons per hour, the plant could produce 28-28-0 at a rate of 40 tons per hour and the 32-16-0 at about 20 tons per hour. Note that the melting point of the 28-28-0 is 235°F and this temperature for the 32-16-0-4S is 220°F. The average melting point of NPK mixtures produced from ammonium sulfate, phosphoric acid, sulfuric acid, ammonia, and potash is about 350°F to 400°F. Therefore, when urea is added to the formulation, care must be taken to avoid melting the product. For this reason, if drying is used, this drying should occur at temperatures less than 180°F. The operators should carefully monitor the product temperature from the cooler or dryer to ensure that it is less than 180°F. Other data indicate that pH of the product should be kept within a range of 5.0 to 6.0. At higher or lower pHs, overgranulation will make plant operation impossible.

BULK BLENDING

Most mixtures produced in the United States are dry (granular bulk blends). They usually include diammonium phosphate and potash. When sulfur is required, usually ammonium sulfate is used to supply N and S. Considerable granular urea is used in bulk blending.

An important problem that occurs in bulk blending is segregation of the products after they have been mixed. Many states have laws requiring the dealer to guarantee the grade. One state reports that over one-half of the blends do not meet grade tolerances. Dealers must pay a penalty in such cases. There is, however, technology available to help eliminate some of these penalties. TVA test data show that the leading cause of segregation is the size differences between the ingredients used in the mixture. Tabulated below is a group of materials that has suitable size distributions for a minimum of segregation (6).

Properly Matched Material for Nonsegregating Blend

Material	Cumulative Screen Analysis % Retained on Tyler Screens +6	+8	+10	+14	+20	Size Guide No.
DAP (18-46-0)	<1	36	86	99	100	225
GTSP (0-46-0)	1	21	80	97	100	209
MOP (0-0-60)	5	37	78	95	98	219
Average analysis	2	31	81	96	99	217
Maximum deviation from average	3	10	5	3	2	8

The size guide number (SGN) concept shown above was developed by the Canadian Fertilizer Institute. This number represents the average particle size in millimeters multiplied by 100 and rounded to the nearest unit of 5. The SGN provides a simple means of product identification by particle size which will aid selection of size compatible materials. All material suppliers should provide SGNs for their materials. Guaranteeing this size guide number as we would guarantee chemical ingredients of the product, however, is impractical. It should be used as information to help guide the blender in selecting materials. TVA experience shows that if the particle size fraction of the materials used in the blend is within 10 percent of the average screen analysis of all materials used in the blend, the material will remain mixed when handled and applied properly. When the SGN is considered, usually the number should not have a maximum variance exceeding 15 units. The materials shown in the above tabulation meet these specifications. They should not segregate if they are mixed, handled, and applied properly. Obtaining properly sized materials is very difficult. For this reason, coning of the materials as they are delivered to storage and after they have been mixed should be avoided. Figure 7 is one of the devices we recommend to prevent coning of the raw materials. If the materials are allowed to cone as they are loaded into storage, the larger granules will collect on the edge of the pile and the small ones in the center. Also, the same problem with size separation occurs when materials are added to railway cars and to barges.

Although preventing size separation entirely is impractical, granulation processes can be developed to produce materials so closely sized that when they are coned, the differences are not enough to create a wide size variation of material in the pile. We believe we have new technology of this type in the development of our curtain granulation process for producing granular Urea LS™. Nearly all particles are in the −8 +9 mesh size fraction. Therefore, there is little possibility for the particles to separate. We should be able to develop other processes that will help eliminate this problem. In the meantime, blenders should install equipment such as shown in Figure 8. We have data to show that segregation problems can be minimized by installing these dividers. Mechanical equipment of this type can help solve some of the problems blenders have had in meeting grade requirements.

FLUID FERTILIZERS

Earlier we described how granular ammonium polyphosphate (GAPP) can be produced using TVA's PCR. This product contains about 10 to 20 percent of its P_2O_5 in the polyphosphate form. When GAPP is used to produce suspensions, this polyphosphate converts impurities in the suspension to a fluid form that will not cause storage problems. Granular ammonium polyphosphate can be delivered to the use area as the most economical form of P_2O_5 for the fluid fertilizer manufacturer. The reason for this economic advantage is that the freight rate for granular phosphate products is considerably less than for either merchant-grade or superphosphoric acid. This is because railcars and barges used for shipping granular material can also be used in backhauling grain and other commodities. This allows the freight cost to be distributed over several materials.

Figure 9 shows our recommendation for retrofitting a conventional fluid mix plant to produce suspensions from this lower cost granular GAPP or MAP. This retrofitting includes larger transfer piping (standard 6-inch PVC pipe) and installation of an evaporative type cooler. This cooler has a cone bottom with a capacity exceeding that of the mix tank. The cooler does not have any packing. Fluid is recirculated to the top of the cooler and is cooled by air which is sucked in through the opening at the bottom. Total installation of the cooler and the larger sized piping should be less than $30,000. Using GAPP in this retrofitted plant should make possible a high quality 11-33-0 suspension that can be stored for prolonged periods of time and during winter storage at most U.S. locations. The 11-33-0 suspension can then be blended with other fluids such as urea-ammonium nitrate solution and potash to produce suspensions. Typical grades are 13-13-13, 7-21-21, 20-10-10, etc.

SUMMARY

We have described good examples of how to retrofit mix plants. Granular homogeneous mixtures, bulk blends, and fluid fertilizers can be competitive with each other and will continue to be excellent means of efficiently producing NPK mixtures. We need to move forward. All indicators show we are to have a good year. Fertilizer disappearance figures look good. Total disappearance of nitrogen was up 20 percent, phosphate increased 9 percent, and potassium increased 20 percent in the yearly comparisons. The fertilizer patient has been ill, but the prognosis is good. Let's move forward. We hope we have given you some helpful hints to progress.

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Table 1

Bag Storage Tests of NPK Mixtures that Contain Urea

	Cogranulated		Bulk Blend	
Grade	15-15-15	15-15-15	19-19-19[c]	19-19-19
Formulation, %				
Urea	10	10	33	33
Monoammonium phosphate[a]	27	27	35	36
Ammonium sulfate	37[b]	36[b]	--	--
Potash	26	25	30	31
Conditioning agent	0	2	2	--
Bag condition				
1 month	unsatisfactory	excellent	excellent	excellent
3 months	unsatisfactory	excellent	excellent	excellent
6 months	unsatisfactory	good	excellent	excellent
9 months	unsatisfactory	satisfactory	excellent	excellent

a. MAP 11-53-0 grade

b. Part as ammonium sulfate crystals and part as H_2SO_4 + NH_3

c. Blends of 28-28-0 and potash. 28-28-0 is homogeneous mixture of APP and urea.

Table 2

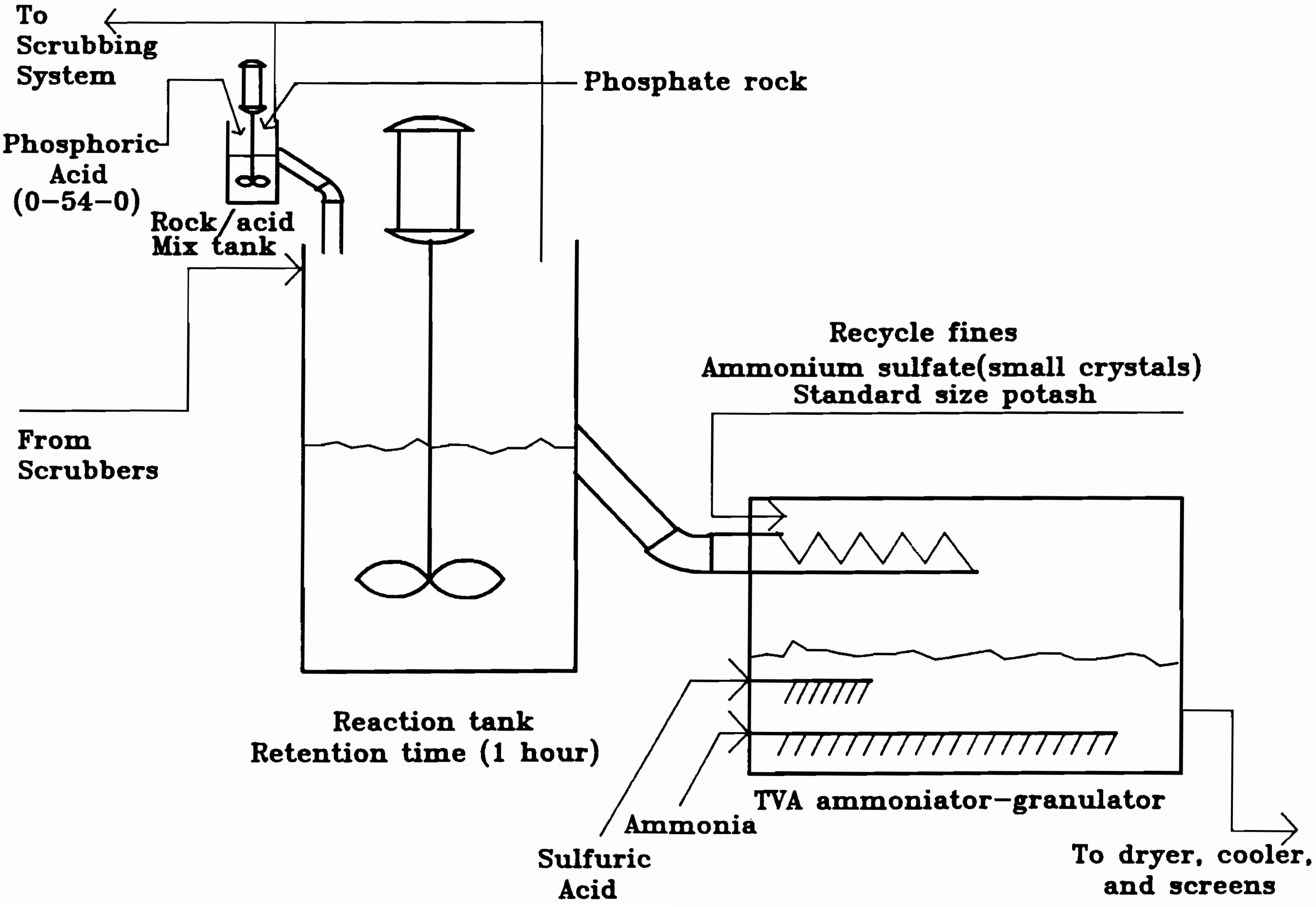
Formulation and Operating Data for Production of Urea-Ammonium Phosphate and Urea-Ammonium Phosphate Sulfate

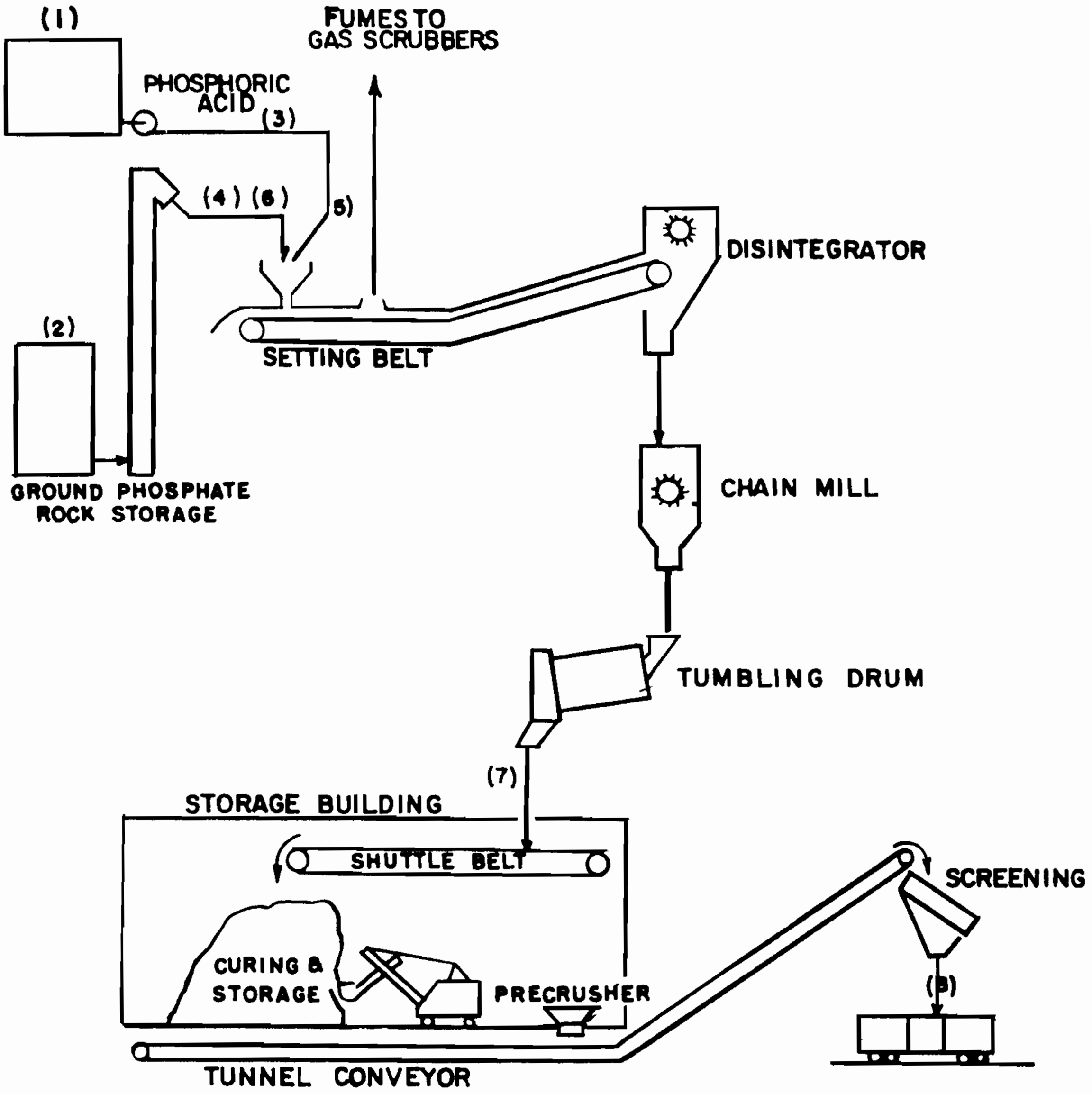
Grade	28-28-0[a]	32-16-0-4S[b]
Formulation, lb/ton		
To PCR		
Anhydrous NH_3	82[c]	172[d]
Phosphoric acid (53% P_2O_5)	1,070	225
Sulfuric acid (93% H_2SO_4)	-	598
Scrubber water	-[e]	65
Water with ammonia	-[e]	25
To granulator		
Anhydrous ammonia	54[c]	-
Urea prills	980	1,097
Operating results		
N:P mole ratio PCR	0.6	1.2
N:P mole ratio product	1.0	1.2
Temperature, °F		
Melt in PCR	303	275
Granulator product discharge	184	185
Cooler product discharge	120	100
Melting point	235	220
Product chemical analysis, %		
Total N	28.2	31.1
Total P_2O_5	28.4	16.4
Water	1.8	0.6
pH of product	5.1	6.0
Critical humidity	55	55
Recycle rate, tons/ton product	1.5	4.5

a. Urea-ammonium phosphate grade produced in pilot plant.
b. Urea-ammonium phosphate sulfate grade produced in commercial plant.
c. Gaseous anhydrous ammonia.
d. Liquid anhydrous ammonia.
e. None added.

Figure 1

PRODUCTION OF TSP SLURRY FOR NPK MIX PLANTS





FPI SEC.—TVA
R S W

FIGURE 2

CONCENTRATED SUPERPHOSPHATE MANUFACTURE

SOLUBILITY OF $(NH_2)_2SO_4$ IN H_2SO_4 AND H_2O VS. TEMPERATURE FOR 35% H_2SO_4 SOLUTION

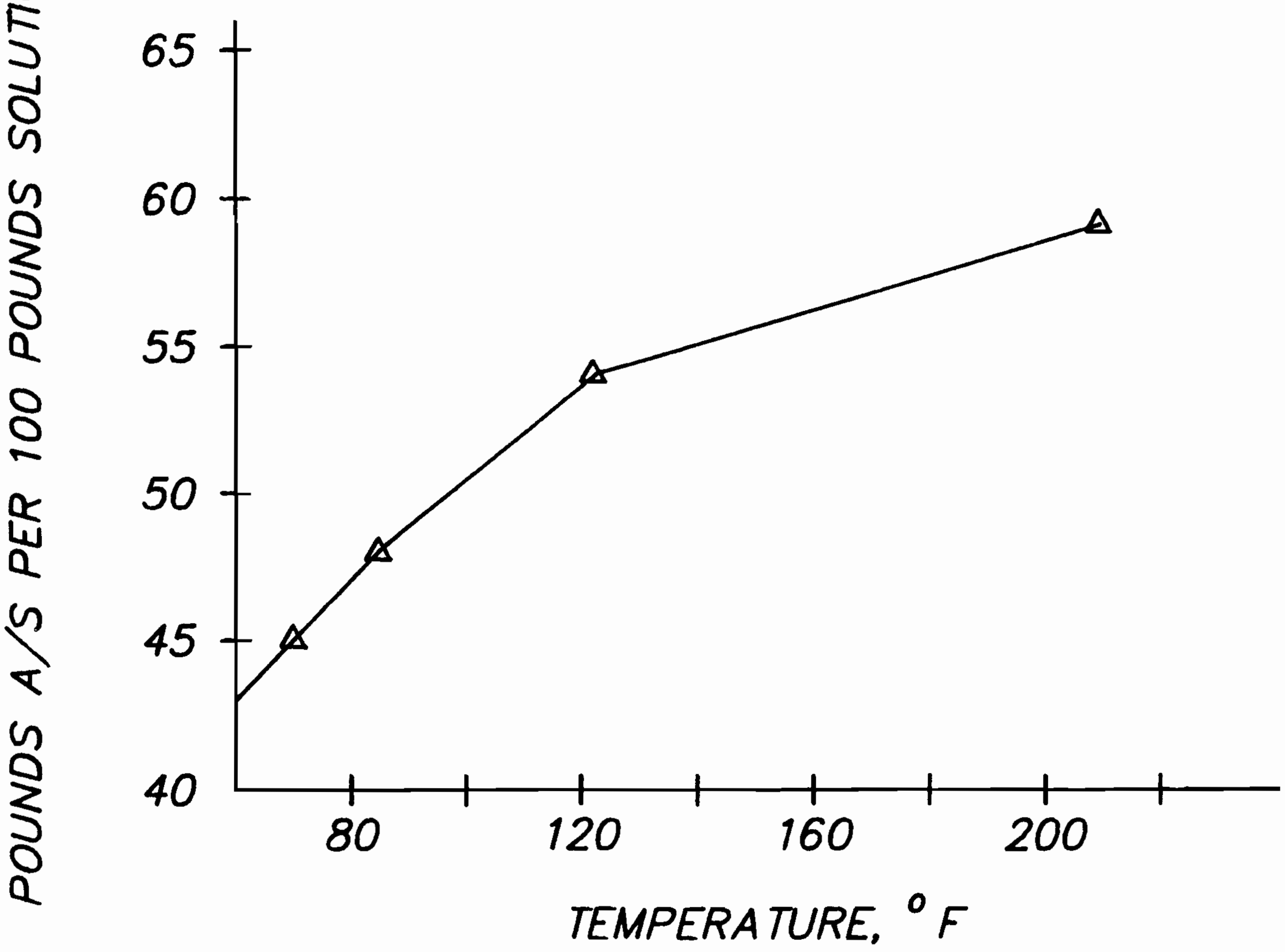


FIGURE 3

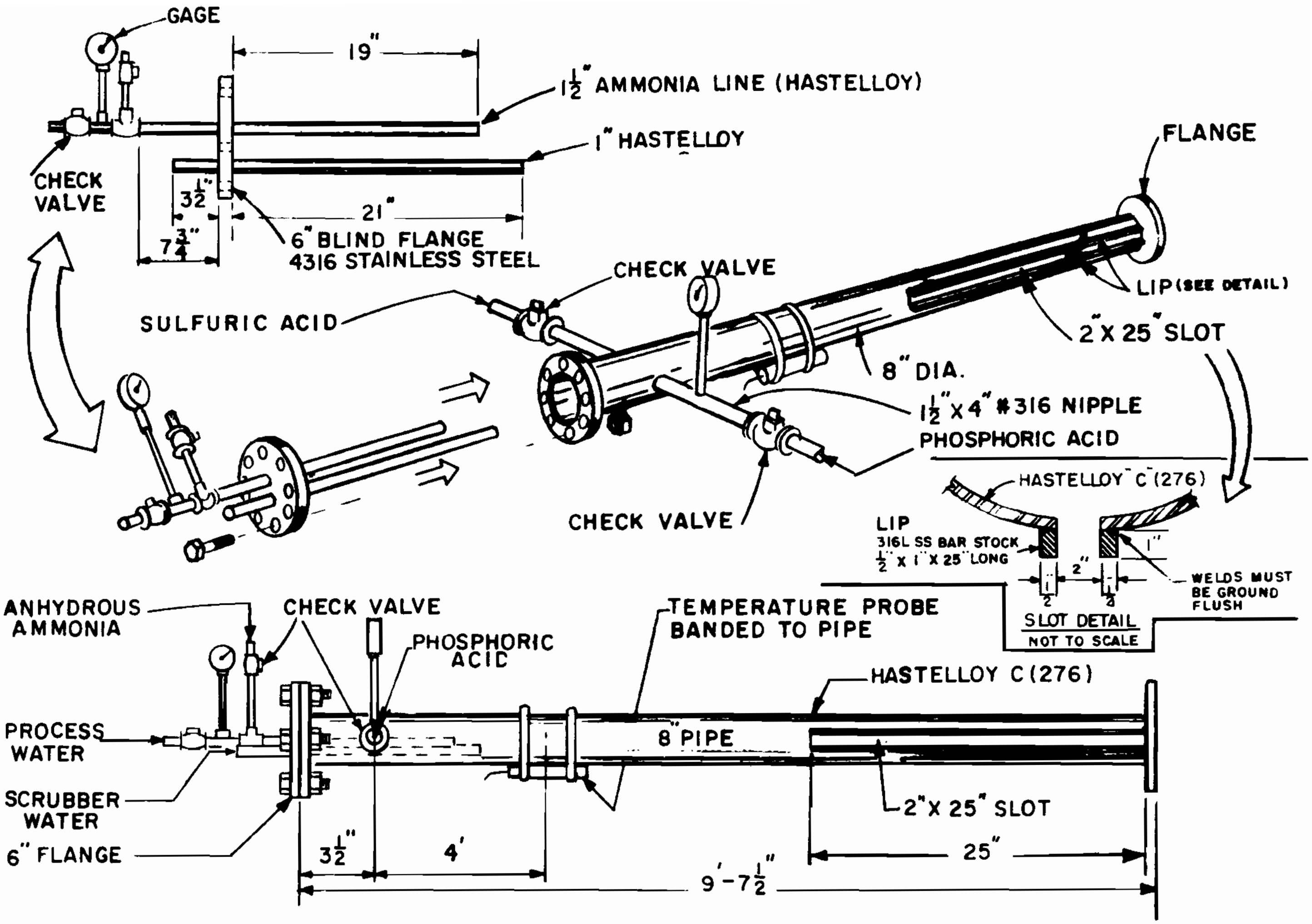
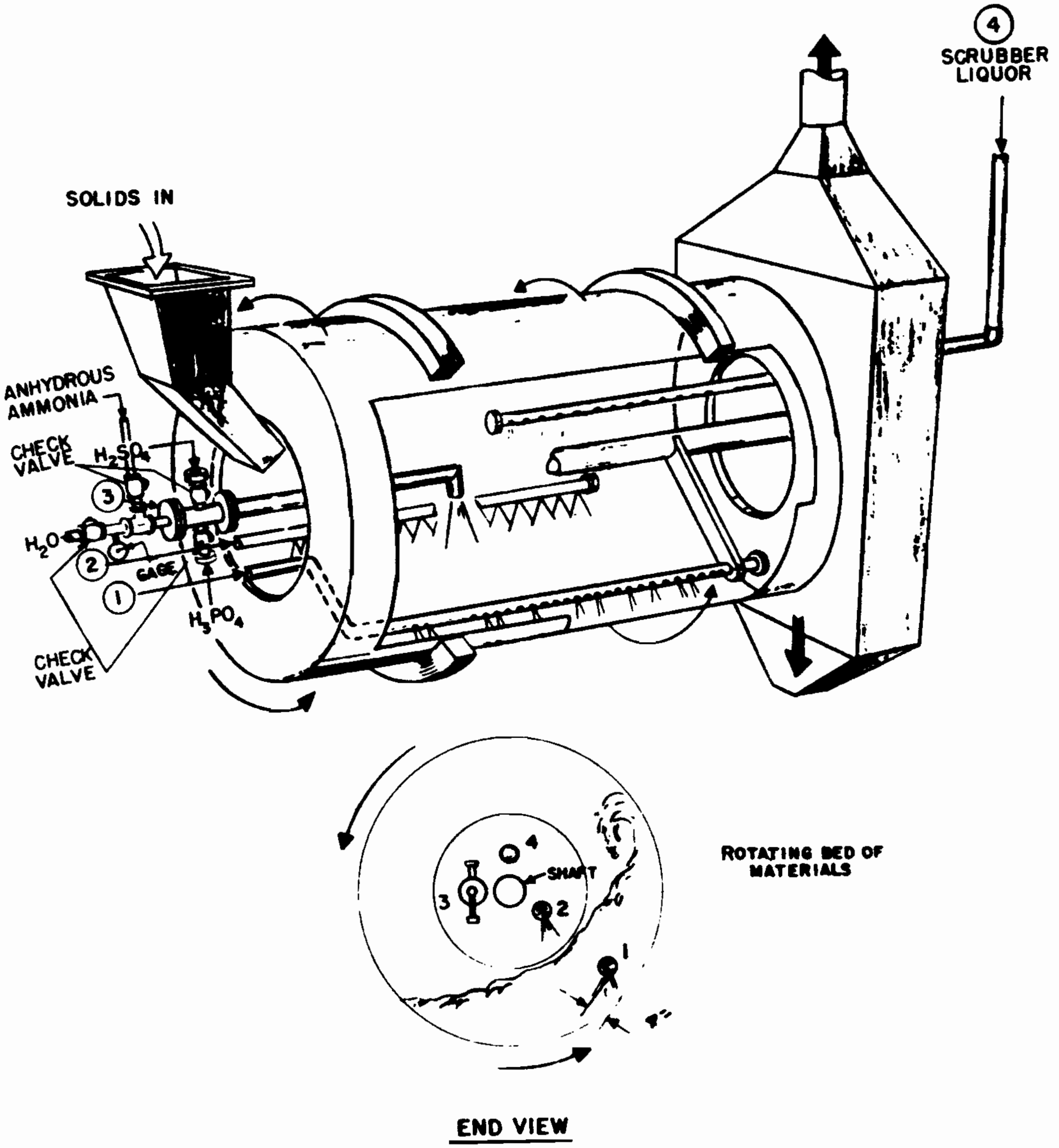


FIGURE 4

PIPE-CROSS REACTOR
8-INCH DIAMETER HASTELLOY "C" REACTOR TUBE



① AMMONIA SPARGER — LOCATED AT THE 4 O'CLOCK POSITION $4\frac{1}{2}$" FROM GRANULATION SHELL WITH HOLES FACING THE ROTATING STREAM OF MATERIALS. OVERALL LENGTH - 12 FEET. ONE HUNDRED AND FORTY TWO $\frac{1}{16}$" HOLES ON ONE INCH CENTERS WITH SMALL QUANTITY OF WATER ADDED TO PREVENT CAKE AROUND SPARGER.

② PHOSPHORIC ACID SPARGER — LOCATED TO DISCHARGE PHOSPHORIC ACID ONTO THE TOP AND NEAR THE CENTER OF THE ROTATING BED OF MATERIALS. OVERALL LENGTH - 8.9 FEET. SIXTEEN $\frac{3}{8}$ INCH HOLES ON THREE INCH CENTERS.

③ PIPE-CROSS REACTOR —

④ SCRUBBER WATER — LOCATED ABOVE THE BED IN GRANULATOR TO DRIBBLE SCRUBBER WATER ONTO BED.

FIGURE 5

LOCATION OF PIPE CROSS REACTOR AND SPARGERS IN AMMONIATOR-GRANULATOR

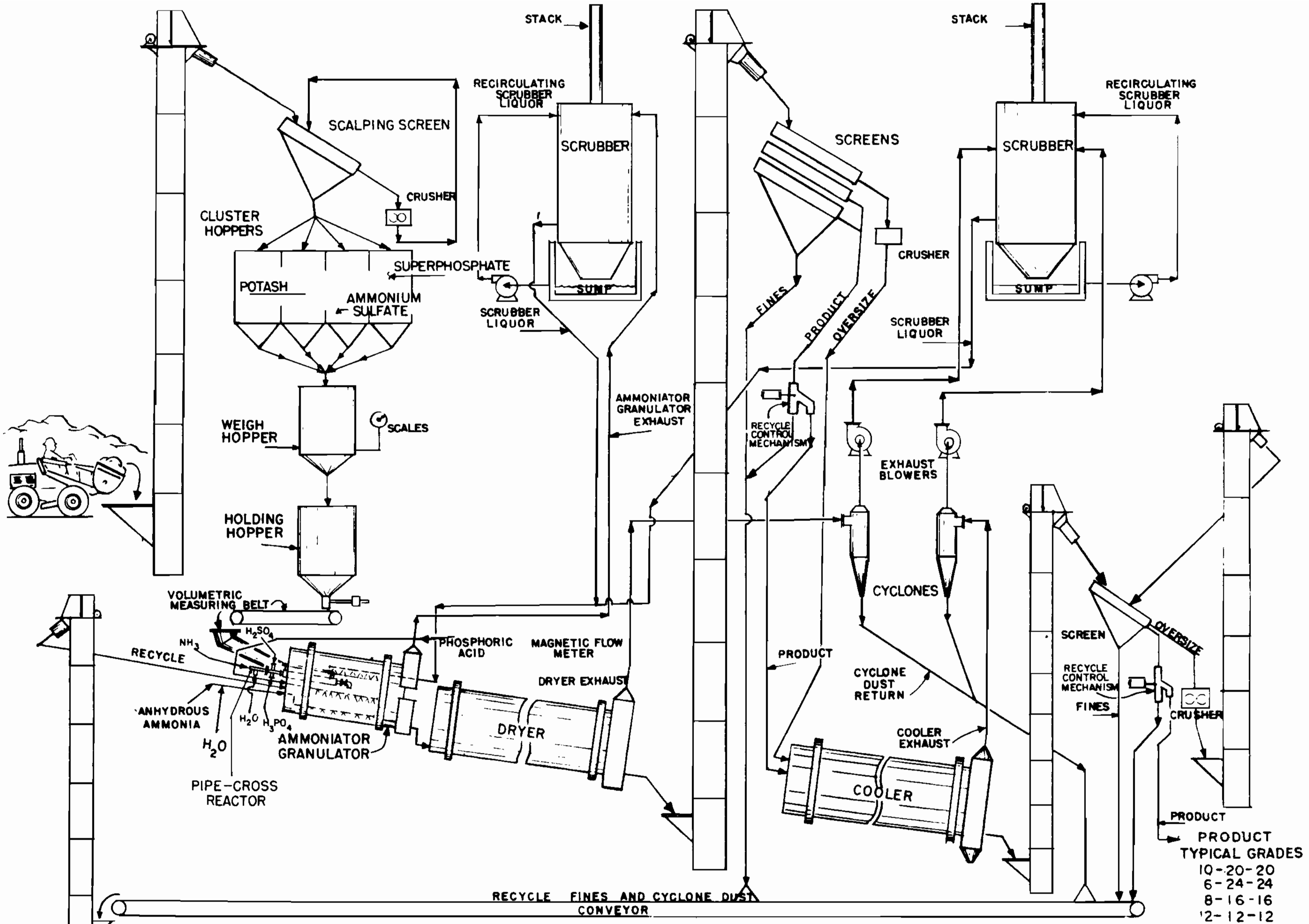


FIGURE 6

AMMONIATION-GRANULATION PLANT FOR AMMONIUM PHOSPHATE SULFATE PROCESS USING PIPE-CROSS REACTOR

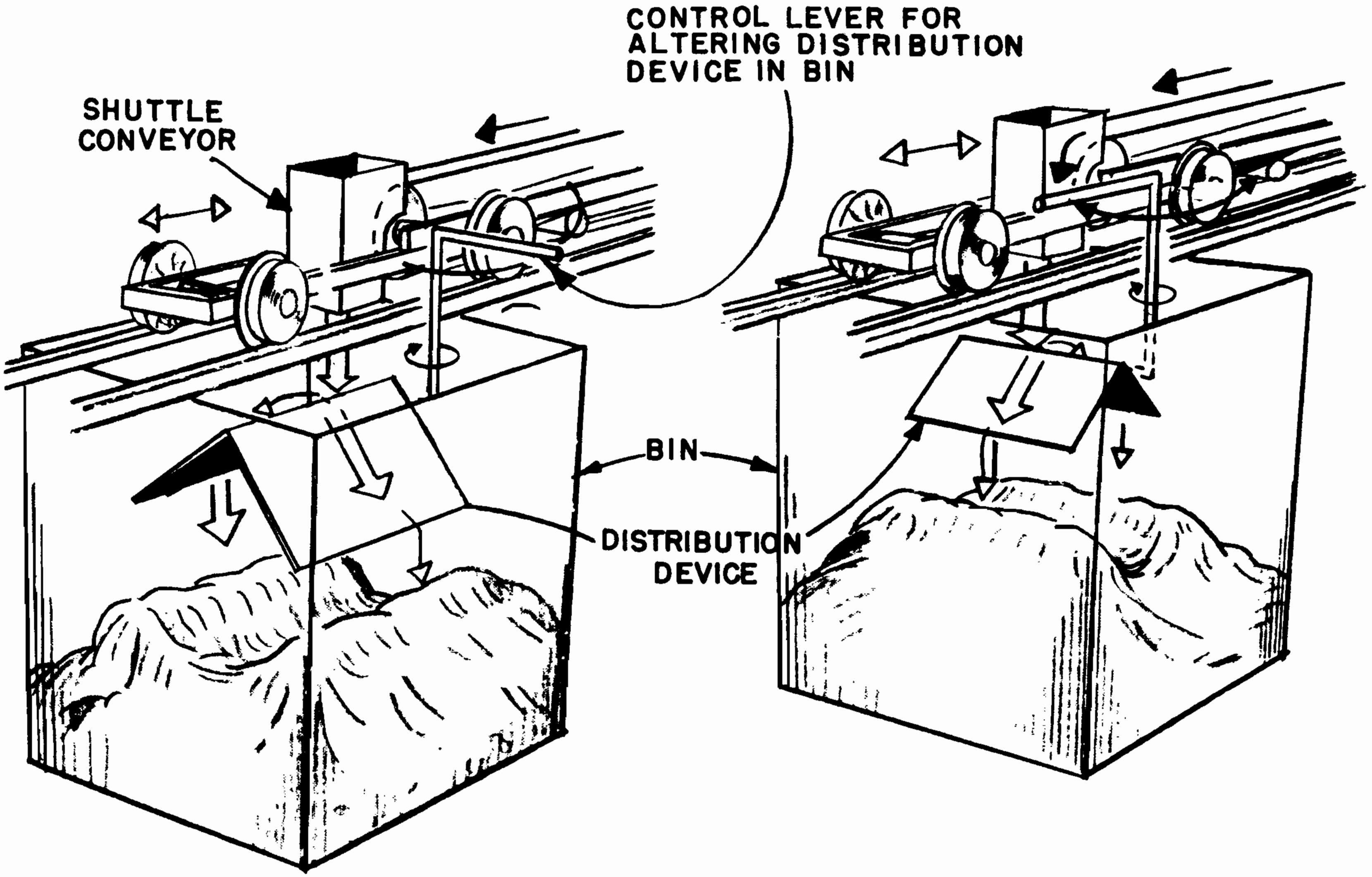


FIGURE 7

DISTRIBUTION DEVICE TO PREVENT CONING OF MATERIAL IN BINS

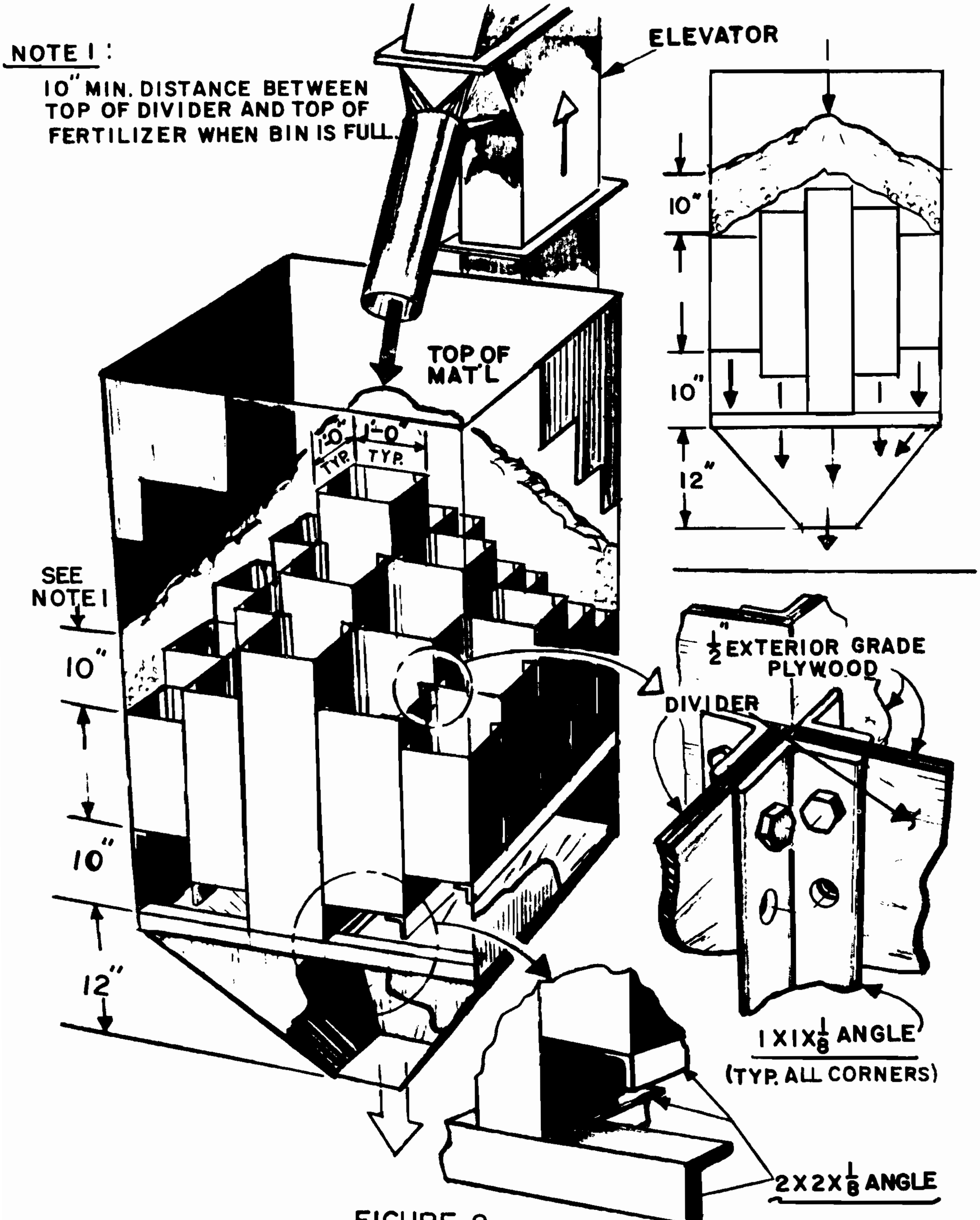


FIGURE 8
ANTI-SEGREGATION DIVIDERS FOR HOLDING HOPPER

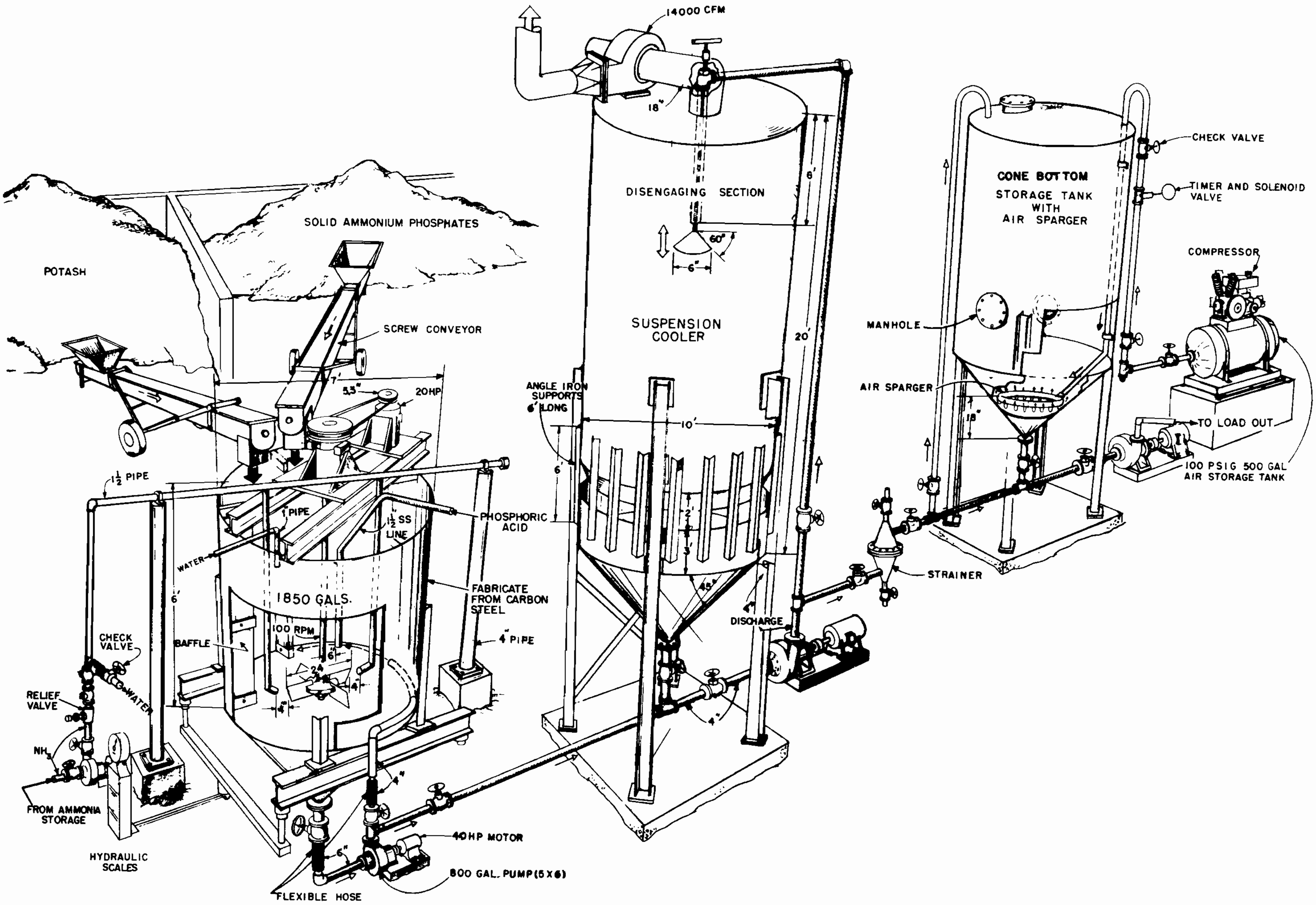


FIGURE 9

SUSPENSION PLANT-10-TON BATCH TYPE-FROM GRANULAR AMMONIUM PHOSPHATES

Phosphoric Acid, Granulation and Ammonia Plant Modifications

D. W. Leyshon, P. S. Waters, and B. M. Blythe
Jacobs Engineering

1.0 *INTRODUCTION*

In the highly competitive situation that exists in the international fertilizer scene today, the likelihood of major new complexes is confined to a few locations in the world. Remaining expansion will occur in lesser increments by modifications to existing plants. Modifications to increase capacity, are normal to fertilizer facilities. We'd like to summarize here some techniques that not only increase plant capacity but also improve efficiency and reduce energy consumption. We'll describe some examples of phosphoric acid, granulation and ammonia plant modifications. These modifications, as they may apply in specific situations, can provide a producer with the lowest production costs obviously necessary in today's highly competitive market.

