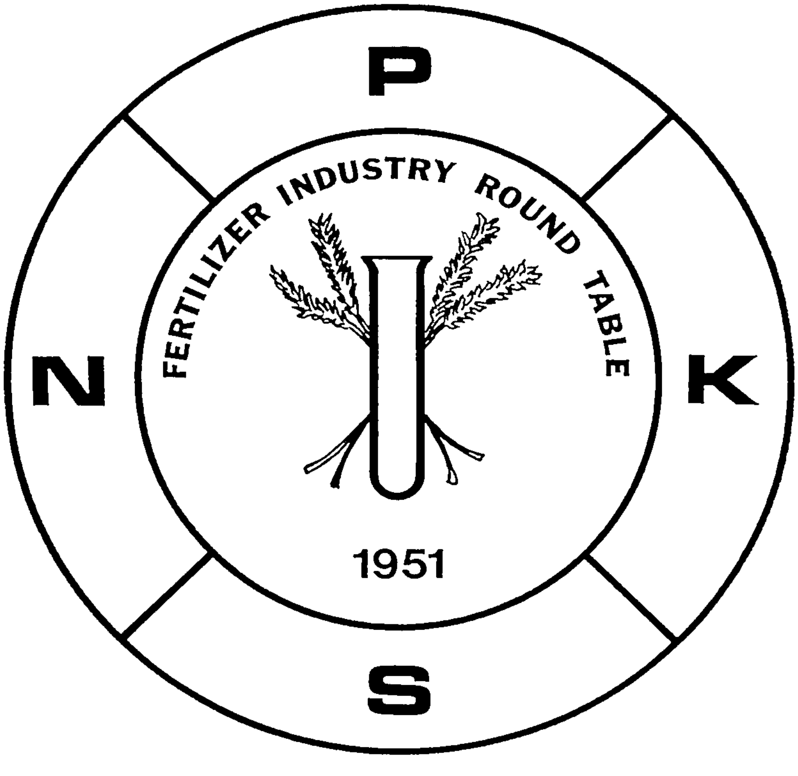
PROCEEDINGS
OF THE
38th ANNUAL MEETING
FERTILIZER INDUSTRY
ROUND TABLE
1988



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1898 – 1988

CO-FOUNDER OF THE FERTILIZER INDUSTRY ROUND TABLE
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Table of Contents

Monday, November 14, 1988
Morning Session I
Moderator:
William F. Sheldrick

Page

Opening Remarks
Thomas L. Howe, Chairman 1

Keynote Address—Dr. Robert Wagner 1

Outlook for Nitrogen—S. J. Challinor 6

Outlook for Phosphate—Garry Pigg 8

Outlook for Potash—Robert C. Connochie 17

Outlook for Sulphur—Cecilia Balazs 20

Monday, November 14, 1988
Afternoon Session II
Moderator:
Frank P. Achorn

Granular Ammonium Polyphosphate—Improved Form of Monoammonium Phosphate for Fluid Fertilizers—Byron R. Parker and Kenneth E. McGill 25

Compaction of NPK Fertilizers for the Guatemalan Market—Mark A. Swisher and Cristian Rodriguez 34

Various Methods for Producing Granular Ammonium Sulfate from By-Products Fines—James C. Mickus 38

Effect of Formula Modifications and Additives on Soil Surface Loss of N from UAN Solutions—Harold D. Blenkhorn 46

Water-Soluble P_2O_5: Some Technical and Marketing Considerations—Frank J. Johnson . . . 53

Tuesday, November 15, 1988
Morning Session III
Moderator:
James J. Schultz

Improvements to CFI's Ammonia Converters Utilizing Casale's Internals—Les Sutherland 59

Modernization of an Agrico Ammonia Converter via the Kellog Vertical Split-Flow Basket Modification—R. G. Howerton and S. A. Noe . . . 75

Cost Reduction Advances in Urea Synthesis Technology—Hidetoshi Uchino and Jong Hyun Park 88

Modernization of Existing Urea Plants—Ivo Mavrovic 96

Namhae Heat Recovery System Update—John J. Tully—Presented by James Shafer 96

Tuesday, November 15, 1988
Afternoon Session IV
Moderator:
Rodger C. Smith

China Phosphates—Maywood W. Chesson 99

Case Study: Blend Plants with High Deficiency Rates—M. M. Handley and J. L. Medbery 112

Canadian Fertilizer Quality Assurance Program—C. D. Crober 126

Measures of Quality in Fertilizer Blending—Jean Cheval and Paul Branconnier 132

Update on Ground-Water Legislation Affecting Agriculture—1987-1988—Roland D. Hauck 136

Wednesday, November 16, 1988
Morning Session V
Moderator:
John Renneburg

New Wave Pest Control Options for the 1990's—John L. Hellman 142

Changing Times for International Freight—Jan E. Jakubowski 145

What's Ahead for the U.S. Barge Industry—Thomas M. Torretti 147

Rail Update—John R. Flournoy 152

What's Ahead for the U.S. Trucking Industry—Jim Fisher 154

Warehousing in the United States from the Potash Producer's Viewpoint—Paul O. Warner . . 157

Clear Span Bulk Storage—Jack L. Brunk 159

Financial Report 162

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Monday, November 14, 1988

Session I
Moderator:

William F. Sheldrick

Opening Remarks

Thomas L. Howe, Chairman

Let me welcome all of you attending this year's Fertilizer Industry Round Table. I would like to extend a special welcome to the number of friends from other countries traveling great distances to share in this educational Round Table program. Your presence demonstrates the international scope and nature of our industry. We hope your visit is pleasant and productive.

This is the 38th annual meeting of fertilizer industry scientists, executives and businessmen, who are intent on examining and challenging new and innovative ideas for improving fertilizer products, their production and their distribution.

There is a saying that is often repeated these days that goes, "The only thing constant is change." Our industry has seen a lot of change in the last few years. If change creates new opportunities, then the fertilizer industry is an exciting place to be.

We see changes in ownership, on the farm level, and consolidation on the producer level bringing with it the closing and sometimes re-opening of fertilizer plants. The importing and exporting of fertilizer materials on a world wide basis creates a whole new set of variable conditions for our industry. A changing weather pattern in the U.S. has brought the worst drought we've seen since the 30's. Government set aside programs encouraged fewer acres planted. The result of the reduced yield and far fewer acres was a rise in commodity prices. The Payment in Kind program created a new business in the trading of PIK certificates along with the increased grain handling for the grain companies. This summer we have seen the rivers un-navigable because of low waters forcing many fertilizer companies to rethink their marketing programs.

Each of these changes create a need that will be met by an industry that adapts and is on the move. The momentum is positive as we look forward to increased acres planted in 1989. There will be additional challenges and unknowns in the future that will impact our industry.

There are unknowns in any election year, because of changes in government direction in programs and business climate. Future challenges involve environmental concerns and new legislation concerning the safety of our ground water.

The Round Table has a tradition of presenting quality topics covering all aspects of our changing industry. The changes impacting our industry today create new needs and opportunities for the innovative engineer or competitive entrepreneur.

This year's topics focus on change and examines fertilizer from the view point of the farmer, to the perspective of the environmentalist; from the suppliers outlook, to the efficiencies in technological improvements; from changes in transportation and storage, to the future changes in biogenetic engineering. Each issue in inter-related and needs to be understood to plan effective technological changes or marketing strategies. A delicate balance between these various perspectives is necessary for our industry to continue producing the food needed to feed our growing world.

The Fertilizer Industry Round Table has brought our industry together for the last 38 years to discuss issues that focus on the future. We look forward to hearing the timely papers that will be presented at this forum.

Keynote Address

U.S. Agriculture at A Dangerous Crossroads?

R. E. Wagner

Potash and Phosphate Institute

As I thought about what I might say to you here today, a number of things came to mind.

- Like the outlook for the fertilizer industry or the impact of fertilizer costs and services on world food supply, but there are experts on this program to handle various aspects of these topics.

- I could talk about how crucial it is for U.S. agriculture to be a big player in global markets . . . and how fiercely competitive the global market has become in contrast to just a few years ago;

- Or how agriculture everywhere must learn to survive and prosper with declining subsidies;

- Or how vital it is that agriculture become more efficient and lower its unit costs of production if farmers are to be even reasonably profitable and competitive;

- Or I could spend the entire time alloted and more, too, on how important it has become for the fertilizer industry to pay more particular attention to environmental effects of its products after they leave the plant . . . right out on the farm;

- Or what it will mean to the fertilizer industry to have acreage coming back into production next year;

- Or speculate on the full implications of the drought, given the fact that grain stocks are down and a major customer like the Soviet Union comes to us, as they did just last week, in a corn-buying spree as part of their drive to increase red meat production;

- Or I could try to crystal-ball the effects of the election on U.S. agriculture . . . and directly or indirectly on global agriculture.

Actually, I will do none of these although I will allude to most. I want to talk with you about another issue that could prove to be more consequential, more formidable than any of the above.

Key people are beginning to raise questions. Is U.S. agriculture close to a dangerous crossroads; has it already taken the wrong turn? Will it be the high road . . . or the low road? The jury is still out, but one thing is clear. Proponents of low-input agriculture threaten to make inroads into the kinds of things that have made U.S. agriculture the envy of the world.

LOW-INPUT A HIGH RISK SYSTEM

In many respects low-input/sustainable agriculture, which has been named LISA by the U.S. Department of Agriculture, is a backslide to practices long ago abandoned in favor of technology that has modernized agriculture so food in adequate quantity and quality at an affordable price can be a commodity attainable by the masses of the world's people. It is most unfortunate that "sustainable" has become closely linked with "low-input". Low-input as perceived by most is not sustainable. Low-input *per unit output* is sustainabale, but that is not what most proponents of LISA are talking about.

Indeed, low-input could even compound water quality problems and increase erosion if great care is not taken to balance nitrogen and other inputs. By its very nature, low-input agriculture is high risk in terms of nutrient use efficiency and agriculture's economic viability.

LISA is fueled by an over-reactive and ill-advised response to concern for groundwater quality. No one disagrees with the need to protect our drinking water, but the key is how best to do it.

If LISA can stand on its own two feet, if it has strength in its own right, it will be a winner.

On the other hand, if cutting inputs is LISA's overriding or only objective regardless of the consequences, then there is trouble ahead. If it gains attention only because conventional farming is perceived to be bad or is made to look bad, LISA's tenure will be very short.

I have confidence that there are enough thinking men and women in agriculture, including farmers, that the low-input crusade will self-destruct in the long term. But it will take time, during which serious damage could be done.

Low-input agriculture has been variously described as having objectives to cut fertilizer and chemical use outright; to mainstream low-input agriculture into the present agricultural system; to move conventional agriculture from excessive use of chemicals to low use and less production, etc., etc.

On the other hand, some will say it is to make agriculture more profitable for farmers and suppliers, more competitive in global markets, and more favorable to the environment. There can be no argument with these objectives . . . even if it means using less fertilizers and chemicals.

SLOW TO REACT TO LOW-INPUT?

However, the concern we all need to recognize is that there is developing an organized effort by USDA, some Land-Grant universities and several activists groups aimed squarely at less fertilizer and chemical use . . . without due regard to the economic consequences to agriculture and, indeed, to the environment. Perceptions and reality are far apart. I submit that we as an industry have been and still are slow to react to this one. We should be at full alert.

What does Assistant Secretary of Agriculture Orville Bentley mean when he says, "Low input farming systems is an idea whose time has come?" Or when Paul F. O'Connell, who coordinates USDA's low-input program, writes, "We have an opportunity to develop new cooperative relationships, and to set the course for the next generation of science and education in agriculture."

Does it bother you that USDA funds project with objectives like these?

1) "Promote low-input, well-managed small-farm systems . . . " (Promote? Where is the scientific evidence? Or is that important anymore?)
2) "Investigate the feasibility of *eliminating* fertilizer and herbicide input . . . " (Eliminate?)

3) "Evaluate solarization as a replacement for fumigation, and cover crop production as a replacement for fertilization . . . " (Cover crops replace fertilizer? What will the cover crops live on?)

Should we be concerned that USDA and USAID sponsored a "Sustainable Agriculture Study Tour" in Kansas, Nebraska, and Iowa this past summer, which turned out to be more "promotion" than "study" and that printed this statement to participants? "The emphasis on sustainable agriculture is most timely since it reflects the current interest by the U.S. Congress, the USDA, Land-Grant Universities, farm organizations, USAID, the World Bank, the general public and farmers themselves, that conventional agricultural systems are not sustainable because of . . . groundwater pollution from extensive use of chemical fertilizers and pesticides, and the high cost of off-farm production inputs."

Does Dr. Clive Edwards, Chairman of Ohio State's Department of Entomology, represent the Land-Grant University thinking when he says, "So many Ohio farmers are interested in low-input systems. We are going to have to look at crops which don't need so much fertilizer and pesticides . . . This is what the future holds—and I want us to be out there leading the way."

Eugene P. Odum, Director Emeritus of the University of Georgia Institute of Ecology, in a letter to Dr. Frank Press, President of the National Academy of Sciences, said this: "We see a major change or transition in agriculture. As diminishing returns on the overdependence on expensive and environmentally damaging fuels and chemicals become more and more apparent, there will be major shifts to 'reduced input agriculture'."

U.S. agriculture was not built with a cutback approach nor is this the time in history to do it, given the pressures to compete with other emerging farm economies around the world. Dr. Charles M. Benbrook, Executive Director of the National Research Council Board on Agriculture, in testimony before the U.S. Senate Committee on Agriculture, Nutrition, and Forestry said, "The way many people use the term 'low-input agriculture' implies to farmers that progress can be made simply by using low levels of inputs. This is both misleading and dangerous."

A USDA MANDATE AND LOW-INPUT ADVOCATE

The ecologists, the environmentalists, the organic farming advocates, and others are a strong coalition. Their political power was put to work in pushing through Congress a $3.9 million appropriation for low input/sustainable agriculture research. A special leaflet prepared by the staff of Rodale's AGRILETTER indicates interest in substantially more funding. "Farmers, scientists, farm groups and USDA officials have already asked Congress to increase funding to $15 million in 1989. Notable among them: The American Farm Bureau Federation and the Deputy Agriculture Secretary Peter C. Myers."

USDA and some land grant institutions take this to be a mandate to promote countrywide low inputting into agriculture with a target on fertilizer and chemicals. The feelings are strong enough that the $3.9 million appropriation in 1988 is increased to $4.5 (not $15 million) in the 1989 budget just approved by Congress. The Soil and Water Conservation Society had originally requested $15.5 million in testimony before Congress. Pressure is building for increased funding in subsequent budgets. While these might not seem like large amounts in terms of government expenditures, the pattern that seems to be developing is significant.

More than a few are concerned that a reputable USDA would take a strong advocacy position and develop strategy to hard sell the adoption of low-input agriculture in the name of research . . . or at the least prior to its being adequately researched. An overzealous effort to indiscriminately cut down on farm fertilizer and chemical use can cause officials to lose objectivity.

Legislation to tax nitrogen use is popping up in a number of states, the intent being to protect our water supplies from nitrate contamination . . . a laudable goal, indeed. The means to that laudable goal is another matter. A fertilizer taxing policy or any across-the-board regulatory restriction penalizes all agriculture . . . both the efficient and the inefficient.

The European experience should be a clear signal to us to be alert to the possible enactment of stiff and damaging tax legislation. In Denmark, for example, there is a proposed one-third reduction in nitrogen use. If that does not occur, a 50% fertilizer tax in 1990 is threatened and the possibility exists of a 100% tax by 1991.

What I am trying to say is that rather than setting out to make a case for low input agriculture, let's first find out whether there is, indeed, a case to be made. That calls for research . . . of more than a year or two duration. That is what USDA should be doing rather than promoting the wholesale early adoption of LISA, low-input/sustainable agriculture. Parenthetically, I would say that the low-input advocacy approach is out of character for the kind of USDA I knew when I was a part of it and have known for half a century.

No one can argue with taking a look at and carefully evaluating under what conditions reducing inputs might have a place in a modern globally competitive agriculture. Indeed, there might very well be places where less nitrogen or even less phosphate and potash should be used. But let's not be blind to the possibility that more fertilizer and/or a better balance of nutrients in high yield agricultural systems could increase the efficiency of the use of our resources and at the same time strengthen the economics of farming operations and protect the environment.

MEY . . . A SYSTEM OF BMP'S

LISA has made necessary a re-visit to basic principles of farm agronomics by which production systems can be adjusted to maximize economics and minimize water quality damage and other environmental hazards. This is the MEY approach . . . call it maximum economic yield, most efficient yield, or whatever. MEY systems are designed to integrate the latest technology and production inputs at optimum and balanced levels with the objectives of low unit cost, high returns per acre, and a clean environment. They are systems in which BMP's (best management practices) are the components. Indeed, MEY is the best possible system or package of BMP's. MEY is a low-input system . . . if it can be defined as low input per unit output.

Ron Olson, Vice President of Top-Soil Testing Service in Illinois, works closely with his farm clients to help them move their operations to MEY production systems. Based on his considerable experience here is what he says in the Sept/Oct 1988 issue of PROGRESS.

"We are in the midst of a quiet revolution in American agriculture—one that promises to surpass the considerable achievements of the Green Revolution. The impact of this movement on all aspects of agriculture is immense—for the farmer, the agricultural lender, the farm retail supplier and the agricultural consultant.

"The maximum economic yield (MEY) concept will fuel the engines of efficiency in this country, creating dramatic challenges and setting farmers free. It also provides the critical tools to help create win-win relationships for all of us who supply farmers with dollars, products, services or information."

Farmer acceptance is gaining rapidly . . . beyond what we thought would happen. An indicator is the MEY farmer club movement. Organizers, which are largely dealers and consultants, find that farmers are eager to participate because they see the MEY club concept as the best way to steer them to more efficient and profitable operations. Emphasis is on total systems.

They are small groups that meet, usually monthly, to tell each other what they are doing and what it has meant to them. Informal discussions and idea exchanges in small group settings, usually no more than 20, are highly informative and useful. Farmer enthusiasm is high and dealers feel this is a way to do something special for their growers.

Already there are some 50 MEY clubs in North Dakota alone. This is a grass-roots North American approach that has caught on and is spreading beyond the borders of U.S. and Canada.

Some might say that by encouraging farmers to adopt MEY practices we are guilty of the same hard sell tactics that we accuse USDA and other low input proponents of doing. The big difference is that MEY is the embodiment of tried and proven practices. To be sure, more research is needed to further refine MEY systems, but the body of information now available gives sound guidance.

Just as one example, take a look at the data in the table which is from wheat research done at Kansas State University.

P_2O_5 lb/A	Yield bu/A	Cost $/bu	Net Returns $/A	Unused N lb/A
0	35	3.91	12	9
20	51	2.84	39	−21
50	64	2.42	58	−45

The results illustrate quite clearly some key points with respect to the plant nutrient part of the system. While the study was with wheat, the principles are equally applicable to all crops. Note that even though application rates of N are not changed, using more P

- decreases cost per bushel
- increases yield
- increases net return
- increases N use efficiency

Taken in reverse these data show equally clearly what can be the consequences of a low-input approach. The all-important cost per bushel goes up. Yield goes down. So do net returns and efficiency of nitrogen use to the point where more was applied than was needed to produce the crop . . . and it was at the lowest input level.

It might be argued that less N would have been more efficient. That is a possibility, but the fact that the crop had to draw 45 lbs more N from the soil than was applied suggests otherwise. Given the fact that the economics and nitrogen use efficiency were best at the top yield level in the study, wouldn't it make sense to explore how to get still more efficiency at the same or higher N rates?

Environmental breakdown comes when there is indiscriminate use of fertilizer, either at high or low levels, without due regard to balance or relationship to other inputs in the system. As I have already pointed out, that is not MEY.

To advocate input cutbacks without carefully researching the economic and environmental consequences in the kind of highly developed intensive agriculture needed to compete for global markets is to do an economic disservice to that agriculture and a social disservice to the environment of all people.

To encourage a system that has a target of the same or less production, puts that system at risk of decline or, at best, freezes it at its present level. Is that what we mean by sustainable agriculture? Is that what we want going into a fiercely competitive global agriculture? I don't think so.

AN ALTERNATIVE AND SUSTAINABLE SYSTEM

There is much talk about alternative crops and cropping systems. MEY is an alternative cropping system in the sense that it is different from conventional agriculture, and relatively few farmers have fully implemented all the parts of the package. Its principles are not new, but how it is constituted and implemented had its beginning only in the early 80s.

It is off to a good start. I say "start" because it has such great potential for farmers of all kinds. Let me illustrate simply by saying that whether we like it or not, efficiency of production is highly related to yield and opportunity for increasing crop yields remains great. Average yields in the U.S. in many cases are no more than one-third of what research shows is the crop potential. It's true, for example, with corn, soybeans, wheat, alfalfa and many others that could be named.

Let's take corn. The highest average yield for the U.S. is 119 bu/A. The highest research yield is 338 bushels. That simply means there is a wide window of opportunity where farmers willing to make the effort can substantially improve their economic position.

The difference between 119 and 338 gives a lot of working space for the farmer to improve his efficiency. Most would not be comfortable trying to achieve the 338 bushels . . . and they should not be. That is the maximum yield, not maximum *economic* yield.

The comfort zone for most farmers might be between 150 and 200 bushels. For the very top farmers somewhere between 200 and 250 bushels is doable. Whatever the comfort zone, this is what we mean by moving toward MEY . . . farmers using the latest technology to reduce unit costs, to increase net returns per acre, to be competitive, and to keep the environment clean.

In an Ohio Cooperative Extension Service release dated September 9, 1988, based on a CAST report prepared by a select group of agricultural leaders from across the nation, Dr. Luther Tweeten, Agricultural Economist, makes a number of pertinent points and presents a well stated case for MEY.

"There are those who would reject technology as damaging to the environment, dehumanizing or counterproductive to farm life. We submit the opposite: If we're going to protect our natural resources and environmental purity and still be an agricultural leader, we better take advantage of technology.

"Opponents of these new methods argue that if farmers are less productive, the laws of supply and demand would give them higher commodity prices and higher incomes. That's true in the short term. But in the long run, the country that is able to produce the most farm products most efficiently will set the pace for world trade.

"We would argue that increased productivity from these kinds of technological advances is good for agriculture, good for the economy and good for the environment."

Dr. M. S. Swaminathan, recently retired Director General of the International Rice Research Institute, with headquarters in the Philippines, and the first laureate of the General Foods World Food Prize, answers the critics of MEY who say it is just for the elite among farmers. Here is some of what he says, "Frequently, the concept of sustainable agricultural production is used to preserve the status quo or revert to outmoded production technology. We need a dynamic concept of sustainability to help meet the needs of an expanding population while maintaining and enriching the natural resource base. In most developing countries, the two major pathways to the production of additional food are greater productivity and more intense cropping. Thus, the smaller the farm, the greater the relevance of high-yield technology."