We believe there is often some synergy in considering modifications in the context of the overall complex, from phosphoric acid production through granulation, and including the integration of ammonia production where possible, and we'll cite one example of this.

This paper cannot treat, in detail, the comprehensive list of modifications which are available to the producer. However, there are some aspects of this subject which we feel bear emphasizing, and we'll dwell on some of these.

2.0 *PHOSPHORIC ACID PLANT MODIFICATIONS*

In the late 1960's and early 1970's it appeared that the hemi hydrate or hemi-dihydrate phosphoric acid processes would begin to displace conventional dihydrate process which had experienced tremendous growth in the early and mid sixties.

The trend to the hemi process has been relatively slow to develop. So slow that some of the initial patents for the process that emerged in the 1960's are now expiring. However, there are circumstances that favor hemihydrate processes, which have definite energy advantages, and some further conversion to hemi will occur over the next few years, particularly as energy costs rise again.

But since there are also situations where the dihydrate process is and will continue to be favored, we will also cover some of the areas of improvement that can be applied to the conventional dihydrate plant.

2.1 Dihydrate Phosphoric Acid Plant Modifications

Many existing phosphoric acid plants have had modifications and debottlenecking to increase capacity. Even some of these have probably not achieved their ultimate capacity.

2.2 Digester Modification

Dihydrate reaction systems have been run and can be run successfully, as low in slurry detention as two to three hours. Generally, a dihydrate modernization includes increased recirculation of slurry which reduces the solid solution loss of P_2O_5 in gypsum and makes it possible to utilize lower detention without an excessive increase in P_2O_5 loss.

Jacobs has performed a number of modification projects to increase output and/or improve P_2O_5 recovery for plants currently in operation. For the multi compartment type reaction system, such as the Prayon process the preferred modification for the vintage 1970 or earlier plant requires substantially increased slurry recirculation. This usually necessitates the enlargement of slurry underflow openings and the enlargement of overflow weirs. This arrangement has been more successful than attempting to get more capacity by installing a new vacuum cooler in series with the first one. In some cases, substantial benefits can be achieved using a low head slurry pump for increased recirculation. Such pumps can move a massive amount of slurry using very little energy.

2.3 Filtration Modifications

The usual situation for an old dihydrate plant is to be filter limiting. Therefore, a supplemental belt filter can be of substantial value. Unfortunately the early versions of belt filters installed in North America for supplemental capacity were mechanically poor. More recently, installations at Texasgulf and Simplot of Enviroclear and Eimco belt filters have proved to be capable of substantial increases in P_2O_5 production per sq. ft. of filter area. Figure 1 is a diagram showing the effect of cycle time on capacity for several gypsums of different filterability. These curves are based on a similar curve from a paper on the Landskrona filter by R. Somerville. However, Jacobs has corroborated the relationship by commercial plant and pilot plant leaf tests, as shown in Figure 1.

2.4 Rock Grinding

Wet rock grinding, as practiced in the USA, currently consists of either open circuit grinding or closed circuit grinding using screens or cyclones. These closed circuit devices are called on to operate at 65% solids or higher on highly viscous slurries.

There are at least two other closed circuit grinding systems which can operate at higher efficiency. One is a centrifugal screen classifier which combines screening with centrifugal force to oppose the naturally viscous slurry. This 270° DSM screen is shown in Figure 2. It has been used in many wet cement plants to make a 48 mesh separation, but as yet has not been applied in phosphate rock circuits.

The other method which could increase grinding capacity over existing screening systems is the classic metallurgical wet grinding system shown in Figure 3. In this system, the efficiency of separation is sharpened by dilution of the mill slurry prior to classification.

Jacobs also offers a partial grinding process which utilizes screening in its dry grinding mode, Figure 4, and hydraulic sizing in the wet process, Figure 5. This process operates on material in the float concentrate size range, 25% to 45% plus 35 mesh. It would be applicable to Florida rock where some portion of flotation concentrate is used in the phosphoric acid plant. However, at the present time, most US phosphate mines blend back concentrate with pebble before shipping to the acid plant. In cases where substantial quantities of concentrate are used, some energy savings could be achieved by keeping the concentrate separate and by-passing the finer fraction around the mill.

2.5 Rock Blending

Many European plants purposely blend rock from several sources. Mixtures frequently contain some Florida rock which generally improves overall gypsum filtration and supplies soluble silica to reduce corrosion.

A case can be made, particularly in areas away from the phosphate mines, as for instance the lower Mississippi River area, for rock blending. A mixture of rocks could provide some of the better aspects of both. Use of North Carolina or North African phosphates in a blend with Florida rock could substantially reduce sludge problems, and improve DAP product grade problems. In some cases lower magnesium can be achieved. The use of phosphates containing low I & A, like those mentioned above, could extend the useful life of some high impurity Florida rocks. A good example of this concept has been the blending of Nauru rock with Christmas Island rock, which has been standard practice in Australia for over 25 years. The latter rock is virtually untreatable alone because of its high I & A. Yet millions of tons have been utilized economically. Small scale continuous phosphoric acid pilot plants, like one that Jacobs operates, can identify the operating characteristics of blends.

2.6 Conversion to Hemihydrate Processes

Some of the factors that favor conversion to hemihydrate are:

- Energy Benefits
- Poor Gypsum Filterability (Less than 0.6 TP_2O_5/sq.ft.)
- Improved Product Acid Quality
- A plant with Excess Filter Capacity
- Availability of Rock with 15% Moisture or less
- Low Rock Cost (Single Stage Hemi)
- High Rock Cost (Hemi-Dihydrate Process)

The benefits of higher strength acid have been well expounded by hemi process proponents. Interest in conversion has fluctuated with payout costs. In general, a limitation has been the high cost of congeneration equipment, rather than the cost of hemi conversion itself. Benefits for hemi operation can run as high as \$20 to \$30/T P_2O_5 in extreme circumstances. Usually this occurs where sulfuric acid plant steam is not available and fuel must be otherwise used for concentration of P_2O_5.

A word might be said for the improved acid quality achieved particularly in the single stage hemi process. The hemi process rejects about 50% of the Al_2O_3 in the rock, depending on the hemi product acid strength. It also produces an acid of low sulfate content. This latter aspect has no benefit to DAP grade, but it does for TSP. The desulfated hemi acid will raise TSP APA by over 0.5%, or conversely will allow for working off more sludge in TSP.

One major deterrant to conversion to hemihydrate in Florida has been the necessity to have a rock moisture of no more than about 15%. This was achieved in one conversion by using a spiral concentrate phosphate. The specifics of each situation need study to determine if unground concentrate plus ground pebble can be used in conjunction with an extra wash stage on the filter. Jacobs has under consideration also, sponsorship of a multiclient study for this rock moisture problem, to be carried out in its laboratory.

To date the most successful hemi plants have been the single stage plants, although significant future potential exists for the two stage process. This is particularly true because of the much higher yields obtained. Where single stage hemi plants are currently in operation, it is likely that eventually second stages will be added. It's simply a matter of economic payout. One factor that favors two stage operation is the relatively poor water soluble recovery achieved in hemi filtration on conventional Bird-Prayon filters. This P_2O_5, plus the solid solution P_2O_5, is recovered in the two stage process, boosting recoveries to the 98% P_2O_5 range.

3.0 GRANULATION PLANT MODIFICATIONS

Quite a number of recent articles describe methods of increasing capacity and updating granulation plants (1).

One example of a successful DAP upgrading project is a modification engineered by Jacobs, which provided an increase of about 50% in capacity. This was achieved by increasing solids recycle by means of elevator and dryer modifications, the addition of a tailgas scrubber and the addition of a larger preneutralizer, to describe some of the major changes. The incremental cost of upgrading in this instance was substantially less than the same capacity would cost in a new plant. There are in existence, many granulation plants built in the 60's which, at their advanced years, may require some major overhaul of equipment. This frequently offers the opportunity of increasing capacity and efficiency at the same time, at much less cost than a new plant.

Another recent modification project by Jacobs, the conversion to alternate production of monoammonium phosphates in a GTSP plant, involved the addition of 10" TVA type pipe reactor. That work included scrubber modification to accommodate ammonia recovery in a plant formerly set up to use once through pond water. An eductor venturi scrubber, similar to that shown in Figure 6 was a key element in the modification. This type of scrubber can be inserted into an existing scrubbing system without requiring a fan change since it generates its own head, so to speak, and, in fact, could be used to increase gas flow through the system. This ejector venturi, employing a high rate of solution flow, has been very successful in absorbing the ammonia slip contained in the off-gases from the granulator.

In the above MAP conversion, the strength of P_2O_5 used is well below that required to make the process self drying, but the Pipe Reactor is doing an excellent job, with very low Ammonia slip, in a plant where no preneutralizer exists. If acid in the range of 47% P_2O_5 were available this 10" pipe reactor system could produce well in excess of 90 TPH of MAP.

The two projects described above are examples of relatively different modifications. Since, no two plants are alike, each project has its own specific requirements.

The above TVA type Pipe Reactor project is a successful application of the pipe reactor. The plant has not been run on DAP, but the reactor is similar to the one operated to make DAP at Royster in Florida for over a year. We believe the scrubbing system is capable, with minor modifications, of handling high tonnage production of DAP from the Pipe.

In considering processes where granulation moisture is reduced as in pipe reactor processes, it is well to bear in mind that low moisture, highly viscous, slurries do not dry well and may require extended drying time. We like to cite the example of pouring an ammonium phosphate slurry only ¼" thick into a pan and attempting to dry this. The slurry will be wet on the bottom even after drying in a hot oven overnight because a hard impervious crust forms on the surface. On the other hand a slurry of the proper viscosity when spread over a large surface area of hot recycle solids will dry in a matter of minutes, if not seconds. Jacobs granulation processes and those generally practiced in the USA, use high throughput, thin film drying and low dryer detention compared, for example, to European practice. The claimed advantages for very low recycle pipe or pressure reactor DAP processes, as practiced by several European process vendors, are not apparent to us. The demonstrated operating rates versus major rotary and gas handling equipment sizes, compare unfavorably with U.S. DAP practice.

We will not go into a detailed discussion here of many modifications that are possible to improve energy efficiency, ammonia recovery etc. However, two techniques rather fit together. This is to use tailgas scrubber circulating water to vaporize ammonia and to use the steam made available to preheat the quench air used in the dryer. A diagram of the first half of the process is shown in Figure 7. A substantial amount of steam is available for air heating but in most cases only part can be used for air heating because the low pressure steam temperature is relatively low. Usually from 20% to 50% of the dryer fuel can be displaced.

Before we leave the subject of granulation modifications it should be stated that we prefer to run DAP and MAP with gaseous ammonia. It reduces P_2O_5 acid strength and tends to reduce fuel consumption by pushing the granulator temperature slightly higher. Ammonia slip is usually more with gaseous ammonia in the granulator, but this can be handled. In that context, where the ammonia plant and the granulation plant are nearby, it makes sense to deliver to the granulation plant gaseous ammonia at a pressure of about 75 psig to 100 psig directly from the ammonia plant. This avoids the cost of compression and the steam required to revaporize in the granulation plant. The overall saving is about 500,000 Btu/ton of DAP, which is perhaps $2.00/T of DAP. While there are not too many opportunities to integrate ammonia plants and granulation facilities, this concept should be considered where the opportunity presents itself.

In terms of relative economies, an important aspect of production cost is the "large single line" concept. This suggests working and modifying some plants to the utmost capacity and shutting down others.

The cost of modifications to existing granulation plants can be in the range of 0.5 million dollars to 5.0 million dollars, depending on the level of upgrading desired or economically possible. However replacement cost for a 100 to 120 TPH DAP plant is likely to be at least 12 million dollars for the battery limits portion.

4.0 AMMONIA PLANT ENERGY IMPROVEMENTS

Since the energy shortages and cost increases of the seventies many changes have been made in ammonia plant processes. Energy consumption has dropped from around 43 to below 30 mm Btu/ton of Ammonia in new plants offered today. Many of these innovations can be applied to existing plants with very impressive project payouts. This section of our paper will discuss several of these which together total 8.5 mm Btu/ton of ammonia.

4.1 Use of Gas Turbine Drives

The use of a gas turbine for one of the major drives can significantly improve the energy consumption. Gas turbine efficiencies, with heat recovery from the flue gas to 300°F are typically 5M Btu/HP compared to 11M Btu/HP for a 900 psig steam turbine drive. This represents a saving of approximately 1.8 MM Btu/ton of ammonia product.

Conventionally, the exhaust from the gas turbine is routed to the primary reformer as combustion air. The lower oxygen content of the gas turbine exhaust increases the flow in both radiant and convective sections. If other energy saving measures are in place, the amount of auxillary firing required in the convection section is reduced, and this counterbalances the increase in flue gas flow from the use of gas turbine exhaust. A reduction in Flame temperatures in the primary reformer is achieved resulting in increased tube life.

Alternatively, the exhaust from the gas turbine can generate high pressure steam in a wasteheat boiler, reducing firing in the reformer convection section.

4.2 CO_2 Removal Section

Standard MEA CO_3 removal systems have a heat requirement of about 85M Btu/lb mole CO_2 removed. Most plants using MEA systems have added inhibitors and increased the solvent concentration to about 30% MEA, reducing heat input to about a 55M Btu/lb mole. The latest MEA retrofit systems which include a rich solution flash have a requirement of about 45M Btu/lb mole of CO_2.

Potassium Carbonate CO_2 removal systems, require about 45-50M Btu/lb mole CO_2. The use of a lean solution flash and a thermo compressor can lower this to 25-30M Btu/lb mole of CO_2, or about 1MM Btu/ton of ammonia. These flash cooling/thermo compressor systems have been in operation since the mid-1970s.

Hydraulic turbines may be used to recover the power as the rich solvent is let down from absorber to stripper pressure. They will normally be used to assist in driving the lean solvent recirculation pump.

Exxon Hindered Amine Promoted Hot Potassium Carbonate Scrubbing System

Exxon has a process based on the use of a sterically hindered amine promoter. In a commercial trial of the promoter in a natural gas plant, a 50% increase in acid gas removal capacity was achieved over conventional DEA promoted potassium carbonate with no equipment modification. Reboiler heat load requirements were reduced by 30%.

4.3 Replacement Ammonia Synthesis Converter

The use of a radial flow type ammonia converter unit significantly decreases loop pressure drop. The Haldor Topsoe or Ammonia Casali Converters utilize an internal interbed heat exchanger which increases conversion. This increase can either augment production capacity and/or decrease plant energy consumption. Heat exchange, rather than quench, in the converter raises the exit temperature allowing higher temperature heat recovery. Capacity increases of 25% and a total loop heat recovery of 2 MM Btu/ton of ammonia are typical.

4.4 Molecular Sieve Synthesis Gas Drying

Conventionally synthesis gas is added to the loop after separation of some ammonia product (primary ammonia).. The combined circulation is then cooled to recover more ammonia (secondary ammonia). This removes final traces of water and carbon dioxide which can deactivate the synthesis catalyst. The circulating gas is then reheated and passes to the synthesis converter.

Molecular sieves have been used since 1977 to remove water and CO_2 making this secondary separation unnecessary. Because the makeup gas is not mixed with the loop circulating gas, until after separation of the ammonia product, the converter feed is more dilute in ammonia. A larger differential ammonia concentration is effected, which lowers the recycle rate. This and the simpler flow path translate into lower recycle power. Potential energy savings are 0.5 MM Btu/ton of ammonia.

4.5 Steam Reforming Area

To maximize the efficiency of an ammonia plant, it is essential that heat be recovered from the reformer flue gas to the lowest practical temperature (250–300°F), and that the maximum amount of heat be recovered at the highest possible temperature level.

Combustion Air Preheat: Combustion air preheat is conventionally practiced where fuel costs are high. The use of air preheating can save approximately 1 MM Btu/ton of ammonia.

Jacobs has executed several combustion air retrofits on both side-fired and top-fired reforming furnaces and can provide a system which is both economic and arranged so that access to the reformer furnace burners is maintained.

Feedstock Saturation: Low grade convection section heat may be recovered by preheating water which is subsequently sprayed into a packed tower in countercurrent flow to natural gas feed. Steam evaporates providing part of the process steam, and the water is then recirculated to the preheat loop. Heat recovered from low temperature flue gas replaces the fuel required to generate process steam. Use of saturator systems can save 2 MM Btu/ton of ammonia.

4.6 Selective Carbon Monoxide Oxidation

Carbon monoxide exit from the LT shift converter is determined by equilibrium and approach temperature. Typically, there is 0.1 to 0.2% CO in the LT shift reactor product with fresh catalyst. This increases to over 0.5% as the catalyst ages. This CO consumes hydrogen in the methanator while producing methane, which must be purged from the synthesis loop.

Englehard has developed a selective carbon monoxide oxydation system, based on a proprietary precious metal catalyst. The shift effluent is cooled and steam condensate is removed. It is then reheated to reduce relative humidity. A stoichiometric quantity of air is then added, (stoichiometric to carbon monoxide), and the carbon monoxide is selectively oxidized to carbon dioxide over the precious metal catalyst.

Energy savings attributable to the use of the Selexo process at a constant production rate, are approximately 0.15 MM Btu/ton.

4.7 Argon Recovery

Argon currently sells for between $250/ton and $380/ton in the United States. Approximately 14 TPD of Argon can be recovered from the purge of a 1000 TPD ammonia plant, leading to a potential revenue of $1.7MM per annum.

4.8 Energy Savings Schemes not Suitable for Retrofit Situations

Several production schemes are in operation in modern ammonia plants that are not suitable in a retrofit application. Both the ICI AMV and the Braun Purifier process which use superstoichiometric quantities of nitrogen in the reforming area to shift the reforming heat load from the primary to the secondary reformer, and then remove the excess nitrogen by cryogenic means, are unsuitable because they significantly increase the flow rate in the reforming, shift and CO_2 removal areas of the plant, and also the amount of CO_2 that must be removed from the process gas. The low loop pressure of the ICI AMV scheme also necessitates virtually complete replacement of the synthesis loop equipment. Likewise, the Fluor scheme which uses propylene carbonate for carbon dioxide removal at high pressure is unsuitable, as it necessitates complete replacement of the CO_2 removal and methanation sections of the plant.

JACOBS AMMONIA PROCESS DESIGN SIMULATION CAPABILITIES

Jacobs employs a full suite of computer programs to simulate ammonia plants based on natural gas and naphtha feedstocks via steam reforming, and fuel oils, residual oils and coal via steam oxygen/air partial oxidation. These programs include the Aspen process simulator developed by MIT and a suite of proprietary programs. The individual components which comprise our ammonia plant simulation capabilities are as follows:

Primary/Secondary Reforming: This program performs heat and material balances across primary and secondary reformers. For a given feedstock and steam feed, it computes the reformed gas analysis and heat load in the primary reformer, and the air to carbon ratio in the secondary reformer.

Primary Reformer Radiant Section Simulation: Accurate simulation of the primary reformer radiant section is essential for an accurate estimate of reformer tube temperatures and tube life. This program calculates individual gas compositions, and hence, inside film coefficients at increments down the reforming tube. On the flue gas side, the program solves the radiant field and calculates the flue gas analysis and radiative and convective heat flows, vertically and horizontally occuring in the furnace box. The radiation on the tubes, and tube thickness, are used to calculate both longitudinal and radial reformer tube metal temperature profiles, and tube life.

Carbon Monoxide Conversion: This program calculates the heat and material balance across the high and low temperature shift converters and optimizes catalyst volumes for interbed quench and/or heat exchange situations.

Methanation: This program simulates the methanation process.

Ammonia Synthesis: This program calculates the ammonia synthesis loop heat and material balance, including the makeup and purge requirements, quench stream flow rates and converter interbed heat exchange requirements. The nonideality of ammonia is taken into account in these calculations.

5.0 CONCLUSIONS

There are many methods by which a fertilizer producer can reduce costs. We are sure most producers have looked at many of these in the past. However, as conditions change the benefit from many of the modifications we have discussed will also change. It is unlikely that any plant will benefit from all of these but some may show a very short payout.

The ability of a producer to make the most of his existing facilities is vitally important. This optimization process is a continuing and evolving one and, we believe, warrants constant update to ensure that a producer is reaching his minimum operating cost.

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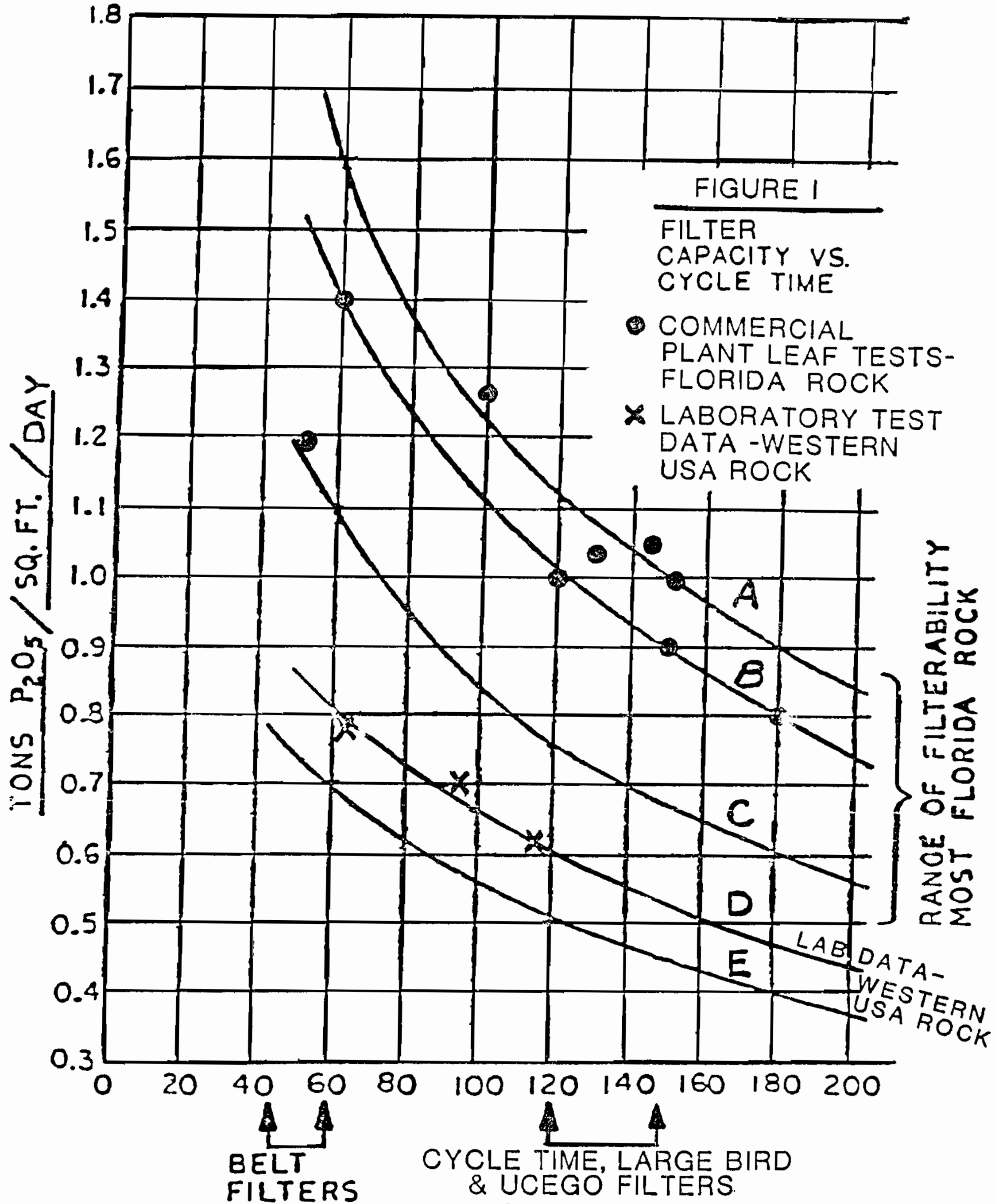
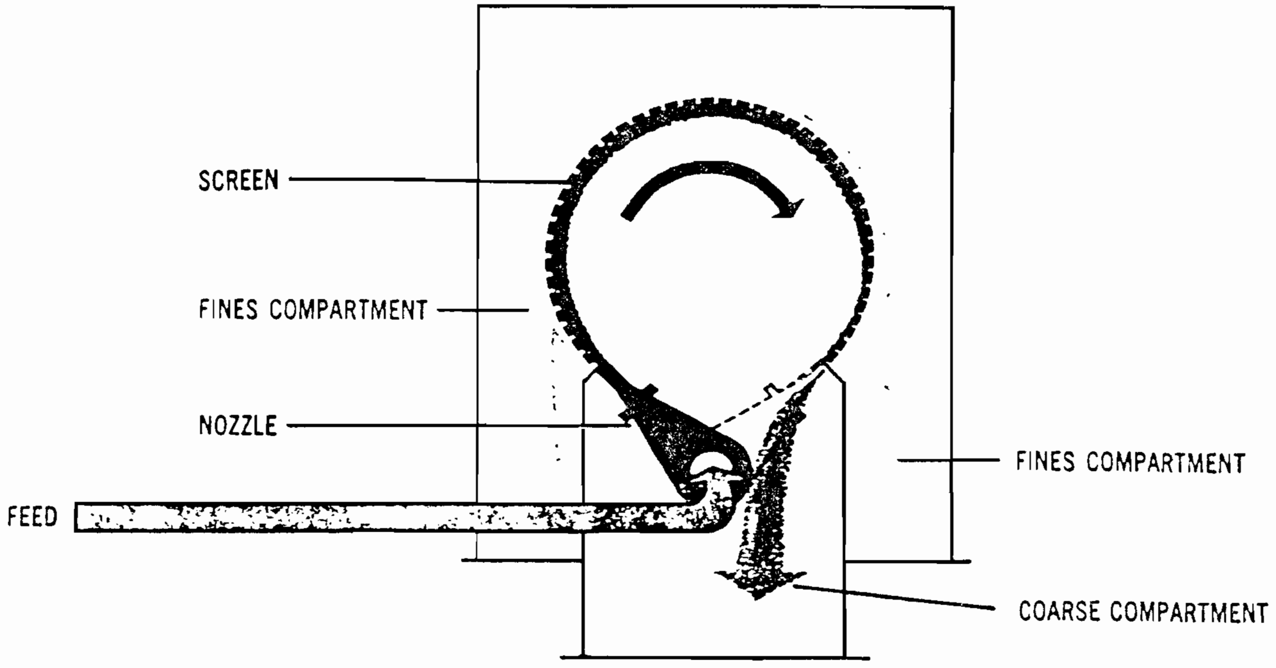


FILTER CAPACITY
VS
CYCLE TIME AT
CONSTANT VACUUM

JACOBS ENGINEERING CO.
LAKELAND FLORIDA



270° DSM SCREEN

FIGURE 2

CLASSIC METALLURGICAL WET GRINDING FLOWSHEET

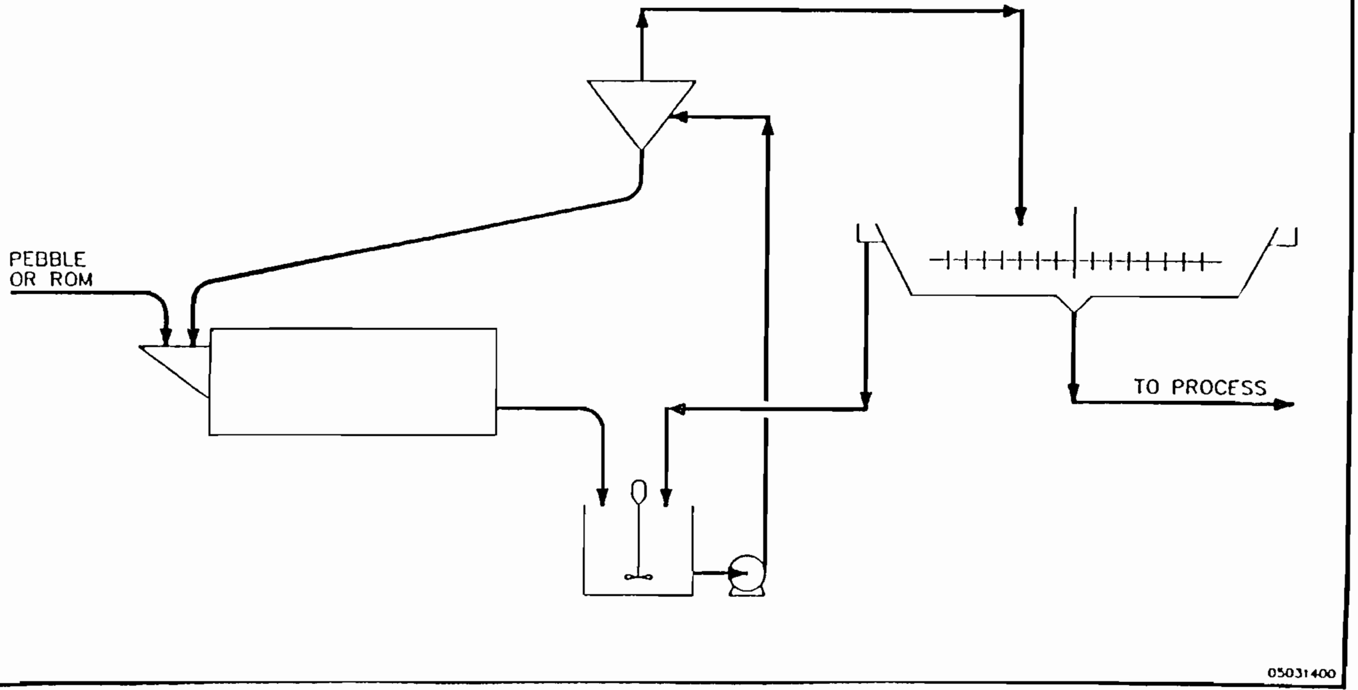


FIGURE 3

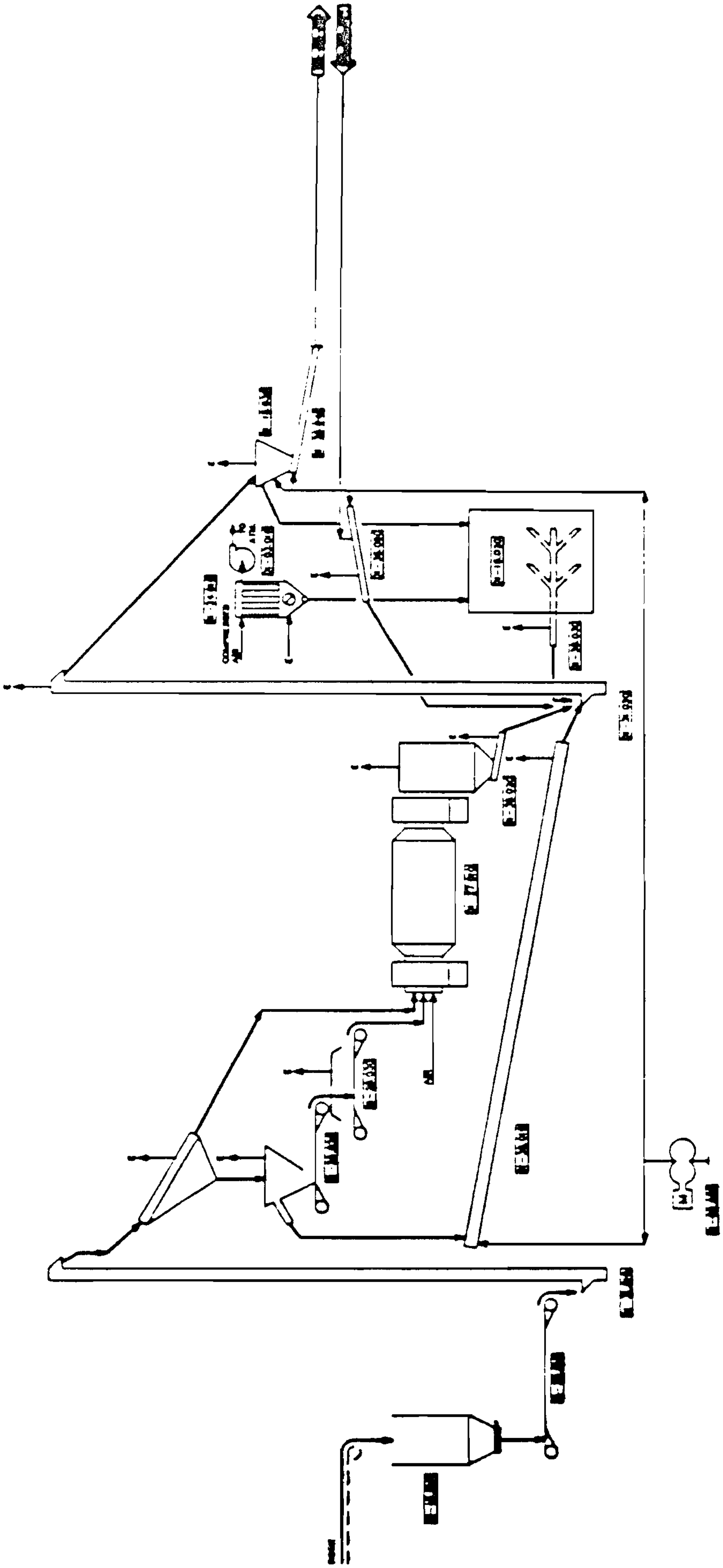


FIGURE 4

JACOBS PARTIAL GRINDING PROCESS FOR PHOSPHATE ROCK

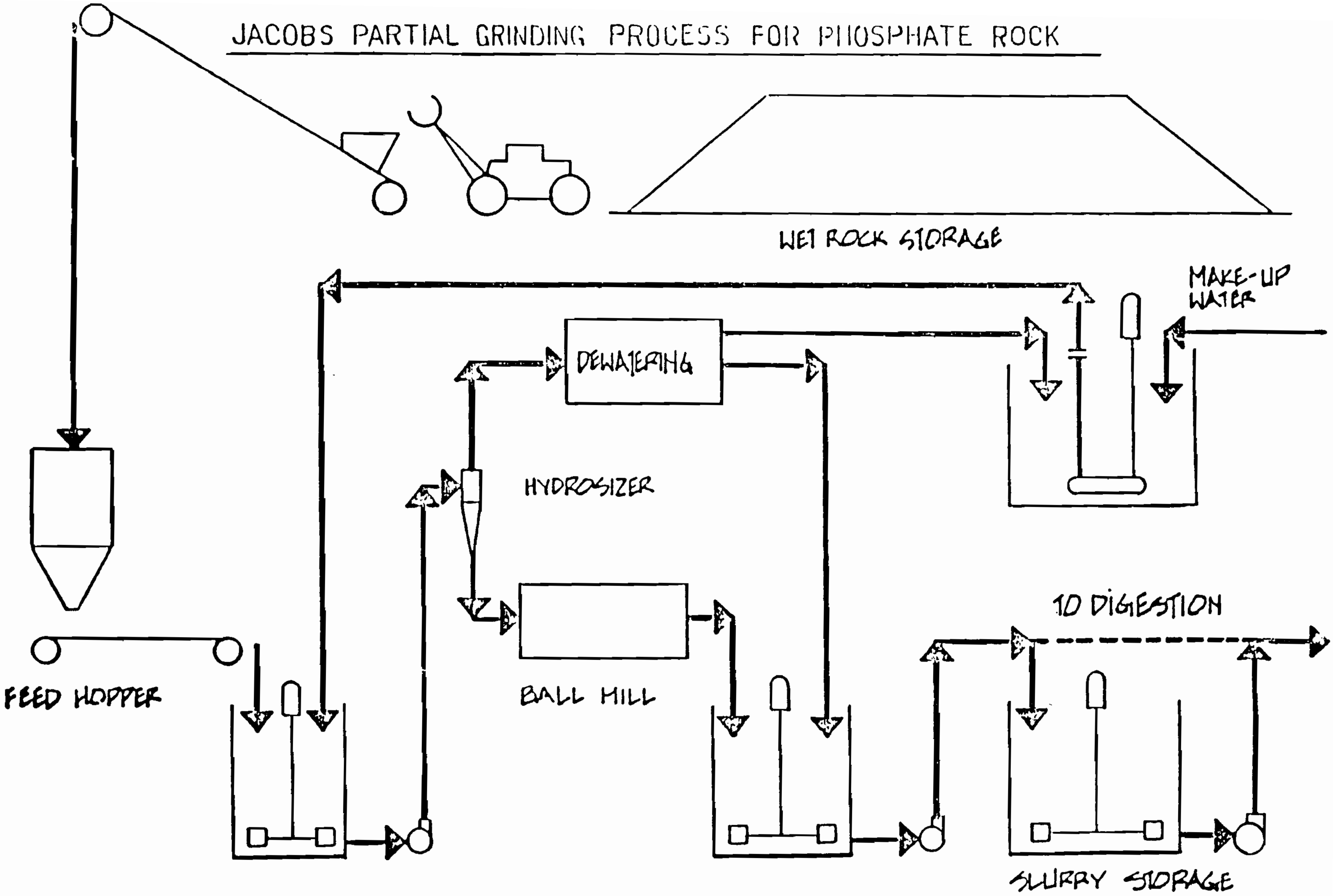
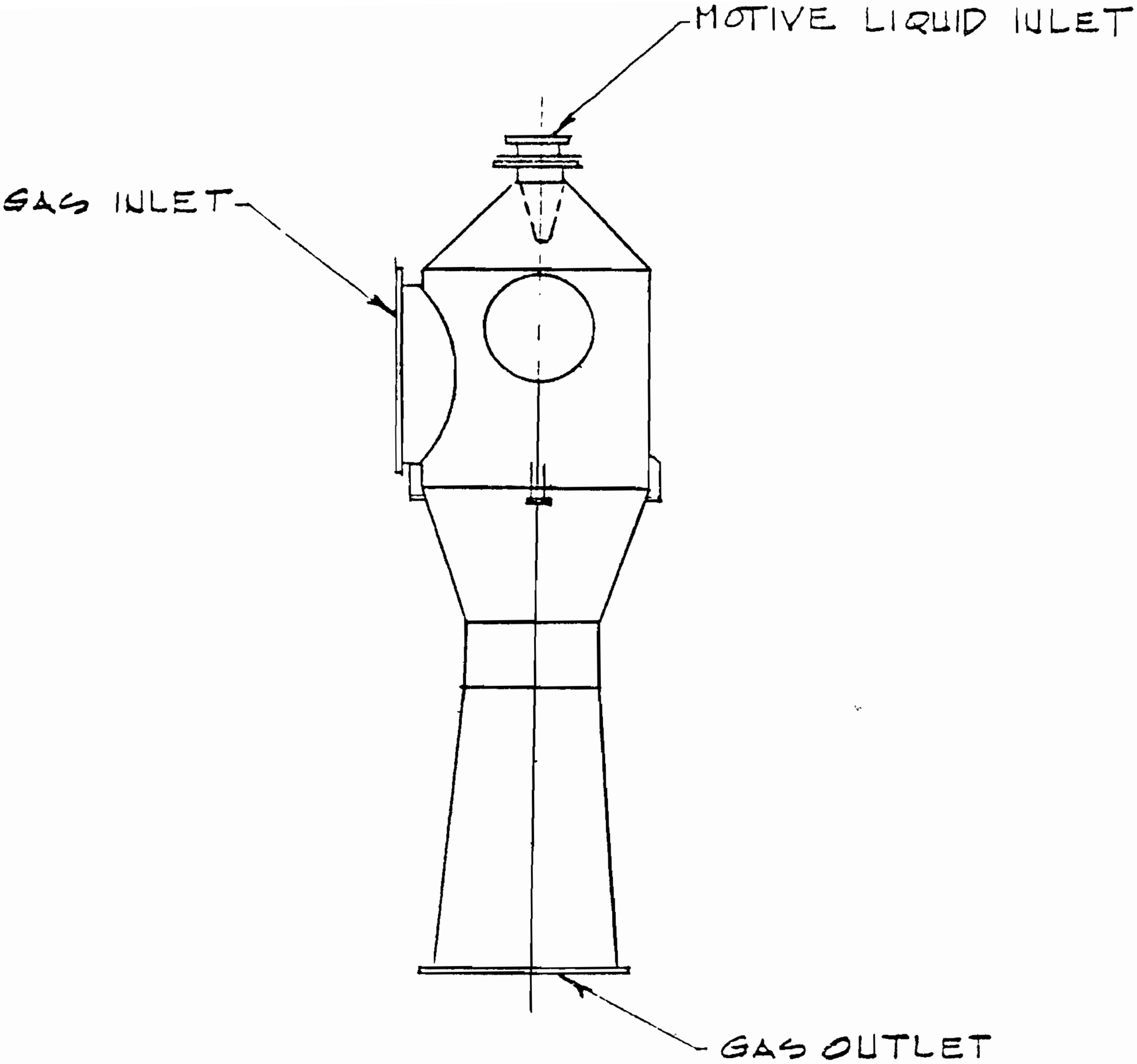


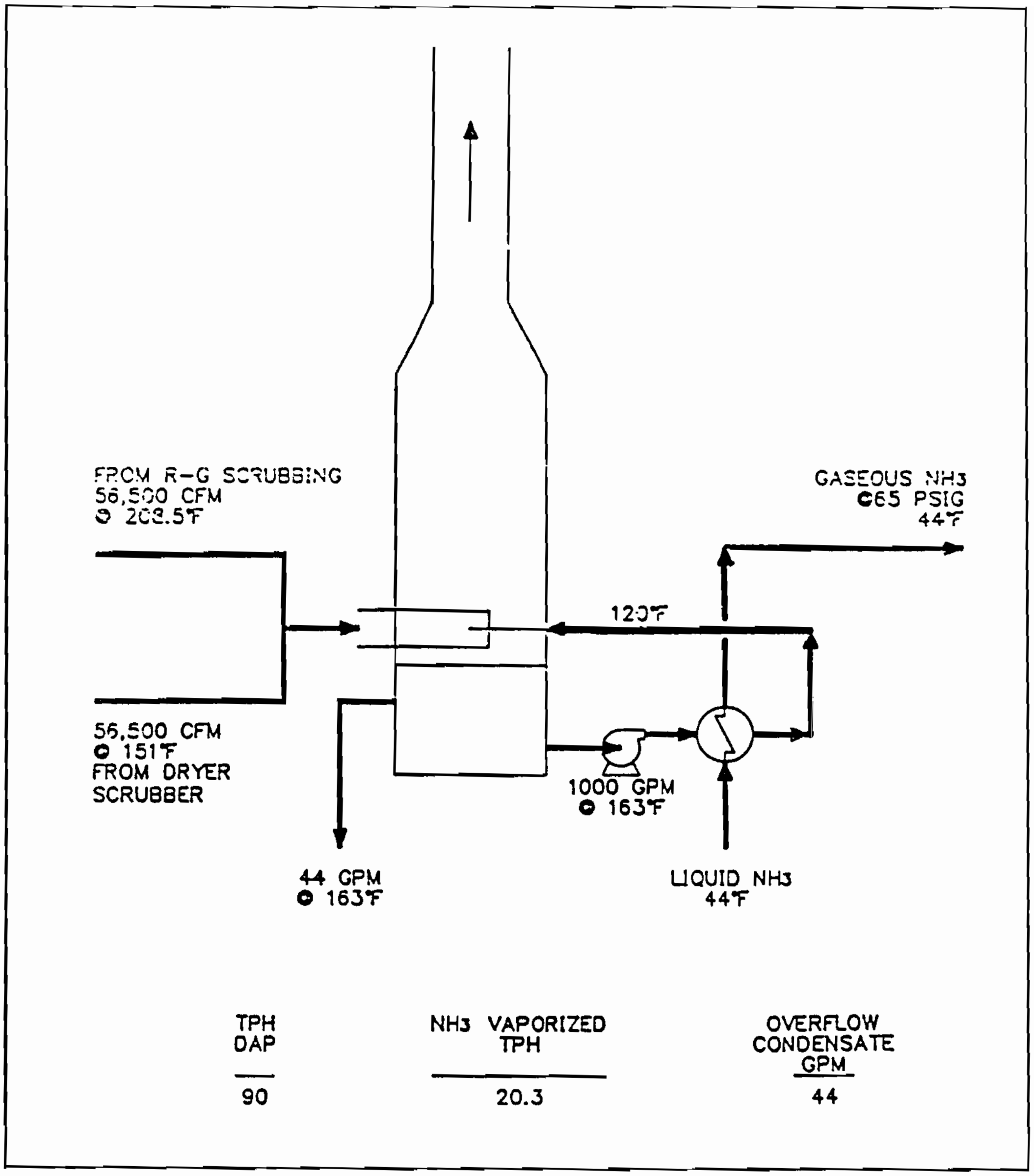
FIGURE 5



EJECTOR VENTURI

NO SCALE

FIGURE 6



TPH DAP	NH3 VAPORIZED TPH	OVERFLOW CONDENSATE GPM
90	20.3	44

FIGURE 7

HEAT RECOVERY FROM TAILGAS
SCRUBBING SOLUTION

98,117 CFM
163°F

Phosphogypsum Utilization—Davey McKee Corp/Florida Institute Phosphate Research Program Update

By Tim Kendron

Davey McKee Corporation

PAPER NOT AVAILABLE AT TIME OF PUBLICATION

Tuesday, November 3, 1987

Morning Session III
Moderator:

Joseph E. Reynolds, Jr.

Ramifications of Protectionism and Quotas on World Fertilizer Distribution Patterns

Ford West
The Fertilizer Institute

The growing trend in the international fertilizer business is the increased number of *countries* who have and are expanding their involvement in fertilizer production and trade. Examples include Morocco, Jordan and Saudi Arabia. These governments have the natural resources, they need to find employment opportunities for their citizens, they need to expand their GNP and in most cases, they need ways to generate foreign exchange. World fertilizer trade, therefore, is not tied to basic economics i.e. supply vs. demand but, is tied to world governments economic politics and internal political pressures.

Thus, quotas, tariffs, counter trades, protectionism and dumping sites are the new buzz words in international fertilizer trade and are key indicators to world fertilizer distribution patterns.

The most common approach world wide to protecting a nation's fertilizer industry is through tariffs. Import tariffs charged on fertilizer products exported from the U.S. are costing the U.S. industry $150–$200 million per year based on the latest published tariff tables and declared fertilizer export volumes available from the U.S. Department of Commerce. The import tariffs, which represent cost or lost value, to U.S. fertilizer producers range from 4 percent to 100 percent of declared value including freight, depending on product.

The U.S. does not impose import tariffs on fertilizer products from any country and has not since 1922. Many countries which impose heavy tariffs on fertilizer imports from the U.S. enjoy duty-free access to markets in the U.S. Fertilizer producers in these countries, often operating with direct or indirect government subsidies, are free to compete with U.S. producers for U.S. domestic markets, while penalizing U.S. product entering their own borders.

In the trade bill pending before Congress, the Senate at TFI's request approved an amendment clearly identifying that tariff reduction for groups of products entering the U.S. duty-free but which U.S. products face tariffs imposed by other importing countries would be a major objective on the multilateral trade negotiation (MTN) currently underway in GATT.

The most damaging tariffs faced by the U.S. are those that are discriminatory and directed only to certain trade partners, often the U.S. Such tariffs have a very negative impact on U.S. exports.

The EEC imposes an import duty of 12.4 percent on urea (a nitrogen fertilizer) originating from the U.S. or Eastern Europe. Urea imported from U.S. competitors in third world countries (excluding the Middle East), however, is essentially free of duty although subject to quota limitations.

The EEC import duty on ammonia from the U.S. and Eastern Europe is 12 percent, while ammonia from our competitors in Venezuela, Trinidad and Mexico comes in duty-free. The import duty on diammonium phosphate ("DAP") from the U.S. is 6.6 percent, while DAP from our competitors in Morocco, Tunisia, South Africa, and Jordan enters duty-free.

Turning to Latin America, the U.S. has lost urea business in Colombia to Venezuela since urea from Venezuela, an Andean-Pact member, is exempt from the 6.6 percent import duty. In 1985, the Chilean and Venezuelan governments signed an agreement to lower the tax on Venezuelan urea to 15 percent compared to the tax on U.S. urea of 30 percent. Consequently, U.S. regular urea customers in Chile are placing their orders with the Venezuelan urea producer.

Import quotas are another means for industry protectionism, used many times for trade retaliation. Such was the case in early 1986 when the EEC set a tonnage quota on ammonium phosphate fertilizer from the U.S. The quota, 327,000 tons per year, was set as a retaliation for U.S. quotas on imports of EEC semi-finished steel products. The quota cut U.S. exports by one-third. In FY 1985, the U.S. shipped to the EEC 1.2 million tons of ammonium phosphate fertilizer.

There are a number of non-tariff barriers to international fertilizer trade. More and more frequently, foreign governments are requiring sellers of products to buy back an equivalent monetary amount of goods from the importing country. Indonesia is the perfect example of this. Fertilizer exporters have had to take back wood, rubber and other "non-traditional" export articles (oil has been excluded since it is considered a traditional export product) in order to sell fertilizer to Indonesia. These requirements make it difficult for a U.S. manufacturer to participate in this business due to the general lack of knowledge about counter-trade.

India is insisting more and more on countertrade. Pakistan has a barter requirement. Furthermore, the government of Pakistan does not accept barters handled by individual companies, but only through other government entities. As a result, the U.S. fertilizer producers have found it necessary to sell to Swedish, Finnish, Czech and Bulgarian government companies which have barter agreements with the Pakistani government. The U.S. government does not support these barter activities so no U.S. agency has a similar barter agreement with Pakistan.

The U.S. DAP industry lost a $120,000 DAP sale to Pakistan, financed by the Agency for International Development (AID), in September because of a Pakistan barter agreement.

Many countries have bi-lateral trade agreements under which fertilizer is being "swapped" for other products. An example is Russian urea going to India under such an agreement. Ecuador has similar agreements with Eastern Europe whereby Ecuadorian bananas are exchanged for Romanian urea. This reduces the market left to U.S. exporters. Frequently a bi-lateral trade agreement with the U.S. does not work since U.S. exports to the foreign country already exceed U.S. imports from such country.

TABLE I

Country	Range of Tariffs	Calculated Tariff Cost to U.S. Exporters FY '85
	(percent)	($ million)
EC	4 – 13	16.6
Far East		
India	0 – 60	40.2
Pakistan	6 – 85	37.5
South Korea	5 – 25	19.5
Taiwan	5 – 25	7.1
Philippines	10 – 20	2.3
South America		
Brazil	10 – 80	20.5
Chile	20	6.2
Venezuela	1 – 100	3.4
Mexico	40	3.0
World Total (includes countries not listed above)		178.9

TABLE II
Economic Impact of Fertilizer Tariffs
Summary Tables
(FY 1985)

Product	Value of Exports $ millions	Calculated Tariff $ millions
(to all countries)		
Diammonium Phosphate	1,277.3	73.5
Urea	208.1	38.3
Ammonia	162.0	27.1
Phos. Acid Wet Process	163.8	21.5
Concentrated Superphosphate	185.4	7.3
Ammonium Sulfate	54.8	4.9
Phosphate Rock	370.1	4.5
MAP	75.5	1.8
		$178.9

Certain countries have unnecessary product specification requirements which tend to discriminate against U.S. products. Some of these specification requirements are based on ignorance, but some are imposed to keep U.S. products out of the market. This is particularly the case in the EEC where the water solubility specification of Granular Triple Super Phosphate ("GTSP"), a phosphate fertilizer product, is set at 93 percent. U.S. product is generally 80-85 percent water soluble because of the nature of U.S. phosphate rock, the principal raw material used to make GTSP. On the other hand, our competitors in Morocco and Tunisia can meet the 93 percent specification because of the nature of their phosphate rock. Since there is no agronomic difference between 80-93 percent water solubility for fertilizers, the 93 percent specification is strictly a non-tariff barrier imposed against the U.S. producers.

In August, 1984, TFI filed a petition under Section 301 of the Trade Act of 1974 to ascertain whether the 93 percent water solubility requirement was a non-tariff barrier and illegal under GATT provisions. U.S. and European trade negotiators met on the petition in 1984 and 1985. However, the U.S. industry increased exports of TSP to Europe in early 1985 and the U.S. trade negotiators advised not to push the case through a full course GATT compliant process. The case is pending but not actively pursued.

Although the U.S. does not impose import tariffs on fertilizer products from any country and has not since 1922, the U.S. industry has been very active since 1980 in using U.S. trade laws to protect itself from injury by imports that benefit from pricing below fair value or subsidization.

TABLE III
U.S. International Trade Commission
Nitrogen Fertilizer Investigation

Date	Product	Countries
1928	Urea	
1979	Anhydrous Ammonia	USSR
1980	Anhydrous Ammonia	USSR
1986	Urea	German Democratic Rep., Rumania, USSR

In December, 1986, the U.S. Department of Commerce required importers of urea from East Germany, Romania and the Soviet Union to post bonds of 144 percent, 54 percent and 85 percent respectively, thus raising import prices. The effect, according to USDA, was urea imports from these countries fell 56 percent (680,000 tons). However, U.S. urea imports actually increased 3 percent. Urea imports from Canada and Italy increased 227,000 and 155,000 tons, respectively, while imports from the Netherlands, Trinidad-Tobago, Venezuela and the United Arab Emirates accounted for an additional 323,000 tons.

TABLE IV
U.S. International Trade Commission
Potash Investigation

Date	Countries
1969	Canada, France, Federal Republic of Germany
1981	Canada
1984	Israel, Spain
1984	East Germany, Israel, Spain, USSR
1985	USSR
1987	Canada

As everyone in the industry knows, the International Trade Administration of the U.S. Department of Commerce issued in August preliminary dumping determinations of potash against Canada producers. The U.S. customer service is requiring a cash deposit or the posting of a bond equal to the estimated amounts by which the foreign market value of potassium chloride exceed the United States price as shown in Table V.

TABLE V

Maufacturer/Producer/Exporter	Weighted-Average Dumping Margin
PCS	51.90%
IMC	9.14%
PPG/Kalium	29.67%
Central Canada Potash	85.20%
Potash Company of America	77.44%
All Others	36.62%

While Canada supplies over 90 percent to total U.S. potash imports, it is unclear if other importing countries will try to take advantage of the circumstances as occurred in the 1986 urea dumping case.

Protectionism, quotas, dumping have become the way of doing business in International Fertilizer Trade. With more and more governments entering the trade area, we can expect the present day norm to continue.

TABLE VI
Potassium chloride: U.S. imports for consumption by principle sources, 1977–86

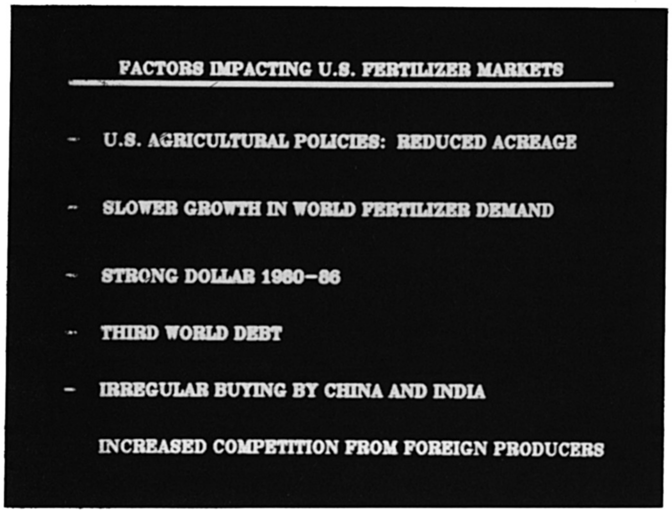
Source	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
	Quantity (1,000 short tons)									
Canada	7,882	7,915	8,848	8,424	8,052	6,310	6,989	7,923	7,729	7,042
Israel	225	366	304	344	449	618	549	442	406	342
East Germany	10	20	61	54	55	46	135	102	27	74
Spain	56	33	23	12	24	55	58	12	0	0
U.S.S.R.	23	32	13	42	0	66	68	138	0	27
All other	9	22	27	31	20	59	75	22	71	51
Total	8,205	8,388	9,276	8,907	8,600	7,154	7,874	8,639	8,233	7,536

The Impact of International Trade on U.S. Fertilizer Markets

Dr. Michael R. Rahm
Cargill Fertilizer Division

INTRODUCTION

Increased competition from foreign producers is one of several factors that has impacted U.S. fertilizer markets in recent years. The list of policies and events that have adversely affected the U.S. industry is long and familiar and this session addresses many of the important factors.



FACTORS IMPACTING U.S. FERTILIZER MARKETS

- U.S. AGRICULTURAL POLICIES: REDUCED ACREAGE
- SLOWER GROWTH IN WORLD FERTILIZER DEMAND
- STRONG DOLLAR 1980-86
- THIRD WORLD DEBT
- IRREGULAR BUYING BY CHINA AND INDIA

INCREASED COMPETITION FROM FOREIGN PRODUCERS

The above figure lists some of these factors including: 1) U.S. agricultural policies that have reduced planted acreage, 2) slower growth in world fertilizer demand, 3) third-world debt, 4) a stronger dollar in 1980–85, 5) irregular buying by India and China, and, of course 6) increased competition from foreign producers, particularly state-controlled enterprises.

Of these factors, U.S. agricultural policies that have sharply reduced planted acreage have had the biggest adverse effect on the domestic fertilizer industry. For example, after peaking at 23.7 million nutrient tons (mnt) in 1981, U.S. fertilizer use has fallen 23% or about 5.4 mnt. U.S. nitrogen use has fallen by about 2.3 mnt, the equivalent of the annual capacity of over eight 1000 ton per day ammonia plants or over two and one-half times the increase in U.S. urea imports. Since 1981, U.S. phosphate use has fallen 1.5 mnt, the equivalent of the DAP granulation capacity of three Jorf Lasfar plants and U.S. potash use has fallen 1.6 mnt, equal to the capacity of 1.25 PCS Rocanville mines.

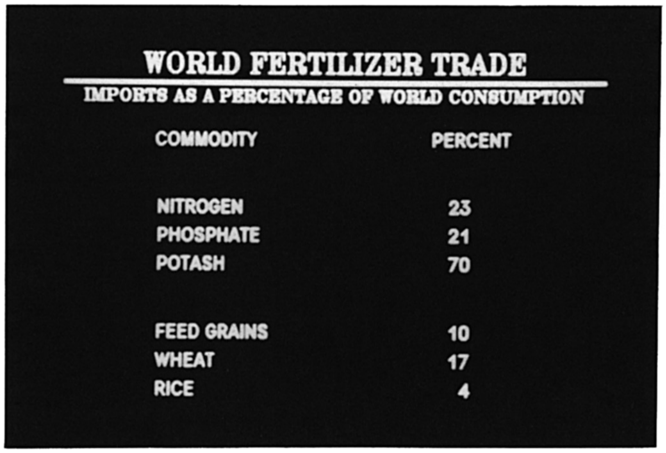
Foreign competition has and will continue to pressure the U.S. industry. Imports have had the biggest impact on nitrogen markets with net imports accounting for 10%–20% of domestic use in the past few years. U.S. phosphate producers will face much stiffer competition from the North Africans beginning later this year as new granulation capacity comes on stream.

The impact of foreign competition on the U.S. industry, however, has been amplified by the sharp drop in domestic demand. Some of the impact in the future will be mitigated by a recovery of U.S. planted acreage and domestic fertilizer use. The biggest challenge of the domestic fertilizer industry is to promote agricultural and economic policies that enhance the comparative advantage of U.S. agricultural production.

This presentation is organized into two parts. The first describes and assesses the recent developments in world production and trade on domestic markets. The second addresses the impact of U.S. agricultural policies on fertilizer markets. The analysis focuses more on the nitrogen markets and considers developments since 1981.

WORLD PRODUCTION AND TRADE

Trade statistics clearly illustrate the global dimension of fertilizer markets and the importance of world fertilizer trade. International trade accounted for over 20% of world nitrogen and phosphate use and about 70% of potash use in 1985 and 1986. By comparison, international wheat, rice and feed grain trade in 1985 and 1986 accounted for roughly 17%, 4% and 10% of world consumption.



WORLD FERTILIZER TRADE

IMPORTS AS A PERCENTAGE OF WORLD CONSUMPTION

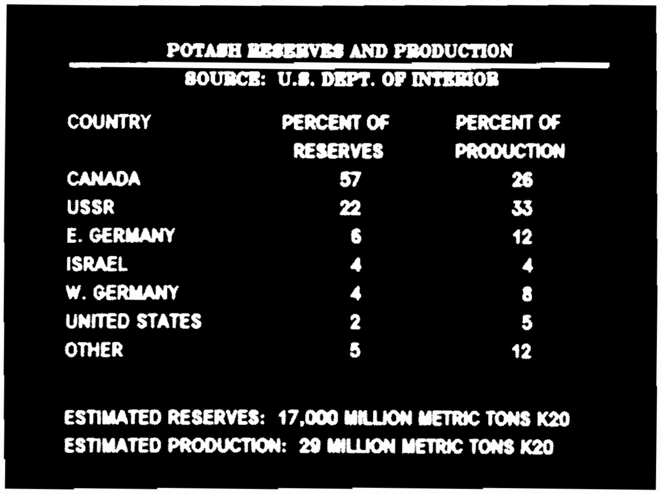
COMMODITY	PERCENT
NITROGEN	23
PHOSPHATE	21
POTASH	70
FEED GRAINS	10
WHEAT	17
RICE	4

Resource Ownership and Production

The importance of trade results from the fact that the resources required for the production of the three major nutrients are concentrated in a relatively small number of countries.

Potash

Concentration of resource ownership is greatest for potash and phosphate. For example, the United States Department of Interior estimates that the USSR and Canada account for 60% of potash production and 80% of reserves. Four countries, the USSR, Canada, East Germany and West Germany, account for 80% of production and 90% of reserves.



POTASH RESERVES AND PRODUCTION

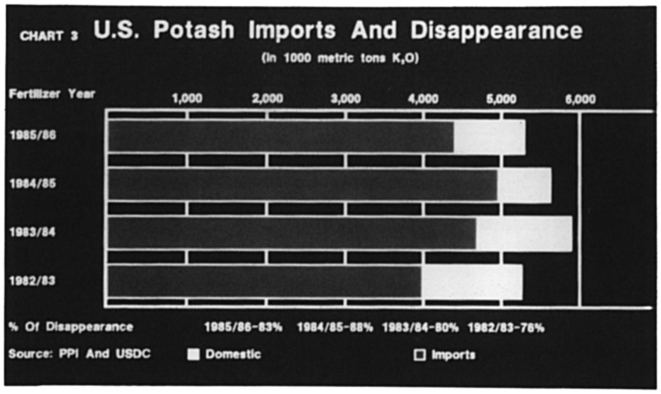
SOURCE: U.S. DEPT. OF INTERIOR

COUNTRY	PERCENT OF RESERVES	PERCENT OF PRODUCTION
CANADA	57	26
USSR	22	33
E. GERMANY	6	12
ISRAEL	4	4
W. GERMANY	4	8
UNITED STATES	2	5
OTHER	5	12

ESTIMATED RESERVES: 17,000 MILLION METRIC TONS K20

ESTIMATED PRODUCTION: 29 MILLION METRIC TONS K20

The United States relies on imports for about 80% of its potash use and Canada accounts for about 90% of U.S. potash imports. Thus, the current dumping suit against Canadian producers impacts over 70% of U.S. potash tonnage. It clearly would have been less costly to directly compensate domestic producers for allowing Canadian imports into the United States at pre-investigation prices. With the U.S. dependent on foreign producers for 80% of its potash needs, the reduction of this trade barrier is an important factor in improving the cost-competitiveness of the U.S. agriculture.

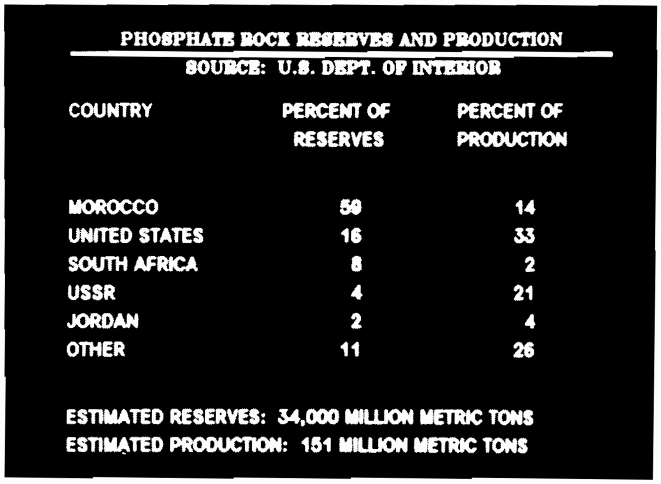


Phosphate

In the case of phosphate, the concentration of rock deposits nearly equals that of potash. Five countries, Morocco, the United States, South Africa, the USSR and Jordan, account for nearly 90% of proven reserves. Morocco owns almost 60% and the United States owns about 16% of world rock reserves. The United States, Morocco and the USSR mine about two-thirds of world rock output.

Since 1982, North African producers have increased phosphoric acid capacity more than 75% from 2.5 million metric tons (mmt) to over 4.4 mmt. North African producers now account for 12% of world phosphoric acid production capacity compared to 8% just five years ago.

In addition, North African finished phosphate production capacity has more than doubled since 1982, increasing from 1.1 mmt P205 to about 2.3 mmt P205. North African finished phosphate capacity was about 12% of U.S. capacity in 1982. After the new plant under construction comes on stream later this year and early next year, North African finished phosphate capacity will equal about 25% of U.S. finished phosphate capacity.



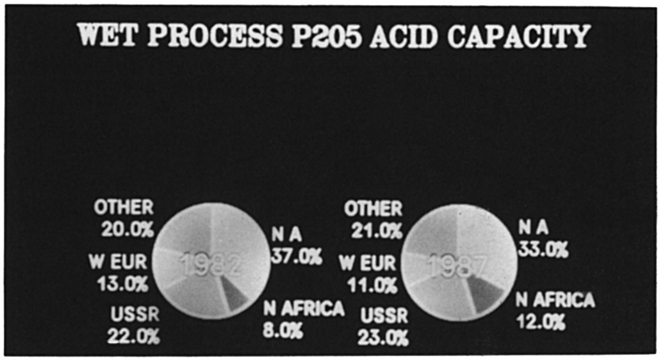
PHOSPHATE ROCK RESERVES AND PRODUCTION

SOURCE: U.S. DEPT. OF INTERIOR

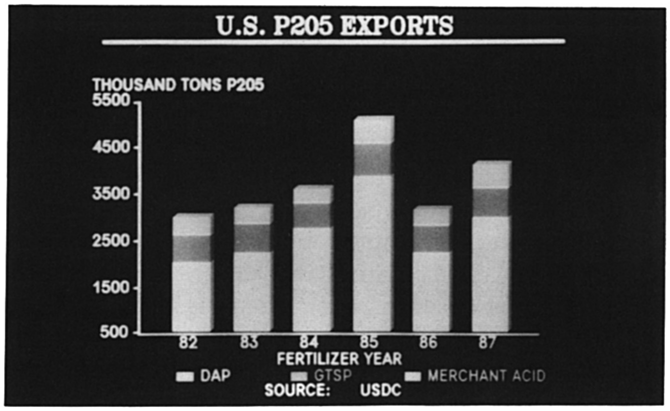
COUNTRY	PERCENT OF RESERVES	PERCENT OF PRODUCTION
MOROCCO	59	14
UNITED STATES	16	33
SOUTH AFRICA	8	2
USSR	4	21
JORDAN	2	4
OTHER	11	26

ESTIMATED RESERVES: 34,000 MILLION METRIC TONS

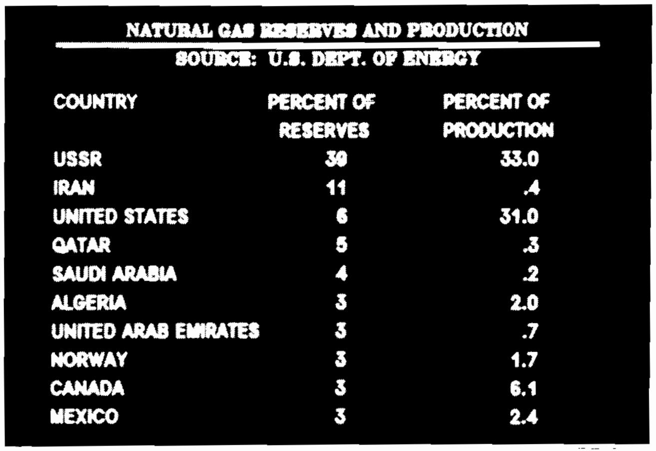
ESTIMATED PRODUCTION: 151 MILLION METRIC TONS



The increased finished phosphate capacity in North Africa will provide stiff competition to U.S. dry products in key markets. The United States exports about half of its P205 production, and shipments of DAP account for about 65% of U.S. P205 exports. Over the past few years P205 exports have fluctuated wildly, increasing 42% in 1985, decreasing 38% in



1986, and increasing 32% in 1987. Sporadic buying by India and the Peoples Republic of China (PRC) accounted for much of the variation.



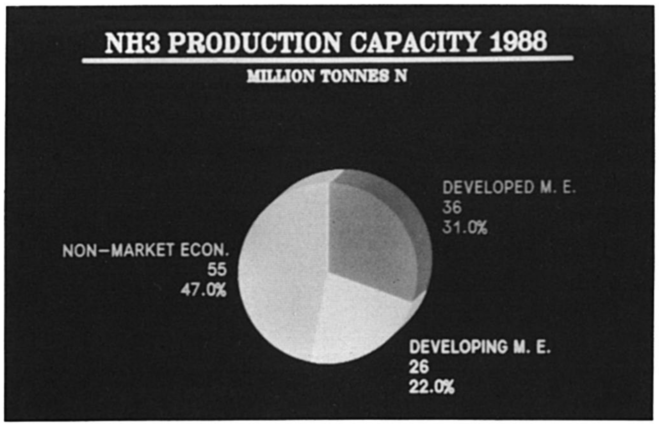
NATURAL GAS RESERVES AND PRODUCTION

SOURCE: U.S. DEPT. OF ENERGY

COUNTRY	PERCENT OF RESERVES	PERCENT OF PRODUCTION
USSR	39	33.0
IRAN	11	.4
UNITED STATES	6	31.0
QATAR	5	.3
SAUDI ARABIA	4	.2
ALGERIA	3	2.0
UNITED ARAB EMIRATES	3	.7
NORWAY	3	1.7
CANADA	3	6.1
MEXICO	3	2.4

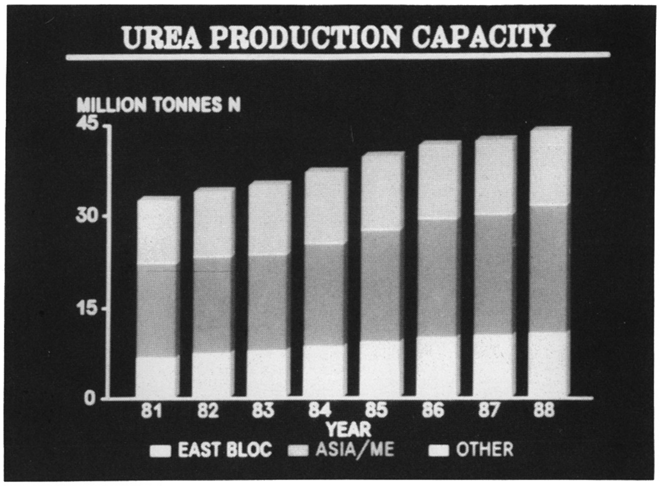
Nitrogen

In the case of nitrogen, a larger number of countries possess natural gas deposits, the most widely used feedstock for ammonia production. Resource ownership, however, is still concentrated in a relatively small number of countries and regions. For example, the USSR and the Middle East account for 65% of natural gas reserves. The USSR alone possesses nearly 40% of world gas reserves. North America owns about 11% of reserves and accounts for nearly 40% of world gas production.



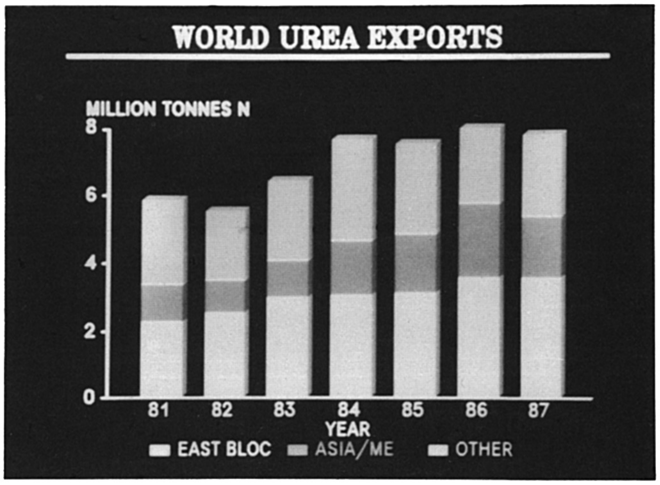
NH3 PRODUCTION CAPACITY 1988

Today, world NH3 production capacity totals about 117 mmt N. Much of the growth in ammonia capacity has taken place in gas-rich countries under the direct or indirect control of governments. Since 1981, capacity has grown at an annual rate of about 3.2%. Nonmarket economies account for nearly half of world capacity and developing market economies account for roughly one-fifth of capacity. Most of the projects in the developing market economies have some form of government involvement. Thus, about 70% of the world's ammonia capacity is either directly or indirectly controlled by governments whose goals often include employment or foreign exchange earnings objectives.



UREA PRODUCTION CAPACITY

Since 1981, world urea production capacity has grown even faster at about 4.4% per year from 32 mmt N to 42 mmt N in 1987. Of the 10 mmt N increase in urea production capacity, East Bloc countries have accounted for about 3.5 mmt N or 35% of the increase while Asian and Middle East producers have accounted for 4.4 mmt N or 44%. Today, the East Bloc countries account for over 25% and Asian and Middle East producers account for about 47% of world capacity. Since 1981, U.S. and Western European capacities have remained unchanged and today each region accounts for less than 10% of world capacity.