FAO says that the needed increase in world food production by the year 2000 will require "a massive 63 percent from increased production per unit area. It is here that mineral fertilizers come prominently into the picture. The largest contribution (to food production) will have to come from higher yields through fertilizer use."

How does all this square with low-input agriculture? MEY and LISA, as commonly perceived, are two distinctly different concepts . . . very different versions of what is good for North American and, indeed, world agriculture. The one . . . in addition to being a high risk approach in terms of unit costs, profits, competitiveness, and environmental quality . . . ignores the dynamics of opportunity to improve in the areas which have been at the heart of progress in American agriculture. If we are talking low input per unit output . . . which is not what is meant by most low inputters . . . then it is MEY, the best of sustainable agriculture.

Never has there been a greater urgency for farmers to get serious about becoming more efficient. Industry has had to do it to survive the recent tough years. Farmers have had the protection of government payments, which in too many cases actually encourage inefficiency. Governments around the world are realizing that the cost of that kind of luxury on a sustained basis is prohibitive. How can we prepare farmers to become, in the vernacular of the industry, "lean and mean"? It won't happen by denying them the necessary inputs for efficient production.

INDUSTRY'S ROLE AND ITS URGENCY

Industry has a key role to play at this point in agricultural history. Let's not be misled that the current low-input effort will just go away anytime soon. Or, that it is not important enough to be concerned about simply because we might not hear much about it at times. Make no mistake, the inner circles are hard at work. And you will be hearing more about it even on an international scale.

In September of this year USDA co-sponsored with Ohio, Pennsylvania, and North Carolina State Universities the "International Conference on Sustainable Agricultural Systems." Dr. E. T. York, Jr., Distinguished Service Professor and Chancellor Emeritus, University of Florida, commented, "I thought it was a good conference but I was concerned about the manner in which the USDA Sustainable Agricultural program was linked with 'low-inputs'. In my opinion this is a serious mistake to link sustainability with low inputs.

How to incorporate low-input agricultural techniques into conventional farming systems will be the focus of a national conference next March in the heart of American's grain belt. It will be sponsored by the Soil and Water Conservation Service in cooperation with USDA, EPA, and a number of agricultural and conservation organizations. Others are on the drawing boards.

So what can the industry do? One thing it must not do is to continue its complacency. Another no-no is be defensive and negative. Defense alone does not win many battles.

Fortunately, the industry has MEY in place or moving into place. It's a positive alternative to low input. It addresses the weaknesses of the low input approach.

The time is right for the industry to give solid support . . . to stand tall and make MEY its trademark. It is a scientifically sound and economically and environmentally viable system that the industry can support with confidence. It should be a part of the marketing program of every company. Proprietary products and service still can be the individual company focus within the MEY system. PPI will continue to foster it and make every effort to be of all possible help whenever and wherever companies might request it. Please call on us.

As the industry trademark, MEY would be good for all of agriculture . . . farmers and suppliers alike . . . and for a quality environment. Indeed, this is an unusual opportunity for supplying industries to serve agriculture . . . and their own best interest at the same time.

Outlook for Nitrogen

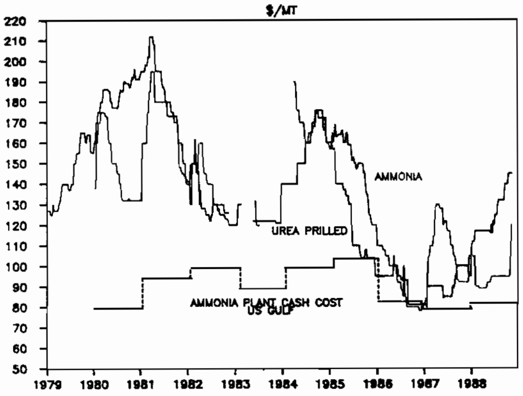
Stuart Challinor, ICI Fertilizers
United Kingdom

BACKGROUND

The world's nitrogen fertilizer industry is currently in the process of recovery from the most severe recession ever. Though demand has continued to increase in most developing and centrally planned economic regions it has plateaued or decreased in many West European countries and in North America principally because of the cereal surplus. However, on a world scale, the strength of demand is not at the root of the industry's problems. The recent market imbalance has been caused mainly by excess supply from new plants in developing and centrally planned regions.

The imbalance between supply and demand has lowered ammonia price levels to the effective floor price represented by the cash cost of low cost US Gulf producers (Figure 1). Plants with higher energy costs have been idled or permanently closed in both North America and West Europe. However, in the past year, area prices have increased considerably, mainly because of the return of China to the market, and ammonia prices also show signs of recovery. What then are the prospects for the nitrogen industry?

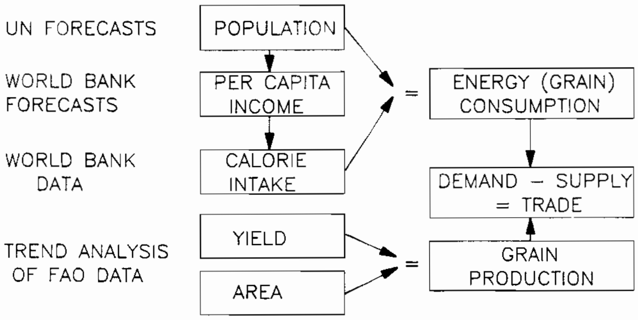
US NITROGEN EXPORT PRICES FOB GULF FIG 1



1. *THE OUTLOOK FOR NITROGEN DEMAND*

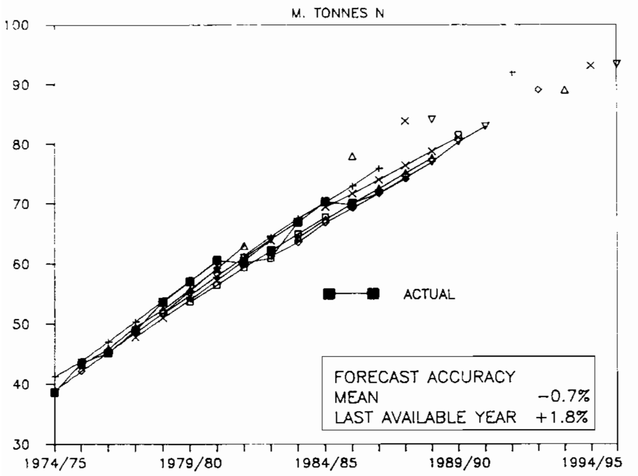
World demand for nitrogen (and other plant nutrients) is ultimately derived from the demand for food (effectively grain). Most forecasters therefore model demand on a regional basis in relation to factors such as population growth, economic growth and the relationship between per capita real income levels and food energy intake (Figure 2). The track record of these forecasts is generally good at world level (Figure 3).

WORLD REGIONAL GRAIN SUPPLY/DEMAND MODEL FIG 2



WORLD NITROGEN DEMAND FORECASTS

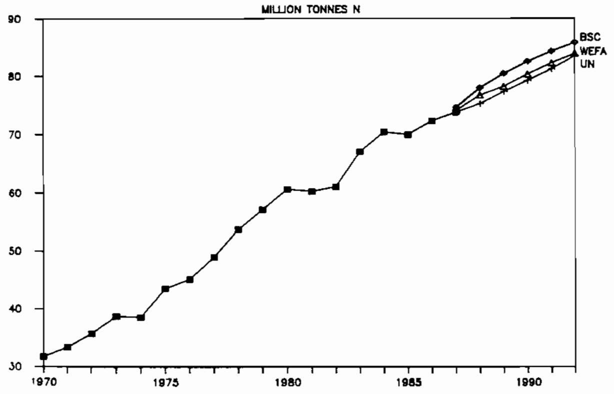
FIG 3



Forecasts on a regional basis are more hazardous because food supply potential must also be considered. This brings world trade in cereals into the model which is a prime determinant of the nitrogen market in the USA and, to a lesser degree, the EEC. Views differ as to how the politics of world trade will affect the level of cereal production in the USA and the EEC and thereby the respective nitrogen markets. However, most forecasters are agreed that at world level the nitrogen market will continue to increase at something close to its underlying linear trend (Figure 4).

WORLD FERTILIZER NITROGEN DEMAND

FIG 4



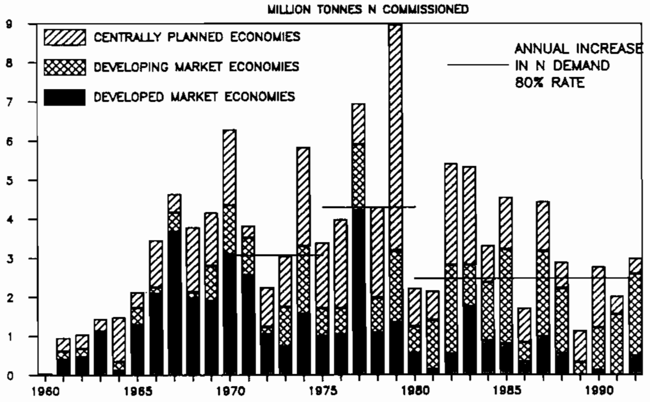
2. *THE OUTLOOK FOR NITROGEN SUPPLY*

Nitrogen supply is modelled at ammonia plant level, taking into account likely closures and new investment and assumptions regarding operating rates. Because of the lead time in building new capacity, it might be assumed that, based on known investment intentions, a 5-year forecast of ammonia supply might be derived with some certainty. History shows that this is not the case and that the most likely source of error in forecasting supply/demand balances is on the supply side.

The problem facing nitrogen producers is that new ammonia capacity is not introduced smoothly to match market growth (Figure 5). In recent years annual capacity additions of 4/5 million tonnes have been made though market demand is only increasing at half this rate.

WORLD NEW AMMONIA CAPACITY

FIG 5



SOURCE:FAO/UNIDO/WORLD BANK

Views differ considerably between forecasters on the supply side (Figure 6) not in terms of ammonia capacity but in terms of supply (operating rate). The FAO/UNIDO/World Bank group envisages an increase in operating rates at world level from 81.4% in 1987/88 to 82.1% in 1992/93. This rate of improvement is about the long-term trend. However, the latest British Sulphur forecast points to the high rates quickly achieved by new plants in recent years and assumes that rates will increase from 82.4% in 1987/88 to 84.1% in 1992/93. Since many new plants are planned to operate in locations or through operators with existing experience in ammonia production, it is probably realistic to assume that the established trend in operating rates will be exceeded.

In terms of the world nitrogen supply/demand balance, the difference between the FAO/UNIDO/World Bank and the BSC operating rate assumptions is crucial—the former produces a notional ammonia deficit of 0.7 MTN by 1992/93 whilst the latter produces a surplus of 2.0 MTN, only slightly below today's level. The latest WEFA forecast falls somewhere between these extremes.

REVIEW OF NITROGEN FORECASTS FIG 6

MILLION TONNES N

	86/87	87/88	88/89	89/90	90/91	91/92	92/93
DEMAND							
UN	72.37	73.84	75.30	77.35	79.28	81.28	83.54
BSC		74.69	78.02	80.48	82.55	84.35	85.85
WEFA	72.37	74.18	76.77	78.28	80.39	82.32	83.96
NH3 CAPACITY							
UN	111.75	114.69	117.09	118.21	121.01	122.72	124.97
BSC	114.6	116.00	118.70	121.10	121.30	124.10	126.70
	(EXCLUDING PLANTS NOT CONTRACTED)				(121.1)	(121.5)	(121.9)
WEFA	112.37	114.63	117.25	118.20	120.96	123.27	124.82
NH3 SUPPLY							
UN	90.95	93.37	95.89	97.33	99.36	100.99	102.56
BSC		95.60	97.90	100.90	102.20	104.60	106.60
N BALANCE							
UN	0.719	1.222	1.964	1.108	0.862	0.218	−0.751
BSC		3.900	2.500	2.600	1.500	1.800	2.000
	(EXCLUDING PLANTS NOT CONTRACTED)				(1.40)	(0.30)	(−0.2)
WEFA	1.717	2.628	2.647	2.741	1.957	1.595	1.291

3. *PRICE PROSPECTS*

The short-term price prospects for ammonia are bullish. History shows a quite remarkable relationship between US maize and ammonia prices lagged 6 months (Figure 7). Insofar as maize prices reflect the fortunes of the farm economy in the world's major producing region, this is not as surprising as it may first appear.

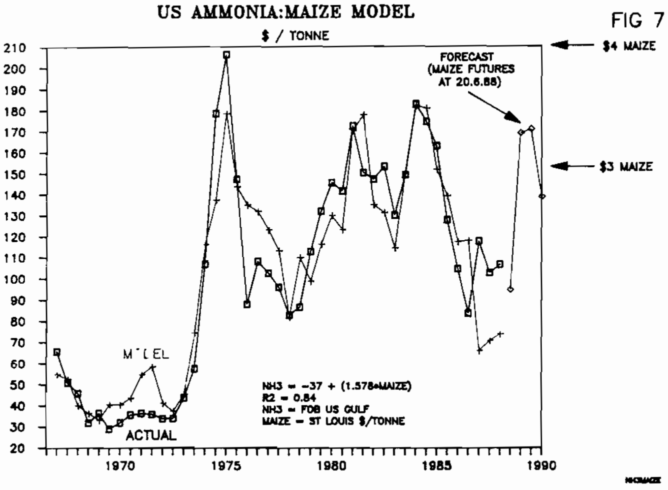

US AMMONIA:MAIZE MODEL

FIG 7

The 1988 US drought has had a major impact on maize prices. If maize prices in 1988/89 remain at around $3 per bushel, the model suggests that ammonia will reach about $150 FOB US Gulf in 1989. Further out the prospects depend on the 1989 US harvest.

Supporters of the ammonia/maize model have spent a few anxious weeks watching static US ammonia prices which have lagged someway behind urea, but have been relieved to see barge prices rise by upwards of $20 in recent days.

In the longer-term, US droughts excluded, the prospect of the world ammonia supply tending to exceed demand would put prices back into the $105/110 region (Figure 8). It all depends on one's view regarding relatively small changes in operating rates.

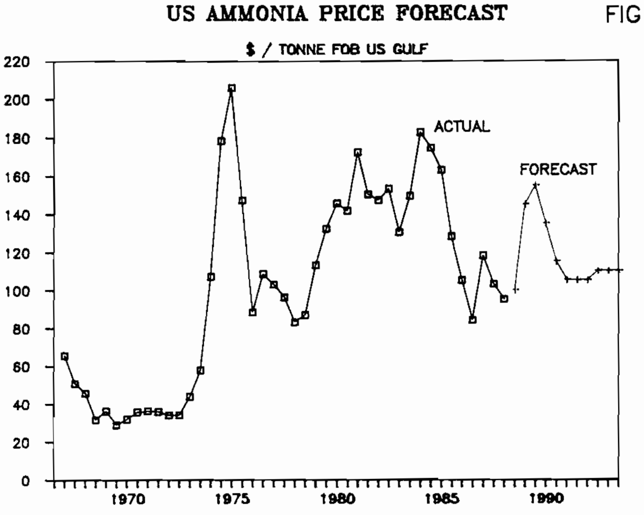

US AMMONIA PRICE FORECAST

FIG 8

Outlook for Phosphates

Garry Pigg

Agrico Chemical Company

As we get a little older, and I might add a little wiser, we learn what to do and what not to do. I learned not to volunteer someone from my company to speak at these functions—it seemed like a good idea at the time. However, at the moment I wished I would have keep my mouth shut.

I also learned what qualifies you to be an "expert" and give an outlook for phosphates. That being someone who either works for a phosphate producing company, someone involved in marketing phosphate fertilizers, someone who can spell phosphate or someone who can lay his hands on published information about phosphates and can, and I use this term loosely, paraphrase the information in such a manner that you would believe I thought of it first. What makes me this expert, is that I can lay claim to all four of the qualifications, although for the first ten years I wasn't sure I was spelling it correctly.

All kidding aside, I'm honored to stand before you and tell you how truly wonderful it is to be in the phosphate business today. A couple of years ago it wasn't near as nice given the economic climate back then. I don't intend to remind you of what things were like, I would rather talk about today, and more importantly, tomorrow.

Fig 1 No outlook speech in the fertilizer industry would be complete without a short comment about the basis for fertilizer demand today or why it should be even greater tomorrow. I'd mention a growing population and the desire for better diets if that would lend credence to the arguments. But this is a factor all too well known to point out—especially to this group here today.

Fig 2 I'd like to spend my time this morning looking briefly at some forecasts of global phosphate demand, some of the major developments and trends in phosphate production worldwide, and spend several minutes looking at the U.S. phosphate situation. In examining the U.S. situation, I'll also cover the agricultural condition to give you a better vantage point from which to measure my forecasts.

Fig 3 Certainly if we were to take the time to look at a forecast of world phosphate demand, it would take much of the morning and could last well into the afternoon. We would examine the in-depth factors happening in each country, or at least the major countries. In our effort we probably would mention population, food demand, food production, arable land, cultivation practices, weather patterns, current fertilizer application rates, changes in these rates over time, economic and political elements and so on.

In each of our own ways, we would derive a "reasonable" forecast of future demand, assuming we would accurately assess what current demand is. Ultimately we would suggest the individual country, or the world as a whole, would grow at some compound factor. I guess our forecast would range somewhere between 2% and 4%. Certainly those experts more qualified than I would probably argue amongst themselves why one number and not the other. In the end they would likely shrug their shoulders and wait another year to see what develops.

Fig 4 But let's look at some of those forecasts and see who's correct. Who's to say. I would propose that those who would believe consumption will rise at the upper level would be more inclined or willing to make future investments in the phosphate industry and as such could justify the apparent high projections. One thing we can agree on is that the experts disagree. Oh by the way . . . the experts have been wrong in the past.

Fig 5 In spite of the past and somewhat errant forecasts of these specialists, lets settle on an average growth of between 2 to 3%, coincidentally, about the same rate as forecasted by the collection of IFA members serving on the various committees who jointly examine consumption patterns. I might note that this 2% to 3% translates into a figure between 8 hundred thousand to 1 million tons of P_2O_5 annually or a new Jorf Lasfar every 18 months.

Fig 6 Switching to supply, we continue to see new development in several areas. Most notably within a wet phosphoric acid sector which is approximately 31 million tons today. Non phosphoric acid supplies of P_2O_5 principally in the form of normal super phosphate and basic slag in addition to partly acidulated phosphate rock accounts for a capability of about 15 million tons today. Most of this is located in areas of China and the Soviet Union.

Fig 7 Looking specifically at phosphoric acid based phosphate production, we see that North America accounts for approximately 12 million of the 38 million tons of installed phos acid capacity. I have to point out that the United States is operating at over 95% of its installed capacity, where as Eastern Europe would account for an operating rate of somewhere around 70%.

Fig 8 And, of course, United States enjoys a very comfortable position in its cost structure as noted by this slide contributed by Fertecon. In its recent DAP study, Fertecon has examined the prospects for DAP production and trade in the world and the future for that industry. Overall, DAP manufacturing cost for the major producers are somewhere between $110-$130 per metric ton of DAP centered primarily around the $122 to $125. Much of this depends, however, on phosphate rock and sulphur costs.

Fig 9 With today's low value of the dollar, the United States' producers are even in a more comfortable position against many other countries involved in trade and for that reason enjoys a healthy share of world DAP trade. As you can see by this illustration, the United States accounted for 73% of world DAP trade last year. That figure will be about the same in 1988 as U.S. exports of DAP are up about in line with world DAP exports. Looking ahead to 1993, Fertecon believes that Morocco will be a very major player in world DAP trade. While we might take issue with some of the figures shown in this slide by Fertecon, I use it only to point out that the United States is a major—the major DAP marketer in the world today and will remain that throughout the 1990's.

Fig 10 Focusing more closely on the United States phosphate situation, I would now like to take a brief turn and discuss some of the aspects of agriculture with you. How agriculture has changed in the last year, and what we can expect in the ensuing year.

Fig 11 All of us know very well that the U.S. encountered one of the most extreme droughts in recorded history. It was compared to the dustbowl days of 1934 and 1936.

Fig 12 This September the United States Department of Agriculture released its first estimates of this year's corn crop, and not surprisingly it was a very short crop. Total corn production is estimated at 4.67 billion bushels, a drop of nearly 34%.

Fig 13 The reason I really point out this chart to you is to show you the supply and use for grains and oilseeds in the United States. While there are to many numbers to cover in detail in this session, I'm only really trying to focus on the ending stocks shown in the rectangle at the bottom of the chart. As you can see, ending stocks of feedgrains are going to drop nearly 60% by the time of next year's harvest. Wheat a comparable amount and soybeans are very very low.

Fig 14 If we were to look at this in graphic detail you would see that overall stocks will be coming down to approximately 75 million metric tons compared with over 200 million tons just 2 years ago. This is an even larger drop than we had following the PIK year and as such has created a very different situation in world agriculture.

Fig 15 My next illustration shows the major farm program details between 1988 and 1989. Last year we had a 20% set-aside program for feedgrains with an additional 10% Paid Land Diversion that was optional for producers. Participation was very high. This year, the secretary has announced that the set-aside program will be 10% with no Paid Land Diversion. The wheat program will drop from a 27½% acreage reduction program, also to 10%. And while for soybeans there's no official program, in recent legislation passed, soybeans can be planted on a producer base acreage without penalizing the producer. Also that same bill provides for sunflowers on the same basis as soybeans and oats can be planted on virtually any acreage.

Fig 16 This does not include, however, the long term conservation reserve which is now estimated at

28 million acres. You can see that more clearly on this chart where we build up to the overall total of approximately 400 million acres of U.S. crop land in crop production. Estimates for next years corn planting go from a figure of about 68 million acres this year up to 75-77 million acres and as high as 77-78 million acres of wheat. The soybean estimate also, is somewhere around 64-65 million acres planted. Those three crops account for approximately 70-75% of phosphate use in the United States. In total, most experts expect U.S. crop plantings will increase approximately 10% in the coming year and will cause a significant increase in fertilizer consumption.

Fig 17 You can see more clearly that when it comes to phosphate—corn is king. It is well over 50% of the consumption of U.S. phosphate and with changes in acreage, also come changes in U.S. phosphate consumption. For the coming year based on a figure of 77 million acres, we're expecting phosphate use in the United States to go up on the order of 10 to 11%. But some within the industry would say—well coming off a drought year and low yields, wouldn't that lead you to believe phosphate wasn't taken out of the soil.