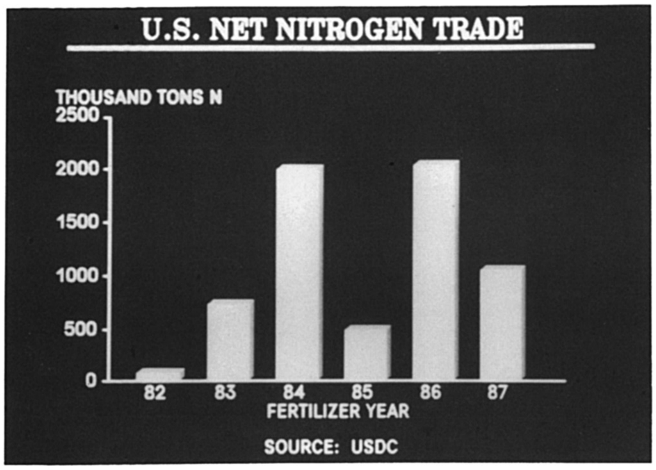
WORLD UREA EXPORTS

It is no surprise that urea trade has grown rapidly at an annual rate over 5% from 5.8 mmt N in 1981 to 7.8 mmt N in 1987. East Bloc exporters have accounted for 1.3 mmt N or 65% of the increase in world urea trade and current exports of 3.6 mmt N represent nearly 46% of world trade.

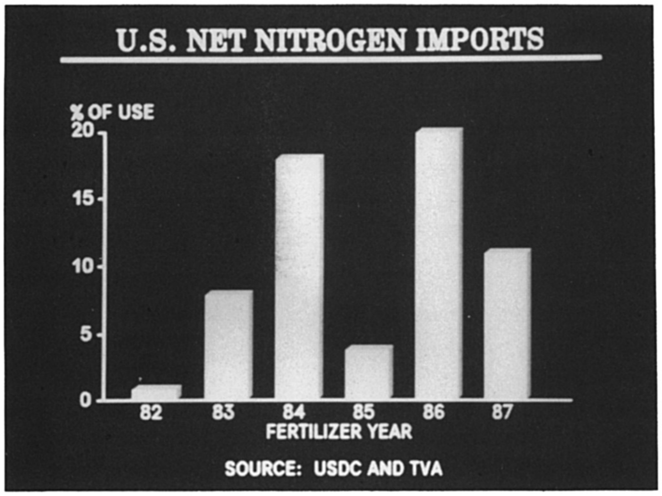
Impacts on U.S. Markets

How have these developments impacted the United States?

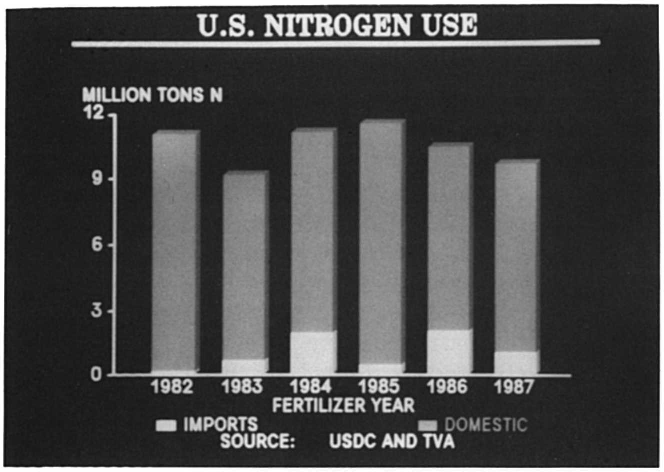
The United States is a net importer of nitrogen and, since 1981, net imports have fluctuated sharply



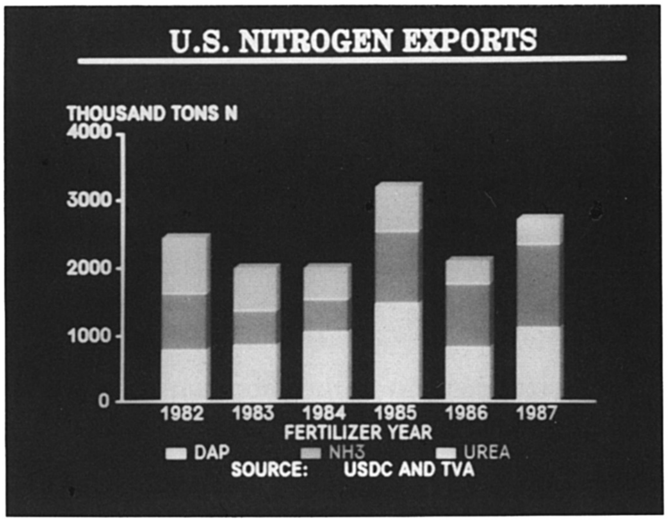
as the result of variations in ammonium phosphate exports and NH3 trade. For example, last year net nitrogen imports fell by more than one million tons N due to large increases in DAP and NH3 exports. U.S. DAP exports were bolstered by a weaker dollar and more consistent buying by China while U.S. NH3 exports also gained from the weaker dollar and production problems in the USSR and Indonesia.



Net nitrogen imports as a percentage of nitrogen use has varied between 4% and 20% in the past 5 years.

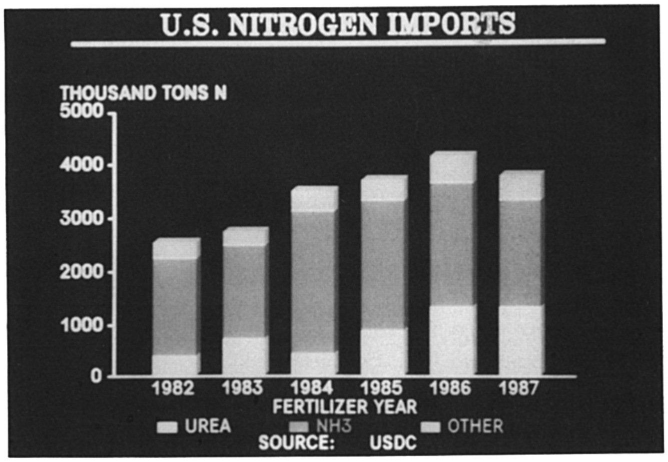


This figure shows U.S. nitrogen use broken into net imports and domestic production. The increases in market share have resulted from a combination of larger net imports and lower nitrogen use.



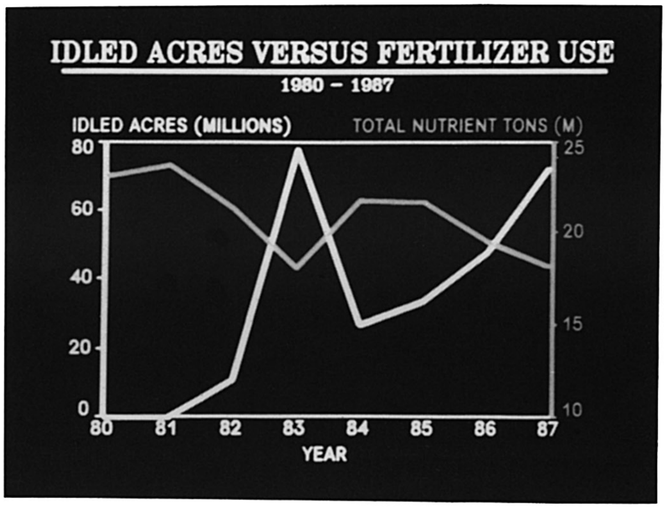
A closer examination of nitrogen exports shows that U.S. urea exports have dropped from over 800,000 tons N in 1982 to about 350,000 tons in 1987.

Urea imports, on the other hand, increased from less than one-half million tons N in 1982 to 1.3 million tons in 1987. Dumping duties on East Bloc sources had no impact on 1987 imports. U.S. urea imports will decrease in the 1988 fertilizer year, but the fall will more likely result from uncertainties about U.S. demand rather than problems in sourcing product.



DOMESTIC FERTILIZER DEMAND

These statistics indicate that U.S. fertilizer markets have been and will increasingly be influenced by foreign competition. However, recent problems of the domestic industry can not be attributed to imports or foreign competition alone. As indicated earlier, the sharp drop in domestic demand has had the largest detrimental impact on the U.S. fertilizer industry and an increase in U.S. planted acreage is the key to improvement in the domestic market.



Fertilizer demand in the short run is driven by acreage which, in the past few years, has been determined largely by commodity programs. As this slide shows, commodity programs have idled about 71 million acres in the 1987 fertilizer year. By comparison, the PIK program of 1983 idled 78 million acres and, as recently as 1981, no land was idled by farm programs.

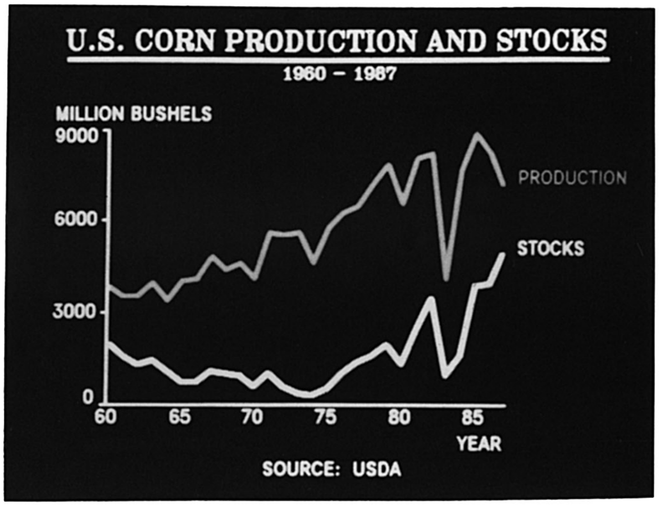
Due largely to lower acreage, U.S. fertilizer use has fallen sharply from its peak of 23.7 million nutrient tons (mnt) in 1981. In 1986 total nutrient use was 19.6 mnt and, when final tonnage numbers for the 1987 fertilizer year became available, total nutrient use will likely show a drop to 18.3 mnt—5.4 mnt or 23% below the peak of 1981.

Grain Market Imbalances

The sharp drop in fertilizer use since 1981 is the result of an effort to correct the imbalance in U.S. grain markets caused by a combination of factors including:

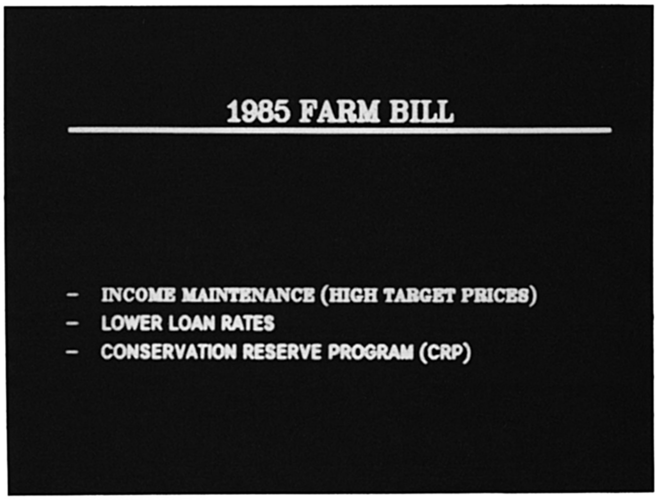
1. High U.S. price supports
2. An increase in the value of the dollar between 1980 and 1985
3. Exceptionally good crops especially in the U.S.
4. Low growth rates world-wide in the early 1980s
5. Burdensome Third World debt

A quick look at corn production and stocks reveals the magnitude of this imbalance. For the crop year ending August 31, carry-out stocks totaled 4.9 billion bushels and the USDA projects carry-out stocks for the 1988 crop year of 4.4 billion bushels. A reduction in corn stocks has begun, but the speed at which stocks are drawn down to levels that permit increases in planted acreage depends on the response of exports and domestic use to lower prices as well as the size of next year's crop. To put the stock numbers in perspective, the USDA's projected ending stock of 4.4 billion bushels is still 25% greater than the level that stimulated the PIK program of 1983.



Food Security Act of 1985

In response to the imbalance in the grain markets, agricultural policy makers, after a long and tough debate, passed the Food Security Act of 1985.



1985 FARM BILL

- INCOME MAINTENANCE (HIGH TARGET PRICES)
- LOWER LOAN RATES
- CONSERVATION RESERVE PROGRAM (CRP)

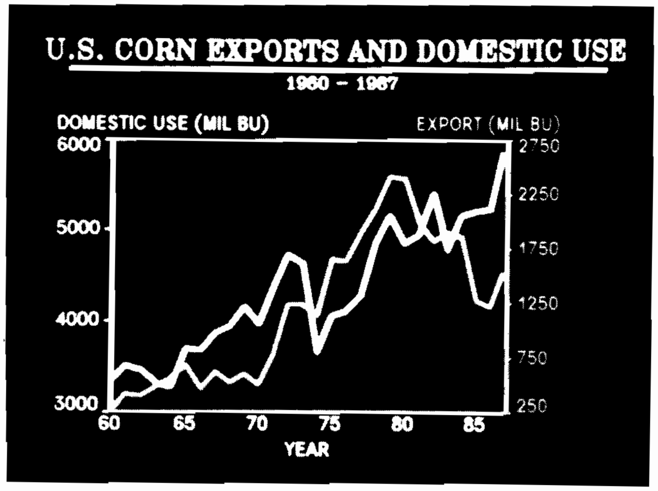
In a nutshell, the 1985 farm bill does the following:

1. Maintains farm income through relatively high target prices
2. Stimulates exports and domestic use by lowering loan rates
3. Establishes a Conservation Reserve Program that seeks to pull 40–45 million acres of erodible land from production by 1990

The 1985 farm bill froze target prices at 1985 levels for the 1986 and 1987 crop years. During 1988–90, target prices will be reduced by about 10%. The 1985 farm bill ties loan rates to a percentage (usually 75–80%) of a five-year average of market prices with a limit (usually 5%) to the amount by which the loan rate can be reduced each year. The 1981 farm bill, passed during a period of double digit inflation, legislated loan rates for the life of the bill at levels that priced the U.S. out of many markets.

After some early concern about the effectiveness of the 1985 farm bill, the current perception is that the

Food Security Act is beginning to achieve some of its goals. While a sharp drop in the dollar and the Export Enhancement Program have contributed to the increase in exports, lower loan rates have stimulated increases in both domestic use and exports.



Impact on Exports and Domestic Use

The figure above shows corn exports and use since 1960. Corn exports peaked at 2.4 bbu in 1979 and then fell by 50% to 1.2 bbu in 1986. In 1987 corn exports rebounded to 1.5 bbu and USDA projects 1988 exports at 1.6 bbu. The increase in domestic use has been even more dramatic. Domestic use peaked at 5.4 bbu in 1982 before dropping to 5.2 bbu in 1986. Use jumped to a record 5.8 bbu last year and the USDA projects total domestic use of 5.9 bbu in 1988.

CONCLUSION

In summary, increased competition from foreign producers is one of several factors that has impacted U.S. fertilizer markets in recent years. The sharp drop in domestic demand, however, has had the biggest impact on the domestic industry and has amplified the importance of other factors such as the growth in foreign competition. The biggest challenge of the domestic fertilizer industry is to promote agricultural and economic policies that enhance the comparative advantage of U.S. agriculture.

Changes in the Domestic Fertilizer Supply Position From 1980's Forward

Patrick E. Peterson
C.F. Industries, Inc.

INTRODUCTORY REMARKS

HISTORICAL PERSPECTIVE

As we entered the 1980's it appeared that the decade ahead would be a period of sustained growth, capacity expansion and overall profitability for the fertilizer industry. At that time, domestic fertilizer use was at an all time high, phosphate exports were at record levels and the U.S. was still a net exporter of nitrogen. In fact, more than one industry forecast was predicting a potential shortage of fertilizer during the second half of the 1980s.

However, as we all know too well, what supposedly was going to be a decade of growth and profitability, turned into a decade of decline and financial hardship. The potential shortages quickly turned into unprecedented surpluses.

The factors which contributed to the decline in the fertilizer industry have been well-documented. The downturn in agriculture, the increased intervention by foreign governments in both the supply and the demand sides world markets, the economic problems in developing countries and the strength of the U.S. dollar were just a few of these factors. Unfortunately, all of these came into play simultaneously and had a devastating impact on the U.S. fertilizer industry.

In nitrogen, for example, the industry operating rate has been below 85 percent of capacity for four out of the last five years. Ammonia production, which totaled some 19.5 million tons in FY 1980, was less than 15 million during the year just ended. This represents a 23 percent decline in production in seven years.

Along with declining volumes, the industry has also had to contend with depressed prices. Ammonia prices, which averaged over $170 per ton in the spring of 1981, dropped below $80 per ton in late 1986. It was not that many years ago when the question was "How would farmers be able to afford to buy ammonia at $300 per ton?" As it turned out, the question is "How can ammonia producers afford to sell ammonia at $80 per ton?"

The answer to that question, as evidenced by the number of plants that have closed, the number of companies that have already exited or are trying to exit the business and by the reduction in the size of the work force employed by the industry, is that the industry can not afford it. In 1981, North American fertilizer producers earned over a billion dollars. In 1986, the industry lost almost a half a billion dollars. Further, it is estimated that no more than 35 percent of nitrogen capacity in North America operated at or above break-even during 1986.

Results in the phosphate sector have been similar. Since 1981, the industry operating rate has averaged slightly less than 80 percent of capacity. This compares to a 94 percent average operating rate for 1979 through 1981.

For almost every phosphate producer in the industry, the 1980s have been a period of depressed markets and massive financial losses. As a result, some 40 percent of industry capacity has been sold or is currently on the sales block.

The potash industry has also suffered. At the beginning of the 1980s, the U.S. potash industry had a capacity of 2.4 million tons per year. Only 1.3 million tons exist today, and without a significant turn in market conditions, 40 percent of that will probably not survive into the 1990s.

For the Canadian potash industry, the operating rate has dropped from an average of over 90 percent at the beginning of the decade to under 70 percent of capacity the last two years. In 1986, it is estimated that over half of the Canadian capacity operated in the red.

OUTLOOK 1988–1990

Given the results that we've seen so far during the 1980s, the question arises as to what the outlook is for the domestic supply for the remainder of the 1980s and into the 1990s.

In looking at the answer to this question, let me first discuss what CF foresees for the next three years, then briefly discuss the outlook further ahead into the 1990s.

For all three nutrients, the domestic supply situation will obviously depend on the outlook for demand.

U.S. fertilizer consumption over the last six years has fallen 17 percent from a high of 23.7 million nutrient tons in 1981 to 19.7 million in 1986. In fertilizer year 1987 demand is estimated to have dropped by another 8 percent to under 19.0 million tons. Excluding 1983, this will be the lowest level of consumption since the early 1970s, and for phosphate in particular, the lowest level in over 20 years.

Unfortunately, the outlook for the next three years is not much more optimistic. The current Farm Bill, and in particular, the Conservation Reserve Provision, will continue to force acreage out of production. As a result, fertilizer consumption is expected to show only minimal, if any, increase until we get into the 1990s.

Given the outlook for the domestic demand, let's now turn to the supply outlook.

Nitrogen

In nitrogen, the domestic supply position has undergone some dramatic changes in the last six years. As discussed earlier, the U.S. industry, which was basically in balance in 1980, has been in a position of significant excess capacity. In 1987, for example, the magnitude of the surplus was equal to four world scale ammonia plants.

Over the next three years, no major shifts are expected in the domestic supply position. Excess capacity will continue to have a strong influence over the domestic market. Although the operating rate for the industry is expected to show some signs of improvement, it is expected to remain below 85 percent through at least 1990.

Imports will continue to play a major role in the domestic supply outlook for nitrogen. U.S. nitrogen imports, which more than doubled from 1980 to 1984, have averaged around 4 million tons in the last four years. For at least the next three years, imports are expected to remain stable at 4 to 4.5 million tons. The primary sources of imported nitrogen products will continue to be Canada, the Eastern Bloc countries and Trinidad.

A key assumption in the nitrogen forecast is that U.S. production costs will remain at competitive levels. Over the last five years, and particularly since 1985, U.S. production costs have declined dramatically. According to data from Blue/Johnson and Associates, the U.S. weighted average ammonia production cost for plants using market priced natural gas has dropped from $151 per ton in 1982 to $75 in 1987, a decline of some 50 percent.

Major factors in the decline in production costs have been the deregulation of natural gas and the effects of the "gas bubble". In combination, these forces have dropped the market price of natural gas paid by U.S. nitrogen producers from an average of $3.54 per million BTUs in 1982 to $1.56 in 1987.

Trying to forecast where natural gas prices will be three years from now is obviously difficult, and to some extent, borders on sheer speculation. In our view, however, we expect natural gas prices to gradually increase but, remain below $2 per MM BTUs through 1990. At least for the next three years, we do not foresee any major shocks to the system or any dramatic price escalations.

Also contributing to the decline in production costs are the steps which have been taken by U.S. producers to make their plants more efficient, particularly in the area of raw material consumption. In 1980, the weighted average gas consumption per ton of ammonia was 36.8 million BTUs. By 1987 the installation of energy saving projects had dropped average consumption to 35.1 million BTUs per ton. Consumption is expected to decline even further to 34.5 million BTUs by 1990, as producers continue to make plants more energy efficient.

Phosphate

Since 1981, the phosphate sector has also been characterized by reduced demand and surplus capacity. Although wet acid production increased by almost five percent during FY 1987, the operating rate for the industry was still only slightly above 80 percent of total capacity.

Like the nitrogen sector, the phosphate sector is expected to continue to face the problem of too much capacity and not enough demand. Through 1990, the industry operating rate is expected to remain below 90 percent of capacity. In addition, the operating rate will likely be subject to a considerable amount of volatility due to the industry's heavy dependence on an unstable export market.

At the present time over half of the phosphate produced in this country is sold in the export market. After a decade of comparatively steady growth, phosphate exports have fluctuated on a year-to-year basis by as much as 35 percent in recent years. The erratic buying patterns of countries such as India and China have been the principal cause of these fluctuations. U.S. phosphate exports have fluctuated from 4.3 million tons of P_2O_5 in FY 1984 to a record 5.8 million tons in FY 1985, down to 4.0 million tons in FY 1986 and, in the fertilizer year just ended, back up over a million tons to 5.1 million.

Over the next three years, P_2O_5 exports are expected to average in the 5.0 to 5.5 million ton range. However, a continuation of the recent swings is almost certain.

Potash

Like both of the nitrogen and phosphate sectors, the potash sector has been and is expected to continue to be faced with surplus capacity. Since 1982, the North American potash operating rate has averaged less than 75 percent of capacity. This compares to an average operating rate in the beginning of the 1980s of 92 percent.

The key factor influencing today's potash market is the dumping case pending in the ITC. The outcome of this case is highly uncertain. Since the U.S. depends on Canada for over 85 percent of its potash supply, the outcome of this case whatever it may be, will have a definite impact on the U.S. domestic supply position.

OUTLOOK FOR THE 1990S

Looking further into the 1990s, the outlook for the domestic supply position becomes anybody's guess. One point you can be assured of is that four out of five forecasts that go beyond five years will almost certainly be wrong and the other will be a lucky guess.

Given that caveat, let me briefly present CF's view of the domestic supply position for the 1990s and assume that it will fall into the lucky guess category.

In all three nutrient sectors, CF expects a significant tightening in the supply/demand balance. In nitrogen, the industry is expected to be in balance by the mid-1990s. However, a host of factors such as an unexpected change in natural gas prices, the impact of the U.S.-Canada free trade agreement, unforeseen changes in world economic or political conditions, or a major break-through in biotechnology could significantly alter the U.S. nitrogen outlook.

In phosphates, the supply/demand balance is also expected to be in equilibrium by the mid 1990s. However, the phosphate industry faces some serious challenges in the years ahead. Increasing competition from the North African producers, combined with depleting reserves and increasing environmental costs, will continue to put pressure on the competitiveness of the U.S. industry.

Another question facing the phosphate industry is "Will stability ever return to the world phosphate market?" The answer is "Probably Not". As long as world markets continue to be dominated by Government Buying Agencies, U.S. phosphate producers will continue to face a highly uncertain and highly volatile export market.

For potash, the question is not "When" but rather "Will" there ever be a sustained balance between supply and demand?" Without a major turn-around in demand or a major restructuring of the industry, the North American potash producers will likely continue to be faced with surplus capacity and comparatively soft markets.

CLOSING

The 1980s have been a difficult time for the U.S. fertilizer industry. However, it is the firm belief of CF Industries that the fertilizer industry is not a declining industry, but rather an industry that is repositioning itself. When the repositioning is complete, we have no doubt that the industry will be more efficient, more competitive and financially stronger than the fertilizer industry of the 1980s.

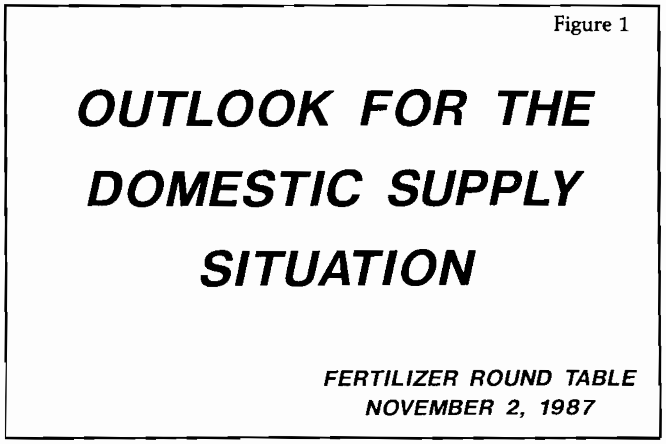


Figure 1

OUTLOOK FOR THE DOMESTIC SUPPLY SITUATION

FERTILIZER ROUND TABLE
NOVEMBER 2, 1987

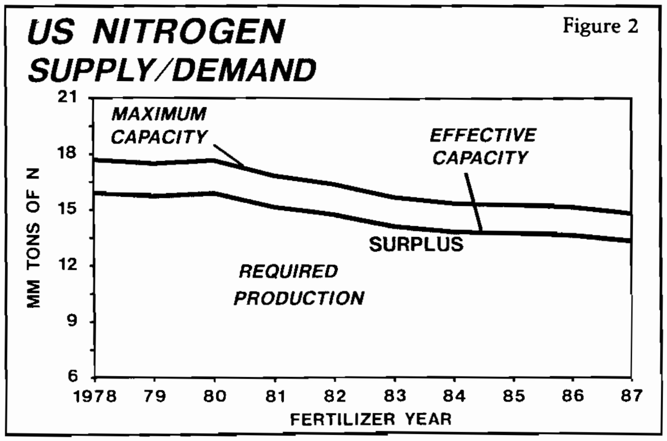


Figure 2

US NITROGEN SUPPLY/DEMAND

Figure 3

QUARTERLY AMMONIA PRICES

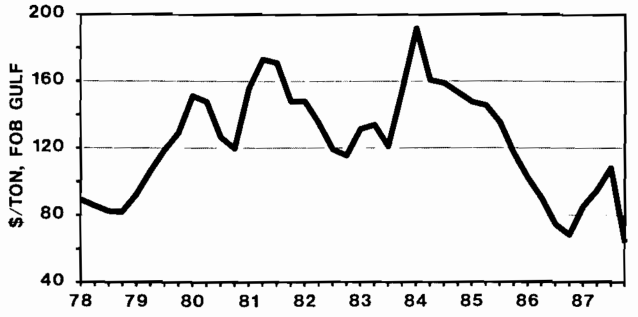
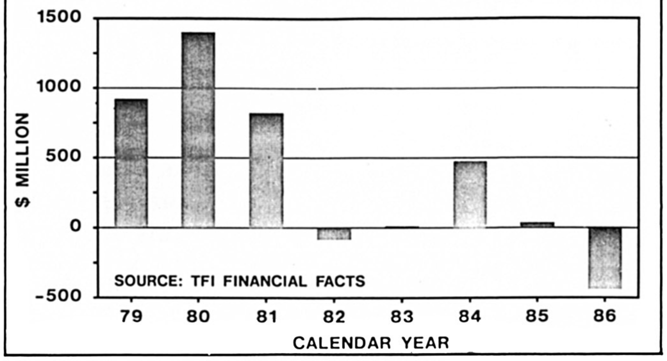


Figure 4

INDUSTRY NET INCOME

INTEGRATED COMPANIES - BASIC PRODUCERS



SOURCE: TFI FINANCIAL FACTS

Figure 5

US PHOSPHATE SUPPLY/DEMAND

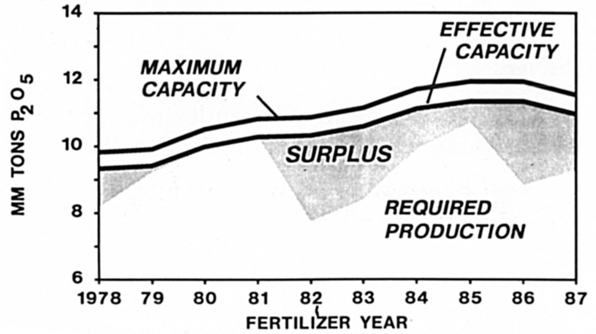


Figure 6

NORTH AMERICAN POTASH SUPPLY/DEMAND

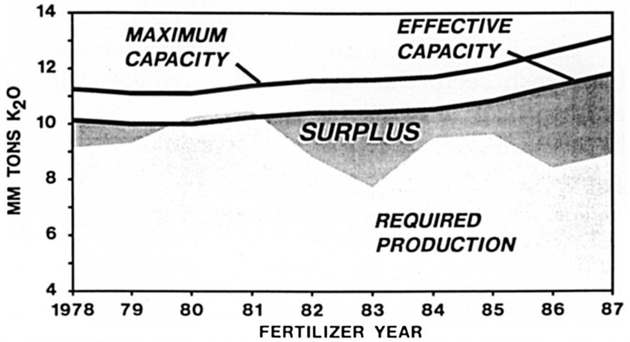


Figure 7

US N-P-K CONSUMPTION

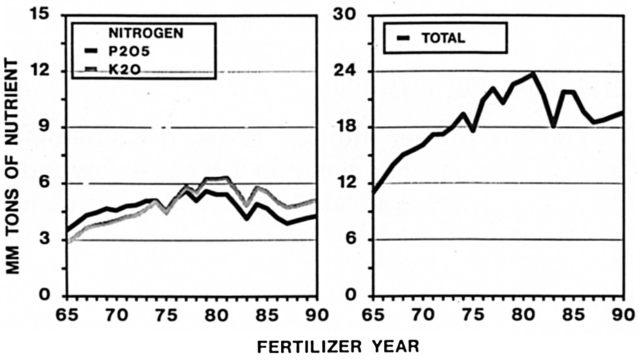


Figure 8

OUTLOOK

1988-1990

Figure 9

US NITROGEN SUPPLY/DEMAND

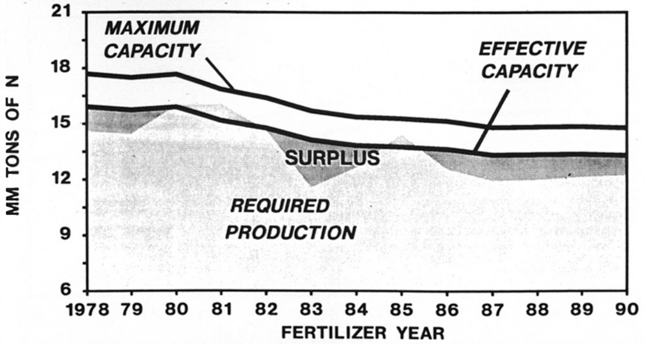
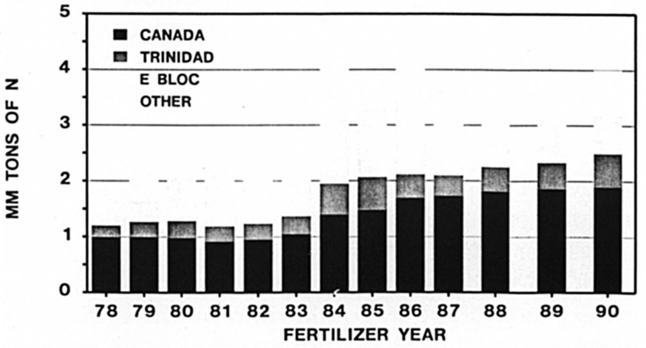
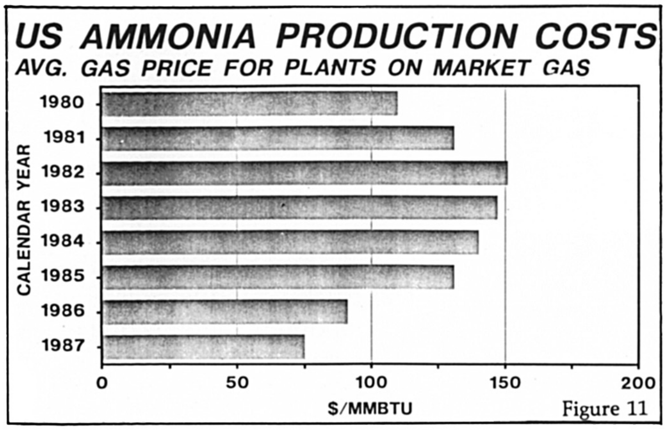


Figure 10

US NITROGEN IMPORTS





US AMMONIA PRODUCTION COSTS
AVG. GAS PRICE FOR PLANTS ON MARKET GAS

Figure 11

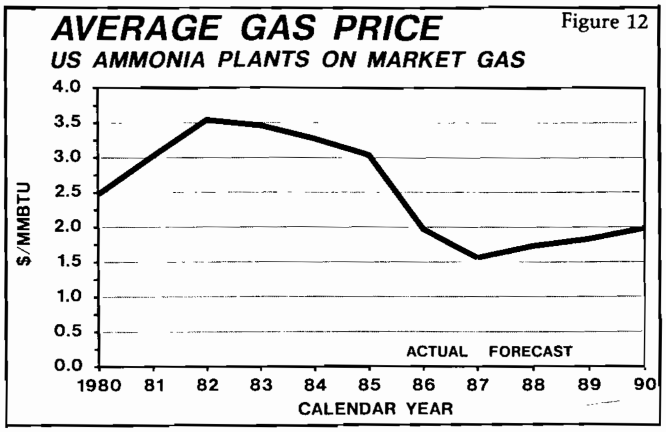


Figure 12

AVERAGE GAS PRICE
US AMMONIA PLANTS ON MARKET GAS

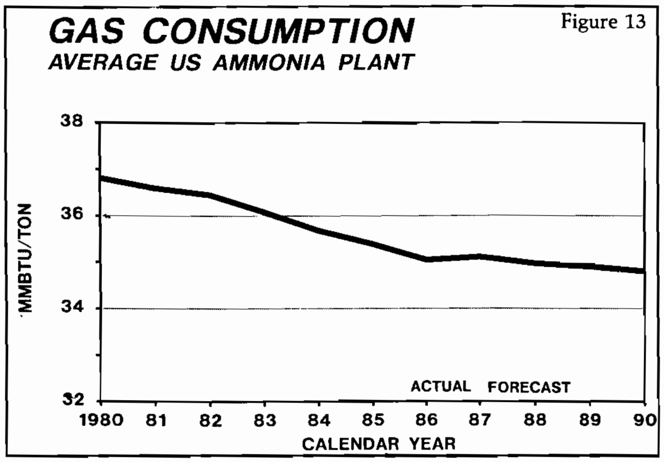


Figure 13

GAS CONSUMPTION
AVERAGE US AMMONIA PLANT

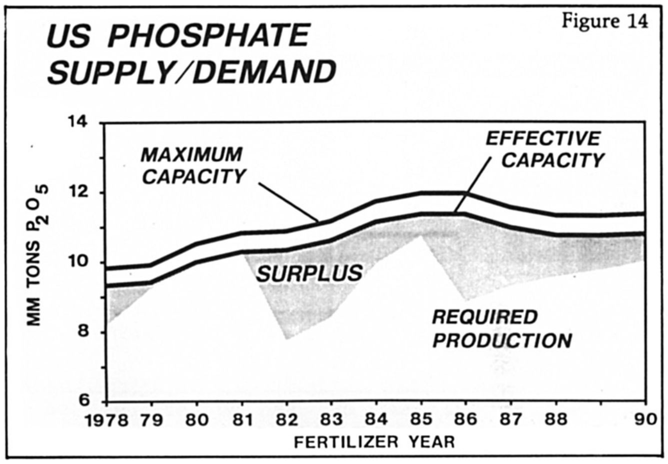


Figure 14

US PHOSPHATE SUPPLY/DEMAND

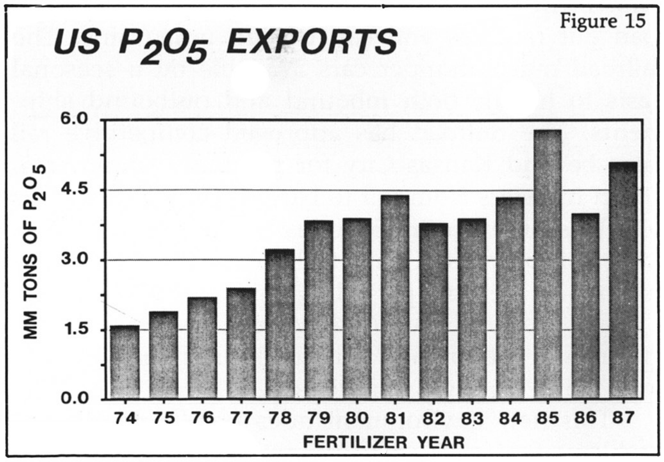


Figure 15

US P_2O_5 EXPORTS

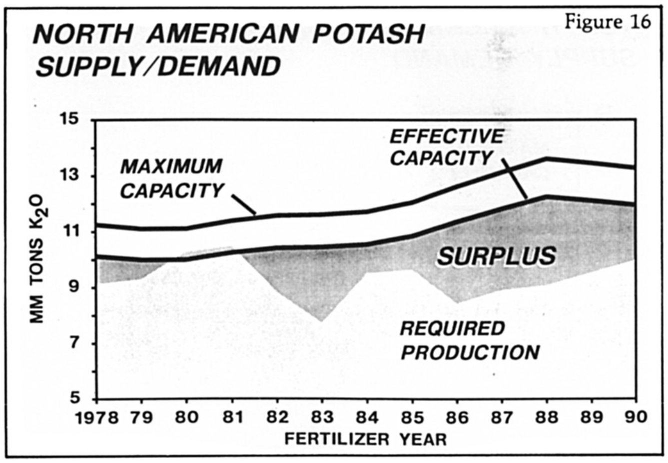


Figure 16

NORTH AMERICAN POTASH SUPPLY/DEMAND

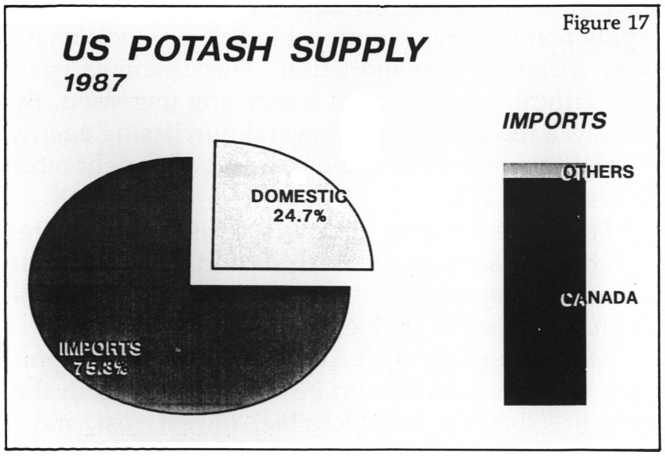


Figure 17

US POTASH SUPPLY
1987

Figure 18

OUTLOOK FOR THE 1990S

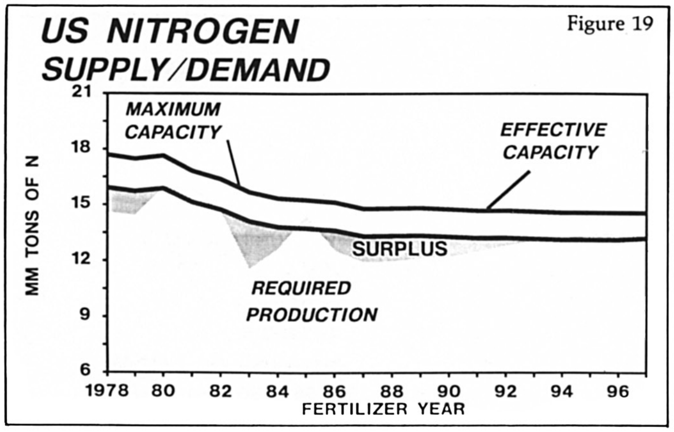


Figure 19

US NITROGEN SUPPLY/DEMAND

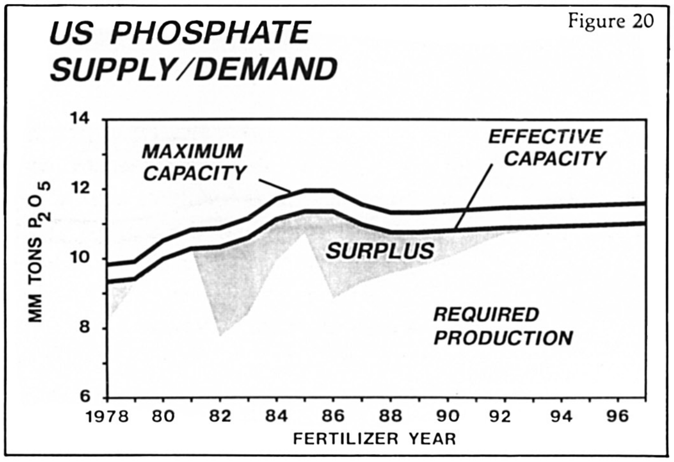


Figure 20

US PHOSPHATE SUPPLY/DEMAND

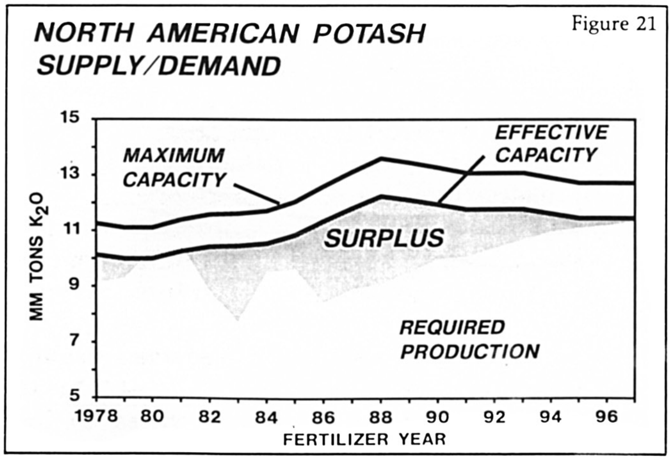


Figure 21

NORTH AMERICAN POTASH SUPPLY/DEMAND

Changes in Domestic Fertilizer Marketing and Distribution Patterns

Charles M. Grau
ConAgra

As I prepared my remarks on *Changes in Domestic Fertilizer Marketing and Distribution Patterns,* I felt that it was impossible to limit any discussion of the fertilizer business to the "domestic" arena.