Fig 18 I guess I'll have to show you this next chart that we prepared which focuses on the application rates of nitrogen, phosphates and potash on corn since 1964 vs. what the corresponding yield has been. As you can see, there used to be an upward sloping pattern—as you wanted to get more output per acre you had to use more fertilizer per acre—until we hit the period of 1985, 1986 and 1987 where we had very favorable weather which contributed to the higher corn yields. This year's 78 bushel per acre crop, noted here, is just below the 1983 PIK year. And of course, yes it would be true that it did not use up as much phosphate to produce that as either the 1986 or '87 yields.

Fig 19 However, as you can see by this chart, there was a period in the early 60's and 70's when the amount of phosphate that was applied on corn, wheat and soy beans was greater than what the crop itself would use. But in that 85, 86 and 87 period, we started taking from the phosphate bank. We started depleting the soil of its phosphate by taking more out than what was put on and this year we might have added a little bit back. But if we're going to get up to that target noted on the previous chart, to obtain the higher yields, we're going to have to change our application patterns and use more per acre, not less.

Fig 20 Even today, the Phosphate and Potash Institute has proven that there are many soils within the United States that test below a recommended level for agricultural production. But this is the same as is in many parts of the globe, most notable would be in China and I think Bill Sheldrick might even be able to comment on this at a later point. He knows that their level of nitrogen use relative to phosphate has been out of line and as such, they have been taking phosphate out of the soils. At the recent IFA-FDINAP conference held in Manila, a gentlemen presented a very good paper pointing out this factor as well. And, of course, that contributes to why many countries in the world have to import fertilizers and why the U.S., because of its productive capacity, is in such a good position.

Fig 21 This chart shows DAP trade during the 1980's. As you can see, its been onward and upward with the exception of the year 1986, which was generally a recession throughout all of agriculture. 1988 is estimated to have reached a record level in terms of world DAP trade. However, I believe 1989 will prove to exhibit the same type of increase in trade as we saw coming from 1983 into 1984, when world commodity prices also increased very sharply. As you can see from the illustration, the four major individual countries accounting for half of world trade are China, India, Iran and Pakistan. West Europe has also become a large importer of DAP displacing much of the indigenous production in the EEC. I point out DAP because it is basically *the* article of commerce in world phosphate trade.

Fig 22 If we focus on the U.S. phosphate situation, we see that DAP also accounts for 75% of U.S. phosphate exports.

This illustration shows the remaining products: MAP, TSP, merchant acid and also something that most people overlook, super acid, which goes mostly to the Soviet Union under OXY's barter arrangement for ammonia. We expect 1989 will exceed 1988 in terms of both world phosphate demand, world phosphate trade and U.S. phosphate exports. The low value of the dollar will help U.S. phosphates in spite of the recent start up of Jorf Lasfar's DAP trains.

Fig 23 Speaking of the start-up of phos acid plants, I would like to share with you this illustration which is somewhat sobering for phosphate producers in that we will start 1989 with more capacity on stream and producing than we left 1986 with. As you can see, today there's approximately 11.3-11.5 million tons of phos acid capacity producing. There would be many in this industry who would have said just a year or two ago, many of these restarted plants would never operate again. Well it shows in an upward market, anything is possible.

I'd like to come back now and put in a nutshell, our expectations for domestic demand, which as we said in the current fertilizer season, will be up 10% and our expectations for export demand which will be up in the order of 9%. Add these up, put them against the capacity—what it would look like is this chart which shows the phosphate supply/demand history in the U.S.

Fig 24 It shows why things have been favorable from a profit stand point for U.S. phosphate producers in 1988—we've been at the narrowest supply/demand balance within the 1980's with the exception of 1980 itself which is not shown on this chart.

You may ask if we project U.S. demand to be up as much as 10% in 1989, why does this chart show a flatness in the 89 domestic demand curve. Well these curves (both domestic and export) are based on shipments and this next illustration which compares producers' domestic shipments with domestic consumption, shows the amount of material that is in the pipeline.

Fig 25 In otherwords, whereas shipments this past year increased 15% over the preceeding year, consumption (certainly affected by the drought) grew only 4%.

As we look ahead into 1989, even with the additional active capacity in place, we do not expect that the U.S. phosphate situation will be that much out of balance. If anything, we may not be able to produce at the level of capacity shown in the preceding illustration. And the reason for that has to do with raw materials. I'll point out one here, just briefly, and that is what the overall phosphate rock situation will be within the United States.

Fig 26 As you can see, phosphate rock shipments both for export and to domestic industry have exceeded production since early 1986. And of course, many would ask, how can you do this. It's simple—you just take from inventory.

Fig 27 Inventories themselves have dropped from a level of about 17 million tons down to what we expect will be less than 6 million tons by the end of this year. If we continue on this pattern, we will have nothing left at this time next year. And, of course, a phosphate man today would tell you, boy we just don't have any inventory. And let me tell you—he's right.

Fig 28 So just as we've had restarts of phosphoric acid capacity in the United States, so too we will probably see increases or restarts within the Florida/North Carolina rock sector. Most notable amongst these would be the IMC/Grace Four Corners mine which has a nameplate capacity of approximately 5 million tons. If I was to have you focus on any part of this illustration, it would be the lower right hand corner. And that is, shipments are estimated to be 45 million tons this year. If Four Corners does not restart, which we think it will, inventories would go through the floor.

Of course the other factor in phosphate production is, sulphur, and we all look forward to hearing Cecilia Balazs's observations on just how much tighter sulphur supplies are going to get and what effects that situation will have on the phosphate industry.

Summing up now

Fig 29 In the world phosphate supply/demand the key points to note are that world demand is growing, in our estimate, about 2.3% a year. It could be higher. But, we do not feel a number of 4% is correct.

As Bill Sheldrick and many other people would say, the best prospects for market growth are in those areas with the most people and/or where there are programs that are striving to increase grain production in line with its population. Those areas would be Eastern Europe, China and India, among others.

We've said that the West European and North American Markets are mature markets. Well, that is a general statement, but in this year, that will not hold true.

Everyone knows that the Moroccans have recently announced a joint communique with Mitsui where they will be adding between now and the year 2000 an additional 5 million tons of P_2O_5 capacity starting around 1994 with an expansion at Jorf Lasfar. This will cause the North Africans, primarily Morocco, to garner a larger share of world trade.

In spite of this, between now and then, most experts would predict a narrowing supply/demand balance. We find this somewhat humorous, in that today, it's a very narrow situation as well.

And I won't overlook the fact that the U.S. will continue to be the world's largest phosphate producer and exporter. This may not hold true as we hit into the next century and given that phosphate rock resources in Florida are on the decline.

Fig 30 Focusing lastly on the United States phosphate summary, we see that the drought has made a one year correction in the U.S. grain situation.

It will encourage a large, approximately 10%, increase in planted acreage and translate into a 10% or more increase in phosphate consumption.

We see that this year we've had pipeline inventory buildup coming off of the last fertilizer year and probably somewhat this fall. But this will not affect consumption whatsoever. It will affect the pattern of domestic phosphate shipments.

We are presently enjoying a very low dollar. This low dollar will, we think, carry forward throughout 1989 and will benefit U.S. exports of phosphate chemicals. But as I pointed out, in order to continue this, raw materials will have to be there.

And with the phosphate rock inventories very low and projected to go lower, even though we've had some restarts of capacity, we think operating rates in 1989 will stay very high.

Of course, I guess, as we look over the history of the U.S. phosphate sector, we've seen the roller coaster rides. We've seen the pendulum swing, back and forth. 1989 and beyond will depend again on weather. It is our hope that the weather is normal and that the swings are not quite as sharp. But as I started out saying, it's a lot more fun to talk about the phosphate situation today, than it was two years ago. I hope two years from now it will be just as good for all of us.

Thank you very much.

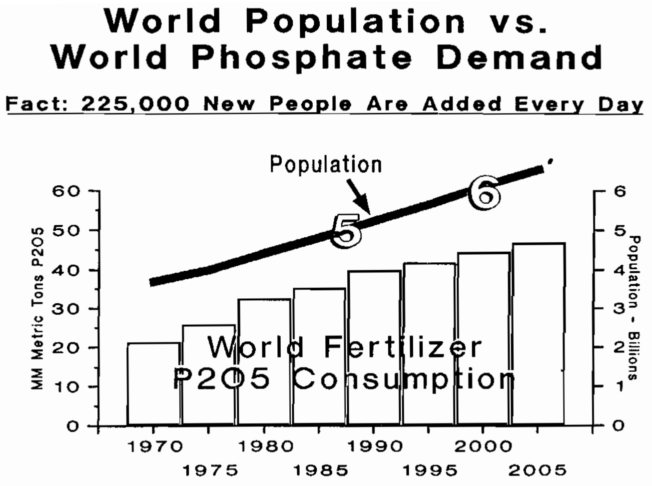


Figure 1: *World Population Growth vs. Phosphate Demand*

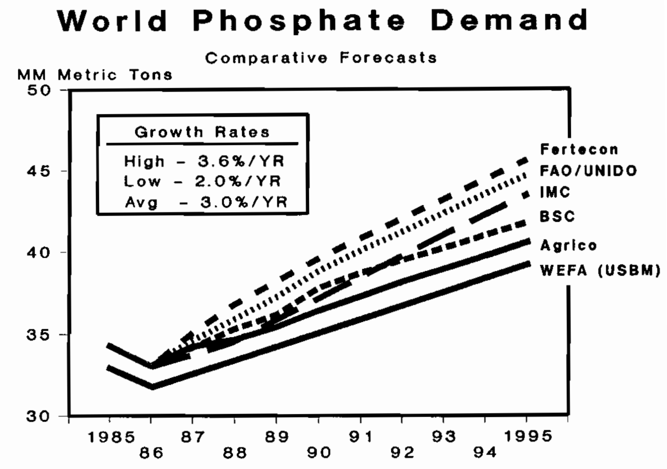


Figure 4: *World Phosphate Demand—Comparative Forecasts*

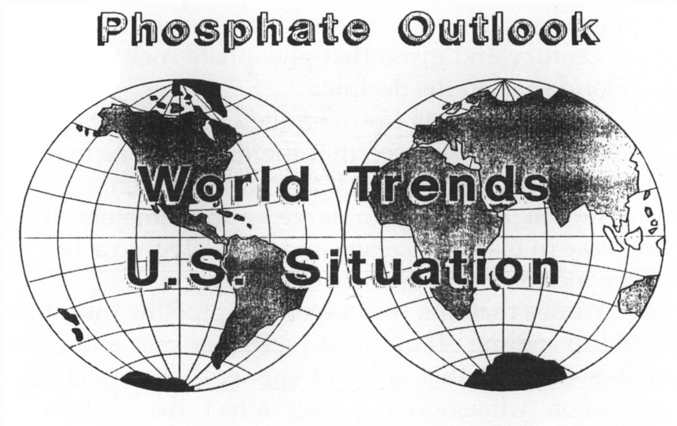


Figure 2: *World Phosphate Demand—Twin Globes (World/U.S.)*

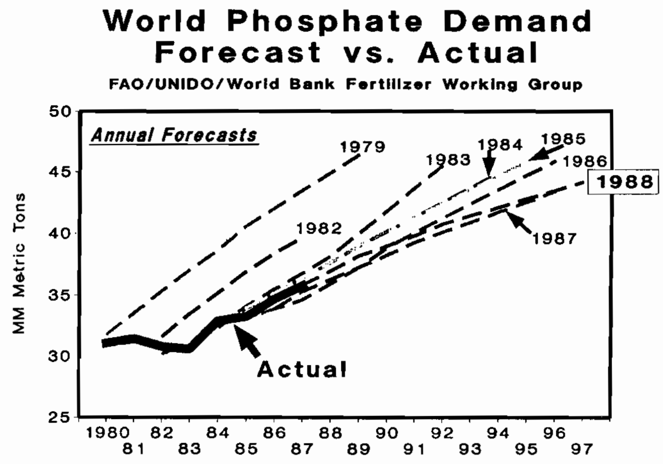


Figure 5: *Phosphate Demand Forecasts—Projected vs. Actual*

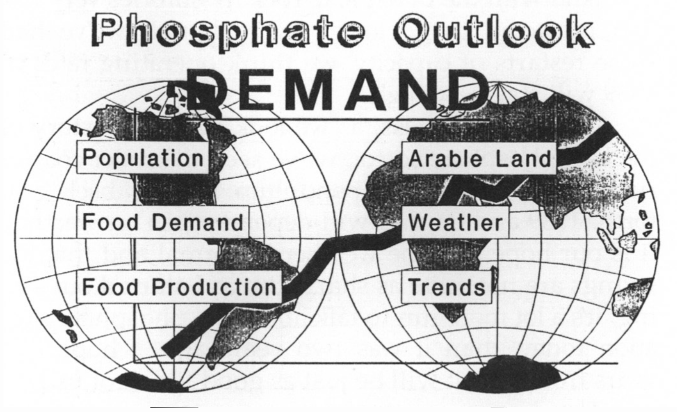


Figure 3: *World Phosphate Demand—Twin Globes (Demand Bullets)*

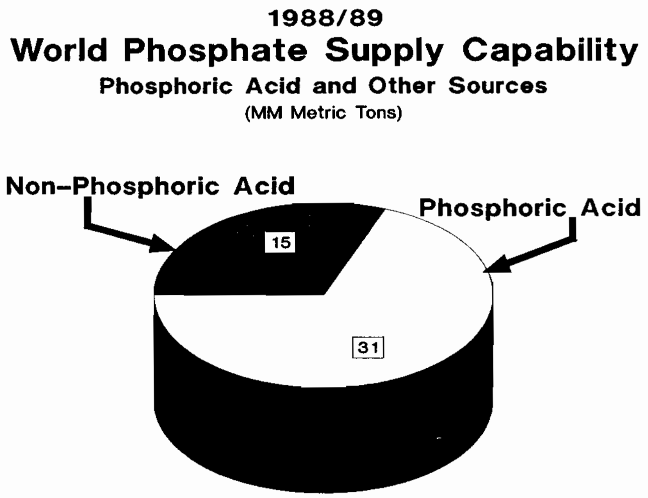


Figure 6: *World Phosphates Supply Capability*

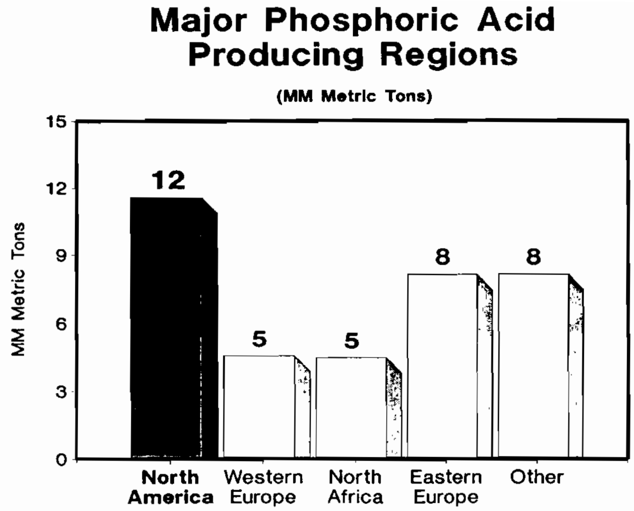


Figure 7: *Major Phosphoric Acid Producing Regions*

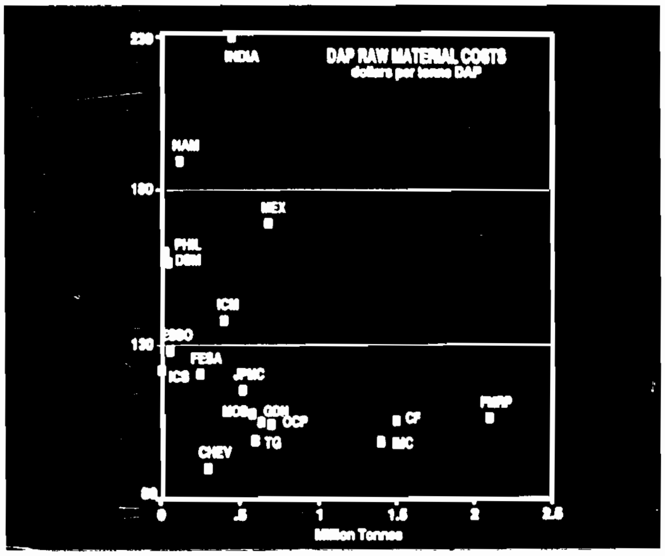


Figure 8: *DAP Raw Material Cost*

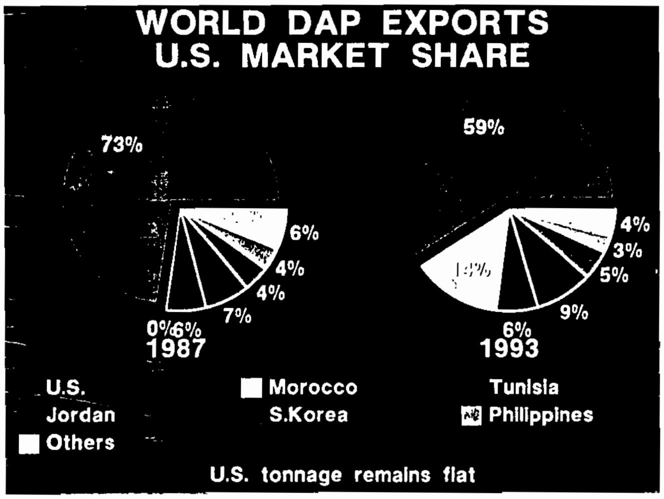


Figure 9: *World DAP Export—U.S. Market Share*

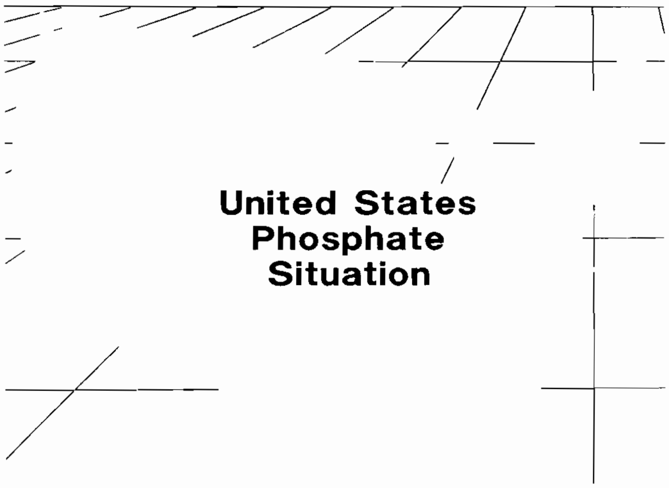


Figure 10: *United States Phosphates Situation*

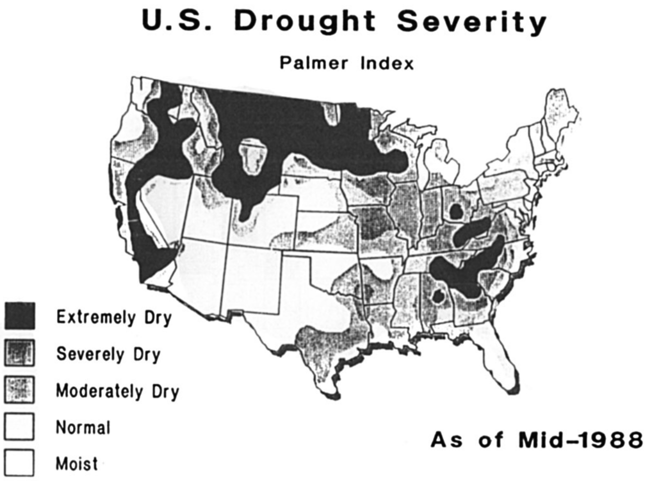


Figure 11: *U.S. Drought Severity*

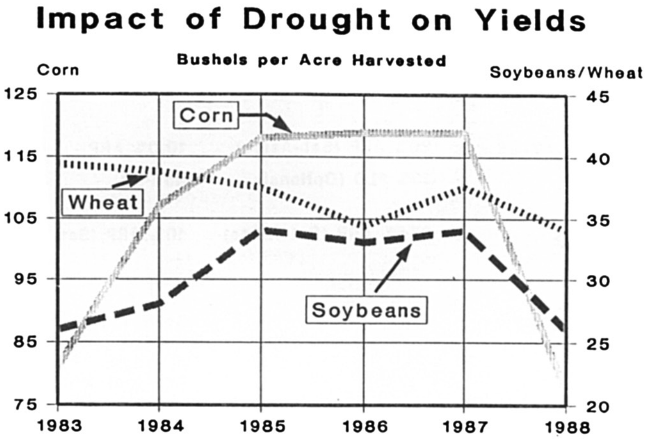


Figure 12: *Impact of Drought on Yields*

Major Grain and Oilseed Supply/Disappearance

Billion Bushels

	Feed Grains 1987/88	Feed Grains 1988/89	Wheat 1987/88	Wheat 1988/89	Soybeans 1987/88	Soybeans 1988/89
SUPPLY						
Beginning Stocks	6.1	5.4	1.8	1.2	0.4	0.3
Production	8.7	5.5	2.1	1.8	1.9	1.5
Total Supply	14.8	10.9	3.9	3.0	2.3	1.8
USE						
Domestic	7.4	6.9	1.1	1.0	1.2	1.1
Export	2.0	1.9	1.6	1.3	0.8	0.6
Total Use	9.4	8.8	2.7	2.3	2.0	1.7
Ending Stocks	5.4	2.1	1.2	0.7	0.3	0.1

Figure 13: *Major Grain & Oilseed Supply/Disappearance*

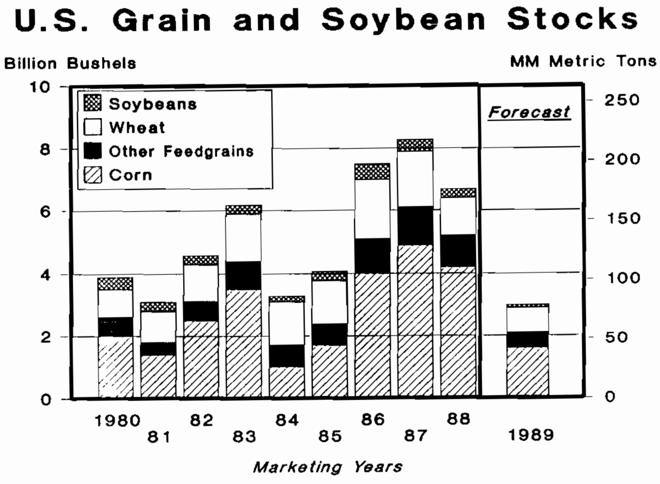


Figure 14: *U.S. Grain & Soybean Stocks*

Major Farm Programs

	1988	1989
Feedgrains	20% ARP (Set-Aside) 10% PLD (Optional)	10.0% ARP No PLD
Wheat	27.5% ARP (Set-Aside)	10% ARP (Set-Aside)
Soybeans	None	Soybeans can be * planted on 10-25% of Program Base Acreages without penalizing producer.

* *To be determined by Secretary of Agriculture*

Figure 15: *Major Farm Programs*

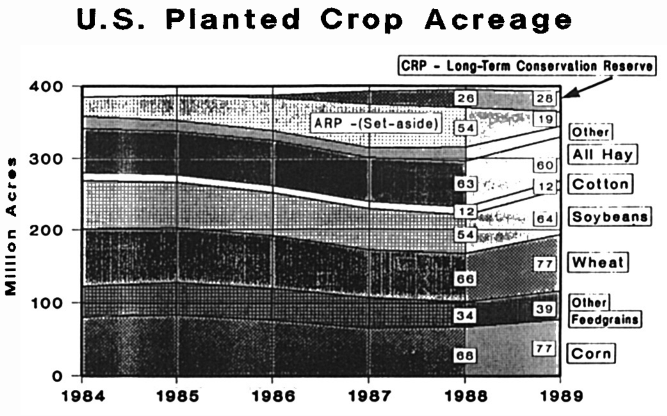


Figure 16: *U.S. Planted Crop Acreage*

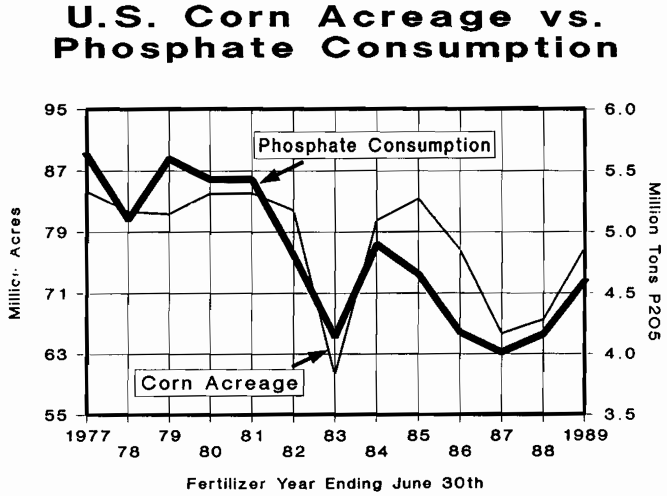
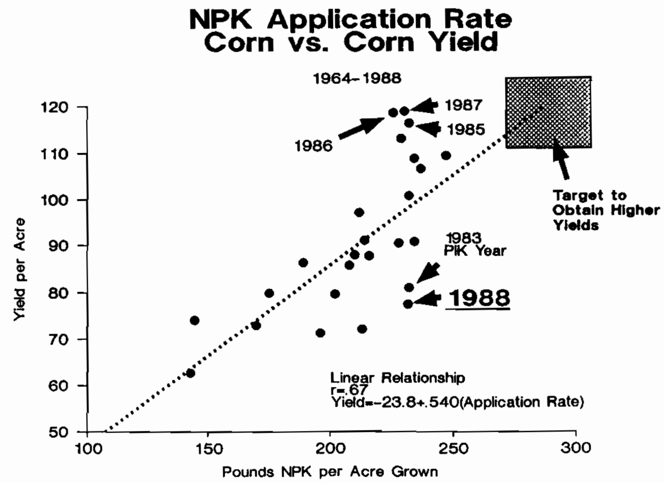
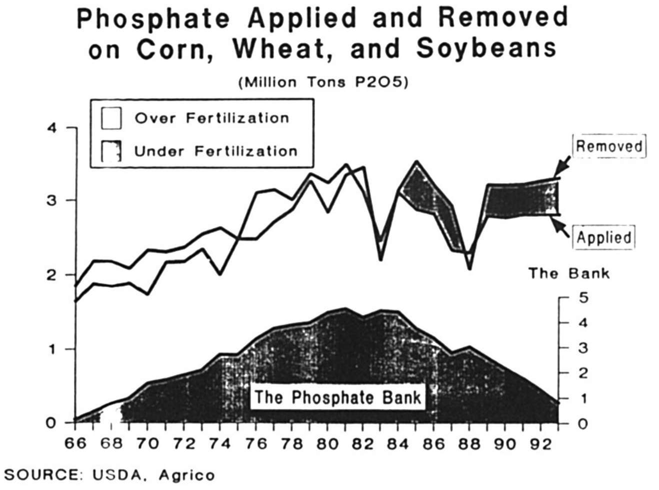


Figure 17: *U.S. Corn Acreage vs. Phosphate Consumption*



Source: DOANE, USDA

Figure 18: *NPK Application Rate Corn vs. Corn Yield*



SOURCE: USDA, Agrico

Figure 19: *Phosphate Applied & Removed on Corn, Wheat and Soybeans*

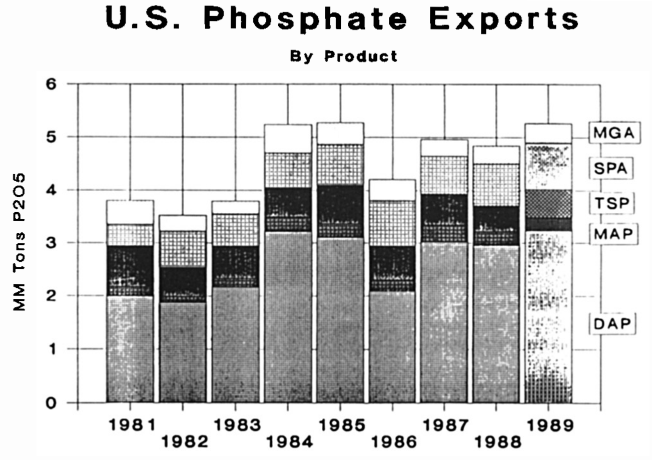
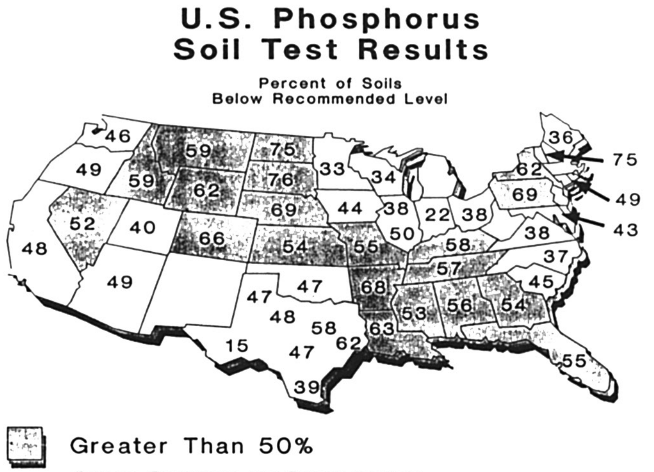


Figure 22: *U.S. Phosphate Exports*



Source: Phosphate and Potash Institute

Figure 20: *U.S. Phosphorus Soil Test Run*

U.S. Phosphoric Acid Capacity Developments

M Tons P2O5

Jan 1, 1987 Operating Capacity		**11,065**
Less 1987 Shutdowns		(645)
Taft, LA (Beker)	(525)	
Depue, IL (Mobil)	(120)	
Plus 1987 Re-Starts		310
Conda, ID (Nu-West)	310	
Jan 1, 1988 Operating Capacity		**10,730**
Less 1988 Shutdowns		
None		
Plus 1988 Re-Starts/Other		810
Piney Point, FL (AMAX/FCS)	190	
Pascagoula, MS (Miss Chem/Nu-South)	230	
Bonnie, FL (CFI)	200	
Other (Farmland/Royster/Seminole)	190	
Jan 1, 1989 Operating Capacity		**11,540**

Figure 23: *U.S. Phosphoric Acid Capacity Developments*

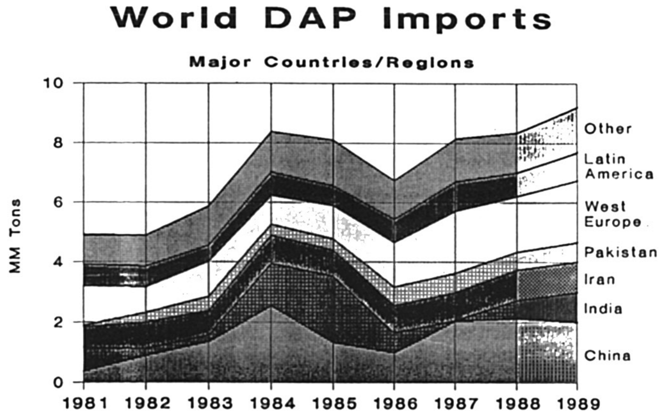


Figure 21: *World DAP Imports*

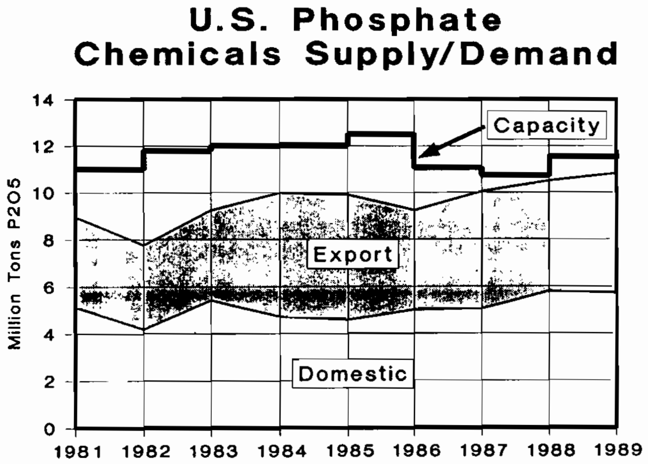


Figure 24: *U.S. Phosphate Chemicals Supply/Demand*

U.S. Phosphate Consumption vs. Producers' Domestic Shipments

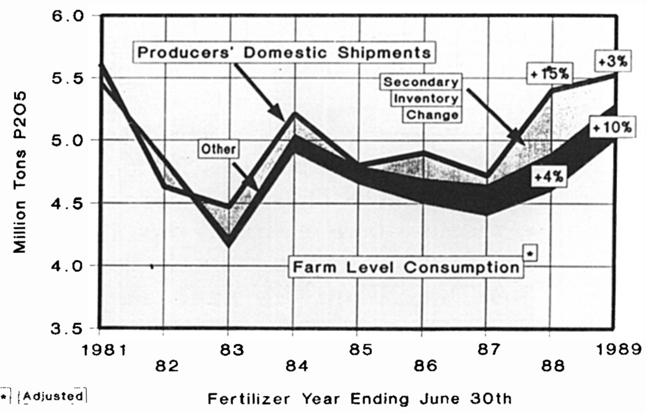


Figure 25: *U.S. Phosphate Consumption vs Producers' Domestic Shipments*

FL/NC Phosphate Rock Production vs. Shipments

By Half

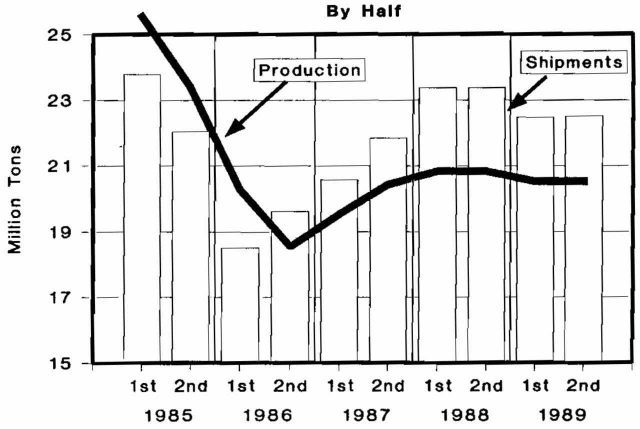


Figure 26: *FL/NC Phosphate Rock Production vs. Shipments*

FL/NC Phosphate Rock Inventory

By Half

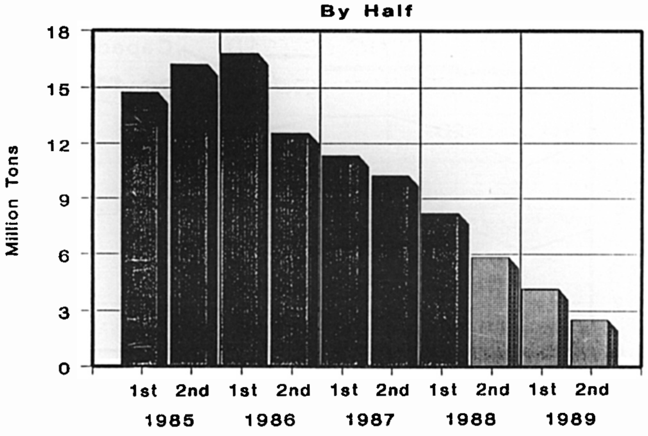


Figure 27: *FL/NC Phosphate Rock Inventory*

FL/NC Phosphate Rock Capacity Developments

MM Tons

Jan 1, 1988 Total Capacity		54.6
Idle Capacity		13.2
Estimated Production		41.4
Possible Re-Starts/Rate Increase		7.1
IMC/Grace Four Corners	5.0	
Nu-West Wingate Creek (Beker)	1.1	
Noranda Hopewell	0.5	
Mobil Nichols	0.5	
Possible Shut-Downs		(2.3)
Estech Watson	(1.4)	
Estech Silver City	(0.9)	
Jan 1, 1989 Operating Capacity		**41.2-46.2**
Estimated Shipments		**45.0**

Figure 28: *FL/NC Phosphate Rock Capacity Developments*

World Phosphate S/D Outlook

- ★ World P2O5 Demand Growth - +2.3%/YR
- ★ Best Growth Opportunities in East Europe and Asia (China and India).
- ★ Mature Phosphate Markets in North America and West Europe.
- ★ North Africa Will Account for A Larger Share of P2O5 Trade.
- ★ Most "Experts" Predict Narrowing Supply/Demand Balance
- ★ U.S. Will Continue To Be World's Largest Phosphate Producer and Exporter.

Figure 29: *World Phosphate S/D Outlook*

United States Phosphate Summary

- Domestic Phosphate Chemical Shipments Positively Affected By 1988 Drought
- FY88/89 Domestic Demand Robust
- Pipeline Inventory Build-Up in 1988
- 1989 Exports Expected to Reach Record Level
- U.S. Phosphate Rock Inventories Exhausted
- Continued High Operating Rates In Spite of Capacity Re-Starts

Figure 30: *United States Phosphate Summary*

The Outlook for Potash

Robert G. Connochie
Potash Company of America

I would like to thank the Fertilizer Industry Round Table for giving me my first opportunity to speak—in the United States—on the subject of potash. I'll be focusing my remarks in four major areas.

I'll start with a long-term forecast for potash supply and demand, and make some comments on apparent pricing trends. Our forecast will be similar, I am sure, to those you have seen in the past.

Although it represents the best thinking of PCA and of some people—such as Blue Johnson & Associates—upon whom we rely very heavily and for whom we have a great deal of respect, my next step will be to tell you why this forecast is wrong. The best of potash forecasts is almost inevitably wrong; so it is better that we recognize this up front, and discuss some possible ways to deal with the problem.

Since elements of the forecast suggest a better business environment for potash than the one we were suffering through a year or two ago, my third step will be to tell you what we think must happen to make this forecast right.

A forecast is only as good as its assumptions; and many of those assumptions hinge on how individual companies, who make up the fertilizer industry, will react to events. That brings me to my final point: what we can do about the future. There is much about the potential for potash which is encouraging; but how can we make it a reality? How can each of us manage our business more successfully? These are real questions which we must try to answer.

The demand side of the potash equation is relatively simple. We know of no information to contradict the conventional wisdom that:

1. World population will continue to increase.
2. Since much of this growth will be in countries where diet is now inadequate, aggregate food consumption must rise at an even faster rate.
3. There are limited opportunities—world-wide—to expand acreage under cultivation, therefore
4. Intensive farming—including optimal fertilization—is an inevitable part of the solution.

These assumptions underlie the forecast of potash consumption shown in Figure 1. The slope of the line—that is, the rate of growth—is not as great over the next seven years as it was in the seventies, but it is still impressive. The experts do not predict a recurrence of the zero-growth situation which we saw during the five years ending with 1986.

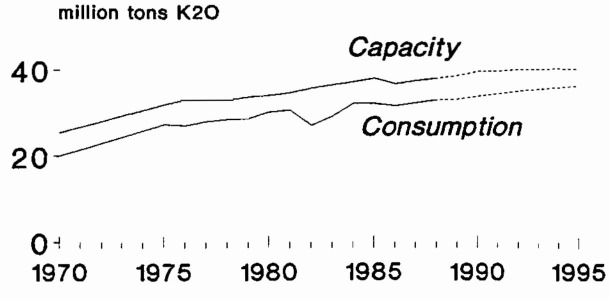
The supply side of the equation is a function of the installed capacity of producers, combined with operating rate. Our view is that:

1. For the medium-term (three to five years) there is adequate production capacity now in place. We estimate that 1988 production—world-wide—will be about 85 to 90 percent of capacity. Canada is operating at significantly lower rate; the rest of the world at a somewhat higher rate.
2. When more capacity becomes needed, the most economical approach, by far, is to expand existing facilities. There are a number of operations where expanded capacity can be brought onstream, on relatively short notice. PCA's New Brunswick mine, for example, could double its current 700,000-ton annual capacity, with a lead-time of two or three years. The economic return on that added capacity would be much more attractive than with any new facility.
3. For the longer term, there are a number of possible projects which have been identified for some time—Canamax in Manitoba, Kalium in Michigan, and BP in New Brunswick, to name three North American examples. Production from these projects may not be needed for many years; but in any event, because of the long lead-times involved, it is unlikely that their impact could be felt in the market before 1995 at the earliest.
4. And finally, unlike the case with many vital resources, there are abundant potash reserves in the world to meet all demand in the foreseeable future.

Referring again to Figure 1, supply-demand balance is reflected in the gap between the projected consumption and capacity lines. The gap in 1980—when the market was extremely tight—reminds us that demand does not have to equal capacity for a tight market and regional shortages to develop.

A few years ago, it was thought that we would see supply-demand equilibrium by the early 1990's. We now believe that it will be a few years later than that. Over the next five or six years, we will see a relatively

FIGURE 1
World Potash
Consumption and Capacity



Source: Blue Johnson

slow but steady narrowing of the gap. If this forecast is right, world production in 1995 will have to be at 90 percent of capacity to keep up with demand.

Turning now to the question of price—a few ground-rules need to be laid. We believe that the price of a commodity is a function of:

- its cost over the long term (and we should remember that full cost must include a sufficient profit element to induce producers to maintain their facilities and expand them as necessary),
- buyers' perceptions about the availability of the commodity,
- buyers' perceptions of the benefits which they will gain through use of the commodity.

On the first point—costs—a glance at some recent annual reports will show that potash prices—as they were two years ago—were not high enough to make potash production an attractive and reasonably profitable business for the long term.

On the second point—perceived availability—it seems that overcapacity will be with us for a few years more, but overproduction—especially in Canada—is, I believe, a thing of the past.

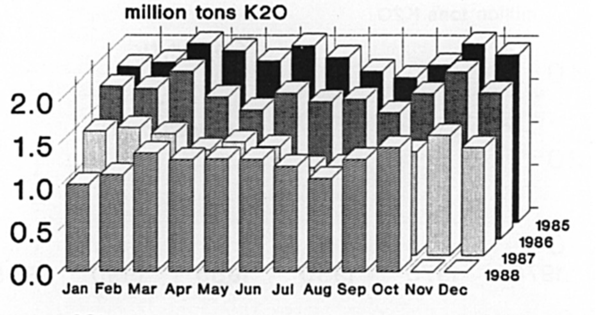
Canadian inventory levels have been found to be a fairly good indicator of short-term availability, at least in North America. In the graph in Figure 2, the bars in the back row show how over-production in 1984 and 1985 was reflected in excessive inventory by the end of 1985. By the end of 1987, levels may have become a little too low, given the amount needed to fill the pipeline, particularly here in the United States.

The moderate inventory levels of 1988 reflect rational production decisions which suggest reasonable availability but no oversupply.

On the third point—perceived benefits—we have already discussed the need for increasing food production. Organizations like the Potash & Phosphate Institute have shown conclusively the benefits of fertilizers in achieving that objective, and the economic gains which can accrue through the use of optimal fertilization.

FIGURE 2

Potash Inventory
Canadian Producers



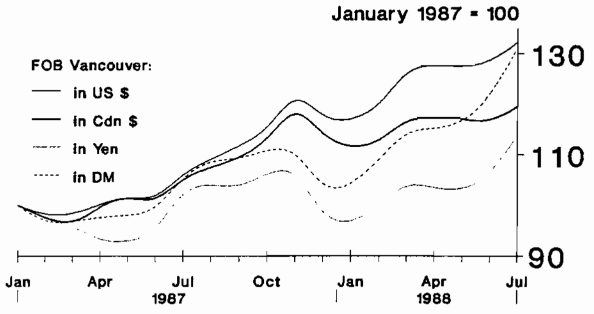
Source: PPI

We have not prepared a specific price forecast for this paper. One of the problems is that "price" means something significantly different to each one of us.

As an example, the graph in Figure 3 shows 18 months' history for Vancouver export pricing movement—calculated in different currencies at the monthly exchange rate. It is clear the price went up. But did it go up about 12 percent (as calculated in Japanese yen), 18 percent (as calculated in Canadian dollars) or over 30 percent (as calculated in U.S. dollars)? A sale to Japan is denominated in US dollars; but the fertilizer manufacturer's revenues may be in yen. PCA's production costs are in Canadian dollars. Which do you use, and what does it mean? We should remember also that pricing of Canadian potash moving into the United States market—during this same period—followed a very different pattern.

FIGURE 3

Potash Price Index
Four Major Currencies



A second problem is that one must have a clear understanding of the pricing point. With freight and other distribution costs a major pricing component, a price increase of 20 percent, FOB a mine in Saskatchewan, could mean a 10 percent increase, or less, delivered to a farmer in Iowa.

It is difficult, therefore, to devise a single, specific price forecast which would be useful to a wide audience. Nevertheless, we do have some fairly strong views about future price trends:

1. Prices have gone up substantially. They needed to, as was explained earlier. They are unlikely to fall significantly, even on a seasonal basis.
2. In the North American market, we expect further increases. These will be more modest than those of the past 18 months, perhaps more in line with the general rate of inflation.
3. In international markets, price increases may be more substantial, as these markets move into closer balance with the North American market.
4. These trends should continue for several years, perhaps until the mid-1990's, at which time (if supply and demand are in balance)

further real-terms price increases may be expected.