Marketing success, or failure, depends on the efficiencies that can be wrought out of the distribution system whether it be on rivers, roads, rails, pipelines or vessels.

Don't let me mislead you into thinking that buying prices are not all that important . . . obviously, the cost of the material is rather paramount. However, most buyers in their respective class, will probably have similar costs.

For us marketers to gain a market place advantage over our equally aggressive competitors, and to have the ability to supply our customers with reasonably priced products, a thorough understanding of the deregulated rail and trucking industry is a must.

The potential impact of deregulation is one of the more significant changes that has occurred in our industry. We have observed that the greatest change in attitudes and business practices has been in the railroad segment.

Coupled with . . . and aided by . . . deregulation, several railroads are now managed by a new generation of "railroaders". They are aggressive, marketing oriented and profit driven. They are openly out to regain market share from the rivers and roads segments.

One innovation being promoted by most railroads is an "intermodal" program. One example of this approach is a program being promoted by the Union Pacific Railroad and Mid-West Terminal Warehouse Company in Kansas City. The program starts with incentive rail rates from major production or import points. The product is moved to large warehouses that are equipped to unload or load hopper cars. In this example, the warehouse has extensive load out facilities and can unload unit trains. The railroad makes hopper cars available on a seasonal basis to handle both inbound and outbound shipments. The railroad has approved competitive rail rates beyond Kansas City for product reshipments. Direct transfers from rail to barge can be handled by Mid-West. On site truck scales are provided for customer shipments. Other railroads and warehouse companies are now providing similar services.

Obviously, there are extra costs associated with intermodal shipments, but total costs may be less than going through warehouses.

This new environment does pose a new set of problems for us shippers. To get the greatest advantage, we now must know all freight rates from every supply point to every conceivable delivery location by every means of transportation. This becomes even more critical if freight rates start being increased. By the way, a recent survey of several purchasing agents showed that over 70% of them expect all freight rates to increase in 1988.

For large volume shippers, this requires the gathering, dissemination, analysis and storage of vast amounts of information. Lesser volume shippers will also have the same problems, on a smaller scale.

More employees and new sophisticated computer software will have to be employed to gain the assurance that the best possible, lowest cost, most efficient mode of transportation is used.

When I began my remarks, I stated that it was now impossible to talk solely about the domestic fertilizer market and have any kind of clear picture of the changes that have occurred.

Obviously, we all agree, since two of the five subjects being discussed this morning have the words "World" and "International" as their theme.

If imports continue to supply a significant portion of the fertilizer commodities needed in the interior usage areas . . . and I believe that they will . . . the distribution system now has to be considered when our Supply Department contemplates which port to bring vessels into. Then, the Operations Department has to decide on the most economical way to move the product away from the vessel and out to the market place.

Based on available TFI data, imports of NH_3 are in the range of 2.5 million tons per year; Urea, 3 million tons; the grand daddy of all imports, potash, at some 7 million tons, nitrogen solutions, 500,000 tons; and, phosphates, including phosphate rock, 700,000 tons per year. Total imports are about 13.5 million tons, or some 30.7% of U.S. demand.

It is with this off-shore supply that a thorough knowledge of all the transportation options become crucial. We all know the impact that an extra $2.50 handling charge, or a $7.00 warehouse charge, or $10.00 trucking bill can have on our margins.

The revival of the railroads is causing a ripple effect on the barge and trucking system. They are not going to give market share back to the railroads without a fight.

Trucks will continue to provide the vital link for the hundreds of dealers whose warehouses are not on rail.

While deregulation provided shippers with more flexibility, RE-regulators now seem bent on imposing some new restrictions. For example, in the area of leased owner-operator truckers, the IRS is now attempting to classify leased employees as employees of the lessee organization, which could adversely affect the status of owner-operators and the trucklines who use them.

If the IRS prevails, some owner-operators would lose their independent status. Shippers would have to include owner-operators in their pension and insurance plans. Anticipating the proposed changes, the American Trucking Association and the Interstate Carriers Conference have asked the IRS to make exceptions for owner-operators.

In response, the IRS came up with a five part asset test for use in determining if an owner-operator is supplying substantial operating assets such as trucks . . . or whether the owner-manager is supplying only services.

Independent operators who do not want to be tagged as "employees" must meet all five conditions:

1. Sole ownership of a rig with a replacement cost of at least $60,000.
2. The vehicles actual purchase cost must be at least $10,000.
3. To be sole owner, the driver or his spouse must own at least 85% of the assets at all times during the tax year.
4. The independent driver cannot have any financial connection with the carrier, meaning the company cannot provide financing for the truck, nor can the owner-operator have any ownership in the business or receive "cost-plus" payments.
5. Payment to the driver for services must be at least double what a comparable employee would receive.

Shippers who have substantial investments in specialized equipment such as anhydrous ammonia bottles and suspension grade fluid fertilizers, may be adversely affected by these changes. If shippers had to put on company owned trucks to handle our business needs, we would find company owned trucks and hired drivers with unacceptable amounts of idle time in the eight to ten months of the off-season, and, could not provide adequate levels of service in season.

Another potential problem exists with the distribution of one of our key fertilizer products. This headline appeared in the Harlingen (Texas) Morning Star just 6 weeks ago. Even though it was on page 10 of the grocery ad section, this kind of position publicly exposed by a federal government official can only lead to more controls and regulations.

Mr. Roberts, director of the Office of Hazardous Materials Transportation, was testifying before a House Sub-Committee on the transporting of one of the highly toxic components of rocket fuel, nitrogen tetroxide.

Apparently, Mr. Roberts was drawing an analogy to the shipment of rocket fuel by stating that "One of the largest toxic commodities transported in the United States is anhydrous ammonia."

In a later clarification, a staff member in Robert's office noted that anhydrous ammonia is not as toxic as nitrogen tetroxide, but added, "There are ammonia storage facilities in most small towns and on many farms."

Let's let this headline serve as a reminder that we must constantly promote safety in all of our operations. We must never let such a disaster occur due to negligence or carelessness. The intrusion by units of state and federal governments into the areas of normal business practices in our industry will continue to proliferate, in my opinion. We might as well recognize up front that the odds of seeing positive or progressive rules and/or regulations is not in our favor. In this era of special interest legislation, the special interests of the farm supply business sector are somewhat near the bottom of the list.

In spite of the efforts and skill of our industry groups . . . The Roundtable, TFI, N.F.S.A., etc . . . we must be prepared to adjust to, and adapt into our various companies, the rising tide of "Liberal Legislative License".

Contrary to our need to reduce overhead and other costs, we must maintain professional advisors, either on our payroll or through consulting agreements. We must expedite the infusion of new capital for safety and environmental projects.

However, whether we agree or disagree . . . like or dislike . . . support or challenge . . . we all have an obligation to be good corporate citizens.

Well, I got a little off track and carried away when I mentioned "government". Let me move back to the subjects I wanted to cover.

As far as trucking . . . we will just have to wait and see what the IRS comes up with.

The third leg of the distribution chain, that I will briefly discuss, is the barge system.

Even though the barge movement of bulk commodities is probably going to remain competitive with rail, it is my opinion that river warehouses will play a lesser role in the future. An exception to this general statement will be the few warehouses that have modern, high speed unloading and load out equipment and that has the capability to trans-load barges into rail cars and/or trucks or vice versa.

I base my opinion on the availability of competitive rail rates into the interior of the market from the mines in Canada or the plants in Florida. As I said earlier . . . every time product is handled, the cost goes up.

Barges do offer another advantage for volume buyers . . . the ability to use the barges as floating storage bins as an adjunct to truck and rail shipments.

Don't take my comments wrong. I am not against barge shipments. My company ships thousands of tons of fertilizer in barges every year. In fact, we own 6 anhydrous ammonia barges and have access to over 400 bulk commodity barges through a sister company.

I am merely giving you my opinion in general terms . . . the possible changes I see occurring.

The pipeline industry raises more questions than answers in my mind. Will the Gulf Central lines be sold? Will tariffs be deregulated? Semi-deregulated? Will pumping rates be reduced? What will the reduced volume do to the current rate structure? How many production plants on the pipeline will continue in business? Will supply and demand on the MAPCO line be adequate to maintain the system? What's the future of nitrogen solutions on the Williams system now that Agrico has been sold to Freeport?

Probably the answer to most, if not all of these questions, is that there won't be many significant changes, at least in the near term.

Now that I have shared with you the images in my distribution crystal ball, let me try to call up the spirits that are experts in marketing.

The images in this crystal ball are even less clear than the distribution ones were. And no wonder, with terms like 0-92, Conservation Reserve Program, Acreage Reduction Program, Parity Payments, Commodity Loans, PIK, PIK and Roll, Potash Duties, Urea Duties, etc., etc., etc.; rolling around the political scene.

Fortunately, it now appears that 0-92 doesn't have much of a chance of getting out of the Senate. Thanks to the efforts of thousands of people who communicated their feeling to their respective elected officials, the potential impact on the U.S. Treasury and on the whole agricultural business segment has been recognized.

With the major threat of 0-92 now less ominous, the outlook for our business looks more positive to me.

Further acreage reductions will continue through 1990, primarily due to the Conservation Reserve Program. The U.S.D.A. is committed to enrolling 40 to 45 million acres by 1990. Some 20 million acres are already enrolled.

Most of us still have vivid memories of 1983 when we were almost PIK'ed to death. Set-a-side acres went from 10 million to 76 million acres.

In 1984, set-a-sides dropped back to 21 million, then began to increase at a rate of 7 to 26 million acres per year. At the current rate, set-a-side acres in 1988 will be greater than the set-a-side in 1983 and my projections are that set-a-side acres will remain greater than 1983 levels through 1991. This projection assumes that the 1985 farm program remains basically intact.

I said I think the outlook for our business is more positive now. You may wonder how or why, based on the reduced acres. Two major changes have occurred since 1983. One, the fertilizer industry has done a rather dramatic job of restructuring itself through mergers, consolidations, plant shut downs and, just plain going out of business. We are now able to profitably operate at the reduced demand levels.

The second major change from 1983 is that most of the acres now going into the set-a-side programs is marginal land. Some is so marginal that it should never have been brought into production to begin with.

The 230 million acres that will be farmed in the next four years will be more productive on a per acre basis giving the farmer a better return. When the farmer is more profitable, he is going to be able to purchase more yield producing inputs—fertilizers and ag chemicals. That is why I feel positive.

Those of us gathered here today are members of an elite group of agri-business people—we are the "Survivors", the ones who reacted correctly to the dramatic changes that have occurred during the past four years.

We had to make some tough decisions to qualify for membership in this club. Closing or selling off unprofitable assets, laying off or terminating employees, holding off on making capital expenditures, tightening up on credit terms, reducing product lines, reducing inventory levels and becoming better managers overall . . . were and remain . . . the keys to survival.

Our customers of today and tomorrow . . . the American farmer . . . are also survivors. They are emerging leaner and smarter. They will be tougher to sell. They will demand more from their suppliers. They will expect to see positive results from the products and services they purchase.

Every potential customer for fertilizers, pesticides and seed will still have from 3 to 10 suppliers in most areas from whom to pick to purchase their needs.

I make this point for one primary reason. Particularly at the retail level, with fewer acres being devoted to grain production, further consolidation of the fertilizer business, is probable and feasible.

With the requirements for new capital expenditures for information systems, environmental needs and safety equipment that I alluded to earlier, the marketing arm of our business must have sufficient resources and profits to not only sustain the present facilities, but also to make improvements and to grow.

I project that this further consolidation will occur through the affiliation of small businesses with regional marketing organizations or with one of the national companies. These affiliations will provide the necessary support in the areas of distribution, purchasing, safety, accounting, insurance and working capital availability.

There will still be several thousand, single outlet dealers that will be able to grow on their own. These will be the well managed, well financed operations who can adapt to the ever changing market place.

From all these changes, I still see four distinct marketing groups moving forward . . . the Cooperatives (as a group), 4 or 5 national marketers, 10 to 15 large regional marketers, and, a large group of independents. However, there will be far fewer, but much stronger, members in each group.

This is a positive direction and will benefit the entire ag economy. If the American farmer is to regain his position as a low cost producer of grain, and compete effectively in the world market, he must have access to the best value in his crop production inputs.

The farmers' suppliers also have to be low cost producers and marketers. Let me emphasize that I said low *cost,* not low *profit,* businesses. Lest we get caught up in the trap that put many of our departed brothers and sisters out of business, we must continue to implement and enhance the management techniques that carried us through the past few years.

The Food Security Act of 1985, more commonly known as the Farm Program, is slowly having a positive impact. Farm income is at an all-time high. Exports of farm commodities are quietly moving upward. Carry over surpluses are predicted to decline offering further support to a recovery period.

The major points of the Farm Bill are:

—new loan rates with decreasing values through 1990

—new target prices with provisions for reductions

—continued deficiency payments through 1990

—acreage reduction programs through 1990 with a planned reduction of a minimum of 12.5% of base acres with a maximum reduction 20% of base acres so long as the carry over of corn in any year exceeds 2 billion bushels

—established maximum payment of $50,000 per person per year

—established Conservation Acreage Reserve

—10 to 15 year contracts

—rental payments based on bids

—payment in cash or PIK certificates
1986 5 million or more acres enrolled
1987 10 million or more acres enrolled
1988 10 million or more acres enrolled
1989 10 million or more acres enrolled
1990 5 million or more acres enrolled
Total 40 million or more acres enrolled

—benefits for 59 other areas from cricket control to watermelon check-off

While political actions remain pretty much unpredictable, there is a glimmer of hope that some rational actions will occur . . . the apparent demise of 0-92 for example.

I believe that the recent irrational action taken by the Department of Commerce against the Canadian potash industry will be resolved on a more reasonable basis than is now proposed.

As I have already stated, neither the fertilizer business nor the farm commodity business is a domestic business any more. Every action taken in the United States has international implications and causes international reaction.

For example, if import duties make Canadian potash unreasonably high priced, there are other producing countries that can step in and fill the void. If American grain is priced above the world market, other nations will gladly sell their products.

I don't intend to get into a debate, or take sides, at this forum, on the issue of import duties, but I will state my personal opinion. The fertilizer industry, as the largest supplier of inputs into crop production costs, has an obligation to its customers to be the most efficient supplier of those inputs that is economically feasible.

I firmly believe that we can accomplish that assignment and still achieve for ourselves and our stockholders a reasonable return on the capital that we invest in our efforts.

If I summarize my remarks on "Changes in Domestic Marketing and Distribution Patterns" into some semblance of order, I would say that:

1. We can no longer separate the agricultural production business into the U.S., and the rest of the world. This entire industry, from fertilizer production, distribution and marketing all the way through the eventual marketing of the crop is now one large world business.
2. The importation of fertilizer materials will continue to be a major factor in the U.S. market.
3. The distribution system must change to effectively and economically handle the multitude of product sources whether it be the mines of Canada or New Mexico, the plants in Florida or Idaho, production in Louisiana or the arrival of vessels in Stockton, or Houston or New Orleans or Baltimore.
4. Distribution economics may well mean the difference in the profitability or lack thereof, to a dealer in Iowa or Colorado or North Carolina.
5. In the marketing arena, things are looking positive. The financial health of our customers is greatly improved. Due to closings and consolidations, the fertilizer producers and marketers are now much stronger financially. More consolidations will occur in the next 12 months further solidifying the ability of the industry to efficiently serve the needs of our customers.
6. Notwithstanding the unknown of political actions and unstable foreign governments, the world market place appears ready to provide adequate supplies of needed products, and expand their purchases of our surplus production.
7. Finally, I feel good about the business we are in. I see lots of positive things happening. If we remain aggressive, and follow through with our survival strategies, we can once again become an economically solid industry, serving as a key contributor to the turn around in the Agricultural industry.

The current environment we are in reminds me of an event that reportedly took place in one of the beautiful parks here in New Orleans.

There is a statue of a beautiful young maiden reaching out to a handsome young man. They have been frozen in this heart wrenching condition for years.

One day an angel came down, and upon observing the statue, decided to do a good deed. He brought the beautiful maiden and the handsome young man to life. He advised them that they had two hours to do anything they wanted.

The boy, with a gleam in his eye, looked at the girl. She smiled. He took her by the hand and off into the bushes they went. In short order, the bushes started shaking and sounds of glee could be heard. The angel smiled at the thought of the good deed that he had done.

Suddenly, the voice of the lovely young maiden was heard: "Now, it's your turn to hold the pigeon and I'll do the getting even."

Unlike the statue, we are not confined in a frozen "heart wrenching" condition. We are alive and well . . . doing the things we can do better than any one else in the world . . . producing, transporting, distributing and marketing fertilizer.

Let's get even with that pigeon of doom and gloom.

We can feel good . . . we are the survivors . . . WE ARE THE FUTURE!

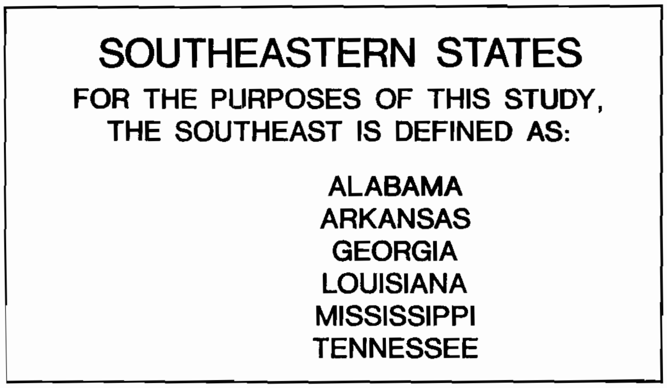
Thank you.

Role of Farm Credits and Other Farm Level Economic Factors

By Donaldson V. Wickens

Farm Credit Bank of Jackson, MS

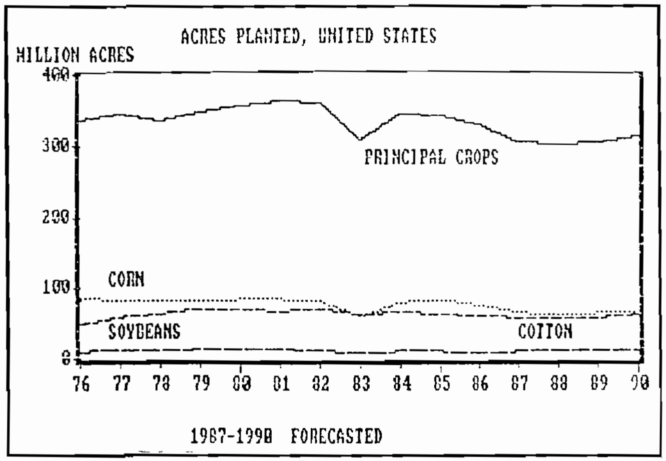
VISUAL PRESENTATION



SOUTHEASTERN STATES

FOR THE PURPOSES OF THIS STUDY,
THE SOUTHEAST IS DEFINED AS:

ALABAMA
ARKANSAS
GEORGIA
LOUISIANA
MISSISSIPPI
TENNESSEE



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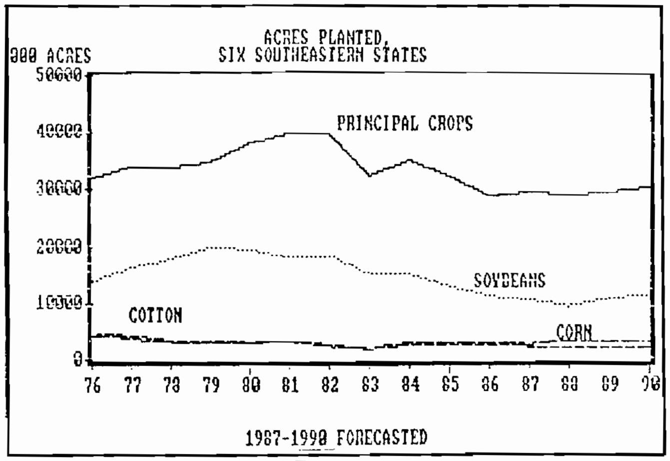

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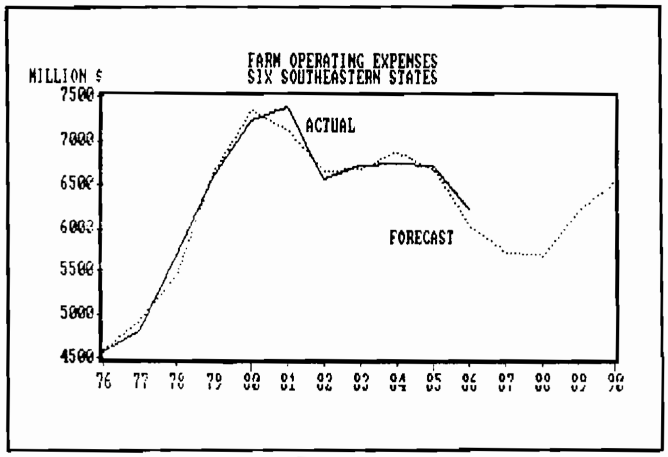

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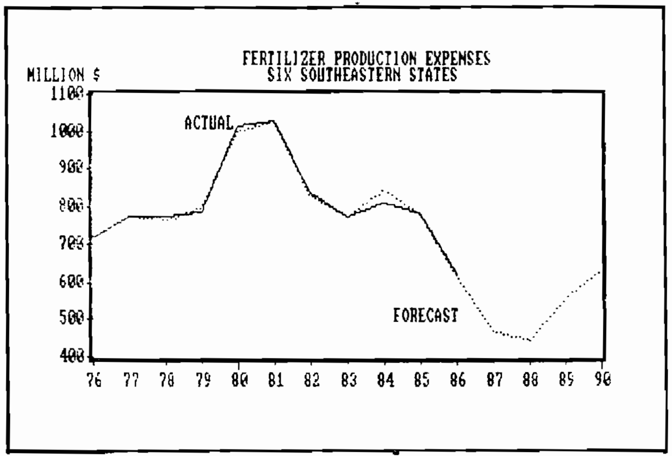

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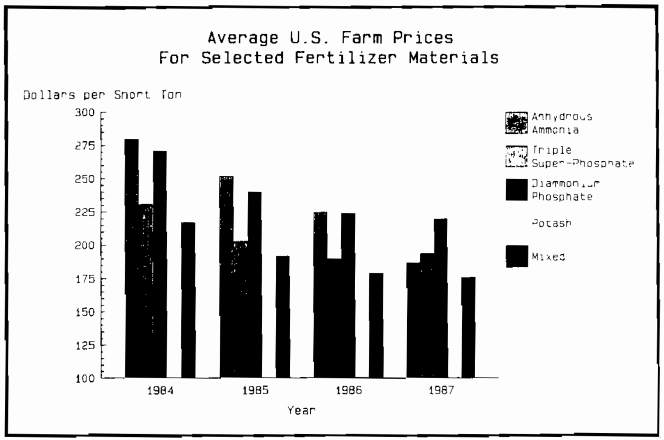

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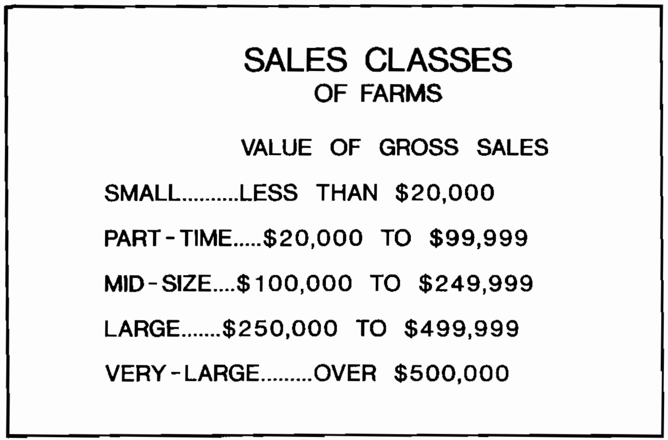


SALES CLASSES
OF FARMS

VALUE OF GROSS SALES

SMALL..........LESS THAN $20,000

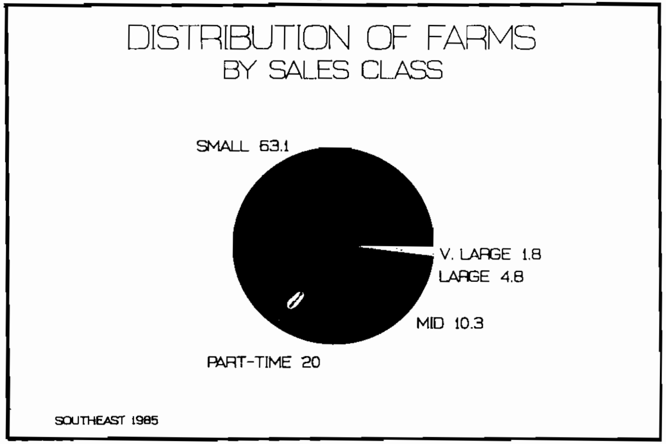
PART-TIME.....$20,000 TO $99,999

MID-SIZE....$100,000 TO $249,999

LARGE.......$250,000 TO $499,999

VERY-LARGE.........OVER $500,000

Figure 6



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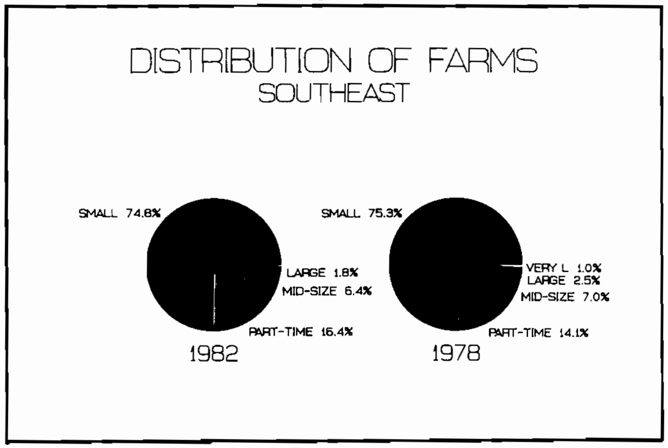
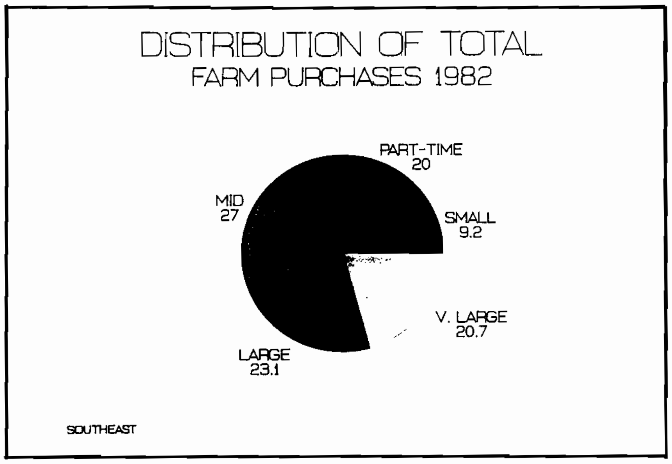


Figure 9



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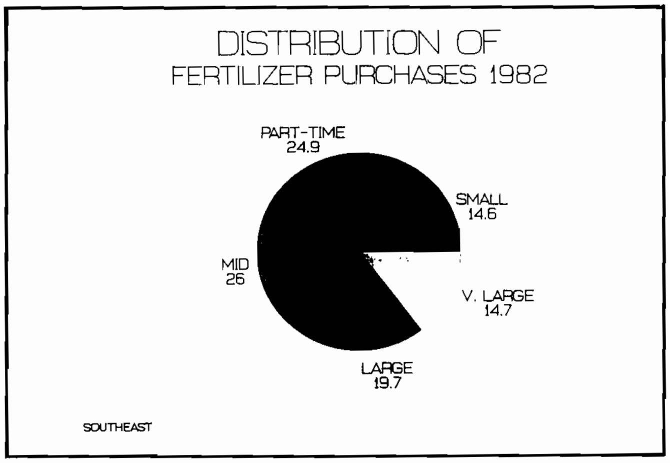

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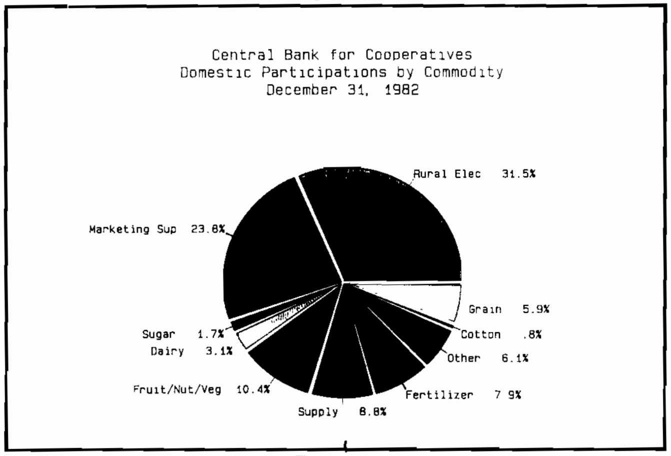

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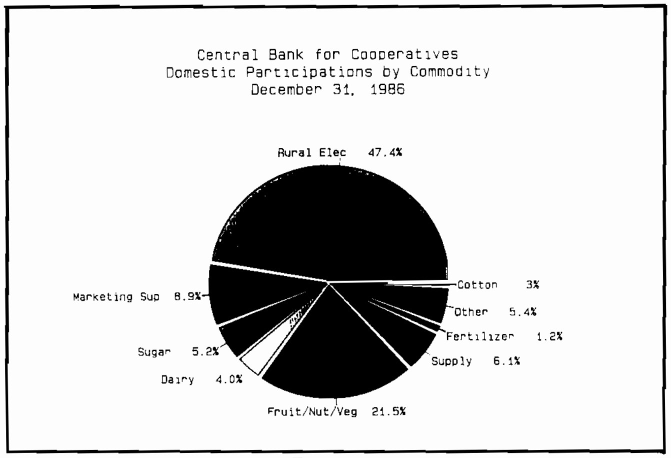


Figure 13

STRUCTURE SUMMARY
SOUTHEASTERN FARM SUPPLY MARKET

1) **FARMS ARE GETTING LARGER.**
2) **FARMERS ARE GETTING OLDER.**
3) **PART-TIME AND MID-SIZE FARMS CARRY A LARGE PORTION OF TOTAL FARM DEBT.**
4) **THE NUMBER OF PART-TIME AND MID-SIZE FARMS ARE EXPECTED TO REMAIN STABLE OR INCREASE.**

Figure 14

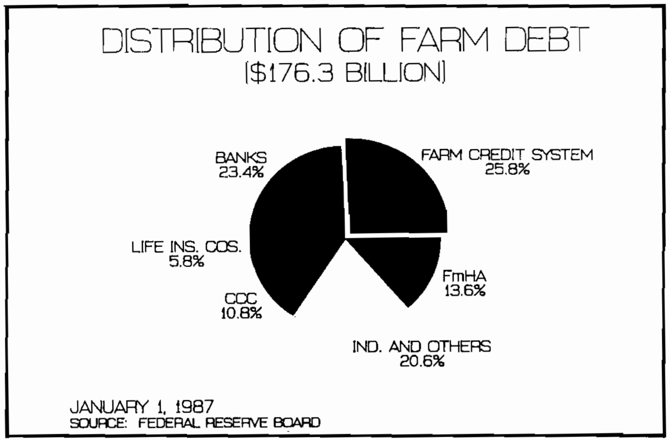
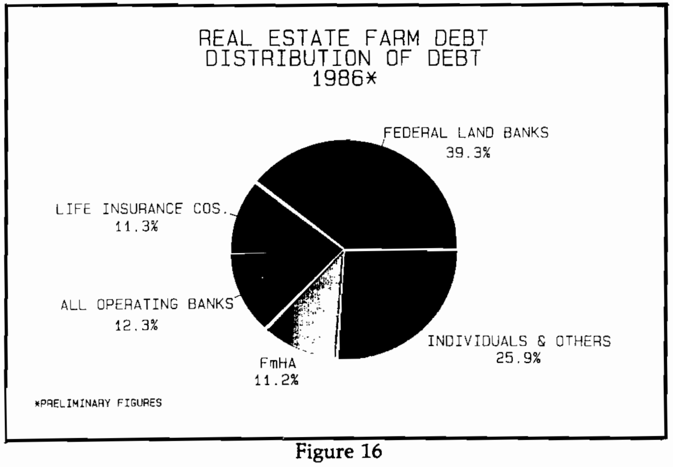


Figure 15



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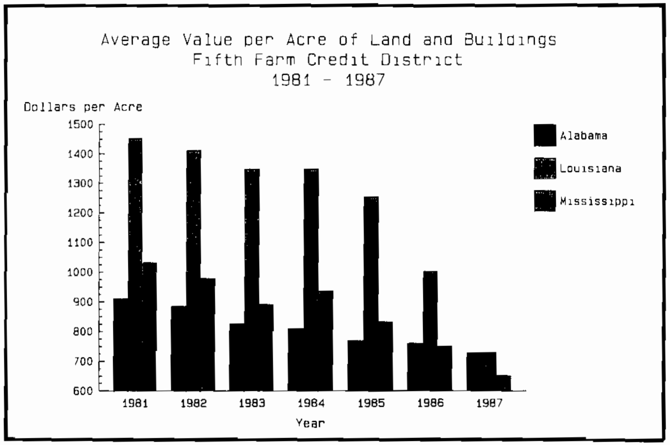


Figure 17

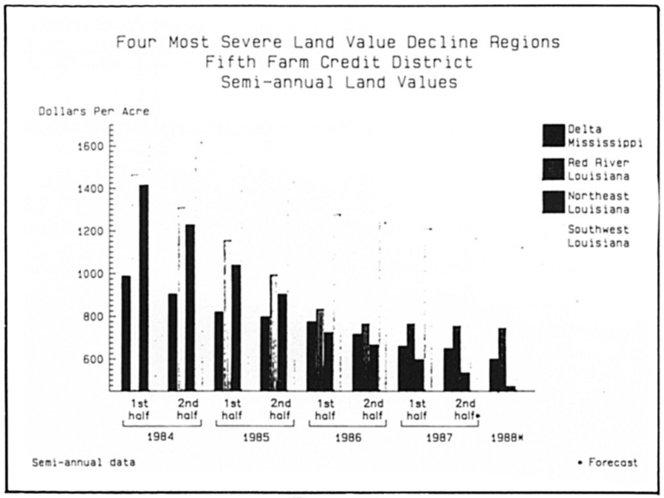
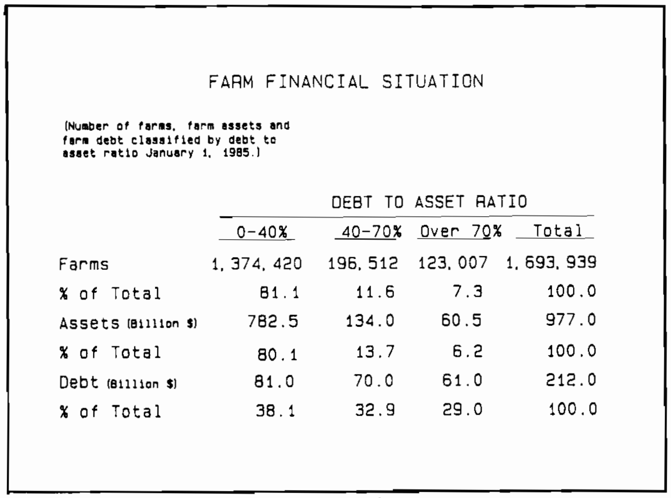


Figure 18

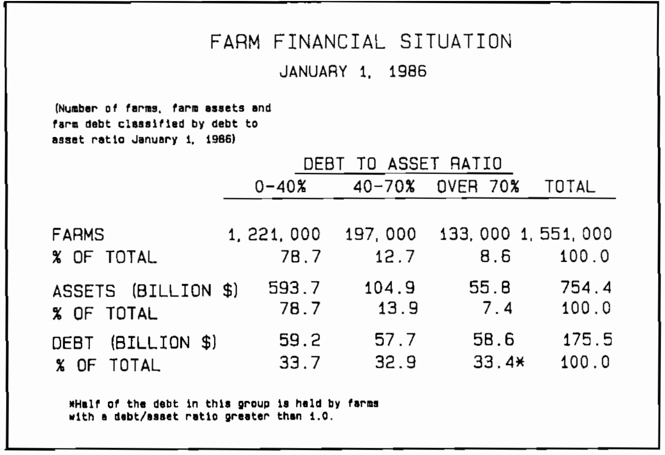


FARM FINANCIAL SITUATION

(Number of farms, farm assets and farm debt classified by debt to asset ratio January 1, 1985.)