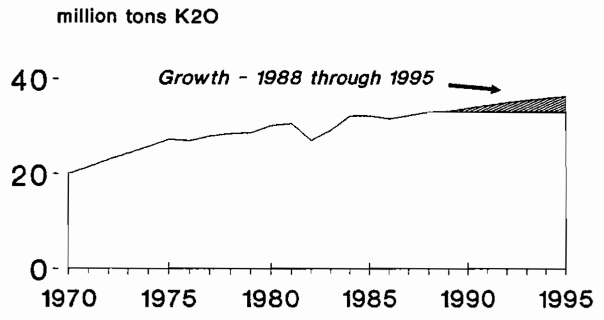
Well, why is this forecast wrong?

Like any forecast, this one is based on a set of assumptions which attempt to reduce complex relationships to manageable proportions. The problem is that such forecasts can, if not used carefully, lull us into a false sense of security because:

1. They may imply a sense of accuracy which is simply not possible. One should be particularly suspicious when projections of annual growth rates are carried out to the second decimal place.
2. They may bury the underlying assumptions on which they are based. We believe that it is far more important to understand the structure of the industry than to concentrate on refining forecasts.
3. Demand-side analysis tends to focus too much on growth. The graph in Figure 4, for example, contains a tiny wedge suggesting that incremental growth—by 1995—will account for just 9 percent of demand. The other 91 percent is demand existing now in 1988. Obviously we will—and must—respond to the demands of growing markets in developing economies. But we cannot afford to ignore the importance of existing buyers and changing conditions in the mature markets of the United States and Western Europe.

FIGURE 4

Growth in World Potash Consumption

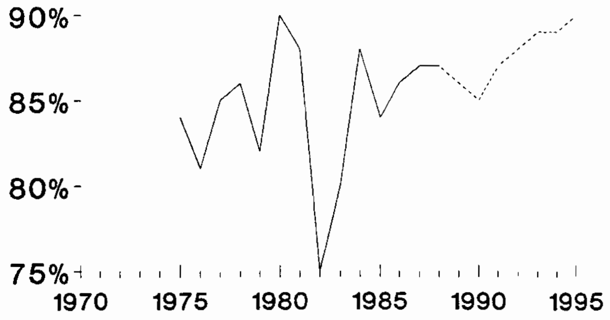


4. Forecasts usually have a hard time dealing with government action, and this is understandable. No forecast made in 1981 could (or did) consider the impact of the Payment-in-Kind program on 1982 and 1983 demand. No 1985 forecast could guess at the impact of the Antidumping action on prices in 1987 and 1988. Nor should we forget that a substantial proportion of the world's production facilities are under the direct control of government, or are subject to the influence of government. These various governments can, and do, respond to other than purely economic factors.
5. And finally, projections are always smoother than historical data. Our forecasts simply don't reflect the cycles. We don't capture the special events. Figure 5 shows a graph of operating rates, for example. The projection for the 1990's is fairly smooth. No one forecast the ups and downs of the past ten years, especially 1982, but it may be wishful thinking to expect that there will be no such ups and downs in the next ten years.

Right or wrong, our forecast suggests a more stable marketing environment, with the potential for improved profitability, for better prices (for the sellers) and for more reliable, financially healthy suppliers.

FIGURE 5

World Potash Operating Rate



By this point, I am sure you recognize that my point is not simply to convince you that the forecast is wrong, but to urge you to think about some fundamental points, and to exercise caution in how you use any forecast.

So what must happen to make this forecast right?

1. New production capacity must be introduced only when justified by sound economics, rather than motivated by government action—based on perceived regional or national interests.
2. Where possible, in developed countries, government policies must continue to support agriculture for food export.
3. In the United States, the current lobbying for so-called "Low-Input Sustainable Agriculture" (or "LISA" as it has become known—which translates into less fertilization, reduced yields and poorer crop quality) must be dealt with honestly and factually.

   The potash industry, largely through PPI, other industry associations and the universities, has always been a proponent of optimum input levels for sustainable agriculture. We believe that "optimum," by definition, includes evaluation of economic, environmental and quality factors. We believe that the application of this view has led to the current strength of the agricultural industry, which is of immense benefit to the entire country, and which is essential for its continue prosperity. LISA jeopardizes the continued achievement of these objectives.

4. For overseas markets, developing countries must have the money to grow food, and must understand the importance and the economics of fertilizer in achieving that objective.
5. And finally, the technology and infrastructure needed to get potash from a mine in Saskatchewan onto a rice paddy in China must improve and keep pace—in terms of production, transportation, handling and agricultural practices.

It is up to us—the industry—to make this happen.

North Americans, in particular, must not forget that we are competing in an international business. We compete against international competitors within the North American market and when we send our products offshore. This trend is likely to accelerate.

We must continue to work to maintain and improve farm productivity by encouraging optimal fertilization. In doing so, we must not neglect North American farmers, never forgetting that they remain the biggest single agricultural market in the free world.

We must continue to deal with environmental issues. Concerns are real, and strongly held by responsible people. Pressures to develop solutions will not go away but will intensify. Fertilizer products and application practices must continually improve to meet this need.

We must improve our ability to handle the cyclical nature of our industry. If we allow ourselves to be lulled into complacency in the good years or to sink into despair in the bad years, we run the risk of making serious strategic errors. Those of you in the producing side of the business, in particular, know how long such decisions can haunt you.

And finally, a simple reminder: a stable marketing environment for potash is founded on the long-term relationships between willing buyers and sellers.

PCA had some market research done earlier this year, to improve our understanding of how companies choose a potash supplier. We were not surprised that competitive pricing was found to be important. But what really jumped out at us was the heavy emphasis that buyers place on long-term relationships with a reliable suppliers.

This too was no surprise, but it is something that sometimes gets missed.

Our industry will be more prosperous to the extent that it doesn't get missed. Potash producers strive to develop long-term relationships with their customer-partners in order to provide the maximum in value-added service. We also believe that the most successful fertilizer companies will be those who recognize that indeed we are in the business together, and cultivate long-term relationships with reliable potash suppliers.

In conclusion, I believe

— That potash has a very strong future;
— That there will be unexpected ups and downs;
— That success will come to those who understand the industry and work to anticipate changes;
— That it will be a competitive industry, and that competition will be world-wide.

I also spoke of the need for relationships. I view the Fertilizer Industry Round Table as one of those excellent forums for the exchange of ideas and for the building of relationships. For this reason, I thank you for giving me the opportunity to speak to you today.

Outlook for Sulphur

Cecilia A. Balazs

The Sulphur Institute

I would like to take this opportunity to thank Bill Sheldrick and the Round Table for inviting me to discuss the outlook for sulphur with you today.

Since it is essential we understand past trends before we can make assumptions about the future, I would like to take just a few minutes to describe the important trends in the past two decades which have shaped the industry we know today.

SULPHUR SUPPLY

While annual sulphur production in all forms increased from 34 to 57 million tons between 1967 and 1987, most of this growth took place between 1967 and 1977, during which time production grew 17 of the 23 million ton increase, representing an average annual growth rate of 4.2%. Between 1977 and 1987, production rose by only six million tons averaging annual growth of only 1.1%.

In 1967, brimstone accounted for about half of world sulphur supply, but has now increased its share of total production to over 65%. Again, most of this shift took place between 1967 and 1977, and has remained about the same since then, picking up only a percentage point in market share since 1977.

Pyrites, which was over 30% of production in 1967, has lost market share and is now only 17%. We expect this declining trend to continue as environmental concerns increasingly affect cinder disposal.

Production of sulphur in other forms has remained relatively flat.

Brimstone production grew from 17.5 million tons to 37 million during the past two decades. However, brimstone is produced from several different sources, from the Frasch process, from native ore deposits, and recovered from oil and gas operations.

For many years, production of brimstone from the Frasch process dominated the market. However, during the past two decades the Frasch sulphur share of production has declined from almost 60% to less than 30%. Since mined sulphur is a discretionary source, its production can be adapted to changing demand patterns. Until recently, recovered sulphur was dependent on the demand for energy and thus the motivation to produce was entirely different. While recovered sulphur was once considered a byproduct, we now recognize that this is no longer the case, and sulphur revenues received from high and ultra-sour gas place recovered sulphur in a new perspective.

Perhaps equally as important is an analysis of geographical shifts in production. This chart plots historical production by major region. In North America, production grew about 40%, from 13 to 18 million tons, during the 1967–77 decade and has declined only slightly since then.

Western European sulphur production has remained level at between 7 and 8 million tons during the entire twenty-year period. Its position relative to Eastern Europe, however, fell dramatically during the past two decades.

Asia has tripled production, with most of this growth in China, where pyrites is the major sulphur source; and in Japan where recovered sulphur production dominates.

Dramatic growth has occurred in Eastern Europe, where sulphur production, mainly from Poland and the USSR, has increased 118%, from just under 8 million tons in 1967 to 17 million in 1987. The USSR is expected to become a more important factor in the future.

Included in our "Other" category with significant sulphur production are Latin America and the Middle East. Together with Africa and Oceania, these regions produced about three million tons of sulphur in 1967, with over two million of it coming from Latin America. However, production in Latin America has increased less than a million tons in the twenty-year period.

The Middle East produced almost nothing in 1967, but by 1987, production, principally from Saudi Arabia, Iraq and Iran, totalled just over three million tons.

SULPHUR DEMAND

What about the demand side of the sulphur equation?

In 1967, the world consumed 33.5 million tons. Consumption grew about 50%, or by 15 million tons during the 1967–1977 decade. However, as with supply, growth in demand slowed between '77 and '87, totaling 57.2 million tons in 1987.

This trend parallels world economic growth. During the '70's world GNP increased at a rate of between 4 and 5%, while the 1980's experienced a worldwide economic recession.

Geographical markets for sulphur are changing. North America, the largest consuming region tonnage-wise in 1967, remained relatively stable during the past twenty years.

Western Europe the second largest consumer in 1967, has remained at about 9 million tons.

Eastern Europe has continued a slow and steady expansion, eclipsing North American consumption by more than two million tons in 1987. Consumption in this region has more than doubled over the past two decades and now represents more than one quarter of the world's total.

The most significant growth has occurred in Africa, Latin America and Asia. Africa consumed less than a million tons in 1967 and now is approaching 5 million, a 400% + increase. Similarly, Latin American consumption has grown from about 800,000 tons in 1967 to over 3 million in 1987. In Asia, sulphur consumption totaled just under four and a half million tons in 1967. By 1987, this region was consuming over 9 million tons, a 110% increase. These three regions have become important markets for sulphur and this trend is likely to continue.

But geographical shifts in consumption patterns are not the only significant trend. An end-use analysis shows that, taken in the aggregate, non-fertilizer use of sulphur increased from 20 to 24 million tons between 1967 and 1987, but during the twenty-year period, its share of the market fell from 61 to 43%.

Use of sulphur in the fertilizer sector more than doubled from 13 million tons in 1967 to 33 million tons in 1987. During the period, its share of the total sulphur market increased from 39 to 58%.

Although sulphur use by the agricultural sector increased 20 million tons, its use to manufacture nitrogen and potassium fertilizers declined in market share and increased only modestly in tonnage.

Use of sulphur to manufacture phosphates had the greatest impact on sulphur and this market was vital to the success the industry experienced during the past two decades, accounting for 84% of increased demand.

However, if we segment the phosphate slice of our sulphur pie we can see that greater use of phosphate alone did not account for the increase in consumption.

Some phosphate fertilizers, such as diammonium phosphate (DAP), require nearly one ton of sulphur to produce a ton of P_2O_5, while others, such as nitrophosphate, require no sulphur. Between 1967 and 1987, the production of high-analysis phosphate fertilizer materials, such as DAP, increased from 11% of total sulphur consumption to 39%.

This rapid increase in the use of high sulphur-consuming technologies was the most important factor influencing global demand for sulphur, accounting for 18 of the 24 million ton increase.

Sulphur is an essential plant nutrient in its own right, required for a balanced fertilizer program. Where once it was added incidentally through application of single superphosphate and other fertilizers, as well as through the atmosphere, this is no longer the case and deliberate applications are made on all continents.

While sulphur as a plant nutrient was not a factor in 1967, by 1987, deliberate use of sulphur as a fertilizer totaled some 2 million tons.

FORECASTS OF SUPPLY AND DEMAND

What about the future? We have tried to give you a capsule presentation of the past twenty years, but we must now apply this insight to the future.

The Sulphur Institute works closely with the senior market research personnel from our member companies in developing an annual "Sulphur Outlook," which is presented to our Board of Directors each May.

The forecasts I will be presenting today represent the general consensus of our Market Study Group.

On the supply side, our forecast shows that sulphur production will increase from the present level of just under 57 million metric tons, to a little over 69 million by 1995.

This represents an annual growth factor of 2.5%.

Most of this growth will come from brimstone sources, accounting for 9.4 of the 12.5 million ton increase.

In the brimstone sector, the dominance of recovered sulphur will continue, and the market share of Frasch sulphur will decline from 28% to 24%. While we recognize that additional Frasch sulphur may result from exploration in the Gulf of Mexico and Egypt, we do not believe this will be a factor during the forecast period.

North American production is expected to increase by a modest 2.5 million tons reaching just under 20 million by 1995, with a substantial portion of this increase coming from Canada.

Western Europe is expected to remain at about the 8-million-ton level. Production in Asia is expected to increase by about 2 million tons to a total of about 12 million by 1995.

Latin America may only increase by about a half million tons during the forecast period. A factor in the Latin American picture, however, is Chilean sulphur and we are keeping a watchful eye on this source through The Sulphur Institute's member company in Chile.

Perhaps the biggest question mark of all is the Soviet Union and our Market Study Group follows developments in this region as closely as possible through on-site contacts at Astrakhan.

However, as you can see from these headlines, it was predicted some months ago that massive amounts of Soviet sulphur would come onto the marketplace by the late 1980's or early 1990's.

Opinion has now swayed in the opposite direction and some analysts are predicting that it will be the late 1990's before the market sees any Soviet sulphur, and then only about a million tons may enter world trade.

We take a somewhat conservative view of sulphur production in the USSR and are forecasting Soviet brimstone production will increase by about six million tons by 1995. We expect their pyrites production to decline by a half million tons or more, and smelter acid to increase only modestly.

NEW SOURCES OF SULPHUR

To supplement our evaluation of conventional sources of sulphur several potential large new sources are being examined, including recovery of sulphur at phosphoric acid plants and at coal-burning operations.

Phosphogypsum. Last year, 29 million tons of sulphur used to produce phosphate fertilizers, feeds, chemicals and detergents were converted into 160 million tons of phosphogypsum (PG).

The problems associated with PG disposal are (1) the large acreages needed for storage with the attendant cost and availability of land, and (2) the environmental concerns resulting mainly from the radium and cadmium contents of the PG.

The environmental concerns will in all probability increase and lead to stricter regulations on the disposal of PG, making both future storage on land or dumping in the sea increasingly difficult.

While there are a number of alternatives available to the phosphate producers, on balance, we consider it unlikely that there will be any major impact on sulphur consumption before 1995.

Recovery from coal. Sulphur recovery at coal-burning power plants could also have major impact on the sulphur industry.

Three billion tons of coal containing about 60 million tons of sulphur are consumed annually. Together, the USA, USSR and China account for two-thirds of world coal consumption.

Sulphur emissions legislation in the U.S. has been a regional issue with coal-producing states fighting legislation which would reduce their ability to compete with fuels produced in other areas. Other states, particularly in the Northeast have encouraged reduced sulphur emissions.

During 1988, the regional deadlock was broken when the governors of Ohio and New York worked out a compromise and submitted it to the Congress. The compromise, if passed, will commit an additional $2.5 billion for technological developments and reduce emissions by 1.75 million tons of sulphur by 1993 and 4 million by 1998. This would cut SO_2 emissions to about one-third what they were in the early 1970's. Again, Institute staff continuously monitor and evaluate the potential impact on the sulphur industry. We do not foresee any impact of sulphur from coal before the late 1990's.

WHAT ABOUT THE DEMAND SIDE OF THE EQUATION?

The Institute's Market Study Group has spent considerable time on this topic and is projecting sulphur demand from traditional sources will increase from 57 to approximately 67 million tons by 1995. About 70% of future growth will be the result of growth in phosphates.

Globally, phosphate fertilizer demand is expected to grow by about 2.8% per year, with higher growth rates for this and other fertilizers in the developing regions. The switch to the higher-analysis, sulphuric acid-based phosphatic fertilizers will continue, and phosphate demand will remain a critical factor in determining future sulphur consumption.

Growth in traditional non-fertilizer markets will remain relatively flat, with total non-fertilizer sulphur consumption growing by under two million tons between now and 1995.

The Institute's Market Study Group prepares forecasts of sulphur consumption regionally by fertilizer and non-fertilizer markets. As you can see here, North America does not show much growth, increasing only about 9% during the period, substantially all of which is in the fertilizer sector. Consumption in this region is expected to total about 14.5 million tons by 1995.

Western European consumption will decline, probably by half a million tons. Declines are expected in both fertilizer and non-fertilizer markets.

Consumption in Eastern Europe and the USSR will expand by over 3 million tons according to our projections. Both the fertilizer and non-fertilizer sectors will grow, with growth in fertilizers about a million tons higher.

Asia is a key region and by 1995, consumption of sulphur will reach almost 12 million tons. Most of this growth will be in fertilizers where more than two million tons of additional consumption are forecast.

African consumption will grow by almost two million tons as well, all of it in the fertilizer sector. Plans in Morocco include the building of a second Jorf Lasfar.

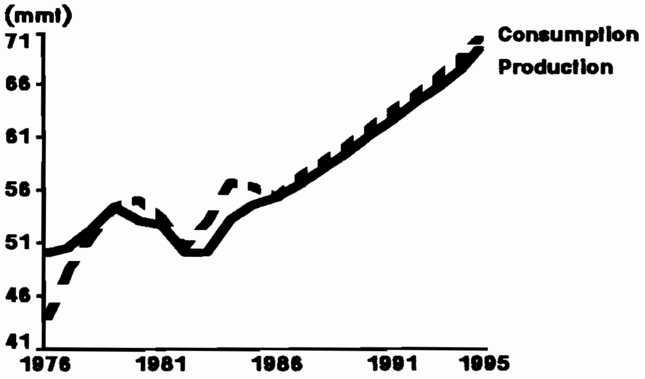
If we put these forecasts for supply and demand in traditional markets together, the picture is one of a balanced marketplace through 1990. Between 1990 and 1995 a surplus develops.

However, if we remove Eastern Europe from our world balance, the world is short two million tons of sulphur.

If we also consider the phenomenal growth in the demand for plant nutrient sulphur (PNS), our supply/demand balance shifts even further.

Sulphur is essential for plant growth, and is required by plants in similar amounts as phosphorus. In sulphur-deficient soils, plant nutrient sulphur removes constraints to crop production and increases N, P, and K fertilizer values. Sulphur is now recognized as the fourth major plant nutrient, following N, P and K.

World Sulphur Balance



Sulphur deficiencies are occurring with increasing frequency throughout the world and have been reported in seventy-two countries.

Deliberate applications of sulphur as a plant nutrient have increased at a very rapid rate. In 1975, application was less than half a million tons. By 1985, this total had reached 1.2 million tons. During the past 2 years alone deliberate application grew 67% to reach 2 million tons. We expect this to reach 5 million tons by 1995.

The Sulphur Institute has an active program of research, development, education and promotion to ensure that this growth continues, and when this growth in demand for plant nutrient sulphur is added to our world sulphur balance, The Sulphur Institute anticipates world demand for sulphur in 1995 will exceed supply by over 1 million tons.

Monday, November 14, 1988

Session II
Moderator:

Frank P. Achorn

Granular Ammonium Polyphosphate— Improved Form of Monoammonium Phosphate for Fluid Fertilizers

Byron R. Parker and Kenneth E. McGill
Tennessee Valley Authority

Ammonium phosphates have been commercially produced since the mid-1930s (*1*), but their production rapidly increased beginning in the early 1960s with the introduction of the slurry process using a preneutralizer and drum granulator (*2*). By 1968 ammonium phosphates had surpassed concentrated superphosphates as the leading phosphatic fertilizer in the United States and they have retained that position since (*3*). Diammonium phosphate (DAP) now accounts for 84% of the 12.8 million tons of ammonium phosphates produced in the United States (*4*), but with the advent of the pipe- and pipe-cross reactor processes developed in the 1970s (*5, 6, 7*), the production of monoammonium phosphate (MAP) has increased in recent years. But more significantly, as shown in the tabulation below, the percentage of bulk blend and suspension plants using MAP has increased during the period from 1980 to 1988 while the percentage using DAP has remained the same or declined (*8, 9*).

Many at TVA's National Fertilizer Development Center (NFDC) continue to believe that MAP deserves a closer look. It has the advantages of a higher phosphate content, excellent storage properties, and low ammonia evolutions during production. It can be readily produced with processes using pipe or pipe-cross reactors and drum granulators without any fossil-fuel drying required. It is an excellent intermediate for suspension fertilizer and can be produced from sludge acids.

Both granular MAP and DAP are well suited for direct application and for bulk blends, but their use in production of suspension fertilizers has grown more rapidly in this decade. Use of solid ammonium phosphates to produce suspensions is now a popular commercial practice because of advantages both in economics and convenience (*10, 11*). Often, solids are the least-expensive-delivered phosphate source for small producers, partly because of lower shipping rates for solids and because they can often be made from lower quality, less expensive acid. Storage of the solids is usually more convenient and economical than the storage of acids. The solids can be rapidly converted to suspensions with simple, economical batch equipment close to the point of use and, since the suspensions are not shipped long distances or stored for long time periods, the quality requirements can be somewhat less stringent than for base suspensions made in a large plant for wide distribution. Usually MAP is a better choice than DAP as a suspension intermediate. With MAP, only ammonia is required to adjust the ammonia-to-phosphoric-acid ratio to the desired range of maximum solubility. This ammoniation reaction generates heat to improve dissolution of the solids. With DAP, however, some additional phosphoric acid is required. Ammonia is readily available in most areas and is commonly stored; whereas, phosphoric acid storage presents more complications, especially for small producers.

Neither DAP nor MAP, however, contains polyphosphate, and suspensions made from these solids are generally inferior to suspensions that contain some polyphosphate. Studies at NFDC have shown that both grade and quality of suspensions can be improved significantly by making them from ammonium polyphosphate (APP) or ammonium polyphosphate sulfate (APPS) solids that contain part of their phosphate in the polyphosphate form. Advantages include the following:

1. Increased solubility
2. Sequestration of metallic impurities
3. Increased fluidity
4. Lower solidification temperature
5. More rapid disintegration and dissolution

Test data show that with a minimum of 10% of the P_2O_5 in the polyphosphate form, a base suspension of 12-36-0 grade can be made with a solidification temperature meeting the $-5°F$ NFDC specification for cold-weather storage and handling. In comparison, orthophosphate suspension made from MAP normally is limited to a maximum grade of 10-30-0 and has a solidification temperature of 0°F or higher. NFDC recommends that granular APP products to be used in production of suspensions contain at least 14% of the

P_2O_5 as polyphosphate to allow for losses during production and storage of suspensions. This paper addresses the competitiveness of granular APP with other ammonium phosphates and gives cost comparisons to assist in determining premium prices over MAP that can be justified.

PRODUCTION OF APP AND APPS BY PIPE-REACTOR/DRUM-GRANULATOR PROCESSES

By the beginning of this decade, a number of granular phosphate producers had already installed pipe or pipe-cross reactors in conjunction with drum granulators (*12, 13, 14, 15*). Results were energy savings, convenience, and improved product quality, and although production of polyphosphate was not an initial objective, NFDC realized the potential for modification of at least some of these plants to produce polyphosphate-containing fertilizers. Pilot-plant studies were carried out at NFDC to identify operating conditions and equipment required. As a result, at least two demonstration-scale plants have since been modified to produce quantities of granular polyphosphate fertilizers.

PILOT-PLANT STUDIES

Pilot-plant studies with processes using the pipe and pipe-cross reactors had been carried out in the 1970s, and by the early 1980s, emphasis shifted to fertilizers containing polyphosphate. Modifications to the process have been described in detail in past NFDC publications (*10, 11, 16*), and the process was demonstrated at the 14th TVA Demonstration of New Developments in Fertilizer Technology in October 1983 (*17*). A simplified process flowsheet is shown in Figure 1.

Initially polyphosphate levels of only 6 to 10% of the total P_2O_5 were obtained. To obtain the desired product polyphosphate levels, additional heat was required. By preheating the feed acid to approximately 240°F, a nominal 11-55-0 grade APP containing an average of 14% of its P_2O_5 as polyphosphate was produced. Similar results were obtained without preheating the feed acid by addition of 130 pounds of sulfuric acid (93% H_2SO_4) per ton of product to generate additional process heat. This is the maximum amount of sulfuric acid that can be added without exceeding the 10% maximum sulfate level in suspensions made from the granular product. Higher sulfate levels resulted in unacceptably high viscosities in the suspension product. This granular APPS product contained an average of 13% of its P_2O_5 as polyphosphate. In other tests, a nominal 12-53-0-2S grade APPS was made when only about 65 pounds of sulfuric acid was added per ton of product and an acid preheat interme-

DEMONSTRATION-SCALE PRODUCTION

NFDC produced nominal 11-55-0 grade APP from merchant-grade acid in a demonstration-scale plant from 1974 to 1983. A total of 200,000 tons of this product, containing about 20% of its P_2O_5 as polyphosphate, was made. It was highly satisfactory for direct application and bulk blending, and numerous laboratory and field tests showed the APP product to be superior to MAP in production of suspensions. However, because the process for making this APP used a pug mill and other nontypical equipment, it was not adopted by the industry.

Pilot-plant testing had indicated that APP could be produced using a drum granulator common to the fertilizer industry. As a result, two plants were modified to produce demonstration quantities of product. One plant was NFDC's demonstration-scale granulation unit at Muscle Shoals, Alabama. The other was a private fertilizer-industry plant located in central Florida. NFDC engineers worked jointly with plant personnel to develop process design and plant modification. Details can be found in a recent NFDC publication (*18*).

The central Florida plant produced a granular APP during two periods of operation in 1985 and 1986. During the first period, approximately 2,500 tons of nominal 11-52-0-2.4S APPS product was made. Some supplemental sulfate as sulfuric acid was added to the process. More than 7,000 tons of a nominal 11-56-0 grade material was produced during the second period. The products typically contained about 10 to 14% of their P_2O_5 in the polyphosphate form. Typical average analyses of the products are given in Table I.

During the same period, NFDC's demonstration-scale granulation unit was being modified to use the energy-efficient fertilizer process shown at the 15th TVA Demonstration of New Developments in Fertilizer Technology in October 1985 (*19*). A total of 2,035 tons of nominal 12-53-0-2S APPS product was made that contained an average of 12% of its P_2O_5 as polyphosphate. A typical average analysis of the product is also given in Table I.

PRODUCTION OF APP BY THE PIPE-REACTOR/ FALLING CURTAIN GRANULATION PROCESS

Pilot-plant investigation of the falling-curtain granulation process for production of granular APP is an outgrowth of NFDC technology developed for granulation of urea (*17, 19, 20*). Pilot-plant tests have indicated favorable results in the production of an 11-56-0 grade having good product qualities. This granular product is well suited for bulk blending because of its uniform sizing and also for making high-quality suspensions because it contains about 15% of the total P_2O_5 as polyphosphate. During the 15th TVA Demonstration of New Developments in Fertilizer Technology in October 1985 (*19*), the pilot plant was operated primarily to show that a granular APP product can be produced by this process, which is noted for its low energy consumption. Sulfuric acid is not used to provide heat in this process. A simplified process flowsheet is shown in Figure 2. The pilot-plant program is continuing, and several process variables are under study. This test program included initial contact with commercial producers to determine if there was a market for such a product (*21*).

Results thus far have shown that, compared with conventional pipe reactor/drum granulation of APP, the present process retains, in the product, a higher proportion of the polyphosphate that is developed in the pipe. This could be a significant advantage in production of high-quality product. Chemical properties of typical granular APP made by the falling-curtain process are given in Table I.

COST COMPARISONS USING APP, MAP, AND DAP

The feasibility of producing granular polyphosphate fertilizers has been shown, as have advantages of using these fertilizers, especially to produce suspension fertilizers. Whether these fertilizers will find a significant niche in the market will depend on the economics of both production and use. Costs given are not detailed, but are simple comparisons with the intent of showing relative advantages of ammonium phosphate fertilizers. The relative advantage may vary by company, plant, location, and time of the year.

Table II shows grade, acid concentrations required, and other pertinent operating conditions assumed for the ammonium phosphate materials. It is assumed the DAP is produced with the common tank preneutralizer, and the MAP and APP are produced with a pipe or pipe-cross reactor; all are granulated in a drum granulator. The production rates and acid feed temperatures are based on pilot- and demonstration-scale operations. The DAP is dried with a fossil-fueled rotary dryer; no drying is required for the MAP and APP. Formulations are shown in Table III along with ammonia and phosphoric acid costs, which are obtained from the 1987 Fertilizer Institute Production Cost Survey with adjustments to account for differing phosphoric acid concentrations.

Total production costs are given in Table IV. In addition to the raw material costs, the costs of further heating the feed acid to make APP, the drying costs for DAP, the fixed costs, and the inplant storage and shipping costs are included. The calculated total production cost of MAP is approximately $2/ton less than that for DAP and $9/ton less than that for APP. This is based on assumptions given in Tables II and III and although they may not be representative of an individual producer's costs, substitution of a producer's costs will allow recalculation of their relative product costs of the ammonium phosphates. A significant cost disadvantage is shown for APP, but this narrows when comparisons are made with sales prices from the October 3, 1988, issue of *Green Markets* for MAP and DAP and estimates from NFDC internal memorandums for the premium that could be charged for APP. MAP has a higher differential between sales price and production cost than DAP and APP, but for APP the differential may be higher or lower depending upon the premium price the market allows.

Table V shows the production costs compared also on the basis of P_2O_5 and plant nutrients. MAP has a lower production cost on a ton-of-product, P_2O_5, and plant-nutrient basis than DAP. APP has an advantage over DAP on a P_2O_5 basis and is slightly more expensive than MAP in all cases. However, to give a more balanced picture, production cost comparisons of both bulk blends and suspensions made from ammonium phosphates should be made. That information is given below.

Bulk Blends: The cost of making 1-1-1 ratio bulk blends at a Midwest U.S. location using either MAP, DAP, or APP is shown in Table VI. The ammonium phosphate prices are based on central Florida FOB sales prices from the October 3, 1988, issue of *Green Markets* with transportation to the Midwest added. Urea is used as a supplemental nitrogen source and granular potash as the source of potassium. Prices of these two materials are also delivered Midwest prices. Use of DAP gives a slightly lower blend, raw-material cost than MAP; and the cost with APP is less than $2/ton higher. In this instance, changes from the September 29 to October 3 sales prices given in *Green Markets* changed the relative order of the phosphate sources and increased the differential between APP and DAP by almost $1.50/ton. This indicates that the choice of ammonium phosphate source is not a simple choice, but should be based on the prevailing prices at the time and place of production. With other advantages previously stated, APP may still be an excellent choice of a granular phosphate for use with blends.

Suspensions: Comparative raw-material costs of making suspensions at a Midwest location from MAP and APP are given in Table VII. It is assumed that a base suspension of a 10-30-0 grade is made, and to obtain similar quality suspensions, 14% of the phosphate is included in the formulation as polyphosphate. The polyphosphate is furnished either by APP or by supplemental 10-34-0 solution when MAP is used. Anhydrous ammonia is used as the supplemental nitrogen source. The raw materials cost/ton of the base suspension containing polyphosphate is more than $10 less using APP than when MAP is used.

A more surprising result is the comparison of the use of APP and of MAP as the only phosphate sources. The raw-material cost of the suspension made with APP is lower by almost $3/ton, and as an added bonus, this suspension containing polyphosphate has production advantages and will be of superior product quality. Some of this is due to the differing phosphate contents of the solid ammonium phosphates and is dependent on the assumed price premium for APP. As this premium changes, so would the relative raw-material costs of the suspensions.

SUMMARY/CONCLUSIONS

The feasibility of producing granular APP has been demonstrated using the pipe- or pipe-cross reactor and drum-granulator process and later with an improved process using a falling-curtain drum granulator. APP also has distinct advantages over other ammonium phosphates, especially when solids are used to make suspension fertilizers.

The economic feasibility of producing and using APP may not have yet been conclusively shown in the market. This study, however, indicates cost advantages of using APP rather than MAP for making suspensions and indicates that, depending upon actual prevailing conditions in the market, APP will likely be competitive for direct and bulk-blend applications. NFDC continues to recommend that both producers and consumers look to APP as a substitute for both MAP and DAP, and let their actual costs and market potential dictate the selection of an ammonium phosphate product.

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TABLE I
Typical Analysis of Granular Polyphosphate Products

Plant[b]	Product[c]	Chemical analysis, wt % N	P_2O_5	S	H_2O	Polyphosphate, % of P_2O_5	Sulfuric Acid,[a] lb/ton product	Production Tons	Date
Pilot-plant production									
GPP	APP	12.5	55.4	—	0.6	14	0	52	Jun 1984
GPP	APPS	12.6	53.6	2.0	0.7	13	67	21(est)	May-Jun 1985
GPP	APPS	12.5	51.7	2.9	0.8	13	130	16(est)	Apr 1983
CGPP	APP	11.0	56.0	0.4	0.5	14	0	30(est)	1985-1988
Demonstration-scale production									
PI	APPS	11.3	52.3	2.4	0.3	11	—	2,500(est)	Apr 1985
PI	APP	11.3	56.4	1.2	2.0	12	0	7,045	Feb-Mar 1986
NFDC	APPS	12.1	52.9	2.0	0.4	12	65	2,035	Aug-Sept 1985

[a] Sulfuric acid of nominal 93% H_2SO_4 concentration.

[b] GPP = Granulation pilot plant, NFDC, Muscle Shoals, Alabama.
CGPP = Curtain-granulation pilot plant, NFDC, Muscle Shoals, Alabama.
NFDC = TVA's National Fertilizer Development Center, Muscle Shoals, Alabama.
PI = Private industry commercial plant, central Florida.

[c] APP = Ammonium polyphosphate.
APPS = Ammonium polyphosphate sulfate; sulfuric acid fed to process.

TABLE II
Production Data for Calculating Production Costs of Ammonium Phosphate (AP) Fertilizers

Product	Nominal grade	Process[a]	Production rate, ton/h[b]	Feed phosphoric acid Temp, °F	Conc, % P_2O_5	Energy requirements, Btu/ton AP product Acid preheat	Drying
MAP	11-52-0	PR	65	150[c]	47	0	0
DAP	18-46-0	PN	50	150[c]	40	0	300,000
AAP	11-55-0	PR	65	250[c]	54	110,000	0

[a] PR = Pipe- or pipe-cross reactor and drum-granulator process.
PN = Preneutralizer and drum-granulator process.

[b] Based on production experience in a central Florida granulation plant.

[c] Assuming acid leaves evaporators at 150°F. For APP, acid is further heated to 250°F with steam in a shell-and-tube heat exchanger.

TABLE III
Raw Material Costs for Calculating Production Costs of Ammonium Phosphate (AP) Fertilizers

Raw material	Formulation, lb/ton MAP, 11-52-0	DAP, 18-46-0	APP, 11-52-0	Raw-material cost, $/ton NH$_3$[a]	P$_2$O$_5$[a]	MAP, 11-52-0	DAP, 18-46-0	APP, 11-55-0
Ammonia, NH$_3$	277	514	300	103.37	—	$ 14.31	$ 26.58	$ 15.51
Phophoric acid								
40% P$_2$O$_5$	—	2,300	—	—	204.74[b]	—	94.18	—
47% P$_2$O$_5$	2,213	—	—	—	208.23[b]	108.28	—	—
54% P$_2$O$_5$	—	—	2,037	—	211.72	—	—	116.45
				Total raw-material cost	=	$122.59	$120.76	$131.96

[a] Weighted average of production costs from "The Fertilizer Institute Production Cost Survey for the Year Ended December 31, 1987."

[b] Prices adjusted from the 54% P$_2$O$_5$ cost basis to reflect the decreased cost of concentrating the acid to a lower concentration. It was assumed that 3.5 million Btu's were required to concentrate a ton of P$_2$O$_5$ from 40% to 54% concentration at a cost equivalent to $2/million Btu's.

TABLE IV
Total Production Costs of Ammonium Phosphate (AP) Fertilizers

Product	Production cost, $/ton AP product Raw[b] materials	Acid[c] preheat	Drying[d]	Fixed[e]	Inplant shipping and storage	Total	Sales price,[a] $/ton product FOB plant	Delivered[f]
MAP	122.59	—	—	11.47	3.00	137.06	172.50	194.50
DAP	120.76	—	0.60	14.91	3.00	139.27	164.50	186.50
APP	131.96	0.32	—	11.47	3.00	146.75	177.50[g]	199.50

[a] Obtained from *Green Markets*, October 3, 1988, for central Florida plant FOB prices.

[b] From Table II.

[c] Assume excess steam from sulfuric plant that can not be used to cogenerate electricity sold at $0.01/kWh (1 kWh = 3,414 Btu).

[d] Based on use of natural gas at $2/million Btu.

[e] Fixed cost of $696/hour estimated from "The Fertilizer Institute Production Cost Survey for the Year Ended December 31, 1987." Basis was use of a DAP plant with a production rate of 50 tons/h and capacity of 65 tons/h.

[f] Includes estimated transportation cost by barge from central Florida to Midwest of $22/ton product; cost by 95-ton railcar would be $39.03/ton product.

[g] Premium over MAP prices estimated based on unpublished, internal NFDC memorandum dated November 9, 1987.

TABLE V
Comparison of Ammonium Phosphate (AP) Production Costs on Different Bases

Material Nominal grade	MAP 11-52-0	DAP 18-46-0	APP 11-55-0
Production cost, $			
Product, ton	137.06	139.27	146.75
P$_2$O$_5$, ton	263.58	302.76	266.82
Plant nutrient, ton	217.56	217.61	222.35

TABLE VI
Raw-Material Cost of 1-1-1 Ratio Bulk Blend[a]

Phosphate source	Raw materials Source[c]	Requirements, ton/ton AP product	Cost $/ton	$/ton AP product
MAP	MAP, 11-52-0	0.3626	194.50[b]	70.53
	Urea, 46-0-0	0.3232	147.50[d]	47.67
	Potash, 0-0-60	0.3142	125.00[d]	39.28
				157.48
DAP	DAP, 18-46-0	0.4210	186.50[b]	78.51
	Urea, 46-0-0	0.2563	147.50[d]	37.80
	Potash, 0-0-60	0.3227	125.00[d]	40.34
				156.66
APP	APP, 11-55-0	0.3481	199.50[c]	69.45
	Urea, 46-0-0	0.3329	147.50[d]	49.10
	Potash, 0-0-60	0.3190	125.00[d]	39.88
				158.43

[a] Nominal 19-19-19 grade.

[b] *Green Markets*, October 3, 1988, FOB plant sales price, central Florida, with transportation cost to Midwest added (see Table IV for details).

[c] All products are granular.

[d] *Green Markets*, October 3, 1988, sales price Midwest or mid-corn belt.

TABLE VII
Raw-Material Costs of 10-30-0 Base Suspension

Phosphate source	Raw materials Source	Requirements, ton/ton AP product	Cost $/ton	$/ton AP product
MAP	MAP, 11-52-0	0.4527	194.50[a]	88.05
	10-34-0, 65% poly	0.1900	177.50[b]	33.73
	Ammonia	0.0379	127.50[b]	4.83
	Clay	0.0200	106.00[c]	2.12
	Water	0.2994	0.08[c]	0.02
				128.75
MAP	MAP, 11-52-0	0.5769	194.50[a]	112.21
	Ammonia	0.0444	127.50[b]	5.66
	Clay	0.0200	106.00[c]	2.12
	Water	0.3587	0.08[c]	0.03
				120.02
APP	MAP, 11-55-0	0.5455	199.50[a]	108.83
	Ammonia	0.0486	127.50[b]	6.20
	Clay	0.0200	106.00[c]	2.12
	Water	0.3860	0.08[c]	0.03
				117.18

[a] Granular.

[b] *Green Markets*, August 29, 1988, Midwest delivered price.

[c] NFDC internal cost estimates.

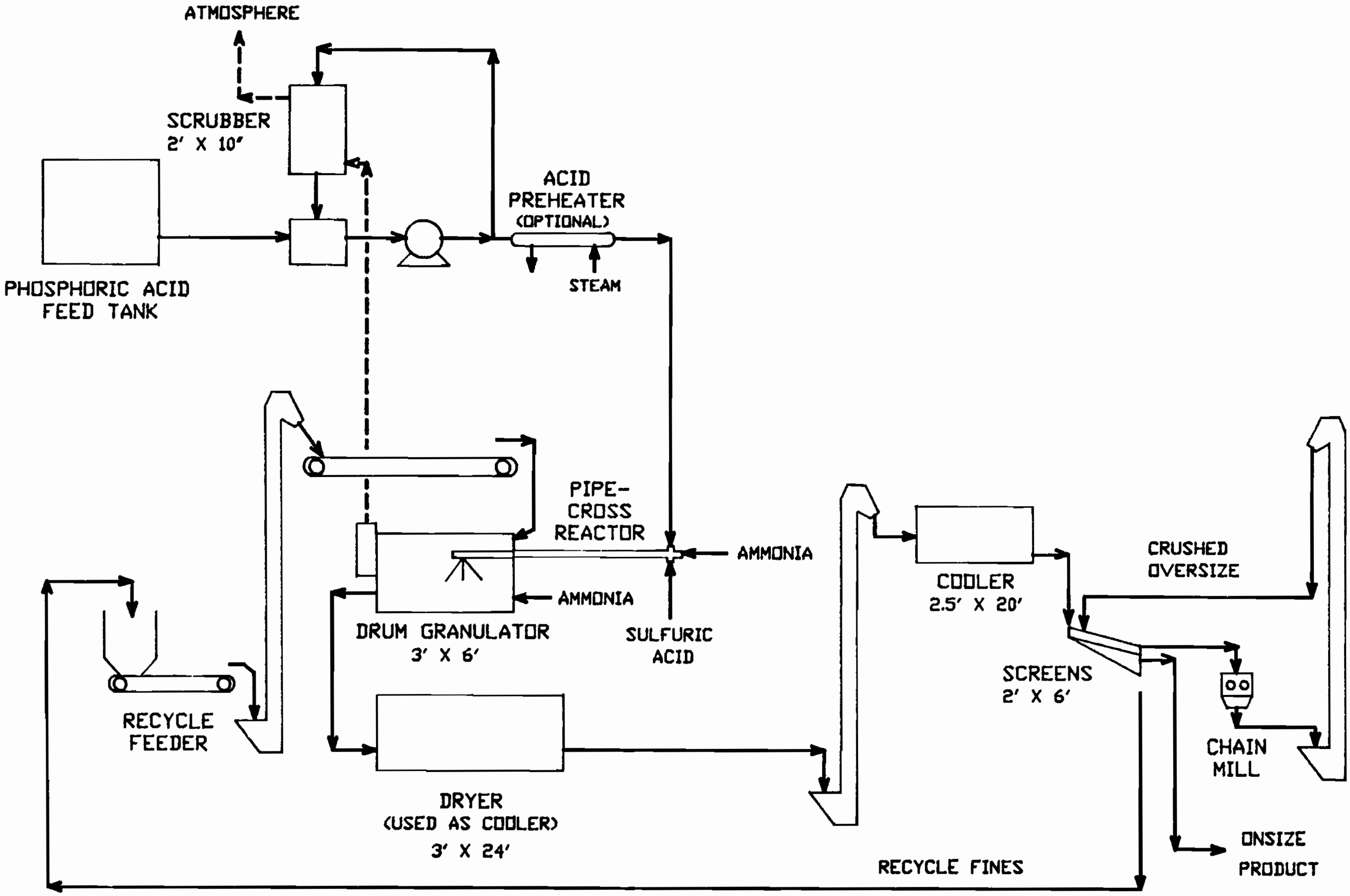

FIGURE 1

Process Flow Diagram of NFDC Granulation Pilot Plant for

Production of Granular Polyphosphate Fertilizers

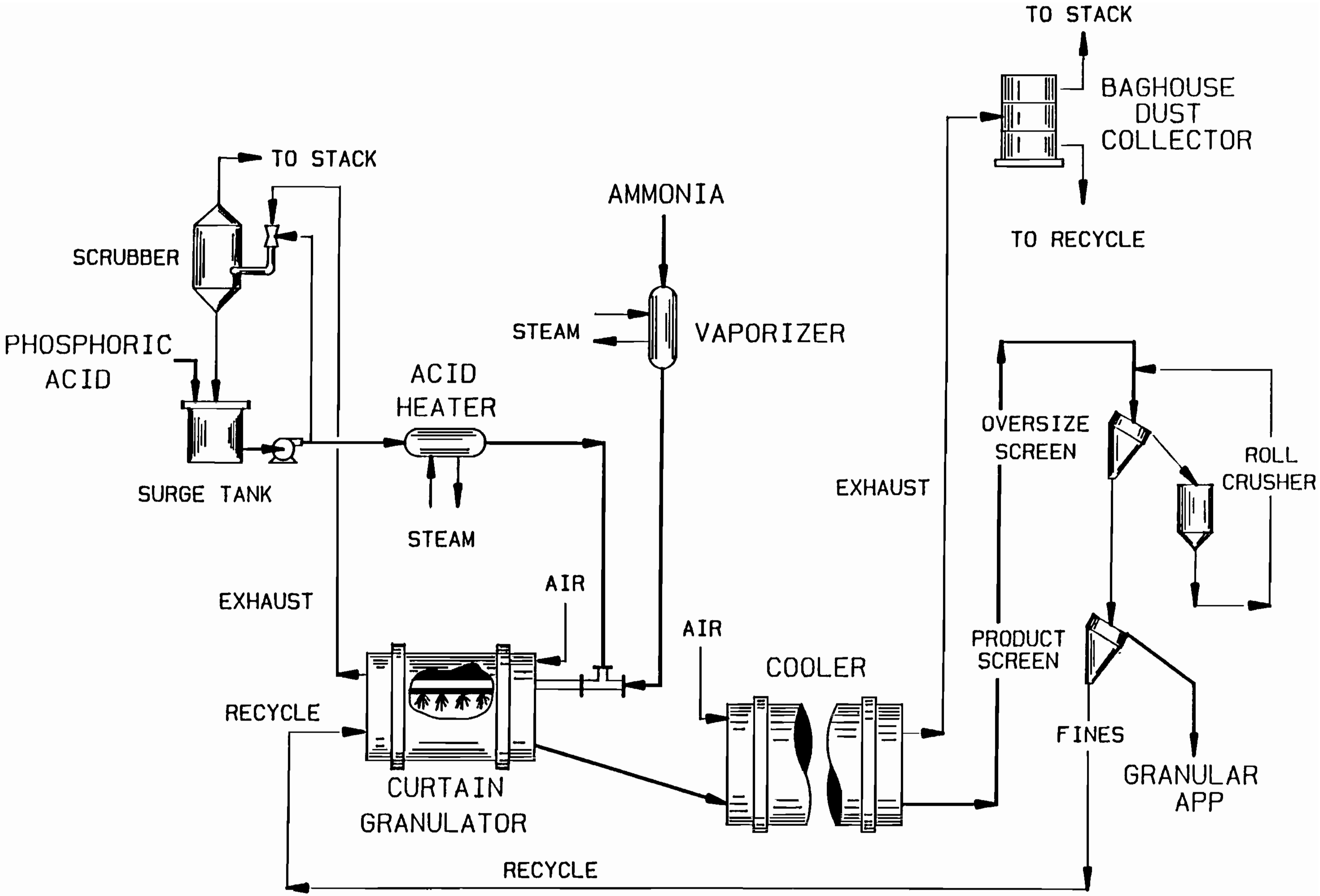

FIGURE 2

Pilot Plant for Curtain Granulation of Ammonium Polyphosphate

Compaction of NPK Fertilizers for the Guatemalan Market

Mark A. Swisher and Cristian Rodriguez
Fertilizantes Quimicos De Guatemala
Ferquigua