	DEBT TO ASSET RATIO			
	0-40%	40-70%	Over 70%	Total
Farms	1,374,420	196,512	123,007	1,693,939
% of Total	81.1	11.6	7.3	100.0
Assets (Billion $)	782.5	134.0	60.5	977.0
% of Total	80.1	13.7	6.2	100.0
Debt (Billion $)	81.0	70.0	61.0	212.0
% of Total	38.1	32.9	29.0	100.0

Figure 19



FARM FINANCIAL SITUATION

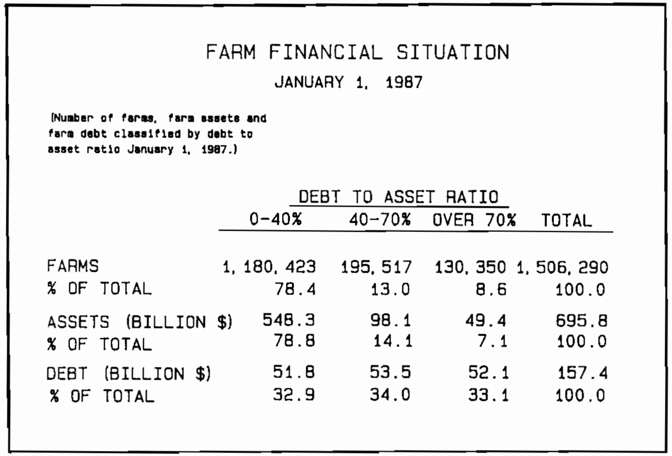
JANUARY 1, 1986

(Number of farms, farm assets and farm debt classified by debt to asset ratio January 1, 1986)

	DEBT TO ASSET RATIO			
	0-40%	40-70%	OVER 70%	TOTAL
FARMS	1,221,000	197,000	133,000	1,551,000
% OF TOTAL	78.7	12.7	8.6	100.0
ASSETS (BILLION $)	593.7	104.9	55.8	754.4
% OF TOTAL	78.7	13.9	7.4	100.0
DEBT (BILLION $)	59.2	57.7	58.6	175.5
% OF TOTAL	33.7	32.9	33.4*	100.0

*Half of the debt in this group is held by farms with a debt/asset ratio greater than 1.0.

Figure 20



FARM FINANCIAL SITUATION

JANUARY 1, 1987

(Number of farms, farm assets and farm debt classified by debt to asset ratio January 1, 1987.)

	DEBT TO ASSET RATIO			
	0-40%	40-70%	OVER 70%	TOTAL
FARMS	1,180,423	195,517	130,350	1,506,290
% OF TOTAL	78.4	13.0	8.6	100.0
ASSETS (BILLION $)	548.3	98.1	49.4	695.8
% OF TOTAL	78.8	14.1	7.1	100.0
DEBT (BILLION $)	51.8	53.5	52.1	157.4
% OF TOTAL	32.9	34.0	33.1	100.0

Figure 21

Tuesday, November 3, 1987

Afternoon Session IV
Tour—Freeport-McMoran Plant, Donaldsonville, Louisiana

Below is copied a letter addressed by Dave Leyshon, Director of the Fertilizer Industry Round Table to Mr. Dick Woolsey, Plant Manager of the Freeport-McMoran Facility:

November 16, 1987

Mr. Dick Woolsey
Plant Manager
Agrico Chemical Co.
P.O. Box 71
Donaldsonville, LA 70346

Dear Dick,

On behalf of the Board of Directors of the Fertilizer Industry Round Table and all the attendees (120 in total) that made the recent plant visit to the Donaldsonville facility, I'd like to express our sincere thanks for a well organized and very informative tour.

Being a veteran of numerous previous tours conducted by IFA, the International Fertilizer Manufacturers Association, and by the Fertilizer Society of London, the tour of your plants measured up with the best I've encountered, and we appreciate the efforts put forth by Freeport-McMoRan.

We had about 35 foreign visitors in the group, who, I'm sure, were impressed by the size of the facility and its excellent appearance.

I'd also like to praise Jim Chandler, who was the tour guide on my bus, for his first class job. I heard numerous compliments about the informative and efficient job done on the other busses.

When you get down to Lakeland, Dick, please give us a call.

Best Regards,

Dave Leyshon

Dave Leyshon

Wednesday, November 4, 1987

Morning Session V
Moderator:

Leo C. Cook

Agronomic Differences Between Nitrate and Ammoniacal Nitrogen

B. R. Bock
Tennessee Valley Authority

Renewed interest in agronomic differences between nitrate and ammoniacal N stems partially from new evidence that higher yields can be achieved by controlling the relative levels of ammonium and nitrate in soil. Resulting yield increases may play a role in reducing unit costs of crop production and enhancing the competitiveness of U. S. agriculture in world markets. The role of N fertilizer in nitrate contamination of ground and surface waters is becoming an important issue in the United States and many other developed countries. Controlling the relative levels of ammonium and nitrate in soil can reduce the loss of nitrate from cropping systems into ground and surface waters. Thus, the topic, agronomic differences between nitrate and ammoniacal N, is very relevant in today's agriculture and could very well significantly impact the fertilizer industry in the not too distant future.

The relative levels of ammonium and nitrate present in soil can affect 1) crop nutrition, 2) N availability to roots, and 3) N losses from the root zone. These differences will be discussed as they pertain to cereal cropping systems. The relative levels of ammoniacal and nitrate N *applied* can affect ammonia volatilization losses from surface applications of N fertilizer, soil pH, and liming requirements, but these factors will not be discussed.

NITROGEN FORM APPLIED VS. NITROGEN FORM IN THE SOIL

If one were to poll State soils extension specialists about the agronomic differences between ammoniacal and nitrate fertilizers, a common answer would be that ammoniacal and nitrate fertilizer sources are generally equal agronomically when each N source is used properly. This response is generally accurate because, with current predominant practices, ammoniacal fertilizers convert rather quickly (often in two to three weeks) to nitrate in warm, fertile soils. After converting to nitrate by the process known as nitrification, ammoniacal fertilizers generally have the same agronomic effect as if a nitrate fertilizer had been applied in the first place. Nitrogen released from soil organic matter is first available to plants in the ammonium form, but most of this N is thought to convert to nitrate before being taken up by plant roots. Plant-available N remaining in the root zone from one crop to the next is almost all in the nitrate form. Consequently, the question of agronomic effects of ammoniacal N is relevant mainly in situations in which ammoniacal fertilizers convert relatively slowly to nitrate. What are these situations?

Conversion of ammonium to nitrate is slow in cool soils that occur between late fall and early spring in much of the United States. This conversion process is also slow in flooded or water-logged soils because of a limited oxygen supply for microbes which perform the conversion. However, most of the N fertilizer for cereals is applied when soil conditions are conducive to relatively rapid conversion of ammoniacal N to nitrate. Under these conditions, one or more of the following practices are required to maintain significant levels of ammonium in soils:

- Use of nitrification inhibitor with ammoniacal N source—multiple applications are required to inhibit nitrification for a significant part of growing season.
- Application of ammoniacal N source in drip irrigation water—nitrification is slow because ammoniacal N source is placed near emitters where soil is saturated or nearly saturated with water.
- Banding ammoniacal N sources, particularly anhydrous ammonia and urea—this practice alone results in less control of nitrification than the previous two practices.

When one or more of these practices are used, significant levels of ammonium can be maintained in soil, and a potential exists for observing agronomic differences between ammoniacal and nitrate N sources. Some common fertilizer sources of ammoniacal and nitrate N are listed in Table 1.

NUTRITIONAL EFFECTS ON CROP GROWTH AND YIELD

Solution Culture Studies

Much of the information about effects of ammonium and nitrate on cereal growth and yield has been obtained from solution culture studies. Compared with studies in soil, solution culture studies facilitate relatively precise control of ammonium, nitrate, and other plant nutrient levels at root surfaces. Optimum ammonium/nitrate ratios for cereal crops have not been well characterized, but growth is generally greater with combinations of nitrate and ammonium than with either nitrate or ammonium as the sole N source (Hageman, 1984; Bock, 1986). This is shown for vegetative growth of wheat in Figure 1.

The greater cereal growth with combinations of nitrate and ammonium may be associated with several aspects of plant physiology. With nitrate as the sole N source, N uptake rates may be too low or the rate of nitrate conversion to ammonium within the plant may be too slow for optimum growth. Lower growth with nitrate as the sole N source may be related to energy requirements for converting nitrate to ammonium within plants or for controlling pH within plants. In terms of these factors, adding additional N or altering other soil and crop management practices probably will not substitute for optimizing ammonium/nitrate ratios supplied to plant roots.

Greater cereal growth with combinations of nitrate and ammonium than with either nitrate or ammonium as the sole N source may also be related to pH at root surfaces or an imbalance of mineral nutrients other than N. Where these problems exist, soil management practices may substitute to some degree for altering ammonium/nitrate ratios in optimizing plant growth.

In solution culture studies, cereal growth has often been decreased with excess ammonium as shown in Figure 1. These decreases in growth may be due to a build-up of ammonia to toxic levels in plants, depletion of carbon reserves in the process of detoxifying ammonia, or decreased N uptake rates. Alternatively, decreases in cereal growth due to excess nitrate are rare.

Results from solution culture studies suggest that cereal yields can be increased in the field by maintaining more of the crop's N in the ammonium form than is maintained with current N management practices (referred to below as enhanced ammonium nutrition). Solution culture studies also suggest that ammonium/nitrate ratios may need to be controlled rather precisely to avoid ammonia toxicity.

Greenhouse Studies with Soil as the Growth Medium

Enhanced ammonium nutrition increased spring wheat yields 15 to 47% and increased grain sorghum yields 15 to 18% in a series of greenhouse studies at the National Fertilizer Development Center (NFDC), Table 2. Figure 2 is typical of results in these studies in that yields generally were not reduced with higher ammonium rates than required for maximum yield. This lower sensitivity to excess ammonium than observed in solution culture studies may be due to the relatively low mobility of ammonium in soil which moderates the rate of ammonium uptake, thereby preventing ammonia toxicity. Ammonium mobility in soil and its implications for N availability to roots will be discussed later in more detail.

Cereal growth responses to enhanced ammonium nutrition have been less consistent with soil than with nutrient solutions as the growth medium. For example, Len spring wheat, which responded well to enhanced ammonium nutrition in NFDC greenhouse studies with soil as the growth medium (Table 2), gave a similar response to enhanced ammonium nutrition in solution culture but not in soil in a joint University of Illinois study (Table 3).

Inconsistent responses to enhanced ammonium nutrition in different soil systems may be due to differences in ammonium availability to roots. Ammonium availability may vary among soils and with environmental conditions because of differences in rate of ammonium movement to roots, ammonium placement in soil, and ammonium "tie-up" by soil. Another reason may be that, in some soils, crops may take up sufficient ammonium from soil organic matter before the ammonium nitrifies. However, as mentioned earlier, this is not thought to be likely under most soil conditions. More research is needed to determine ammonium availability to roots as affected by important soil factors.

Field Studies

Field studies also have given rather inconsistent responses to enhanced ammonium nutrition, but some general trends appear to be emerging for corn. Greatest responses to enhanced ammonium nutrition tend to be in high yield systems, and, within a given cropping system, greatest responses are usually obtained with the highest yielding hybrids. These points are illustrated with relatively high yield systems from Indiana (Table 4) and Ohio (Table 5). In the Indiana example, B73 X Mo17 gave a 45 bu/A yield response to enhanced ammonium nutrition. In the Ohio example, Countrymark C747AX gave a 36 bu/A response to enhanced ammonium nutrition. These responses were obtained with hybrids that were presumably selected in cropping systems that provided predominantly nitrate nutrition. Perhaps cereal yields can be increased even further with enhanced ammonium nutrition by selecting genotypes specifically for their ability to respond to enhanced ammonium nutrition.

Little is known about the attributes of corn hybrids associated with responsiveness to enhanced ammonium nutrition. However, there is some evidence that prolific hybrids and hybrids that accumulate relatively large portions of their N during grain fill are more responsive to enhanced ammonium nutrition. Further research is needed to determine whether genotypes of various cereal crops can be developed which are more responsive to enhanced ammonium nutrition. More research also is needed to determine optimum ammonium/nitrate ratios in relation to stage of crop growth.

NITROGEN AVAILABILITY TO ROOTS

Nitrogen Movement to Roots

Nitrate and ammonium differ greatly in their rate of movement through soil to roots (Barber, 1984). Nitrate moves to roots with soil water by mass flow. The rate of nitrate movement to roots rarely limits its availability to plants except when soils are very dry. In contrast, ammonium moves much slower than soil water and over shorter distances (largely by diffusion) than nitrate. The rate of ammonium movement to roots increases with soil moisture and temperature, and is inversely related with cation-exchange capacity. The rate of ammonium movement to roots can limit its availability to plants when soil conditions are less than ideal for ammonium movement.

Nitrogen Placement Considerations

Nitrate and ammonium differ relative to optimum placement in soil. Because of the relatively high mobility of nitrate is soil, placement of nitrate is generally not critical for assuring positional availability of nitrate to roots. Alternatively, since ammonium is relatively immobile in soil, it needs to be placed below the soil surface to attain more root growth in the ammonium-fertilized soil and to assure that the ammonium-fertilized soil stays moist longer to facilitate ammonium movement to roots. Table 6 shows the type of yield reduction that can occur when an ammonium source is broadcast on the soil surface and a relatively high ammonium/nitrate ratio is maintained. The yield reductions with relatively high ammonium/nitrate ratios were due to N deficiency, particularly in the first few weeks after N application. Ammonium apparently did not move into the root zone sufficiently to optimize ammonium availability to the wheat roots.

Theoretical considerations suggest that, because of its relatively low mobility in soil, ammonium needs to be mixed with a significant fraction of the topsoil to assure adequate ammonium availability to roots (Bock, 1986). This results in a significant portion of the roots being in ammonium-fertilized soil and minimizes the distance ammonium must move to involve an adequate root surface area in ammonium uptake. Research is needed to determine optimum fractions of soil to fertilize with ammonium in various cropping systems.

NITROGEN LOSSES FROM THE ROOT ZONE

Probably the most widely recognized agronomic difference between nitrate and ammonium is their differing potentials for being lost from the root zone (Kurtz, 1980). Nitrate is susceptible to losses by leaching and denitrification (microbial conversion of nitrate to volatile gases in excessively wet soils), whereas ammonium is susceptible to neither type of loss until it converts to nitrate. Thus, preventing or slowing the conversion of ammonium to nitrate is one approach for reducing leaching and denitrification losses from the root zone.

Efficient timing of N fertilizers (applying N as close as practical to the time of primary N use by the crop) is another option for reducing leaching and denitrification losses from the root zone (Bock, 1984). Figure 3 shows that efficient N timing and use of a nitrification inhibitor are both effective for reducing N losses from the root zone as reflected by improved N use efficiency. In this example from a highly permeable sandy loam soil, nitrate leaching was the primary mode of N loss. The N rate required to achieve maximum yield was 120, 180, and 300 lb N/A with sidedress, preplant + nitrification inhibitor, and preplant treatments, respectively.

Split application of an ammoniacal N source and nitrification inhibitor is the primary practice available for providing enhanced ammonium nutrition during a significant portion of the growing season. This same practice should be effective in reducing both N losses from the root zone and the potential for nitrate contamination of ground and surface waters.

SUMMARY AND CONCLUSIONS

Some high yielding genotypes of cereal crops have given substantial yield increases from enhanced ammonium nutrition, even though these genotypes were developed with predominantly nitrate N nutrition. This suggests that potential exists for achieving even greater responses to enhanced ammonium nutrition by selecting genotypes specifically for their ability to respond to enhanced ammonium nutrition; however, the actual potential is unknown because genetic variation in yield response to enhanced ammonium nutrition is not well characterized. The concept of enhanced ammonium nutrition needs considerable development before it is ready for general use by farmers.

Ammonium and nitrate differ greatly relative to N availability to roots, mainly because of greatly differing mobility in soil. Nitrate moves readily to roots in most situations. In contrast, because of the relatively low mobility of ammonium in soil, ammonium needs to be placed below the soil surface and distributed in a significant portion of the topsoil in order to assure positional availability of the ammonium to roots.

Nitrate is susceptible to leaching and denitrification losses, whereas ammonium is not susceptible to these losses until being converted to nitrate. Thus, N management practices required for providing enhanced ammonium nutrition should also reduce nitrate losses from the root zone.

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TABLE 1
Some common fertilizer sources of ammoniacal and nitrate N

N source	Ammoniacal N	Nitrate N
	% of N	
Anhydrous ammonia	100	0
Urea[1]	100	0
Ammonium sulfate	100	0
Urea-ammonium nitrate solution	75	25
Ammonium nitrate	50	50
Calcium nitrate	0	100

[1] Urea is an ammoniacal N source in effect because it converts to ammonium soon after being added to soil.

TABLE 2
Maximum grain yield increases with enhanced ammonium nutrition in greenhouse studies with soil as growth medium[1]

Experiment	Grain yield increase with enhanced ammonium nutrition
	%
Spring wheat: A	47
B	17
C	19
D	16
E	15
F	19
G	19
Grain sorghum: A	15
B	18

[1] Spring wheat A and B (Bock, 1987); spring wheat C to G and grain sorghum A and B (unpublished TVA data).

TABLE 3
Effects of N form on grain bearing tillers and yield of Len spring wheat (unpublished data from cooperative TVA research; Below, Univ. of Illinois)

Growth medium	Nitrate N/ Ammonium N	Yield		Grain bearing tillers
		Grain	Total	
		g/m²		no./m²
Solution	100/0	494	1,029	396
	50/50	631 (28)[1]	1,372 (33)	566 (43)
Soil	100/0	500	962	462
	50/50	486	935	472

[1] Percent increase relative to 100/0.

TABLE 4
Corn yield with high-yielding hybrids as affected by combinations of nitrate from calcium nitrate and ammonium from anyhdrous ammonia + nitrapyrin (Tsai *et al.*, 1982)

Hybrid	No N applied		200 lb N/A			
		% Ammonium N % Nitrate N	0 100	25 75	50 50	100 0
			grain yield, bu/A			
B73 X Mo17	150 a [1]		185 b	214 c	230 d	214 c
B37 X A632	145 a		180 b	191 c	204 c	195 bc

[1] Numbers in given row with the same letter are not significantly different at the 0.05 probability level.

TABLE 5
Corn yield with high-yielding hybrids as affected by enhanced ammonium nutrition (Johnson *et al.*, 1986)

Hybrid	N source [1]		
	UAN[2]	UAN + nitrapyrin	Anhydrous ammonia + nitrapyrin
	grain yield, bu/A		
Countrymark C747AX	228	247	264
Countrymark C733X	211	218	227
LH119 X LH51	227	224	225
CB59L X LH51	204	205	215
CB59G X LH98	202	197	196

[1] 240 lb N/A (60 preplant, 180 sidedress).

[2] Urea-ammonium nitrate solution.

TABLE 6
Effects of the nitrification inhibitor, dicyandiamide (DCD), on soil ammonium N/nitrate N ratios and yield of soft white winter wheat (unpublished data from cooperative TVA research, Christensen, Oregon State Univ.)

	Applied N (March 6)		Soil N (0-4 inches)			
Source	Ammonium	DCD	Mar 17	Mar 31	May 12	Yield
	---------- lb N/Ac ----------		Ammonium N/Nitrate N			bu/Ac
Urea	160	0	3.7	0.8	4.6	109
Urea-DCD	152	8	31.7	27.9	16.8	93
Urea-DCD	144	16	31.0	25.0	21.0	101
					LSD$_{0.50}$	11

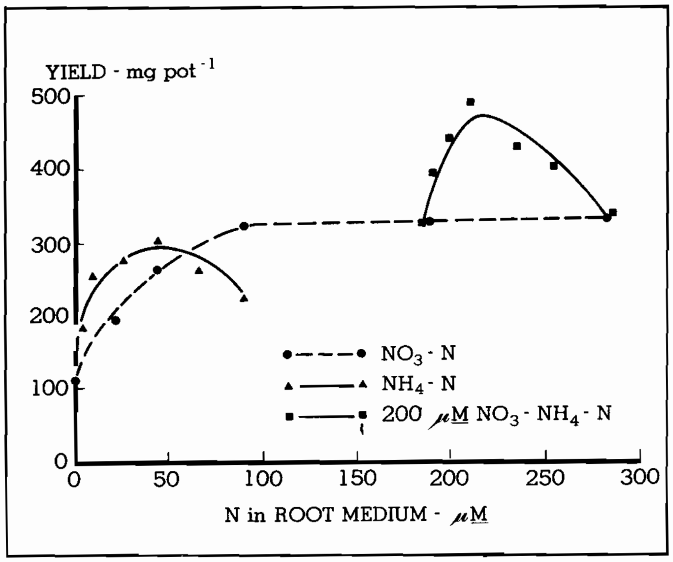


Figure 1. Effects of nitrate (NO_3), ammonium (NH_4), and NO_3—NH_4 combinations on early growth of wheat in solution culture (Cox and Reisenauer, 1973).

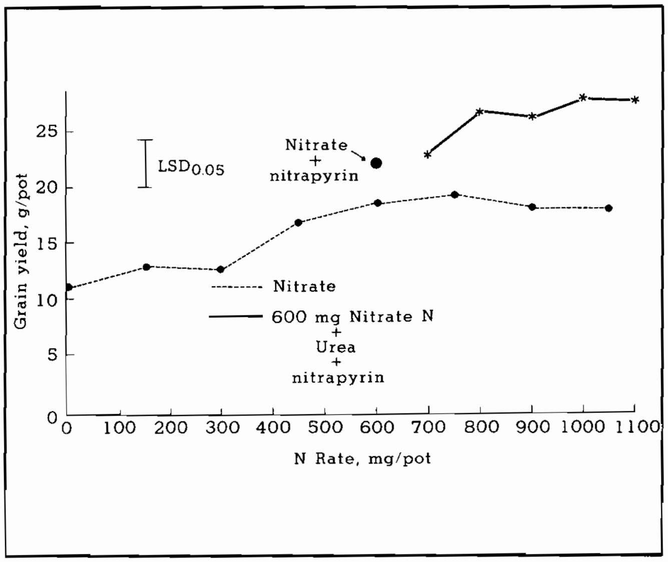


Figure 2. Effects of nitrate vs. nitrate + urea on yield of Len spring wheat (Bock, 1987).

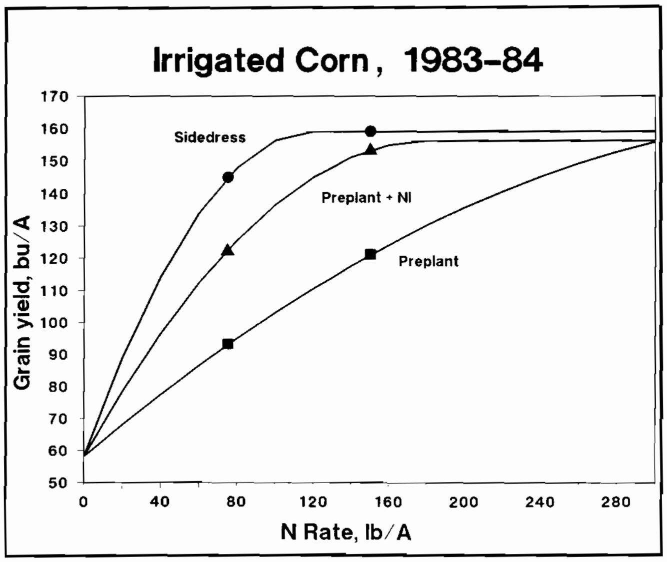


Figure 3. Effects of N application timing and nitrification inhibitor (NI) on yield response of corn to N under leaching conditions (Malzer and Graff, 1984 and 1985).

Research Opportunities and Priorities for Fluid Fertilizers

J. T. Batchelor
Southern Farmers Association

The purpose of this presentation is to discuss research priorities that should be considered along with other work to assist the fluid fertilizer industry. In the most part, what will be presented is a compilation of 1987 recommendations assembled by the National Fertilizer Solutions Association's (NFSA) Technology Committee. The objectives of this presentation are:

- To identify fluid fertilizer agronomic research priorities
- To outline fluid fertilizer application and production opportunities
- To discuss environmental and regulatory concerns

FLUID FERTILIZER AGRONOMIC RESEARCH PRIORITIES

Fertilizer Timing

Continued investigation of the timing of a fertilizer application, especially nitrogen (N) solutions, can do nothing but help improve N efficiency and crop yields. Making such applications with existing secondary tillage and cultivation equipment should make a timely application compatible with a farmer's current production practices.

Many timing studies have been conducted in the last twenty years but there always seems to be room for another investigation to test various combinations of experimental factors. A recent study by Don Eckert of Ohio State demonstrates the continued need for timing studies. In this no-till corn research project, Eckert showed that two corn hybrids (Becks 51X and Greenland 27) responded differently to a 220 lb. N/acre application made either at planting or split between planting and the 6-leaf growth stage. Beck 51X yields were improved by 10 bu/acre while Greenland 27 yields were not improved when the N solution was split, as shown in Figure 1. Because of potential yield and income increases from split application, plus the possibility of being more in harmony with the environment, more N solution timing studies should be conducted in combination with other crops, other fertilizer nutrients and crop factors such as plant population, planting dates, etc.

Fertilizer Placement

In the last five years there has been a concentrated effort to study the effects of placing N-P-K fluid fertilizers. Dr. Stan Barber's (Purdue University) research in particular has shown considerable promise by incorporating several soil chemical and physical measurements into a computer model to predict the need for phosphorus (P) placement on corn and soybeans. Because P is generally the least mobile element found in fertilizers, much consideration and many studies have been focused on placement of P. Consensus opinion in the fluid industry is that the model's prediction should be a factor in making soil test P recommendations.

Further field research is needed to explore placement effects on all crops grown under various environments. To justify this research, let me cite a recent study conducted by Bob Hutchinson at LSU in which he found placement benefits on cotton when he tested several placements of fluid and granular fertilizer. Comparison of treatments, preplant broadcast fluid (PBCF), preplant broadcast dry fertilizer (PBCD), preplant knife (PPK), preplant strip (PPS) and side dress knife (SDK) in Figure 2 show that the PPS treatment was superior to all other treatments in which a 90-60-60 NPK rate (lb/acre) was applied. Assuming no additional costs for application and $0.75/lb for lint (cost difference between fertilizer form not included), there would be a $104.00 and $86.00/acre increase in profit because of selecting the PPS application method over the PBCF and PCBD methods respectively. Although differences between treatments such as these may not exist in all environments, research on fluid placement should continue in order to uncover practices that provide additional profits to farmers.

Foliar Applications

Foliar application of small doses of N solutions (as urea) and other nutrients such as sulfur and KCL is being studied in the United Kingdom (UK). Preliminary UK results of Fluid Fertilizer Foundation (FFF) supported wheat studies have been promising; and similar research should be initiated in the U.S., especially in the high yielding hard red winter wheat growing regions. If U.S. results were found to be similar to those shown in Figure 3, a foliar application of liquid urea would be profitable most of the time. Note, in this study the treatments were: O-N; 203 lb N/acre dribbled and split between tillering and jointing stage (203S); same as treatment 2 plus 36 lb N/acre soil applied at flag leaf stage (239S); and same as treatment 2 plus 13 lb N/acre applied as foliar urea at flag leaf and head emergence (239F). The foliar treatment, 239F, yielded seven bu/acre more than the 203S treatment while the soil treatment, 239S, yielded two bu/acre more than the 203S treatment. The application of foliar urea can increase the value of the crop not only by producing higher yields, but also increasing grain protein when applied at the flag leaf stage and after.

Effect of Urea that Contains Biuret

The only thing I want to mention here is that there still seems to be dealer concern over biuret content in urea. Because of all the imported urea that has entered into the U.S., biuret concentrations have been suspected to be higher in the imports than in the domestic urea. Some dealers think that foreign urea plants are not designed the same as updated U.S. plants and urea from these plants could contain as much as 5% biuret. Many dealers don't want to risk causing problems with their customers even though many would like to take advantage of lower priced urea. They want to know the biuret content of various urea sources and they want better information that will explain the effect of biuret on germination, developing seedlings and foliar applications for vegetable, citrus and other sensitive crops. If available, information should be circulated to fertilizer dealerships, especially the data describing biuret rates which are detrimental when applied too close to or in contact with seed. Since the knifing of urea containing solutions is gaining in popularity and biuret could be concentrated in the fertilizer band, more research is needed to study sensitive crops such as cotton and vegetables.

FLUID FERTILIZER APPLICATION & PRODUCTION TECHNOLOGY OPPORTUNITIES

Application Technology

Although the technology of fluid dynamics is highly advanced in other industries, its application in the fluid industry has not been developed. Our industry has just not capitalized on the available technology. I think this will change but not as fast as it could.

However, John Schuller of the University of Florida is taking initial steps to assemble and assess an integrated fluid application system using related industry technology. In this system, spacial location equipment involving microwave transanglelation, nuclear magnetic resonance,and satellite global positioning in conjunction with various memory systems and microprocessors will be evaluated on the basis of cost, accuracy and repeatability. When perfected and retrofitted to the custom fluid applicator, application effectiveness can be expected to be at its peak.

More basic to the immediate application equipment requirement, is the need to get farmers properly equipped so *they* can apply suspension fertilizers. Obviously, there is excellent equipment which can do the job and some dealers do well in selling or leasing this type equipment. However, to gain more fertilizer market share with suspension fertilizers a shift to farmer application will have to take place in many regions of the U.S.

It's a mystery to me why the point injector system or so called spoke applicator has not been commercialized more than it has. This applicator has been shown to have several agronomic, energy and environmental advantages. It has improved corn yields, increased fertilizer uptake, reduced fuel costs, improved conservation and reduced fertilizer leaching when compared to conventional knifing in no-till or minimum-till corn. To illustrate the yield advantages in no-till corn, the results in Figure 4 compare preplant point injection (PPPI), preplant knife (PPKN), split point injection (SPPI) and split knife (SPKN) applications of a NPK fluid fertilizer. Obviously, a 10 to 20 bu/acre yield advantage of the point injector over the conventional knife should gain attention. Others have shown similar responses that favor the point injector when applying clear liquids. Because of the supporting data developed in several conservation tillage studies, it's time to start widespread commercialization of this application. However, the suspension application capabilities need to be further tested and applications need to be tested on cotton and other crops.

Manufacturing Higher Quality Suspensions

The aim of making a high quality suspension is to be able to store the product for greater periods of time, transport the product longer distances and have problem-free applications. To obtain this goal, the fluid fertilizer dealer needs more information on:

- Use of crystal growth inhibitors and modifiers
- Ways to keep particle size small
- Use of Fluorine
- Synergistic effects of interacting suspension agents
- Ultrasonic gelling

Suspension quality is so important to the dealer and to the farmer who makes his own application, that simple tests should be developed to allow dealers to predict with a high degree of confidence the short and long term handling characteristics of suspension materials.

Impurities in MAP Sources Need to be Assessed

MAP has been the cheapest form of phosphate used in suspensions, but the variation in the amount of impurities among the available MAP sources causes inconsistency in the quality of the suspensions blended by the dealer. It would be very helpful if a dealer had an impurities profile of each load of MAP that he purchased and knew what to do by knowing the impurities levels. Ways to improve the handling characteristics of MAP suspensions in addition to what has already been mentioned would be to: 1) prevent impurities from being in the final product or 2) develop other methods to keep small crystals suspended.

It appears that MAP will continue to be a major source of phosphate in suspensions. Producers who sell MAP that contains low levels of impurities and/or will provide an impurities analysis, plus formulating suggestions will be favored by suspension dealers.

ENVIRONMENTAL REGULATORY CONCERNS . . . A MAJOR PRIORITY

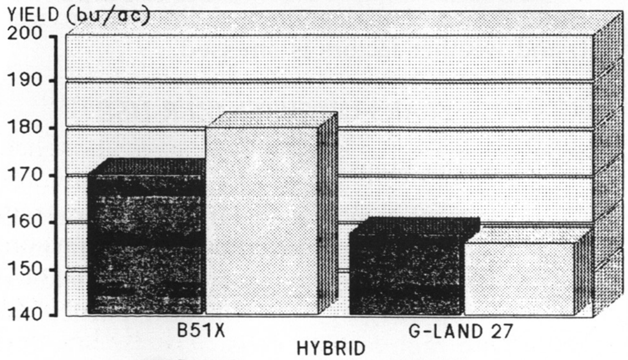
The highest priority facing the fluid fertilizer dealer today is complying with state and federal environmental and safety regulations. Since these issues are new and there is a lack of clear guidance, the dealer is in a quandary and in many cases does not know what to do or who to turn to. The fluid dealer would greatly benefit if an organization, such as the National Fertilizer Development Center (NFDC), would provide leadership. Even though NFSA has developed a product containment guide for dealer use, more direction is needed. NFDC could help fluid dealers by:

1. Developing and demonstrating a total compliance program that would meet specifications set in environmental and safety regulations.
2. Being totally involved with state and federal regulatory bodies and taking position as a mediator, participant and coordinator in environmental and safety issues that affect fluid dealers.

CONCLUSIONS

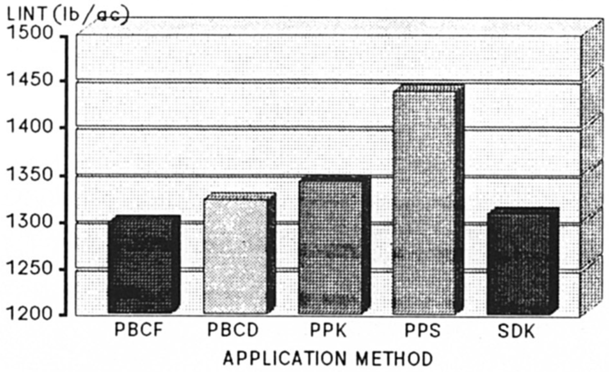
1. If work has been completed in any of the areas I have covered, it needs to be effectively communicated to fluid fertilizer dealerships.
2. Specific research and other project plans should be formulated and carried out to investigate the priority areas presented in this paper.

Fig 1. EFFECT OF SPLIT N SOLUTION APPLICATION ON CORN HYBRIDS



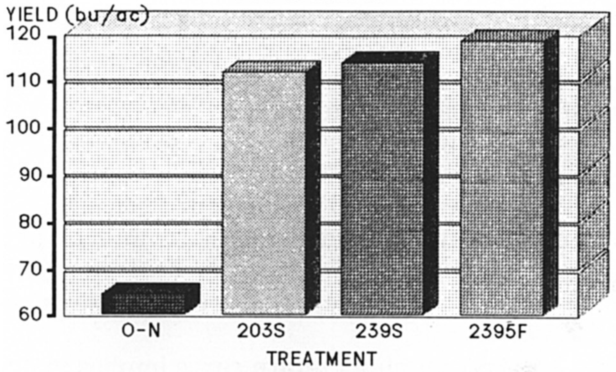
NOTE: N RATE = 220 LB/AC; ECHART, 1986 FFF SYMPOSIUM

Fig 2. EFFECT OF MULTINUTRIENT PLACEMENT ON COTTON LINT YIELD



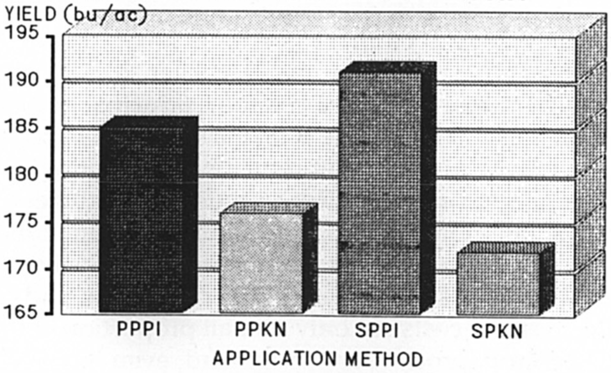
NOTE: FERT = 90-60-60; HUTCHINSON, 1986 FFF SYMPOSIUM

Fig 3. EFFECT OF FOLIAR N APPLICATION ON WHEAT



NOTE: SMITH, 1986 FFF SYMPOSIUM

Fig. 4 POINT INJECTION COMPARED WITH KNIFED FERTILIZER ON CORN



NOTE: TIMMONS, 1986 FFF SYMPOSIUM

Improving Agronomic Efficiency of Fertilizers

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GENERAL INTRODUCTION

The efficiency of use of fertilizer is measured in several ways by scientists.

For most agricultural situations the agronomic efficiency is adequate as a measure of crop response to applied fertilizer and of the effectiveness of its use.

Agronomic Efficiency (kg/ha) = (Yield of saleable crop$_F$ − Yield of saleable crop$_C$) divided by weight of fertilizer nutrients (N) applied

where F = fertilized crop, C = unfertilized check, and N is plant nutrient being studied.

Crop response to increasing rates of available fertilizer nutrient is curvilinear with the initial part of the curve becoming steeper and straighter as the benefit to be obtained from fertilizer use increases. A typical response curve for maize (Engelstad and Parks, 1971) is given in Figure 1.

The farmer applied fertilizer to convert a cash expenditure into an increased income. In other words, maximum net return per unit area is the farmer's goal; the efficiency of fertilizer use is only one aspect of this.

Use of a typical net return curve implies that the farmer should apply that rate of fertilizer at which the cost of the last kilogram of fertilizer applied produces an exactly equal value of crop. At this point, fertilizer use efficiency is low; beyond this point, the farmer begins theoretically to lose money and wastes fertilizer.

Developed country farmers have, however, tended to use higher levels of fertilizer than is necessary for maximum profit for four principal reasons.

1. The nature of the response curve is such that in practice the net return curve is quite flat at the maximum. Recommended fertilizer application rates for Maximum Economic yield (MEY) moreover do not change greatly with changes in fertilizer and crop prices; and fertilizer costs are only a small proportion of total crop production costs, and even indeed of actual cash costs. Most farmers therefore give that extra bag of fertilizer for insurance against possible yield loss.
2. The intense marketing activities of the commercial sector encourages farmers to use "that extra bag" and although fertilizer recommendations are based on good quality soil analysis, sample results show that private sector laboratories often recommend higher levels of fertilizer use than do the state laboratories.
3. Soil erosion is a constant feature of much U.S. crop production and is particularly severe in the Corn Belt. Soil erosion removes the fertile topsoil and farmers have compensated for this soil loss by using increased levels of fertilizer.
4. Fertilizer recommendations for nitrogen are complicated as these should take into account not only available nitrogen in the topsoil, but also, in some areas, subsoil nitrate levels and rainfall and also nitrogen returned to the field as crop residues, plowed down leguminous crops, manure used, and nitrate added in irrigation water. As nitrogen is the big booster of maize yields and particularly as nitrogenous fertilizers were cheap, high levels of fertilizer nitrogen use were always considered desirably by maize growers. As a consequence, maize growers have tended to ignore on-farm sources of nitrogen, such as leguminous crops and manures.

Under commercial conditions improving the agronomic efficiency of fertilizer use has been a farm-level objective only insofar as farmers were aware that good agronomic practices plus ample fertilizer use ensured maximum profit per unit area.

Fertilizer nitrogen applied at levels above those required for maximum yield accumulates temporarily in the soil (Figure 2, Broadbent and Carlton, 1979). This situation has led to fears of uncontrollable ground water pollution by percolating fertilizer nitrate-nitrogen and of surface waters by fertilizer nutrients carried off in the runoff. Even with judicious N fertilizer management, however, N losses due to denitrification and leaching probably cannot be avoided completely although physically attainable minimum levels of these losses are consistent with relatively high return from N in most cropping systems (Bock, 1984).