Our fertilizer group is now 11 years old. The oldest bulk blending plant was built in 1977 on the south coast of Guatemala in Escuintla. Granular bulk materials were imported through El Salvador to our first plant which has a bulk capacity of 6,000 MT and a bagged capacity of 20,000 MT. This plant rapidly became too small for the market with the abandoning of Guatemala by Fertica and the immediate acceptance of blended product by our customers, therefore a second facility was constructed on the same site and on stream by 1979. It has a bulk capacity of 17,000 MT and a bagged capacity of 8,000 MT.

Due to political problems in El Salvador which continue to this day, using the Acajutla port of El Salvador became dangerous. Consequently in 1980 a port facility was constructed 5 km from the Guatemalan Atlantic port of Santo Tomas. Not only did this facility supply the Escuintla plants with raw materials but also opened new markets for us, including Del Monte Banana Company, whose installations are 45 km from our plant. This plant also made possible the construction of a new blending plant in Teculutan, 175 km from Santo Tomas, which began operations in 1982. The Atlantic facility holds 10,000 MT of bulk and 3,000 MT of bagged product. It can receive up to 3,000 MT/day using our own discharging equipment and out load 2,000 MT/day of bulk or bagged product. The Teculutan plant holds 16,000 MT of bulk product after a 25% capacity expansion in 1987, and 6,000 MT of bagged product. Our present "modus operandi" calls for Teculutan to supply the Atlantic half of the country, while Escuintla supplies the Pacific. Teculutan uses 13 different raw materials including granular urea, granular ammonium sulphate, CAN, DAP, MAP, TSP, granular MOP, potassium nitrate, potassium sulphate, kiserite, boron and other micronutrients, while Escuintla basically uses only 6 of the above raw materials. The current of 1988 shows production of 40,000 MT of NPKS in Teculutan, 40,000 MT of NPKS in Escuintla plus 50,000 MT of straight raw materials, basically urea and ammonium sulphate, while Santo Tomas bags 60,000 MT of urea, ammonium sulphate, standard MOP, potassium nitrate, CAN, etc.

Even though bulk blends have a wide acceptance in Guatemala, especially with the progressive farmer, partly because of our insistence on use of only granular products, a small portion of the market has never accepted blends, preferring one color homogeneous NPKS from Europe. Until 1984 our company imported small quantities of these NPKS to satisfy this portion of the market. Our competition in Guatemala is basically importers who buy bagged NPKS from Eastern Europe, and who have successfully exploited this lack of confidence in the blends. Therefore, in 1986, studies were started on inventing a way of producing an homogeneous NPK fertilizer in a plant size compatible with the Guatemalan market. Besides trying to capture the 20–30% of the NPK market that never bought from us, other considerations were obtaining lower raw material costs by buying standard products instead of granular products, lower final product costs by using a filler containing local raw materials, complementing our existing bulk blend plants by producing granular products emphasizing local products, and doing all this with a plant small enough to be economical.

After much discussion, compaction was decided to be the best alternative to fit the objectives, and after visiting distinct facilities in Canada, Ohio and Europe, Koppern compactors were decided to adequately fit our needs. Sackett has been with our company since our first bulk blending plant 11 years ago. All of our blending equipment and discharging equipment in all our plants was bought from Sackett and assembled by us. All of our personnel, upon consultation, wanted to take advantage of this relationship between Sackett and our company, therefore the final deal called for Koppern to supply two 750 mm by 430 mm roller presses with its accompanying equipment of force feeders, hydraulic pumps and grease pumps, while Sackett supplied the engineering and critical feeder equipment. We assembled the plant and fabricated hoppers, ducts, elevator segments, etc. on location in Teculutan. Construction of a prestressed concrete structure was begun in November of 1985 and production began in March of 1987.

Costs of the final installation can be broken down as follows;

1. Building-4700 sq m building to house machinery and 25,000 MT of bulk product, compaction facility and 5,000 MT of bagged product . . . USD600,000
2. Koppern equipment of 2 compactors, accessories and spare parts . . . USD900,000*
3. Sackett equipment and engineering . . . USD800,000
4. Local construction costs including electrical installation, labor, etc. . . . USD200,000

After many fits, and false starts, the plant started production in March of 1987 and compacted 23,000 MT of NPKs from March to October. After a two month shutdown period to modify certain aspects of the production facility, we started up in February of this year and to date have compacted 50,000 MT of NPKs this year; acceptance of the product has been so good that our production capacity of 8,000 MT per month has been reached three times this year. Basi-

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* Exchange rate 1986 was USD 1.00 = 2.70 DM, now USD1.00 = 1.80DM.

cally we produced 25,000 MT in three months and didn't have the capacity to satisfy the market, therefore, we are seriously considering an expansion in 1990 to three production lines, or three compactors.

The flow sheet of the plant in descriptive terms starts with front end loaders, which feed a bulk conditioner, which in turn feeds six material bins. A Toledo batch computer prepares the individual batches, feeding the product into a weigh hopper first, then to a four ton rotary blender. A second elevator raises the product to a double row cage mill, which grinds the product (basically urea) to $-60+100$ Tyler mesh, before depositing the mixed and ground product into a primary hopper. Recycle product and primary product are mixed in a pug mill before passing over magnetic humps and splitting the flow into two flows, where chain conveyors convey the product to the force feeders. An overflow is needed to assure sufficient flow of product to the compactors, overflow product from the chain conveyors is connected to a flake conveyor directly beneath the compactors. Variable speed force feeders or screws feed the compactors which deposit the flakes onto a conveyor to be fed to elevators which carry the product to double deck Tyler screens, currently $-4+8$ Tyler mesh.

The screens divide the product into over-sizes which are routed to the chain mills and back to the elevators, under-sizes which are returned to the pug mill by a recycle chain conveyor, and on-sizes which go directly to the bag or bulk hopper.

Fan and cyclones are set in the middle of the plant to collect all dust from the dust producing areas and return this product to the same recycle chain conveyor. Emissions to the outer environment are practically nil, as is product loss in the system.

All products compacted are recorded because of the high quantity of variables controlled in the operators room; velocity of fresh feed through the double row cage mill, velocity of fresh feed versus recycle feed to the pug mill, velocity or RPMs of the force feeders, hydraulic pressure on the floating roller of the compactor, speed of the chain mills, size of the final product by changing screens. Upon changeover from one product to another, many of these variables change, due to different raw material composition of the formulas.

Most of 1987 was spent learning about the plant and teaching our employees to correctly operate the plant.

The biggest advantages in compaction from our point of view can be summed up as follows:

1. FLEXIBILITY—We thought that we would have production runs of 2-3 days per formula and consequently would have to maintain large stocks of bagged product to satisfy the demand for our product. However, we have run as low as 10 tons of product through the plant and can calculate closely whatever formula we choose to, as few as 200 bags of 100 lbs. Changing formulas is not the headache we expected. We stop feeding primary product and compact only recycles periodically until no recycles exist. Turnaround can be accomplished in as little as 20 minutes.

2. PRESCRIPTION SALES—We can use many raw materials. At present we use urea, ammonium sulphate, phosphate rock, MAP fines, standard MOP, kiserite, boron, zinc oxide, K-Mag, gypsum and dolomite, plus other micronutrients. With this mix of raw materials, we can make fertilizers for different crops in different areas. Coffee and cardamoms are excellent examples of crops grown in areas where phosphate rock is a viable and cheap manner of obtaining slow release phosphorous. Boron is a very expensive raw material, deficient in practically all Guatemalan soils, but in different proportions. We can add .5, 1 or 2 per cent boron, depending on the necessity of the crop and farmer. For basic grains it is easy for us to alter concentrations of P and K and at the same time add micronutrients.

3. BULK BLENDING/COMPACTION PLANT COMPATIBILITY—There are some raw materials that we cannot compact economically at this time. However, we can mix raw materials that are difficult to compact such as kiserite, with something like MAP or MOP, and produce a mixture that has a better granulometry than imported granular products. Our blending plants have traditionally used granular ammonium sulphate as filler in formulas such as 16-20-0 or 20-20-0. Now we can make a substitute filler using urea, MAP and gypsum which is much cheaper than granular ammonium sulphate. We can also compact different types of phosphorous to obtain different agronomic reactions, such as MAP and Phosrock. The flexibility offered to the farmer by having both plants together is enormous, we have made more than 200 different NPK + micronutrient combinations. We also have flexibility in using different raw materials to make the same fertilizer, taking advantage of price fluctuations in the international market. Remember that Guatemala is a small country, about the size of Ohio, that plants a tremendous diversity of crops, such as bananas, coffee, sugar cane, tobacco, melons, vegetables, flowers, strawberries, citrus, and more, at elevations of sea level to 10,000 feet, in soils ranging from volcanic to tropical rain forest, with rainfall of 5" to 300" per year.

Guatemala is not different than many tropical countries, using 4 or 5 different NPK fertilizers is not agronomically correct. We are proud to note that we handle 22 different raw materials and we believe that flexibility and customer satisfaction are the way to correctly supply a tropical country with fertilizer.

A large wet granulation plant for all Central America would be a disaster for individual farmers and huge plants usually only contribute to the debt burden of these countries.

3. EMISSIONS—The Fertica plants in Central America have had problems with air pollution, and

one of our major objectives was to have no environmental problems with this plant. With the dedusting system now in place, we have no emissions from our stack.

4. OPERATING COSTS—We were most concerned about the energy consumption of the plant, comparing our bulk blending plant which has 375 KW transformers, with the compaction plant with 3,000 KW transformers, you might understand our apprehension. But since most of our formulas are easy to compact, our actual electrical cost is USD.53/MT, or 11.9 KWH/MT. Our labor costs and quantity of employees is higher than expected, but still only USD 3.00 per MT.

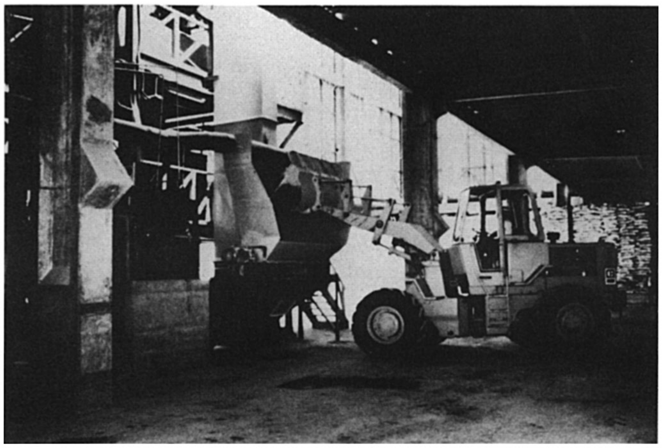
5. LOW DOWNTIME/SIMPLE MAINTENANCE — Last year we shut down the plant for 2 months for repairs and maintenance. This year due to higher demand for our products, our shutdown time will be one month. This year we worked full capacity in the plant for 100 consecutive days and the downtime during that period was less than 5%. There are 50 different machines in the process, but they are all basically simple and most spare parts are items that can be readily obtained in Guatemala. With a good preventive maintenance program, downtime can be reduced to a minimum. After 10 years experience with fertilizers and Murphy's Law, the consensus was to construct two separate production lines, therefore two small compactors instead of one larger model. This factor alone gives us tremendous help in those instances when repairs must be made to a machine. By having two separate systems, we can keep the product moving and prevent bridging in the various hoppers.

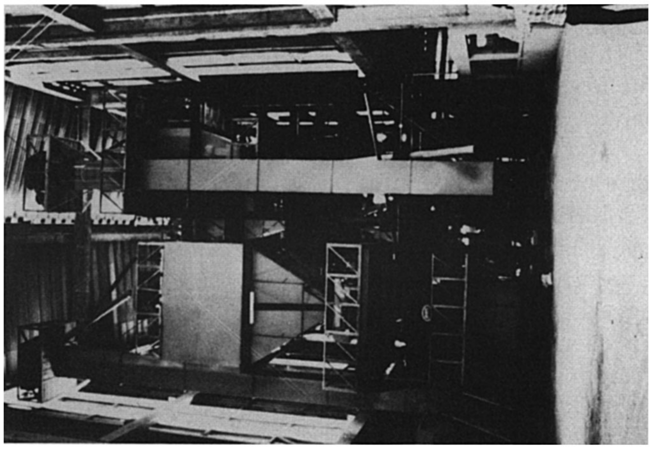
6. DIFFICULTIES/DISAPPOINTMENTS—There are some things that are difficult in the plant, such as compacting any material that is wet. Some raw materials compact better when they have one or two percent water or other liquid added to enhance the compactibility of the product. However, any product with 4% liquid is very difficult to work.

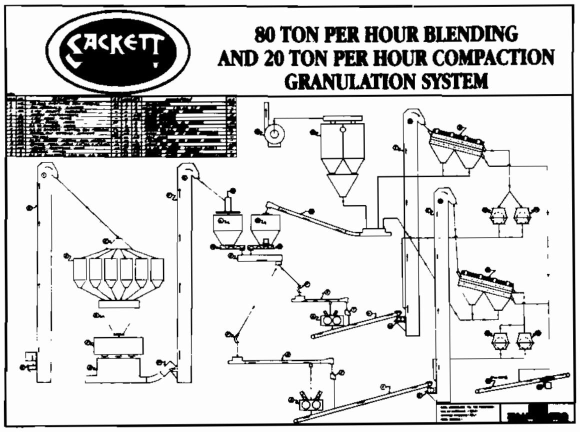
After passing the product through the double row cage mill, where we basically grind urea since all other raw materials are fine, the product is very hygroscopic, and any time we stop the process it is very difficult to start again. Also any dust that escapes the dedusting system rapidly turns humid due to the content of urea in the formulas. Therefore, it is difficult to maintain the plant as clean as the bulk blending plant, for example.

We've also had problems with the dust collection system due to the hygroscopic nature of the products. Dust sticks to the ducts and upon turning off the fan for any reason, any product deposited inside the ducts rapidly becomes very moist and very difficult to recycle.

However, we consider these problems minor, and even though difficult to solve, we can easily live with them. In synthesis, we are so happy with the plant that we would like to offer our plant to anyone for tests of the compactibility of different products. We would also be willing to help anyone with the design of similar compaction plants and/or the transfer of our knowledge and experiences from our plant. Our plant is not a pilot plant, therefore, any trials must be scheduled in advance, preferably between now and our peak season of March. Feel free to contact Sackett or ourselves for any questions you may have considering compaction of NPKS.







TYPICAL SCREEN ANALYSIS AT VARIOUS POINTS FERQUIGUA–GUATEMALA

PRIMARY FEED HOPPER BELOW CAGE MILL

MESH	% RETAINED	% ACCUMULATED
6	0	0
10	.15	.15
14	.55	.70
16	.60	1.30
18	1.06	2.36
20	1.66	4.02
30	1.91	5.93
45	13.67	19.60
60	34.17	53.77
80	25.18	78.95
100	13.67	92.62
<100	7.38	100.00

RECYCLE FEED HOPPER

MESH	% RETAINED	% ACCUMULATED
6	1.07	1.07
10	10.11	11.18
12	6.12	17.30
14	11.63	28.93
16	3.72	32.65
18	13.01	45.66
20	9.56	55.22
30	10.30	65.52
45	23.49	89.01
80	9.32	98.33
100	.37	98.70
<100	1.30	100.00

ENTERING CHAIN MILL

MESH	% RETAINED	% ACCUMULATED
¼	74.57	74.57
4	7.16	81.76
6	13.38	95.11
10	3.88	98.99
12	0.38	99.37
14	0.30	99.67
16	0.11	99.78
18	0.22	100.00

LEAVING CHAIN MILL

MESH	% RETAINED	% ACCUMULATED
¼	25.75	25.75
4	9.94	35.69
6	22.71	58.40
10	17.94	76.34
12	5.88	82.22
14	12.75	94.97
16	1.51	96.48
18	3.09	99.57
20	.43	100.00

FINISHED PRODUCT

MESH	% RETAINED	% ACCUMULATED
6	.41	.41
8	16.94	17.35
10	67.94	85.29
12	8.61	93.90
14	3.38	97.28
16	1.33	98.61
18	.93	99.54
20	.46	100.00

Various Methods for Producing Granular Ammonium Sulfate from By-Product Fines

James C. Mickus, Cargill Inc.
Cameron Bowen, Cameron Chemicals, Inc.

This paper will concern itself only with by-product ammonium sulfates and the present technologies being used to produce a granular grade from these by-products. In the interest of brevity, we will use the symbol A/S to denote ammonium sulfate throughout this paper. Everybody will have their definition of a granular grade but it is mostly accepted that we are talking about particle sizes in which 98% are in the $-6+14$ Tyler range (3.35mm to 1.18mm).

Of all the A/S produced in the U.S., only about 200,000 tons is produced at plants specifically dedicated to it's production. In-place capacity to produce synthetic A/S is considerably greater and does fluctuate with demand. This number is small compared to the quantities of by-product A/S produced in the U.S. as shown in Table 1. The principal quantities of by-product A/S comes from three industries and a brief discussion on each is given below:

CAPROLACTAM

When using phenol/or cyclohexane as the basic raw material in the Raschig process by-product, A/S comes from three of the reaction steps; the manufacture of hydroxylamine sulfate, the manufacture of cyclohexanone oxime, and in the recovery of caprolactam from the oxime rearrangements. A total quantity of 4.4 pounds of A/S is co-produced per pound of caprolactam. Recently, Montedipe of Milan announced that it has developed a modified caprolactam production process which decreases the ratio of A/S to caprolactam to 1.3:1. It is not know at this time whether the major U.S. producers of caprolactam are embracing this modification. The A/S from caprolactam production process which decreases the ratio of A/S to caprolactam to 1.3:1. It is not known at this time whether the major U.S. producers of caprolactam are embracing train. Today about 2.5 million tons of A/S are generated by caprolactam producers in the U.S. and of this quantity 1.3 million tons are produced by Allied Chemical. We have been made to understand that 70% of this quantity is granular and additional crystalizers would be required to increase the quantity.

METHYL METHACRYLATE

Ammonium bisulfate is the direct by-product of the acetone-cyanohydrin process in the production of methyl methacrylate (MMA). This by-product can be further neutralized with additional ammonia to ammonium sulfate, or if equipped with a sulfuric acid recycling unit, ammonia and sulfuric acid can be recovered for reuse. The final option, which no longer exists, would be to discard the by-product. Two of the largest plants in the U.S. have the first two options and they operate basis the conditions of the domestic and export A/S markets. At present, if all of the by-product ammonium bisulfate from the production of methyl methacrylate produced domestically was reacted with ammonia, a quantity of approximately 600,000 tons of A/S by-product would be available.

COKE OVENS

Coking of coal, required in the production of steel from iron ores, produces gases containing ammonia. To prevent the escape of ammonia into the atmosphere, it is recovered by scrubbing with sulfuric acid to yield A/S. It requires about 0.76 lbs of 100% sulfuric acid to produce 1.0 lb of A/S. Fifteen years ago about 22% of all A/S produced was from the coking of coal and it has decreased to about 8% today. It is estimated that about 240,000 tons of coke oven by-product A/S is produced in the U.S. per year.

PRODUCTION OF GRANULAR A/S FROM BY-PRODUCT FINES

There are three processes which can be described as uniquely different and that have gone beyond the pilot stage in the production of granular A/S from by-product fines. For many years the ammoniating manufacturing plants have been considering reprocessing fines and specifically steel mill A/S fines into a granular product. The basic reason that this was not done on a large scale earlier was that there was not enough spread in the price of standard grade and granular product. As long as this difference remained at $10.00/ton or less, the granular plants could not afford to process the fines into granules. However, in the past five years, the market has had a drastic change. Many granulating plants, 60 to 70 on the East Coast alone, which used steel mill by-product A/S to produce N.P.K.S. products began to close down for economic reasons. This has caused a flood of A/S fines on the market, especially from steel mills. Several of the larger mills have A/S stored outside and to meet environmental standards need to dispose of or recycle this product. This factor, among others drove down the price and much of this coke oven by-product A/S can be purchased for as little as $5.00 per ton, and in some cases, the mills have given the product away.