The objective of this paper is to draw attention to the level of use of fertilizers, achievements in improving agronomic efficiency of fertilizers, reasons for shortcomings, and possible impact from environment protection agencies and from new technology. Finally, the need to ensure that fertilizer recommendations are based increasingly on scientific fact, taking into account farmer management skills, soil, environment, and weather factors is stressed.

THE GOLDEN YEARS OF FERTILIZER USE

The Plant Breeder Steps In

Crop varieties available to farmers historically were not high yielding; and the bane of farmers around the world trying to grow higher yields of cereals was crop lodging, an affliction particularly associated with high fertility soils.

As the key crops (wheat and rice) were self-pollinating, a wide range of distinct varieties existed. The challenge, therefore, was to use the various characteristics of the different varieties to produce crops which did not lodge and which therefore could respond in terms of higher yields to higher levels of soil fertility. Breakthroughs occurred over a very short period and rice yields in Japan and wheat yields in the UK soared.

In the United States, the major crop with the potential for rapid intensification was maize, an open pollinated crop; it was not until the introduction of hybrid maize that yields and consequently the demand for fertilizer exploded.

The plant breeder in the developing world also radically changed the agronomic efficiency of fertilizers by doubling and tripling the grain production per unit of nitrogen applied to dwarf wheats and semi-dwarf rice.

Norman Borlaug has called this nitrogen x variety yield interaction the "nitrogen-variety revolution." However, when research results show the effects of increasing levels of fertilizer nitrogen only, it must be assumed that adequate levels of phosphate, potash, and other needed plant nutrients were applied to the experimental site. Therefore, "fertilizer responsive" is the more generally applicable term as this implies that balanced application of the needed nutrients is needed to maximize the nitrogen x variety interaction.

Industry Follows

Given the breakthroughs made by the plant breeders and particularly by the maize breeders, intensified crop production became the objective of U.S. farmers as by exploiting to the full the fertilizer x variety interaction effect crop production and therefore farm profitability could be improved.

Fertilizers increase yields while all other agronomic practices maximize the yield-increasing effects of fertilizers. Therefore soil conditions, time of planting, and plant populations become paramount.

Particularly because of the narrow range of suitable planting dates, heavy investment in high-speed cultivation, seeding, and fertilizing equipment became essential. Agricultural engineering companies responded to market demands by developing a sophisticated range of high-powered machinery.

The fertilizer industry was equally innovative, increasing both the supply and range of products available. Notable among the new products were anhydrous ammonia, diammonium phosphate, bulk-blend solids, and liquids and suspensions. The handling and distribution systems were also innovative in reducing costs through the development of bulk handling systems.

These latter advances were aimed not only at reducing costs, but also at ensuring that the correct amounts of needed fertilizer nutrients were applied in a cost-effective manner—in other words, to increase crop output per unit of fertilizer used by maximizing the effects of plant nutrient interactions.

With this massive investment in increased crop yields, the need to protect these yields became paramount. The control of pests, diseases, and weeds does not increase yields but prevents a loss in yields, and with intensive crop production adequate plant protection becomes an essential insurance program.

The major chemical industries of the world produced a stream of sophisticated organic chemicals to kill weeds and insects, which were so in demand that the agrochemicals bill paid by U.S. farmers soon equaled that of their fertilizer bill. Fortunately, maize is a robust plant; and the agrochemical bill for maize protection has remained considerably lower than the fertilizer bill for that crop (Table 1).

In this period of boom growth from 1950, from very humble beginnings, the U.S. fertilizer industry became a world leader in many of the technology aspects of fertilizer sector development and became at the same time a major producer of all three major plant nutrients, N, P, and K.

Fertilizers were correctly applied to healthy high-yielding crops, and therefore fertilizer use efficiency, in theory at least, was maximized.

Eliminating Legumes from the Rotation

The availability of high-yielding hybrids highly responsive to nitrogen fertilizer combined with the availability of cheap anhydrous ammonia led to widespread abandonment of established crop rotations, which included a leguminous crop, for continuous corn. Not only did corn yields increase but the corn acreage of individual farms also increased dramatically was well, leading in turn to heavily increased demand for fertilizers.

The impact of this change from legumes as an integral part of a rotation to continuous corn is well illustrated in Figure 3, which shows clearly how synthetic nitrogen replaced the symbiotically fixed nitrogen of the legumes. Figure 4 shows how nitrogen fertilizer used on pastures in the U.K. increased as the legumes gave way to grasses in the pastures.

No one was sorry to see the role of legumes decline as they were replaced by a simpler and more effective production technology.

Creating New Problems

With the breakthrough in maize production techniques and the burgeoning economy of the United States right through the 1970s, maximization of production was the objective—surpluses would be absorbed by Russia or China or the rest of the world which was food deficit.

In such a boom situation, the strong marketing infrastructure of the United States blossomed to meet all the farmers' needs and more.

Fertilizer recommendations were based on soil analyses carried out by both the private sector and the universities and in an atmosphere which implied, even if it did not prove, that the best farmers always used more fertilizer than the recommended doses. It would take a very brave or foolish salesman in this atmosphere to recommend less fertilizer than his mentors. The predilection of farmers for using more fertilizer than the county extension agent would normally recommend is not restricted to the United States. Table 2 shows, from the results of an actual survey, that U.K. farmers consistently use more fertilizer on many crops than is recommended by the extension service. Even in developing countries there are many examples of excessive fertilizer use.

Fertilizer has been used as a cure-all for crop production problems caused by disease, moisture deficiency, and particularly to correct the continual reduction in soil fertility due to topsoil erosion and to expand production into marginal areas.

Blame always spreads faster than praise, and fertilizer is now suffering from a negative period in public esteem due to the increasing awareness of the danger of nitrate pollution of ground water and the eutrophication of surface waters due to the runoff from fertilized fields.

THE FATE OF FERTILIZER NUTRIENTS APPLIED TO THE SOIL

Recovery of Fertilizer Nutrients by Crops

Nitrogen—The range of crops and the amounts and types of nitrogenous fertilizers used to grow them is so wide that reports on fertilizer nitrogen recovery by the crop vary greatly. A general figure of around 50% recovery seems to be an average. Dependent on the level of recycling of crop residues, up to one-half of the nitrogen applied to the crop can end up in the soil organic matter; however, as Gilliam et al. (1985) point out, most cultivated soils contain relatively low but stable levels of organic matter and therefore fertilizer N carryover in organic matter is of little importance in long-term N balances.

The basic principles of nitrogen recovery by crops are that:

1. For a given weight of applied fertilizer, N recovery increases as the aboveground weight of the crop increases. Therefore, plants with a long growing season recover fertilizer N more effectively than do plants with a short growing season. Figure 5 (Greenwood et al., 1980) shows this for a wide range of plant species. A practical implication of this is that a well-managed crop will recover nitrogen more efficiently than a poorly managed crop.
2. Recoveries of fertilizer N decline as the level of fertilizer used passes beyond the optimum application rate. General figures from the United States for fertilizer N uptake of some of the more important crops are given in Table 3 (Gilliam et al., 1985). These are fairly depressing figures if it is considered that the unused nitrogen could eventually end up in the ground water.

Phosphorus—The uptake of fertilizer phosphorus is generally below 10% in the first crop and even less in the following crops (Barber, 1978), although Cooke (1985) showed some quite high apparent phosphate recoveries (49% for the kale crop) during a 5-year arable rotation.

Most phosphate research efforts have been aimed at maximizing the phosphate response of the crops being grown. Much emphasis has been given to promoting strong early growth of young plants. This work has tended to emphasize the value of water-soluble phosphate in farm fertilizer programs. The buildup of high levels of phosphate in the soil profile, which should be a farmer objective, has occurred as a residual benefit from the use of this soluble phosphate.

Potassium—Unlike nitrogen and phosphorus, which exist in diverse forms in soils, plant potassium remains as the cation K^-. The degree of movement of potash in the soil profile depends on soil properties, but as its mobility is generally greater than phosphate and much less than that of nitrate, efficiency of uptake is usually intermediate between N and P.

Potassium fertilization presents no problems to most farmers and even where there is significant soil erosion or ground water pollution, potassium is not of immediate environmental concern.

The Effects of Erosion

President Reagan, in 1982, warned that soil erosion in the United States appears to be increasing again with "about one-third of America's cropland experiencing soil erosion—at rates which threaten the long-term productivity of the land." He has also pointed out that about 90% of the excessive erosion occurs on about 10% of U.S. cropland and that agricultural water is being used and wasted in greater amounts than ever.

In order to encourage farmers voluntarily to improve the situation, cost-effective conservation and farming systems are needed and reliable data on costs and benefits must be available to the farmer.

Even where farmers do follow recommended conservation practices, often the only satisfactory solution to erosion control is to take land out of cultivation. The Conservation Reserve Program provided many farmers with a chance to take marginal lands out of production and put them into a soil conserving use.

Figure 6 gives a perspective on erosion from agricultural land by crop production region; Figure 7 shows the quantitative erosion map of the lower 48 states. The volume of erosion in the Corn Belt (probably the largest area of intensive modern agricultural production in the world) is twice that of any other crop production region of the mainland United States, except Appalachia.

The very high erosion levels possible under tropical conditions are reflected in the data for Puerto Rico and Hawaii.

The assessment of the impact of erosion on crop yields is complex as the shifting of land out of cropping and the impact of improved yield-increasing techniques on that land remaining under cultivation confounds the situation. Older data for the United States indicated that for maize on deep, medium-textured soils, loss of total topsoil can reduce yields by 8%–30% (Langdale and Shrader, 1982); however, in most cases, crop yields have not fallen as soil fertility has been built up by the use of fertilizers and better management of crop residues has reduced erosion. Present erosion-induced productivity losses have been estimated to range from 15% to less than 5% when projected into the future (Larson, Pierce, and Dowdy, 1983).

With tropical soils the loss of moisture-holding capacity "pseudo-drought" associated with soil erosion indicates an irreversibility of the damage as the technical and financial resources available to the small farmer of the tropics are often not sufficient to stop the erosion, to improve water infiltration, and to rebuild soil fertility.

Topsoil erosion removes the most fertile layers of the soil which are rich in organic matter and plant nutrients. The effect of erosion, where the soil remains intensively cropped, is to increase the demand for fertilizers. Good soil management is therefore a key factor in maximizing the efficiency of fertilizer use.

Major efforts have been made to develop technologies which would permit intensive crop production while reducing or eliminating soil erosion. Minimum or zero-till, leaving crop residues on the soil surface, contour planting, etc., have all helped; but the fact remains that the major corn-producing area of the United States is also an area where in localized areas soil erosion is serious. Even in England where soil erosion was not considered a problem, intensive wheat production is now being criticized for causing severe wind and sheet erosion. Suppression of the legume component of the cropping system carried with it a future major cost in terms of soil erosion control.

Pollution of Surface Waters

Agriculture is the target for environmentalists worried about pollution from nonpoint sources (NPS). The Association of State and Interstate Water Pollution Control Administrators (ASIWPCA) compared 1972 water quality assessment with 1982 assessments (ASIWPCA, 1985). Agricultural activities were found to be the main contributors of NPS pollution in both lakes and rivers. The predominant river NPS pollution is sediment and the predominant lake and estuary NPS pollutants are plant nutrients.

The Rural Clean Water Program (RCWP) has been active since 1980 in improving water quality using systems of best management practices not necessarily oriented to soil conservation and which includes water, animal waste, and fertilizer and pesticide management.

The Cooperative Extension Service has participated in projects by providing services such as pest-scouting to reduce pesticide use, and manure sampling and soil sampling to match nutrient application with crop requirements. Indications are that such services may offer the most effective and economical approach to agricultural NPK control (Humerik, Smolen, and Dressing, 1987).

Pollution of Ground Waters

Nitrogen is the nutrient around which interest in ground water pollution by agriculture revolves. The Royal Society, 1983, showed that despite almost one million tonnes of fertilizer nitrogen being added to U.K. grassland each year, little was leached out of the rooting zone. In contrast, 440,000 tonnes of fertilizer nitrogen were added to arable soils and perhaps as much as 150,000 tonnes of nitrate nitrogen were lost by leaching each year. It is important to note that the quantities of nitrogen leached varied greatly from year to year and from soil to soil.

Attention is drawn in this report to the fact that plowing new land often releases more nitrogen than can be taken up by the crops; and as the store of soil nitrogen in the U.K. is about 150 times greater than that added annually as fertilizer, decomposition of organic matter can lead to major nitrate losses from the soil profile. Indeed, a significant part of the present nitrate burden of certain aquifers in the U.K. is attributed to the plowing up of old grasslands in the period 1939–50.

The general conclusions of this report are that the contributions of soil organic matter, crop residues, animal manures, and fertilizers to increased crop yields must be more fully researched in order to develop nitrogen fertilizer practices which will maximize the efficiency of use of nitrogen by the crop and at the same time reduce the risk of nitrate contamination of ground water.

Since this U.K. paper was written, environmental issues have surfaced in the EEC as major political issues. Denmark is already bringing in legislation on the reconciliation of agricultural policy and environmental interests. The Danish approach seems to be a combination of a direct tax on nitrogenous fertilizers, combined with a rationing system. Emphasis is also laid on the value of reforestation and the use of extensive grazing systems for land marginalized by the new legislation (Dubgaard, 1986).

Soileau and Hauck (1987) have reviewed the results of U.S. research on fertilizer nitrogen movement in percolating waters. This research shows that the amount of fertilizer-derived N that leaches below an active rooting zone can be minimized by prudent fertilizer and/or irrigation practices. Correlation of well-water nitrate-nitrogen (NO_3—N) concentrations with fertilizer consumption data is inconsistent among states and regions; positive correlations are found mostly in the midwestern (Corn Belt) region and in irrigated areas of western states.

The conclusion of these authors is that much more intensive monitoring of nitrogen flux and the movement of nitrate into ground water and the effects of cultivation and fertilizer practices on these fluxes is needed. Hauck (1987) points out that the research sequence

Maximum Yields ⟶ Maximum Profits
⟶ Maximum Economic Yield
⟶ Maximum Acceptable Yield

has developed over the years.

The use of the word "acceptable" implies social awareness and value judgment decisions by people other than the farmer. High profile environmentalists need, as a counterpoint, high profile scientific guidance if agricultural production is not to be unnecessarily trammeled with control orders.

Possible Impact of New Biotechnologies on Fertilizer Needs

The market proof of the anticipated impact of genetic engineering is shown by the fact that chemical companies have spent $10 billion or so in as many years buying up seed companies worldwide, or on research and joint ventures with them (Table 4). Of the big chemical companies, ICI (Imperial Chemical Industries, U.K.) has probably spent the most. In 1985 it bought Garst, a U.S. maize breeder. ICI spends 13% of the R&D budget on pharmaceuticals (the average for successful pharmaceutical companies is about 12%). At the fertilizer side of ICI's activities, very little money is spent on research as such, although a lot is spent on process development. Monsanto also has a heavy research commitment on plant biotechnology.

The Economist (August 15, 1987) gives the reason for this interest of the chemical companies. The companies feel that the $30 billion market for pesticides and fertilizers will be heavily impacted by improved high-yielding crop varieties needing only a minimal of plant protection chemicals.

Genetic Potential for Greater Nutrient Uptake Efficiency

Breeding for greater nutrient efficiency is most simply justified in terms of reduction of the costs of fertilizer needed for crop production. Species and even varieties within a species vary greatly in their ability to take up nutrients from the soil and there is no doubt that sophisticated genetics can improve the yields of crops grown under marginal nutritional conditions (Graham, 1984).

A major interest for the developing world is the production of cereals resistant to aluminum toxicity as there are large areas in the tropical world where this toxicity is a major barrier to the extension of cultivated land.

NITROGEN

Nitrogen is a special case; the rhizobium/legume symbiosis is a major actual and potentially greater source of nitrogen for agricultural crops. Lucerne can fix up to 300 kg/ha of nitrogen, but this can only be used for feeding cattle or plowing down as a green manure for the following crop.

As growing a green manure crop takes land out of cereal production, intensive cereal growers are interested in cereal mono-culture and farmers prefer the land-sparing productivity associated with the use of nitrogen fertilizers.

The challenge of biotechnology is therefore to develop schemes in which BFN could replace nitrogen fertilizers while maintaining the same grain production levels.

There appear to be three possible lines of research (Bremyer and Hill, 1987):

1. Auto-sufficient cereal crops
2. Symbiotic fixing cereal crops
3. Leaky legumes

1. *Auto-Sufficient Cereals*

By using bioengineering techniques, cereal crops capable of fixing atmospheric N without the intermediate role of bacteria could be developed. These cereals would probably be lower yielding than the classical nitrogen fertilized varieties. Seeds of such varieties would initially be very expensive, but prices would fall rapidly as growers multiplied their own stocks. Therefore, if a breakthrough does occur, it will impact on agriculture very rapidly.

2. *Symbiotic Fixing Cereals*

Interest in what Burns & Hardy (1975) described as *associative symbiosis*, the association of heterotrophic N_2-fixing bacteria in the rhizosphere of higher plants, was stimulated in the mid-seventies following the high prices of fertilizer in 1973–74.

Unlike the legume-rhizobium system, this rhizosphere system appears to be a loose association of the plant and its associated N_2-fixing bacteria. Researchers felt, however, that manipulation of the plant and the bacteria could lead to significantly increased N-fixing capacity (Dommerques & Rinaudo, 1979).

Development of a maize rhizosphere N-fixing capacity either loosely associated or actually symbiotic, would be dependent on the use of special inoculants posing all the management problems associated with high performance strains of rhizobium.

3. *Leaky Legumes*

An ideal situation would be where a high N-fixing legume such as soybean leaked nitrate from its roots and this nitrate was used by an associated cereal crop. Such a system would certainly reduce the soil erosion associated with maize mono-culture and would need little nitrogen fertilizer; however, maize production would fall in comparison with the maize mono-culture system.

Such a technology, if it became available, would be a boon to the low production systems often used in developing countries as the major constraint to the use of legumes there as a source of nitrogen is the natural reluctance of the farmer to lose a year through growing a green manure.

Legumes are not altruistic, perhaps the scientist can make them so.

POSSIBLE IMPACT OF NEW TECHNOLOGIES ON FERTILIZER USE EFFICIENCY

Fertilizer Products

The historical evolution of fertilizer products was first a move towards water soluble nutrients, e.g., single superphosphate replaced ground phosphate rock and Chilean nitrate and later ammonium sulfate replaced organic nitrogen sources. The second stage was the move to higher analysis materials, e.g., triple superphosphate replaced single superphosphate and ammonium nitrate replaced ammonium sulfate, and urea then replaced ammonium nitrate.

The production of multinutrient granular fertilizers, which began in the 1920s, has ceded pride of place to bulk blends of high-analysis products. The use of high P and K bulk blends complemented by anhydrous ammonia became the backbone of Corn Belt fertilization. Finally, solutions and suspensions competed with bulk blends. All of the latter changes were essentially cost reduction driven and were unrelated to nutrient use efficiency except insofar as improved handling properties led to improved application practices. However, even in terms of application methodologies the impact on efficiency was minimal as most U.S. fertilizer, other than anhydrous ammonia, is applied to the soil surface. Subsoil placement must surely become increasingly important in the future.

New fertilizer products are unlikely to have any impact in the foreseeable future, but modifications of existing products may.

This latter aspect of product development is particularly linked with the low efficiency of fertilizer nitrogen use by crops.

A technology with promise for use on upland crops is the control of nitrification; this has the potential for reducing the levels of soil nitrate developed from fertilizer ammonium and also perhaps of eventually permitting control of the ammonium to nitrate ratios in the soil. Such an achievement would not only reduce the risk of pollution from nitrate leaching but would also enhance cereal yields by maintaining higher than typical ammonium/nitrate ratios in the soil, particularly during the reproductive growth stages (Bock, 1986).

The fertilization of flooded rice is a special case. Urea is the major form of nitrogen fertilizer used for rice production, and figures ranging from 11% to 61% for the loss of urea-N from the system have been found. An important cause of this loss is ammonia volatilization following the hydrolysis of the urea in the floodwater of the rice paddy; this pathway of loss can be avoided by ensuring that the urea is placed or moved below the oxidative layer of the soil-water interface before it is hydrolyzed. Split applications of urea have been the standard practice for improving the efficiency of urea but improvement is still needed.

Four alternative techniques have been studied; they are:

1. Incorporation of urea in the soil of the drained paddies followed by reflooding of the paddy.
2. Coating of urea as typified by sulfur-coated urea (SCU).
3. Deep-point placement of solid urea.
4. The use of urease inhibitors.

With good water control techniques (1) is possible and the improvement of urea performance becomes a question of field management. Unfortunately, much rice is grown without adequate water control and therefore 2, 3, and 4 remain the major routes for the improvement of urea efficiency.

IFDC has carried out a major field study in India of the performance of SCU (TVA 20% release rate in 7 days) compared with the deep-point placement (by hand) of large urea particles (1–2 gm) [Martinez, Diamond, and Dhua, 1983]. Although there were large variations in yield effect between sites, the potential of both deep-point placement of urea and sulfur-coated urea to improve the agronomic efficiency of the applied urea is clearly demonstrated. The average agronomic efficiencies from 162 experiments were equal to 16, 21, and 22 kg of paddy/kg of N applied in the form of prilled urea (split applications), hand-placed urea particles, and SCU, respectively.

If it is recognized that 20% of the urea in the SCU is not released, then the efficiency of the SCU nitrogen which was released to flooded rice was very high. Deep-point placement was also very effective. Both of these technologies could be improved in the case of coated ureas by decreasing costs and in the case of deep placement by developing a methodology acceptable by the millions of small rice farmers.

Technology (4), the use of urease inhibitors, is of universal agricultural interest as surface applied urea can lose considerable amounts of ammonia by volatilization following hydrolysis by the universally present enzyme urease; advances have been made, but the cost of the urease inhibitors is currently a major problem.

While urea remains as cheap as it is, there is little hope of widescale pressure to improve its performance.

For phosphatic fertilizers a move to the use of less soluble products (ground phosphate rock or partially acidulated rock) seems possible, although wherever transport costs are high ammonium phosphates will remain the product of choice.

For potash, muriate will remain the standard product.

CONCLUSIONS

A combination of breakthroughs in plant breeding, the application of sound agronomic research results, sophisticated organic chemicals, and the availability of cheap and effective fertilizer revolutionized agriculture from 1950 onwards.

Most of those parts of the world where a marketable surplus of farm produce was considered desirable now have saturated markets. For the developed countries, the only sure change therefore appears to be an increasing downward pressure on farm income as both subsidized agriculture and environmental issues become increasingly politicized.

The relentless growth of the population in Africa, Asia, and Latin America, and the increasing demands for food that this population growth generates, however, points towards an increasing interest in fertilizer use for those regions.

It would seem that North America, Europe, and Japan are mature and even regressing fertilizer markets whose yield increases will come from improvements in plant breeding and improved management practices, the level of fertilizer use being more precisely defined than in the past. The cropped area will decline leading to a lower general demand for fertilizers.

For Asia, Africa, and Latin America the dramatic growth in fertilizer consumption over the past decade cannot be maintained as most areas where fertilizer use is profitable, namely the irrigated rice and wheat areas, are already well supplied with fertilizer. Additionally governments are finding the fertilizer subsidy burden increasingly unbearable. As their populations grow food demand will increase, but because of the poverty of many of these countries food imports will be restricted. Only a general increase in agricultural production in these countries will generate the momentum for development in general and from this momentum the ability to improve people's diet using imported food where necessary. It will take time for this momentum to develop.

Improved agronomic efficiency of fertilizer is needed to improve farm incomes and to reduce whatever pollution hazards exist. This will probably be achieved by a reduction of arable areas, and particularly of marginal land and by improved research. A new effort to eliminate problems associated with the nitrogen nutrition of crops is needed. Attention must be given to the integration at the farm level of the use of manures, crop residues, legumes, and fertilizer with soil, climate, and crop with the objective of maximizing crop performance and avoiding nitrate leakage into the ground or surface waters.

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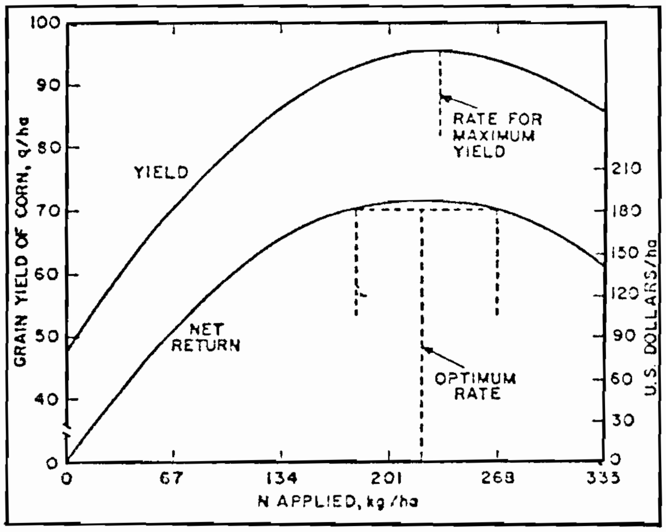


Fig. 1. Average yield response at Knoxville in 1963, as predicted by the quadratic model, its associated net return, and the range in N rate resulting in at least 95% of the highest net return.

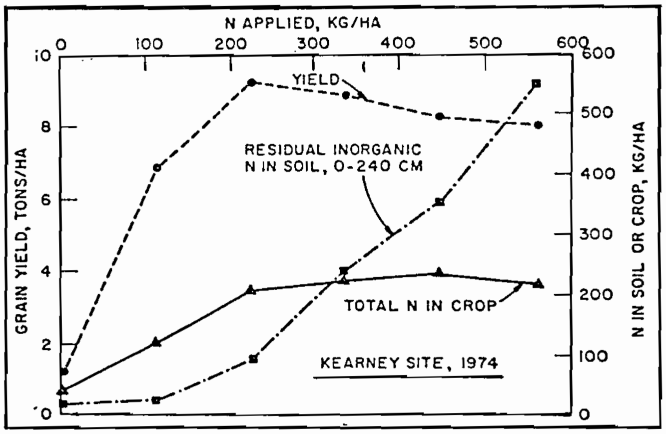


Fig. 2. Yield, crop uptake N, and residual soil N after 1974 crop harvest at the Kearney site.

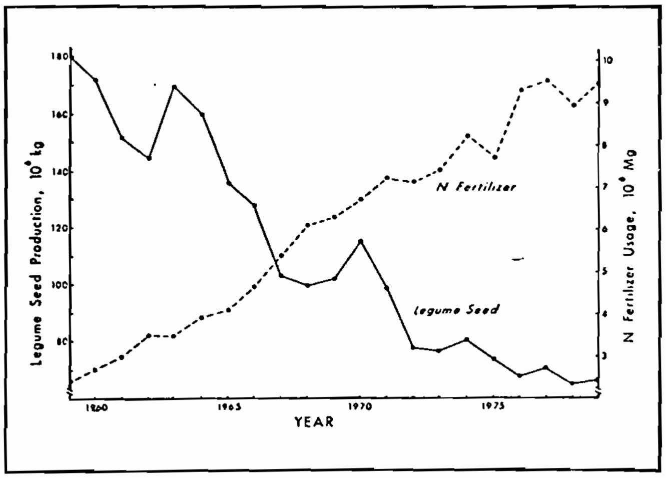
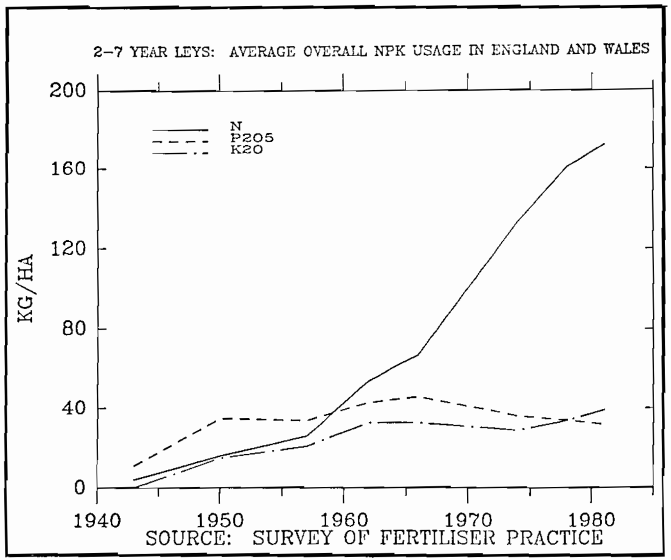


Fig. 3. Legume seed production and fertilizer N use in the USA. 1959-1979.



2-7 YEAR LEYS: AVERAGE OVERALL NPK USAGE IN ENGLAND AND WALES

SOURCE: SURVEY OF FERTILISER PRACTICE

Figure 4

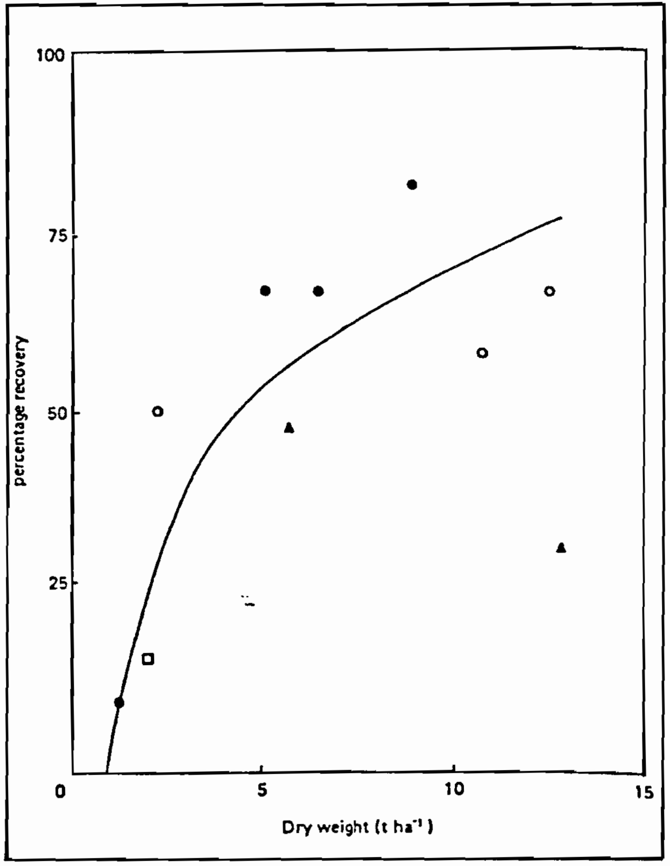


Figure 5. The relationship between percentage recovery of 100 kg ha^{1} of N added as ammonium nitrate fertilizer and the total dry weight of plant material.

▲,Ammarylidaceae; □,Chenopodiaoeae; □,Compositae; ●,Cruciferse. The aberrant point is for leeks (after [97]).

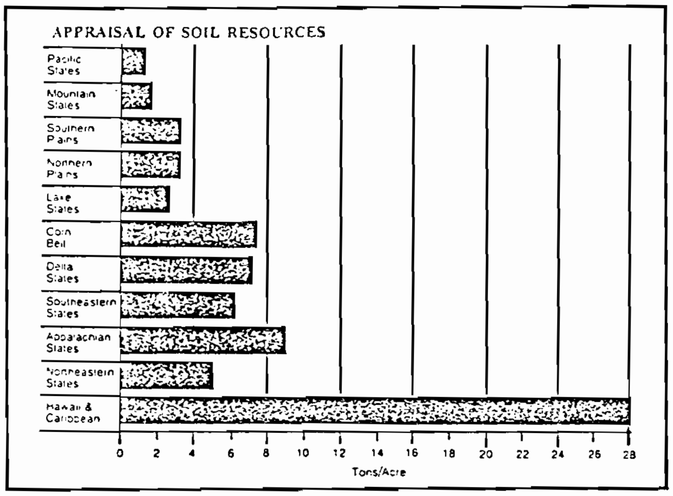


Fig. 6. Estimated average annual sheet and rill erosion on cropland, by crop production region (USDA, 1981b). To convert tons per acre to tons per hectare, multiply by 2.24.

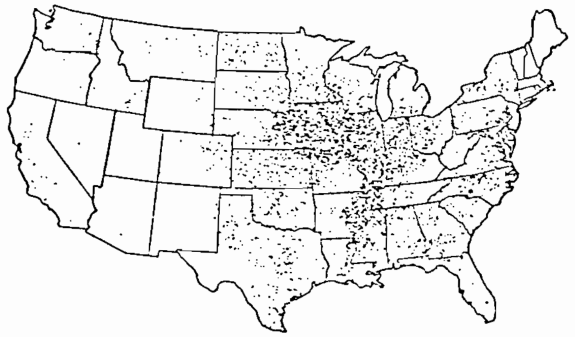


Fig. 7. Total tons of cropland sheet and rill erosion: 1977. One dot equals 250 000 t of soil eroded annually (USDA, 1981).

Table 1. Cash Expenses for Inputs and Crop Production

Cash Expenses	Crop	1983	1984	1985
		- - - - ($/planted acre) - - - -		
Seed	CORN	16.65	18.03	18.47
Fertilizer		48.03	50.93	50.03
Lime and gypsum		1.59	1.58	1.53
Chemicals		19.12	18.52	17.58
Total, cash expenses		200.04	207.64	205.11
Fertilizers, % total cash expense		24.0%	24.5%	24.4%
Seed	COTTON	8.35	8.96	8.79
Fertilizer		21.25	24.28	23.31
Lime and gypsum		1.11	1.17	1.20
Chemicals		48.88	46.73	45.18
Total, cash expenses		300.08	310.72	306.12
Fertilizers, % total cash expense		7.1%	7.8%	7.6%
Seed	SOYBEAN	7.98	10.08	8.74
Fertilizer		7.58	7.70	6.84
Lime and gypsum		1.16	1.15	1.12
Chemicals		19.18	18.35	17.47
Total, cash expenses		112.89	114.58	110.40
Fertilizers, % total cash expense		6.7%	6.7%	6.2%
Seed	WHEAT	6.37	6.49	6.02
Fertilizer		17.69	17.84	15.94
Lime and gypsum		.67	.60	.54
Chemicals		3.27	3.01	2.93
Total, cash expenses		91.99	92.38	89.52
Fertilizers, % total cash expense		19.2%	19.3%	17.8%

Source: USDA.

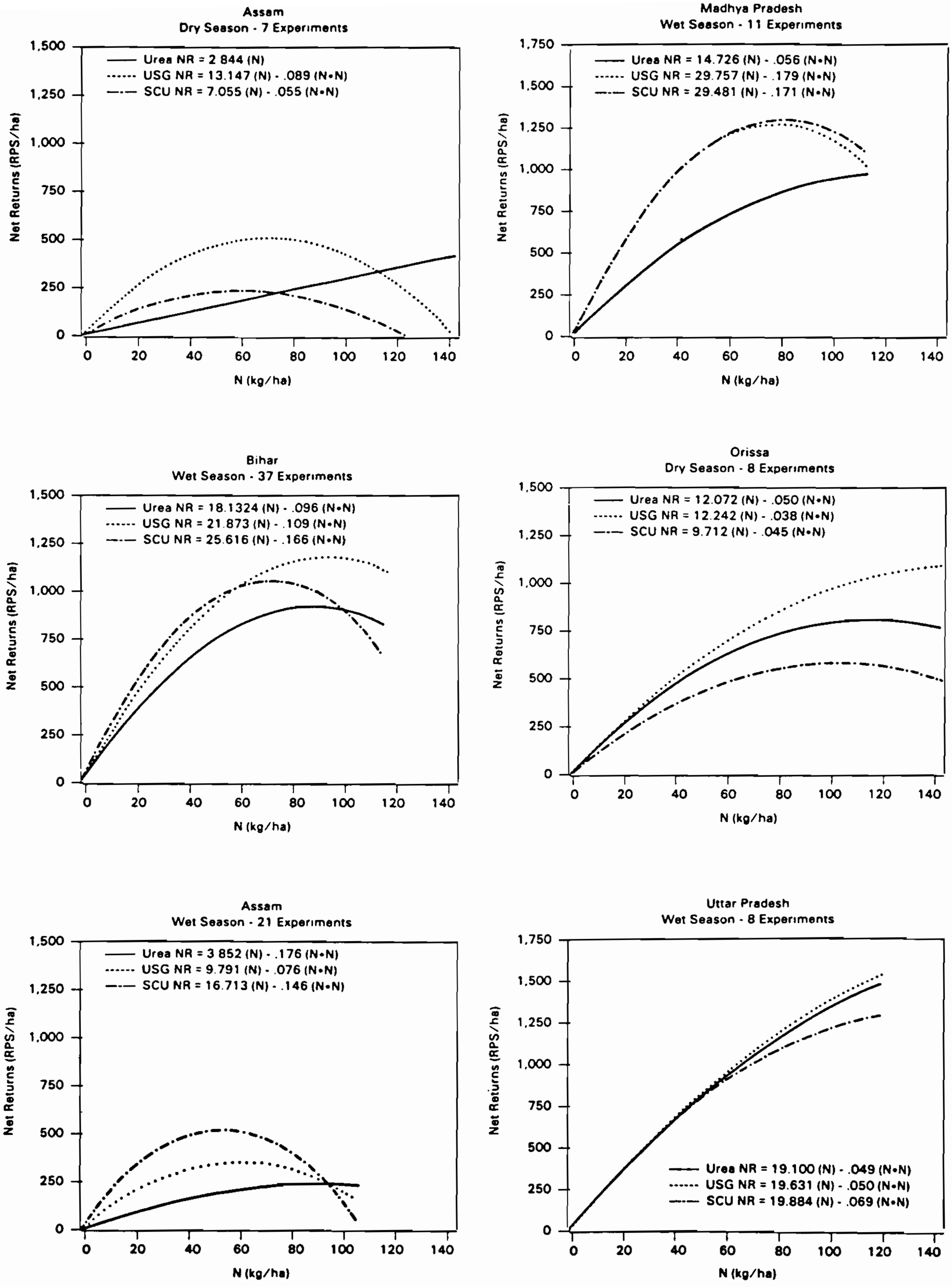


Figure 8 **Graphic Representation of Net Return Curves for Urea, USG, and SCU for Each State and Season.**

Table 2. Recommended and Actual Nitrogen Fertilizer Application Rates in the United Kingdom

	Actual (1984)	Recommended (1985/86)[a]
	(kg N/ha)	
Winter wheat	187	200
Spring barley	98	100
Winter barley	150	100
Potatoes	214	160
Sugar beet	148	100
Oil seed rape	279	175

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a. Given as examples only for crops growing under average conditions.

Source: Agricultural Development and Advisory Service (ADAS).

Table 3. Percent Uptake of Fertilizer N by Some Important Crops

Crop	N Rate (kg/ha/year)	Uptake (%)
Corn	50-168	23-32
Corn	90-360	24-60
Wheat	50-100	21-44
Rice	100	38-44
Barley	60	14-25
Sugarbeet[a]	56-280	12-40

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a. Sugarbeet, *Beta vulgaris* L.

Table 4. The World's Largest Seed Companies

Company	Country of Ultimate Parent	Annual Sales ($m)	Percent of Group Sales	Percent of World Market
Pioneer Hi-Bred	United States	734.5	89.4	4.1
Sandoz†	Switzerland	289.8	8.0	3.2
DEKALB/Pfizert†	United States	201.4	40.0	2.2
Upjohn†	United States	200.0	10.1	2.2
Limagrain	France	171.6	85.0	1.9
Shell-Nickerson†	Britain/Holland	350.0	0.2	1.9
ICI[a]†	Britain	160.0	1.1	1.8
Ciba-Geigy†	Switzerland	152.0	2.0	1.7
Orsan[b]	France	119.0	53.0	1.3
Cargill	United States	115.0	0.5	1.3

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† Parent is in chemicals.

a. Includes all acquisitions.
b. Includes 1986 acquisitions.

Source: Robert Fleming Securities.

Trends in Lawn and Garden Fertilizer Marketing

Al Keller
Agway, Inc.

What are the trends in lawn and garden fertilizer? The basic trend could be called "The Continued Greening of America." Americans have taken their love of growing things and taken it outdoors. Gardening, and lawn care, too, are the new national sports. They provide good exercise out in the fresh air, and produce benefits that jogging can't—aesthetic beauty and food.

Gardening is on everybody's mind. Gardening columns, books and magazines are everywhere. Even the Wall Street Journal has a regular gardening feature. This past summer, The New York Times had this headline splashed across the front page of the Home Section:

"AROUND AMERICA, GARDEN FEVER TAKES HOLD!"

Here are a few facts from this upbeat article:

- More Americans than ever are getting into gardening. According to a Gallup Poll, gardening has been the Number One leisure activity for over three years running.
- Americans are spending more than ever on their gardens and home landscaping.
- Americans are more knowledgeable than ever about gardening and landscaping.
- The mail order seed companies are experiencing unprecendented growth.
- The Garden Book Club sold out its entire stock of a classic gardening book—which sells for $125—and had to reorder 5,000 more copies right away.
- Smith and Hawken, the mail order catalog of very expensive gardening supplies, had 489 customers in 1979. Today, they have over 350,000.

Lawn care is big news, too. According to the National Gardening Survey, 51 million households participated in do-it-yourself lawn care in 1986. That's over 60% of American households taking care of their lawns. While that's down a little bit from previous years, it's still a big number. The good news is that 53% of these households bought fertilizer.

Ladies and gentlemen, there is a lawn and garden boom out there in the suburbs of America, and that boom means tremendous growth potential for the fertilizer industry!

It's all because of the baby boomers. That big bulge of Fifties kids are now 30 to 49 years old. My wife says one of her women's magazines had an article where the sociologists have identified a major new trend. They call it "cocooning."

What they say is that as we get older, we get more settled. We look inward, to home and family, for our self-satisfaction and leisure-time activities.

So the Fifties kids are now 30 to 49. They're settling down. They've got jobs, families and a house. And, if they own a house, they're sure to have a lawn, and probably a garden, too. That's why over half of the $14 billion spent in 1986 on lawns and gardens was spent by the 30 to 49 age group.

And the growth is likely to continue. There are plenty more baby boomers reaching that age when, as the economists say, they form a household. That's why housing starts have been continuing at a strong pace, despite higher interest rates.

September's figures from the Department of Commerce (New York Times 10/25/87) show an annual rate of (1,669,000) one million, six hundred and sixty nine thousand housing starts. It's a little slower than this time last year when the rate was 1,680 million housing starts, but not bad considering the trend toward increasing interest rates throughout 1987.

It remains to be seen what impact the stock market crash will have on interest rates, but don't be surprised if they drop back a bit. Some of the big banks rescinded their interest rate increases right after the first big market drop.

So the simple idea is: more houses, more gardens and lawns, more fertilizer. And that's likely to be good news for the fertilizer industry as a whole.

But looking at the industry as a whole doesn't necessarily reflect what's going on within the industry. Take bag fertilizers, for example. Sales growth isn't very exciting there—it's gradually increasing at best.

Compare that to small package liquid fertilizer—the liquid ready-to-use products. These products are growing so rapidly that they're now considered a separate category. The number of manufacturers was up to nine as of last March, and I'm sure if we took a head count here today, we'd find the number to be quite higher.

Dan Gavin of Dynasty Marketing was quoted in *Lawn & Garden Marketing* as saying: "The wholesale market for the category will reach $50 million in 1987, and $100 million in 1988."

But he also feels that growth of the liquids isn't going to kill sales of granulars. He claims that the granular fertilizer market will suffer no more than 10 to 20 per cent, as liquid buyers will be former lawn service customers—those people unhappy with paying high prices for a few minutes of spraying when they can do it themselves for less.

Dan Gavin also sees the liquid fertilizers reaching a large part of the population which presently doesn't fertilize. This is borne out by surveys for the Andersons, which show that one-third of their Greensweep buyers were not fertilizing at all before.

But with any product growing this explosively, I would admonish anyone who assumes the old standby won't get hurt, to go back and look at what happens when a new innovation becomes accepted as the standard. Kerosene lamps and candles gave way to electric lights, adding machines gave way to sophisticated pocket calculators, computers and word processors have eliminated typewriters and pencilled in spreadsheets.

Don't be like the automakers in Detroit when faced with the Japanese. You bagged fertilizer people need to stay on top of this one. Don't assume that you won't get hurt. Change is happening in this industry, and you can't stop change. But you *can* encourage it, work with it, and profit from it.

The convenience of liquids is opening up new marketing possibilities, and new users. But bagged fertilizer makers can get creative in marketing, too. Some have said that new users of liquids might include the homeowner with a small lawn who doesn't want to store a bag of fertilizer. Why not offer a smaller portion of granular fertilizer for these customers? For the liquid buyer wanting to give his lawn a "pep pill" so it will look its best for a party, how about marketing a small package of granular as a "Quick pick me up treatment".

You see, the trend here isn't necessarily toward liquids over bags. The growth is really in *convenient applications*. Where granular can be considered messy and awkward—those bags are hard for the ladies to lift!—liquids are seen as simple and convenient.

Also propelling liquids forward is good marketing. Liquids are taking a free ride on the coattails of that other successful and convenient packaging innovation, the lawn care man in the spray truck. They're also using strong advertising, with campaigns such as "Goof Proof" and the "Official Fertilizer of Disneyland". And with ad budgets like the $10 million Greensweep is spending this year, it's no wonder you might say that the future is blowing in the wind:

But that wind is also carrying a disadvantage for the liquids. Because they are easily carried by the wind, some customers may be concerned about the liquid fertilizer mixtures getting where they don't belong.

The fact is, consumers today are very concerned about pollution, toxic waste and ground water pollution. Toxic wastes and water pollution are affecting more and more people in the country, and those people are concerned about the pesticides in their lives.

A two-part article in my local Syracuse newspaper this summer talked about chemicals and lawns, and the safety of lawn pesticides. According to the Environmental Protection Agency, 75 million pounds of pesticides were used around homes and gardens in 1985—about one-tenth the amount used on croplands.

As toxic chemicals become a more visible problem across the country, more people are going to opt out of the chemicals for the lawn . . . but they still want that healthy lawn for the "social value," the article claimed. So they question the automatic combination of a fertilizer with a pesticide. This can mean an impact on sales of fertilizers containing grub, crabgrass or broadleaf controls, and increasing growth for organic products.

Walk into your local discount store and you'll notice another trend; the growth of blended instead of ammoniated products. This might not seem right to you, as we here know of the better quality of ammoniated products.

But remember that as a market grows, you tend to get more people who know less . . . *and those people buy on price*. When they're looking at numbers like 30-6-12 or 28-5-11, and they're looking at the prices, the blended segment of the market continue with strong growth.

Another trend we're seeing in the Northeast and elsewhere is The Package Approach.

It seems that no matter what the field, there's a package plan; flying, hotels, Book-of-the Month Club. What it boils down to is making it easy for the consumer to buy and to keep buying. People don't like to read instructions, and they don't want to have to think.

So we make it practically foolproof, by formulating a program with simple steps and telling them which months to take those steps. Remember at the beginning of my talk I said that more people want information on lawn care than on any other gardening subject? Well, this ties right in. People out there are confused about their lawns. They don't know what to do, or when to do it. The Package Approach is another way of making fertilizers and lawn care understandable. That's been the key to the growth of the liquids, the lawn care operators, and the package programs, too.

Of course, the package programs also have advantages for us. We're capturing the entire sale up front, at the beginning. We're also selling more than one application—and that increases volume. So where the small package liquids are encouraging sales a little at a time, the package programs are working the other end—selling more fertilizer in each sale.

It's sort of like ice cream. You can buy a cone, a pint, a quart or a half gallon. The consumer pays a premium on the smaller packages, or saves a little on the half gallon in exchange for boosting the manufacturer's volume.

Continuing with the ice cream analogy, higher butterfat content makes for a richer, thicker, tastier product. That's why Haagen-Dazs has been so successful. In fertilizers, much recent research has been devoted to phosphorus and potassium, and the universities tell us that richer P and K build stronger root systems. The industry is picking up on this research, and the analysis on the bag is changing to take advantage of the new knowledge. Instead of 10-6-4, for example, it's not surprising to find 30-6-11. Don't be shocked to find some new flavors in the fertilizer market, too.

In fact, one new flavor is already available, and that's the winter formula for the Northeast. We know that a late fall/early winter fertilizing is one of the best things you can do for a Northern lawn. According to *Lawn Care Industry* magazine (10/85), the added nitrogen, ". . . promotes rooting, improves spring green-up without the flush of growth normally associated with a spring application, and reduced the incidence of leafspot." This has been confirmed in university studies at Ohio State, which also showed better fall and winter color as a result.

Winter fertilizers are products which work well, yet we need to get that message out to the consumers. Consumers tend to be habitual, and reluctant to make changes in their habits. That's where advertising comes in. Advertising is our great educational tool.

In our business, we use advertising to get people into the store, educate them, and convince them to buy one product over another. The trend in advertising is toward more use of TV and radio to get the message out that it's time to take care of your lawn.

I remember when everyone in the business was floored when Scott's came out with a $10 million dollar advertising budget for their whole line. The year was 1981, and the whole industry spent only $18 million that year. Boy, what a whoop and holler everyone gave out.

Today, $10 million dollars is spent in a year on one product alone, such as Greensweep, the small package liquid fertilizer.

Where most advertising money used to go to magazines, newspapers and direct mail, the bulk of the money now goes to TV and radio—a switch from many other businesses who are just discovering direct mail. It's just that our market is becoming more of a mass market, as seen by increasing sales of our products by the big chain stores. So TV becomes a more and more effective tool for our industry.

The other area that's being emphasized is Point of Purchase. Some people think that's just a fancy marketer's term for signs that wave back and forth under the ceiling vent in the hardware store. But Point of Purchase advertising is becoming more and more critical for us for one reason: education.

The best way to convey product information—and general lawncare instructions is with in-store displays, literature, signs and banners. So Point-of-Purchase is a vital tool in every marketer's bag of tricks. It helps educate the consumer, increases customer satisfaction, assists in correct usage of the products, and best of all, it increases sales.

So, to conclude, let's recap what's going on. A growing home-owning population, reaching that age when they start thinking about lawn and garden care. In fact, let's call it *a certified boom.*

New products such as small package liquid fertilizers, organics, and packages. All are working to divvy up a potentially expanding market, and offer extra choices with quality, convenience and profits.

There's the growth of lower-priced blends and the high P and K products as the low and high ends of the market expand.

And there's advertising like crazy to make it all move!

So be thankful you picked a business that's awakened from a long sleep and has the opportunity to grow like green grass on a sunny tropical island. You can be sure that all those people with beautiful lawns, and all of those teen-agers who mow those lawns, thank you, and are looking forward to the next innovations. And I thank you, too, for letting me speak today.

Micronutrient Recommendations and Choices of Materials for Application

John J. Mortvedt
National Fertilizer Development Center
Tennessee Valley Authority

Higher crop yields which increase plant nutrient demands, use of high-analyses NPK fertilizers resulting in lower quantities of micronutrient contaminants added to soil and decreased use of farmyard manures on many agricultural soils are reasons why micronutrient fertilizers are needed. Soil tests and plant analyses for micronutrients are used in most states to diagnose possible micronutrient shortages. Micronutrient deficiencies are not as widespread as in the past because many fertilizer recommendations include micronutrients when needed.

FERTILIZER RECOMMENDATIONS

Micronutrient fertilizer recommendations vary considerably, but generally follow two main philosophies—maintenance or prescription. For the "insurance" or maintenance approach, the manufacturer or dealer may add low amounts of more than one, and sometimes all, micronutrients to a mixed NPK fertilizer. With this philosophy, the fertilizer is formulated to supply all micronutrients removed by a crop. This system may be wasteful because some or all of the applied micronutrients may not be deficient in a given field.

Some manufacturers produce premium fertilizers which are recommended for a specific crop over a wide geographic area. For example, a premium fertilizer for corn may be a 10-10-10 grade with 1% to 2% Zn, 0.5% Mn, and possibly very low amounts of the other micronutrients. Premium fertilizers for soybeans usually contain higher levels of Mn than Zn, while those for cotton contain Mn and B, and each fertilizer also may contain low levels of the other micronutrients. Because large tonnages of a specific grade are needed for profitable production, market demand for such a grade must be estimated in advance.

With development of bulk-blended granular fertilizers and increased use of fluid fertilizers, there has been a trend to formulate grades for specific fields at the fertilizer dealer level. This has allowed increased flexibility to meet actual micronutrient needs for each situation. Most micronutrient fertilizers are sold as single sources by manufacturers to wholesale distributors or directly to fertilizer dealers who prepare the requested formulations or grades for farmers at their local plants.

Many fertilizer dealers take soil and plant tissue samples for their customers and send them to laboratories for analyses. The dealer then discusses the results and fertilizer recommendations with the grower and together they develop a fertilizer program, including micronutrients if needed. Results of several surveys have shown that growers depend heavily on recommendations made by their local fertilizer dealer; so dealers should know the most effective fertilizers for each situation. These sources vary considerably in micronutrients content, compatibility with NPK fertilizers, and agronomic effectiveness.

MICRONUTRIENT SOURCES

Inorganic sources include naturally occurring ores, manufactured oxides, and metallic salts such as sulfate, chlorides, and nitrates. The sulfates are the most common of the metallic salts and are sold in crystalline or granular form. Oxides of Zn and Mn also are commonly used, and are sold as fine powders and in granular form. Oxysulfates are partially acidulated oxides, and generally are sold in granular form. Inorganic sources usually are the least expensive sources per unit of micronutrient, but are not always the most effective for crops.

Synthetic chelates are formed by combining a chelating agent with a metal through coordinate bonding. Stability of the metal-chelate bond affects availability to plants of chelated Cu, Fe, Mn, or Zn. An effective chelate is one in which the rate of substitution of the chelated micronutrient for cations from the soil is quite low. This maintains the applied metal in chelated form. Synthetic chelates generally are the most effective micronutrient sources, but also are the most expensive per unit of micronutrient. For example, agronomic effectiveness (per unit of micronutrient) of ZnEDTA may be 2 to 5 times higher than that of $ZnSO_4$, but relative costs per unit of Zn as ZnEDTA is 10 to 20 times higher. However, other factors such as ease of mixing chelates with fluid fertilizers, should be considered.

Natural organic complexes are made by reacting metallic salts with some organic by-products of the wood pulp industry or related industries. Several classes of these complexes are the lignosulfonates, phenols, and polyflavonoids. The type of chemical bonding of metals to the organic components is not well understood. Some bonds may be coordinate, as in the chelates, but other types of chemical bonds also may occur. While these complexes are less costly per unit of micronutrient, they usually are less effective than synthetic chelates.

Fritted micronutrients are glassy products in which solubility is controlled by particle size and changes in matrix composition. Fritted micronutrients generally are used only on sandy soils in regions of high rainfall where leaching occurs. Frits are more appropriate for maintenance programs than for correcting severe micronutrient deficiencies.

Agronomic effectiveness of a micronutrient source is defined as the relative crop response per unit of applied micronutrient. Lower rates of the more effective sources are needed to give maximum yields. Relative agronomic effectiveness of five Zn sources banded with a 10-34-0 starter fertilizer at rates up to 3 lb/Ac of Zn for corn varied considerably with Zn rate (Table 1). ZnEDTA was much more effective than ZnO at the lowest Zn rate, but all sources were equally effective at the highest Zn rate (3). Cost per unit of micronutrient also should be considered when selecting sources. Despite greater effectiveness of ZnEDTA in the above study, other Zn sources might be more economical to apply even if higher Zn rates were required

Agronomic effectiveness of Zn and Mn sources is partially related to their water solubility. Highly soluble fertilizers, such as the sulfates, will dissolve soon after soil application and move into the surrounding soil. Since plant uptake is related to root interception of fertilizer-affected soil, micronutrient uptake should be greater from the more soluble fertilizers. Particle size also may affect agronomic effectiveness. Decreased particle sizes result in more particles per unit of applied micronutrient, so more soil should be affected if the fertilizer is uniformly applied. Decreased particle size also increases the specific surface of a fertilizer which should increase the dissolution rate of fertilizers with low water solubility, such as MnO and ZnO. Therefore, granular micronutrients for use in bulk-blended fertilizers should contain a significant portion of nutrient in water-soluble form.

TABLE 1
Response of corn to zinc sources banded with 10-34-0 to a Nebraska soil, pH 7.6 (3)

Zinc source	Zn applied, lb/Ac 0	0.1	0.3	1.0	3.0
	Yield, bu/Ac				
—	62				
ZnEDTA		138	139	155	141
$ZnSO_4$		132	141	131	144
ZnO		124	124	134	144
$ZnSO_4$—NH_3 complex		118	138	134	140

INDUSTRIAL BY-PRODUCTS AS MICRONUTRIENT FERTILIZERS

Use of industrial by-products is becoming a significant factor in micronutrient fertilizer production. With increased government regulations concerning emission abatement of industrial operations, greater tonnages of baghouse dusts and sludges will be collected. Also, spent acids and by-product H_2SO_4 are available for acidulation of by-products containing micronutrients. Use of industrial by-products as fertilizers constitutes a resource recovery instead of costly disposal.

Industrial by-products usually are less costly per unit of micronutrient than products manufactured specifically for fertilizers. Because by-product oxides of Mn and Zn are dusty and difficult to handle, they are partially acidulated with H_2SO_4. Acidulation also results in the formation of $MnSO_4$ or $ZnSO_4$, which are water soluble and should be more available to plants than the non-acidulated oxides. Oxysulfates usually contain lower concentrations of micronutrients and may be more easily blended with NPK fertilizers to product grades containing 1 to 2% micronutrients.

Some industrial by-products also contain certain heavy metal contaminants such as cadmium (Cd), lead (Pb), and nickel (Ni). Concentrations generally are low, so their application rate to soil in micronutrient fertilizers also would be low. For example, application at a rate of 5 lb/Ac of Zn of a by-product $ZnSO_4$ (36% Zn) containing 100 ppm of Cd would result in a Cd application of 0.001 lb/Ac. Results of several TVA greenhouse experiments showed that plant uptake of Cd, Ni, and Pb was not affected by application to Zn-deficient soils of Zn fertilizers made from industrial by-products (5).

APPLICATION WITH MIXED FERTILIZERS

The most common micronutrient application method for most crops is soil application. Recommended application rates usually are less than 10 lb/Ac (on an elemental basis), so uniformly applying micronutrient sources separately in the field is difficult. Therefore, both granular and fluid NPK fertilizers are widely used as carriers of micronutrients. Costs also are reduced by eliminating a separate application.

Micronutrients are uniformly distributed throughout NPK fertilizers by incorporation during manufacture. Because the micronutrient source is in contact with the mixed fertilizer components under conditions of high temperature and moisture, the rate of chemical reactions is increased and plant availability of some micronutrients may be affected.

The main advantage of bulk blending is that micronutrients can be blended with mixed fertilizers to produce grades which will provide recommended micronutrient rates for a given field. Popularity of this method of applying micronutrients has increased in recent years. In 1984, there were about 5,000 bulk-blending plants in the United States with a total annual production of about 20 million tons of fertilizer. Micronutrients were being added to bulk blends at 73% of those plants as compared with 45% in 1974 (6). The main disadvantage in applying micronutrients with bulk-blended fertilizers is that segregation of nutrients can occur during the blending operation and with subsequent handling. Segregation results in nonuniform application, which is critical with micronutrients because their application rates are low.

Segregation can be minimized by properly matching particle sizes of micronutrients with those of the NPK components of the blend. Mechanical devices to minimize coning and segregation of the materials during handling and storage are available. Use of granular oxides of micronutrients, such as MnO and ZnO, with bulk blends is not recommended because availability to plants of relatively insoluble oxides is very low in granular form (4).

Coating micronutrients on to granular fertilizers mostly eliminates the possibility of segregation. Fertilizer solutions are preferred as binding agents because the fertilizer grade is not decreased so much as with use of water, oils, and waxes. Some binding materials are unsatisfactory because they do not maintain the micronutrient coatings during bagging, storage, and handling. This results in segregation of finely ground micronutrients from the granular fertilizer. Agronomic effectiveness of micronutrients coated onto soluble granular fertilizers should be similar to that with incorporation during manufacture. Dry bean yields on a Zn-deficient soil were similar with $ZnSO_4$ or ZnO incorporated with or coated onto a granular mixed fertilizer (Table 2), but Zn uptake was higher with $ZnSO_4$ with either method of application.

Mixing micronutrients with fluid fertilizers has become a popular method of application. Clear liquids are widely used as starter fertilizers; some micronutrients, especially Zn sources, are easily applied

TABLE 2
Yield and zinc concentrations in dry beans, as affected by zinc sources and method of inclusion with a granular NPK fertilizer (1)

Zn source	Method of inclusion	Yield, lb/Ac	Zn in plants, ppm
—	—	11,000	20
$ZnSO_4$	blended	14,800	40
$ZnSO_4$	incorporated	14,600	31
$ZnSO_4$	coated	14,900	34
ZnO	incorporated	14,500	23
ZnO	coated	14,900	26
LSD (0.05)		1,500	3

Fertilizers banded at plantig to supply 3 lb/Ac of Zn.

with these products. Suspensions also are used as micronutrient carriers; oxides can be applied since complete solution is not required.

RESIDUAL EFFECTS

Both Cu and Zn, and B to a lesser extent, have significant residual effects, so applying these micronutrients every year may not be necessary. Repeated annual applications of B, Cu, and Zn eventually could result in an accumulation in the surface soil which could become toxic to some plant species; therefore, periodic soil tests are needed to monitor the micronutrient status of soils being fertilized. When the level of available micronutrient in soil increases as a result of fertilization, application rates of that micronutrient should be decreased appropriately or applications eliminated until levels decrease to the response range.

Iron and Mn do not have significant residual effects in neutral or calcareous soils where they usually are applied, because these micronutrients are easily oxidized to unavailable forms; therefore, annual applications of Fe and Mn are required to correct deficiencies. Foliar sprays, particularly of Fe, generally are more effective than soil applications in providing plant available supplies of these micronutrients.

MICRONUTRIENT USE

In 1968 the Crop Reporting Board of the Statistical Reporting Service of the USDA began publishing summaries of micronutrient use. Data in Table 3 were obtained from reports by known producers of Cu, Fe, Mn, Mo, and Zn fertilizers for use in mixed fertilizers and as direct applications. Boron use data were not included because there were only two major producers. Amounts of Zn and Mn are highest because these micronutrients are recommended for large acreage crops—corn, wheat, soybeans, and rice. The rapid increases in use of Zn, and Mn to a much lesser extent, after 1976 are related mainly to a change in the reporting system which included more producers, especially those using industrial by-products (6). Data in Table 4 are given on an elemental basis, so the actual amounts of micronutrient materials are much higher. This method of reporting was used because micronutrient sources vary considerably in nutrient content. The tonnage of micronutrient materials sold in the United States is only about 1% of the tonnage of NPK materials.

TABLE 3
Amounts of micronutrients sold in the United States (7)

Year	Cu	Fe	Mn	Mo	Zn
			1,000 tons		
1967–1968	2.4	3.5	11.6	0.1	14.5
1971–1972	0.6	1.4	12.4	0.1	15.9
1975–1976	0.5	2.5	8.9	0.11	16.2
1979–1980	1.6	7.1	13.9	0.01	43.9
1983–1984	1.2	6.5	16.6	—	41.1

Amounts expressed on elemental basis.

In 1986, TVA assumed responsibility for collecting fertilizer use data in the United States. Fertilizer use data were obtained from the fertilizer control officials in each State (2), and micronutrient use data were obtained in a separate USDA survey. A similar micronutrient survey was conducted by the TFI in 1986, but as very few micronutrient producers returned completed forms, total micronutrient use data could not be obtained. Efforts will be continued to obtain this information because it is valuable to all segments of the micronutrient market.

Micronutrient use on a worldwide basis also is of interest to U.S. producers because of the export market potential. Unfortunately there is little information on micronutrient consumption on an international basis. Besides the lack of government statistics, distinguishing among end uses of micronutrient-containing chemicals for agriculture or for other industrial uses has been difficult. Until the latter problem is resolved, data on international micronutrient consumption becoming available is unlikely. Individual countries may have reasonable estimates of micronutrient use, but no data were found.

SUMMARY

Micronutrient deficiencies are widespread because of increased nutrient demands from more intensive cropping practices and also from farming marginal lands. Sources of micronutrients are classified as inorganic, synthetic chelates, natural organic complexes, and fritted glasses. These sources vary widely in physical state, chemical reactivity, cost, and relative availability to plants. Some industrial by-products are used as micronutrient fertilizers because of lower costs.

Micronutrient recommendations vary considerably, but generally follow a "prescription" philosophy rather than an "insurance" or maintenance approach. This requires knowledge of relative crop needs, available levels in soil, and most effective sources and methods of application. Soil tests and plant analyses are excellent diagnostic tools to monitor the micronutrient status of soils and crops, especially when micronutrient fertilization programs are in place. Continued research is needed to improve micronutrient recommendations so that crop yields are not limited by improper micronutrient fertilization.

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Biotechnology: Possibilities of Biogenetics as it Relates to Fertilizers and to Plant Growth

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Biotechnology is a field of technical and scientific development that has entered the focus of business and popular imagination in the most recent years. It is perceived as offering great opportunities for improving human conditions and possibilities for profitable servicing of needs. It is also being perceived as a potential threat to man and our environment, as something to be feared and resisted. It is appropriate to point to these conflicting basic views, as this conflict will certainly influence the advance and the user acceptance of the new biotechnology and its products.

Biotechnology exemplified by the breeding of plants and animals, and the fermentation technology of beer, is among the oldest of human technologies.

Biotechnology has made great advances in this century, and the green revolution is but one example.

Great new scientific discoveries have been made and put to use. The most basic and important of these have been in genetics, where new tools are now rapidly becoming available. The use of these tools may transform plant and animal breeding practice in the near future. The possible impact of such new techniques on agriculture and the fertilizer markets form the main subject of this paper. However, modern biotechnology also promises other types of technical advances and products for agriculture: Artificial seeds may further mechanize and reduce field work, and new biological techniques may speed up the slow process of moving new varieties from the laboratories and field stations to large scale seed production. Breeding techniques may increase the availability of pedigree animals.

Development of better, more appropriate tools and systems for crop and animal production, such as more precise irrigation techniques, new analytical systems and improvements in fertilizer use are also part of the general technical advances taking place in the oldest and largest biotechnical venture in the world: Agriculture.

GENETICS: A SCIENCE AND ITS APPLICATIONS

Improvements of crops and livestock by cross breeding and selection has always been part of the technical base of agriculture. A good example is the development of corn in pre-columbian times.

However, the accurate genetic observations by the ancients were combined with a near total lack of understanding of what was taking place in the crossing and selection processes. The rediscovery of Mendel's laws (1900) together with other scientific advances such as the discovery of the chromosomes (1902) rapidly established genetics as a useful and mathematically sophisticated biological science, and made possible the great advances in plant breeding that is still one of the mainstays of modern agriculture.

The insights given by genetics and plant physiology made it possible in many instances to make crosses across the boundaries of species that normally prevents such crosses. Such techniques have given improved crop varieties, and have greatly expanded the genetic material potentially available to the breeder.

The developments in genetics have been steady, and have in the last years been very rapid. The new methods of genetic engineering does in principle make available to the plant breeder all the genes present in the world, and he may even modify these genes to suit special needs. In practice, however, many difficulties and barriers are encountered.

The present gene transfer techniques work well only with certain plants. Genes and their products may not work well in a foreign environment; the identification and selection of interesting genes are problematic; and many fundamental practical, legal and moral problems remain to be sorted out.

However, in spite of these barriers, the plant breeders are now getting new and powerful tools.

The many expensive problems that remain to be solved will slow down the process of bringing the results out into the farmers fields on a large scale. But, in due course, varieties and crops with radically new properties may change the market for agricultural chemicals, and may even influence the fertilizer market.

GENETIC ENGINEERING: IMPACT ON AGRICULTURE

Genetic manipulations as a science and technique is most advanced in microbiology. From this we can expect new products for veterinary practice, as well as mass production of bacteria and vira that can attack specific fungi, insects and weeds, and thus provide specific control agents for such pests. The great specificity of such biological agents is in principle desirable, but restricts the individual markets, and resistance problems are to be expected.

There are also possibilities that certain drugs and high priced natural chemicals may be made by fermentation techniques instead of processing plant materials. The resulting reduced demand is likely to affect only a very minor part of current plant crop production.

In order to induce fertilizer market changes new crops or new uses must be introduced on a large scale. An example could be increased feedstock need for the biotechnological industry. Translated into realities: Corn for ethanol production.

The fermentation process may be improved by genetic techniques, but the demand for ethanol will be determined more by political than by genetic developments. It is, alas, not likely that the new bioindustry will develop high volume products in the near future.

The application of genetic engineering and new biological methods to animal breeding opens up exciting possibilities for solving problems with animal health and productivity. Animals may have a potential for becoming more feed efficient by genetic changes. It is in principle not impossible that chickens can be given new genes that make them excrete digestive enzymes that they presently lack, thus improving their digestion. Such developments might reduce the demand for feed. On the other side, making fish thrive on cheap crop protein might open new crop markets. Both these research goals are complex, and the need for solving the problems involved are not pressing. Developments in this direction is therefore likely to be slow.

It is somewhat different in the field of plant crop genetics, where the new principles and techniques may make it easier to realize classical breeding aims, such as:

Crops with new or improved properties (e.g. better protein composition, new types of oils)
Disease and insect resistant plants and crops
Crops that are herbicide resistant, or that themselves eliminate weeds by excreting chemicals
Crops with improved resistance to environmental stresses such as drought, frost and salt.
Crops giving higher yields and improved nutrient usage.

All these breeding goals are classical in the sense that they have been attacked with considerable success by the plant breeding community in the last generations. New genetic insight and methods will probably increase the speed and extent by which such targets can be reached.

In conclusion the impact of genetic engineering on agricultural practice is likely to be considerable.

GENETIC ENGINEERING: POSSIBLE IMPACT ON FERTILIZER USE

The majority of the developments mentioned are not expected to influence the use of fertilizers. The market for herbicides, fungicides and other agricultural chemicals nay be greatly changed by new varieties, but new high yielding, high quality, resistant varieties will also need nutrients, just like the present plants.

In the same way, the demand for animal food will not change much, as the laws of thermodynamics specifies that even genetically modified animals have to feed.

However, new plant varieties may in the future make it possible to use marginal land for agriculture, or grow new crops in areas where they can presently not be grown, e.g. plants producing tea, cocoa and coffee in the US, cotton in northern Europe. Such developments would maintain and increase the cultivated areas in the developed countries, and would also increase the market potential for fertilizer and farm support services. It would also liberate land in developing nations for increased local food production. Many people regard such a change as necessary and beneficial, though it would give international trade problems of its own. However, any such developments will be gradual and allow the industries that support agriculture time for the required adjustments, and provide new possibilities for those that are both alert and realistic.

Most of the development work taking place in genetic engineering applied to agriculture is therefore not likely to change the need for plant nutrients. However, there are current dreams about the possibilities of making new varieties that use less fertilizers. Examples are varieties that have greatly increased efficiency for phosphate utilization, or plants that can fix their own nitrogen. Presumably even genetics can not do much about the plant need for potassium and the other essential elements.

When we analyze these possibilities, we enter the realm of speculation, but even here the well known and tested rules of science put certain limits to what molecular geneticists might successfully achieve.

PHOSPHATE UPTAKE

It is well known that microorganisms like fungi that live in the root sphere of many plants can assist in making phosphate available to those plants.

Much work has been done by academics and plant breeders using classical breeding and microbiological methods to exploit this phenomenon, but the practical difficulties have proven to be great. The most noticeable successes have been in forestry.

It should in principle be possible to make suitable root-associated organisms especially efficient in utilizing soil phosphate reserves, or in using rock phosphates with minimal treatment requirements. It is further possible, in principle, to design such organisms so that they can only thrive in association with specific plant varieties. This can be done by making the microorganism absolutely dependent on special substances excreted by the plant roots. Such traits may be introduced into plants with present genetic techniques.

Should this strategy be attempted many problems must be addressed. One of these is the possibility that such a phosphate mobilizing organism may spread away from the specially designed host. A widening of the host range might result in geological changes.

There are good biological grounds as to why specially designed microbes probably will have low vitality when at large. The special properties that makes them valuable for our purposes usually puts them at a competitive disadvantage when they are on their own.

However, gaining acceptance for field experiments for plant-microbial combinations that can dissolve phosphates will probably be a slow process. There should be ample time to evaluate the potential and special requirements such plants may have, should they materialize.

NITROGEN FIXATION

Less speculative is the improvement and even extension of microbial nitrogen fixation in association with plants.

Many bacteria have the enzyme system that enable them to fix the nitrogen from air, and convert it to ammonia.

The most well-known of such system is probably the Rhizobia that live in root nodules in symbioses with legumes, such as beans and peas. Related nodular systems are formed on the roots of alder species, where the nitrogen fixing organisms are Frankia species. The plants provide their bacteria with food, and the bacteria repay with nitrogen compounds. The study of these nitrogen fixing organisms, how they interact with host plants, how they bind the nitrogen from the air, and how the make-up of their genes enable them to do this is one of the most active fields of present genetic research.

The goal of making a plant that fixes its own nitrogen has been described as "The Holy Grail of Plant Molecular Genetics". It may be of some interest to discuss if and under what circumstances this goal is meaningful and possible.

Improved soybean nodules: The soybean makes very efficient use of the symbiotic system. However, even this efficiency may be somewhat further improved by molecular genetic methods, by making energy efficient bacterial strains that maximize their ammonia production. This may give somewhat increased yields.

Legumes give root residues rich in nitrogen to the soil, to be used by the next crop. But the effect of improved soybean bacterial symbiosis on the nitrogen need of subsequent crops, and thus on the fertilizer market, is not likely to be large.

Nodulating cereals: Let us assume that it will be possible to construct a wheat plant that has nitrogen fixing nodules. Will such a plant make agronomic sense? The biological nitrogen fixation process is energy demanding. A nodulated plant must supply their root nodules with approx. 11 kg sugar from the photosynthesis in order to obtain 1 kg N. In a cereal plant, 9 kg of grain could be produced if this amount of sugar was made available directly to the ear, instead of to nodules.

Such calculations indicate that a nitrogen fixing plant will only make agronomic sense, if fertilizer prices are high and crop prices very low. Normally it will be more profitable for the farmer to use fertilizer and harvest maximum yields rather than plant nitrogen fixing crops and accept the resultant yield penalty.

This is, of course, not necessarily true for the poor subsistence farmer in the developing countries that has no fertilizer available. For such farmers, new nitrogen fixing plants may provide a great benefit.

Root-bacteria associations: It is well known that there exists other less efficient types of symbiosis. Many plants, including barley, wheat and corn, can be associated with Azospirillium bacteria that live on root surfaces. These bacteria may supply the plants with some nitrogen, but the amounts are small and seem to be important only under conditions when the soil is very poor. The development potential is limited, as the need for energy from the plant makes the benefits from the association questionable.

Nitrogen fixation in the soil itself: Another possibility is to utilize the energy potentially available in straw for fixing nitrogen. Bacteria can be constructed by molecular genetic methods that combine the ability to live off and rapidly metabolize straw with the ability to fix nitrogen. However, the energy requirements for nitrogen fixation also means that such bacteria will be at a severe competitive disadvantage in the fields, where they will have to compete with other straw digesting bacteria that do not have to use a major part of their energy to work for our benefit. Furthermore should this fundamental restriction by some means be circumvented, and such a nitrogen fixing bacterium let loose in the fields, the expected result is an environmental problem. Happily, the biological principles of Darwin make such a scenario highly unrealistic.

Nitrogen fixing plants: There remains, however, a final strategy possible for the nitrogen fixing scientist: To make cells in the plant leaves nitrogen fixing by transferring the necessary genes from bacteria to the plants themselves.

Just like nitrogen fixation, nitrate reduction is a very energy demanding biological process. The plant reduces nitrate to ammonia. The reduction mostly takes place in the leaves without energy and harvest penalty, because the leaves, in contrast to the roots, usually have a surplus of energy. This surplus energy may perhaps be used for binding nitrogen.

However, many problems must be solved before such a theoretical possibility can be realized. Oxygen rapidly makes the nitrogen fixing enzymes inactive. Biological nitrogen fixation is thus not possible in the presence of oxygen. The nitrogen fixing nodules in legumes are made in such a way that the bacteria in the nodules can work in almost oxygen-free surroundings. Similar conditions are operative whenever biological nitrogen fixation takes place. It will not be easy to find leaf cells or organelles where oxygen is not present, but it may not be impossible. Alternatively it may perhaps be possible to reconstruct the enzyme to an oxygen tolerant form, but this is likely to be a major biochemical undertaking. We do not presently know what makes the enzyme oxygen sensitive, nor if this property can be changed.

Further the plant must be able to control the fixing process so that it receives the right amount of nitrogen at the right time. Excess ammonia poisons leaf biochemical processes.

Clearly, many fundamental problems must be solved. It will not be easy to find and bring home the "Holy Grail of Molecular Biology", but the effort is likely to bring insights that may prove useful in other fields of genetics. Already the many years of work on the nitrogen fixing enzymes, their genetic background and control systems are one of the great sources of knowledge in Molecular Biology.

PLANT BREEDING—TIME ASPECTS

Plant breeding is a slow process, much slower than genetic work on bacteria.

To move from one generation of a plant to the next takes months. Even when special techniques are used to shorten this time interval, it remains a slow process. It normally takes 5-10 years or more from the initial breeding work until a new variety is available.

Also, a plant variety has to fit the special field conditions where it is to be used.

Should it therefore prove possible to make an effective nitrogen self-sufficient plant, this trait will have to be incorporated both into the major crop plants and into the main varieties. Even with the enthusiasm that such a possibility is likely to bring forward, this process must take at least a few years. And even such plants will need nutrients from the fertilizer industry. The industry will have time to adjust to such developments—should they materialize.

Again, the main beneficiary from success in this scientific field will most probably be the poor farmer in the developing world, and taking the world as it is, that is most certainly a worthy target. Like the "Holy Grail" it may remain a dream. But there is sufficient possibilities for realization to keep the quest going for the present time.

With all possibilities and limitations considered,—there is every reason to pay close attention to biotechnology and molecular genetics as applied to plant breeding. It is an exciting science which may contribute greatly to the agriculture of the future.

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FINANCIAL STATEMENT

November 12, 1986 to October 31, 1987

Cash Balance—November 12, 1986		17,041.70	
Income—November 12, 1986 to October 31, 1987			
Registration Fees—1986 Meeting	12,832.00		
Sale of Proceedings	2,843.99		
Registration Fees—1987 Meeting and Cocktail Party Receipts	14,500.00		
Total Receipts November 12, 1986 to October 31, 1987		30,175.99	
Total Funds Available November 12, 1986 to October 31, 1987			$47,217.69
Disbursements—November 12, 1986 to October 31, 1987			
1986 Meeting Expense (incl. Cocktail Party)	7,362.15		
Misc. Expense Incl. Postage, Stationery, etc.	213.58		
1986 Proceedings (incl. Postage, etc.)	11,337.59		
Directors Meetings	1,819.74		
1987 Meeting Expense to Date	4,186.64		
Total Disbursements November 12, 1986—October 31, 1987		(24,919.70)	
Cash Balance—October 31, 1987			$22,297.99

Respectfully submitted,

PAUL J. PROSSER, JR.
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