PROCESS I—GRANULATION IN A CONVENTIONAL TVA-TYPE GRANULATOR

In 1986 Harrison and Tittle, U.S. Pat. 4,589,907, produced granular ammonium sulfate from large quantities of by-product A/S fines and small quantities of ammonia and sulfuric acid. This process then was tried and proven at a rate of 13 tons per hour in a full scale granular plant in Peru, IN by a new company incorporated under the name of Peru Agricultural Products. The following information deals with this process. It is a combination of technical and practical data that was recorded in Peru, IN, in December of 1987 through April of 1988.

PROCEDURE

It is recommended that the A/S fed into the ammoniator for granulation be screened. The A/S is very sensitive once in the rolling drum because of the high volume of solutions that are pumped into the bed and combined with a low pH. It is very important to control the incoming virgin feeds, including recycle feed. No real changes were necessary in the granulator. A black iron pipe was used for the NH3 sparger line and a hastaloy sparger line for the sulfuric acid and A/S solution water.

The 8′ × 16′ ammoniator is ideal for this process. A retainer ring should be recessed back 4 feet from the discharge end of the drum. Make up water that is used to cut the sulfuric acid from 93% to approximately 50% should be premixed with A/S crystals to contain at least two percent total nitrogen and not to exceed four percent. The acid and water should be quantified through gallon meters and come together in a header just before entering the acid water sparger line. The acid and ammonia should be formulated to bring the pH of A/S fines to the 2.4 to 2.8 range. Small amounts of alum can be sprayed in the ammoniator as an aid in hardening the granules. However, it is felt that if an eight or ten foot pan granulator was installed below the rolling drum, it would not be necessary for additional material to be added to hold the granules together as they pass through the dryer. We do encourage the counter-current heat system and we suggest the product be at least 290 degrees F as it leaves the dryer. This means the product and the recycle should be cooled. The product should go into storage below 120 degrees F.

The Peru, IN plant needed certain modifications to simplify the flow of material as needed to develop a stable system, to reduce labor cost, to minimize dust and fume emissions, and, of course, to develop an acceptable product at a reasonable cost. The original feed system was developed to feed several materials in their proper proportions for a complete fertilizer mix. The plant required the feed of only one material, by-product A/S. In order to operate the plant, a uniform volumetric feed was required. Modifications were made to by-pass the present hopper system and begin the feed of material at the point that would use the least feed equipment. This reduced labor, maintenance and operating cost. It also reduced dust emissions from unnecessary equipment. A belt conveyor that originally conveyed the material from the feeder to the granulator feed screw had to be relocated slightly to satisfy the process requirement. It required a small structural change, an additional feeder hopper for the feed screw, and an overflow chute to the new material feed elevator hopper. This relocation of the belt was necessary to develop a constant rate of feed to the granulator and prevent an overload from occurring.

A feed chute from the screen elevator is necessary to supply material to the feed screw in order to have material always available and fed at a constant rate. The sparger pipe supports were relocated as they gave rise to too much product being imbedded in the total mass of material in the drum. By and far the conventional granulator was basically adequate and needed only minor modifications.

Fume collections (ammonia and steam) were inadequate. A hood was constructed over the discharge of the granulator to keep the gases contained within the system and away from the operator. A counter-current heat system was used for drying so the dryer was repositioned. This required the installation of new flights, relocation of the combustion chamber, installation of a discharge hood, and new chute to the cooler. The existing cooler intake hood was used on the dryer discharge. The cooler itself was adequate.

The air handling system, while using the present equipment, required major changes to meet with the needs of the process. Relocation of the ducts and change of cyclone flow were necessary. Relocation of the cyclone discharge screw was necessary to get the dust to a location so that it can be further used in the process. The scrubbing system basically was adequate, but much too restrictive. It prevented enough air from being used to properly perform the needed service and modifications of some components were necessary. From the beginning, problems were encountered in balancing the dryer cooler air flows. A combination of improper air pressure drops throughout the system and locating the dryer burners too close to the discharge end of the dryer caused burning of the 20 mesh A/S fines. Emission levels were above those prescribed by the Indiana Department of Environmental Regulations. The dissolving of the fines dust and its return to the system by the slurry route both enhance granulation and eliminated the major source of effluent dust. An additional pump, tank and piping were required. A level sensor and control valve were required to control water levels. The plant flow diagram is shown in Figure 1.

In summary, the most important aspects to attain good operational control are:

1. Weigh and screen solid feeds to the ammoniator.
2. Design the recycle return equipment for a controlled amount of recycle return to eliminate changes in the wet phase.
3. Install a constant reading pH meter located on the discharge end of the ammoniator and monitor continually.
4. Maintain good air flow throughout the drying system with automatic controls on the furnace.

PROCESS II— GRANULATION VIA THE CROSS PIPE PRESSURE REACTOR PROCESS (1)

The plant data to date on this process is very cursory. TVA Engineers began work with the Indiana commercial producer in early 1988 to produce homogeneous A/S granular fertilizer. Figure II shows the flow diagram for this plant and Figure III shows the details of the Hastelloy C-276 reactor originally installed for A/S granular fertilizer production. In the new equipment configuration, a baghouse is directly behind the rotary ammoniator-granulator. The originally installed Hastelloy pipe-cross reactor had to contain a 115 degree elbow to fit beside the baghouse. Also, sulfuric acid and ammonia pumps were selected to deliver the desired feeds at pressures of at least 40 psig to this pipe reactor.

The original pipe-cross reactor installation included ammonia flowmeters for the flow of ammonia to the bed and to the pipe-cross reactor. However, one of these flowmeters was damaged shortly before the A/S project began. Although some granulation was completed in which ammonia was fed to the bed and to the pipe reactor by merely opening valves, lack of a second flowmeter made this test work difficult to assess. The decision then was made to put all ammonia fed to the process into the pipe and let the temperature of the pipe rise. Granulation was readily accomplished with varying percentages of the feed material as by-product A/S crystals and the A/S melt. (The melt composition was varied from a 1.6 to 2.0 mole ratio of ammonia to sulfate). An unusually high temperature (475 degree F) in the pipe was caused by adding only small quantities of water to the 93% sulfuric acid and liquid anhydrous ammonia. The slightly less than 2 mole ratio and the smaller quantity of water in the pipe both contributed to the low ammonia losses which were measured in the range of 1% to 2% ammonia fed to the process. This unexpectedly low ammonia slip enabled the packed bed scrubber on the ammoniator exhaust to be operated with only process water spraying across the bed. Originally, this fiberglass tank scrubber was to operate with acidified water being ammoniated into the 4 to 5 pH range, as has been done in many regional granulation plant granulator scrubbers.

Although the test work was conducted in a Hastelloy C-276 pressure reactor, the reactor will be replaced with a new corrosion resistant proprietary design reactor. This pipe-cross reactor experience has indicated, a Hastelloy C-276 reactor being fed ammonia and sulfuric acid only would produce several thousand pounds of products. The reactor used in this commercial test is undergoing modifications so as to better control the addition of ammonia and sulfuric acid make up ingredients. Further tests are to be done in December 1988. Table II gives the preliminary results of this test.

PROCESS III—COMPACTION (2)

Western AG-Mineral Company (2) recently procured a compactor plant at Gary, IN which uses coke by-product A/S. The compactor is small and is reportedly attaining good granular product at 5–7 tons per hour and 50% yield. A new 305 HP compactor is now being installed and is rated to give 13–16 tons per hour with better yield. This would allow the producer to make 50,000–60,000 tons/year of granular A/S. The operators say that they have learned considerably from production trials using the small compactor. Raw material formulation, compactor and dryer operating conditions are very critical to the production rate and quality. We have been informed that the above operating conditions are so different from what was expected that they have to be kept proprietary and thus specific operating conditions are not set out in this paper. Figure IV shows the schematic of the compaction process.

GRANULE STRENGTH AND ABRASION RESISTANCE

It is noted that mention was made in some of the process descriptions about the use of additives to give granule strength and abrasion resistance. Although not entirely germane to this paper we think a mention of the use of such additives is appropriate. Granule strength in part is a function of proper balance of fertilizer chemistry and raw material sizing. Formulations which do not meet minimum criteria often produce granules which are weak and of poor quality. Granule attrition is the degree or tendency of granules to abrade during shipping and handling, causing degradation and dust formation. Although the individual granule may have strength against breakage, it is possible for the product to display excessive dust through attrition. (3)

We, at Cargill, have worked both with proprietary MgO binders from Martin Marietta and lignosulfates. In our studies we found that granular A/S produced from coke oven fines via the cross-pipe pressure reactor granulator with some specific additives, exhibited better hardness and abrasion/resistance than product produced in which no additives were used. Table III shows the results of abrasion testing via a method prescribed in TVA Bulletin Y-147 on binder based A/S and a control (no binder) produced in plant trials. It is quite evident that the binders used imparted considerable

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resistance to abrasion such as the product would experience in normal handling thru the distribution chain. We doubt, however, that there is any significant difference between the two specific binders looked at in this study. In no way are we promoting hardener/abrasion resistant additives but only calling to your attention some of our experiences. Individual case assessment needs to be made as to finished granule properties and related economics.

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TABLE I
U.S. Annual Production of A/S from Various Sources*

Source	**Quantity (Short Tons)**
Coke	240,000
MMA	600,000
Caprolactum	2,500,000
Synthetic	200,000
Total	3,540,000

* Data derived from interpolation of CEH data and the authors' guesses.

TABLE II
Pressure Reactor (PR) Production Granular Ammonium Sulfate Commercial Producer
Indiana
March 18, 19, 20, 1988

Formulation, lb/ton	
Feed to PR	
Sulfuric acid, 93%	591
Anhydrous ammonia	185
Ammonium lignosulfonate, 48% (in sulfuric acid)	20
Feed to ammoniator-granulator bed	
Ammonium sulfate crystals, fine	1200
PR pressure, psig	45
Production rate, tons/hr	16.5
Production, tons	550
Length of production run, hrs	33.3
Temperature, degrees F	
Pressure reactor	478
Granulator product	225
Dryer product	235
Fluid bed cooler product	105
Heat Input, Dryer, Btu/ton product range	150M–200M
Product, screen analysis, %	
Tyler −6+16	99.7
NH3: H2SO4 mole ratio, melt range	1.6–2.0
Product hardness lbs, average	4.0
Recycle Ratio, tons product/tons recycle	3–4

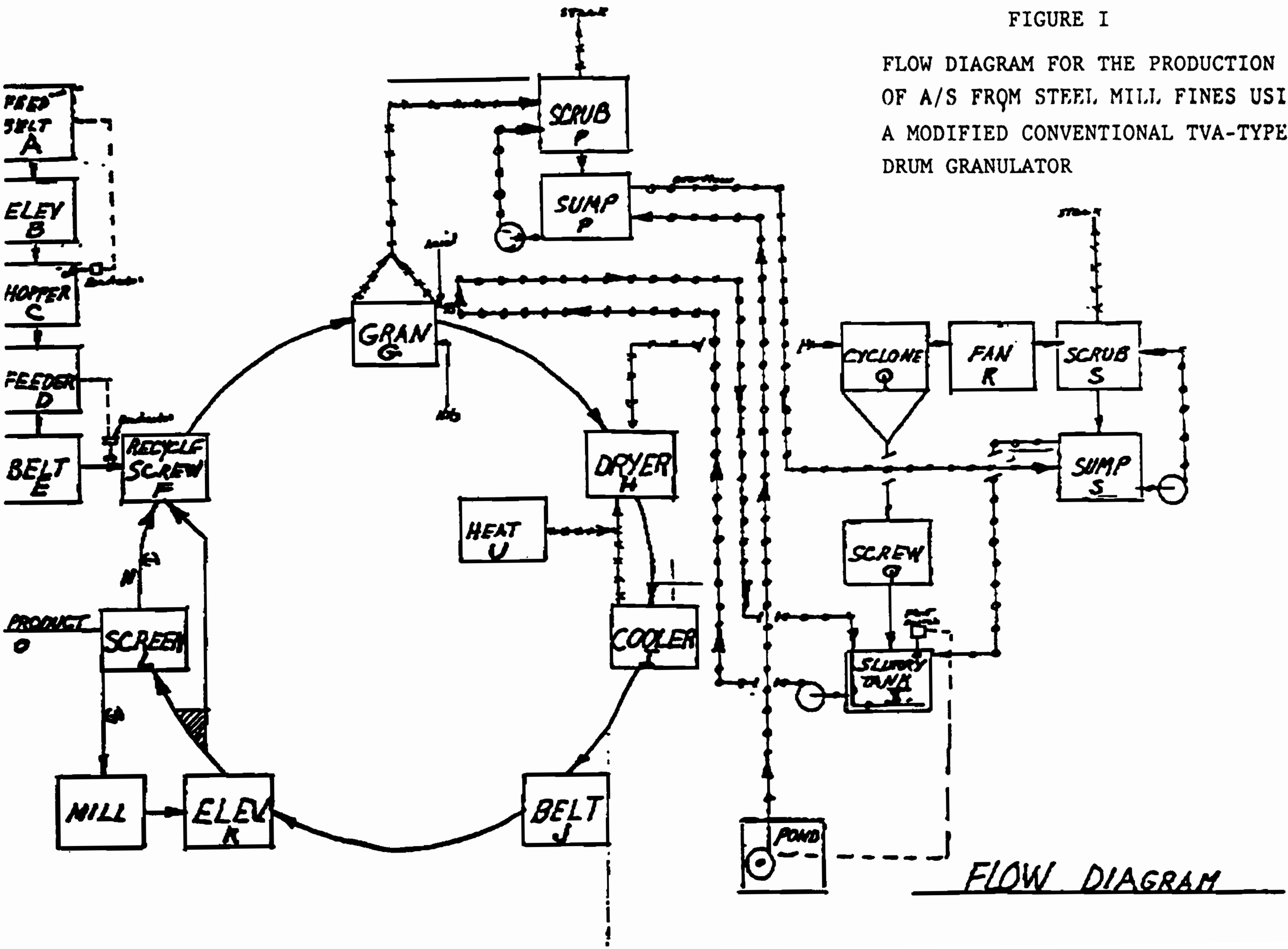
TABLE III
Abrasion Tests on Granular A/S Products Produced Via the Cross-Pipe Reactor With and Without Binders.

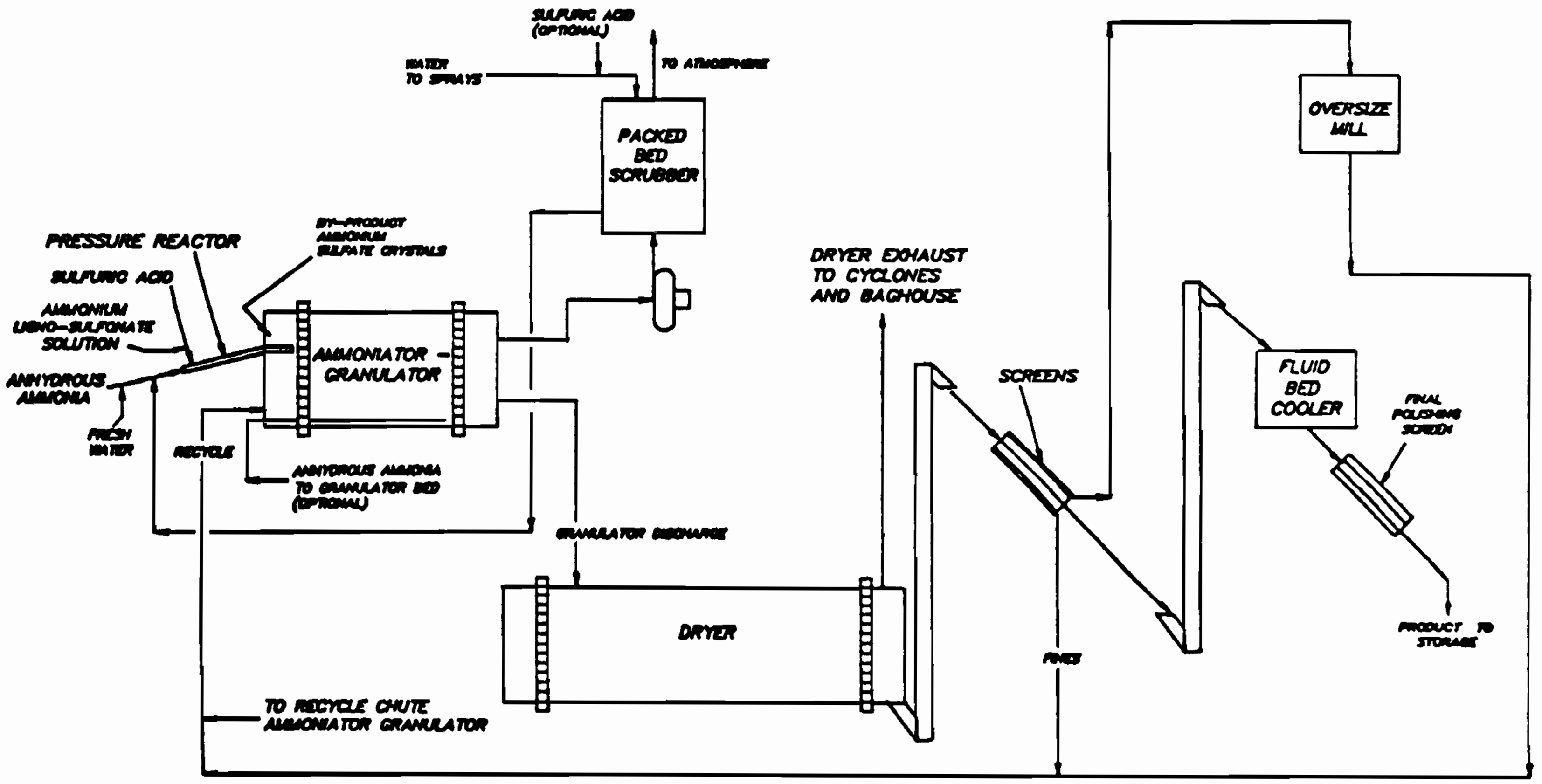
% (−4+30 Mesh)	**Before**	**After**	**% Attrition**
Control (no binder)	99.5	87.4	12.2
*Gran-U-Pel 300 (3%)	99.11	97.0	2.1
Ammonium Lignosulfonate (0.5%)	99.7	98.3	1.4

* Proprietary Martin Marietta binder.

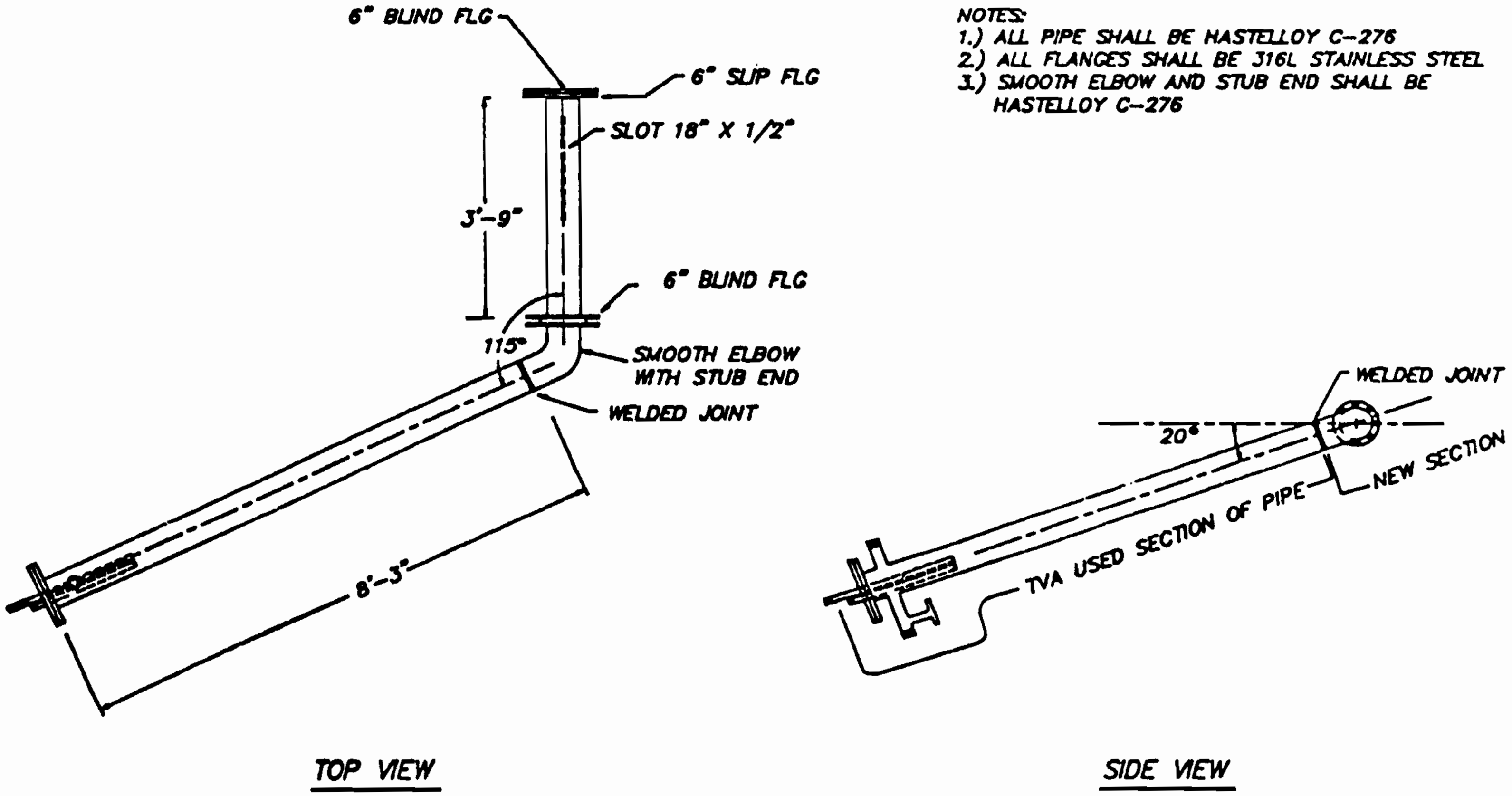
FIGURE I

FLOW DIAGRAM FOR THE PRODUCTION OF A/S FROM STEEL MILL FINES USING A MODIFIED CONVENTIONAL TVA-TYPE DRUM GRANULATOR





FLOW DIAGRAM OF PRESSURE REACTOR PROCESS
GRANULATION OF AMMONIUM SULFATE
FIGURE II



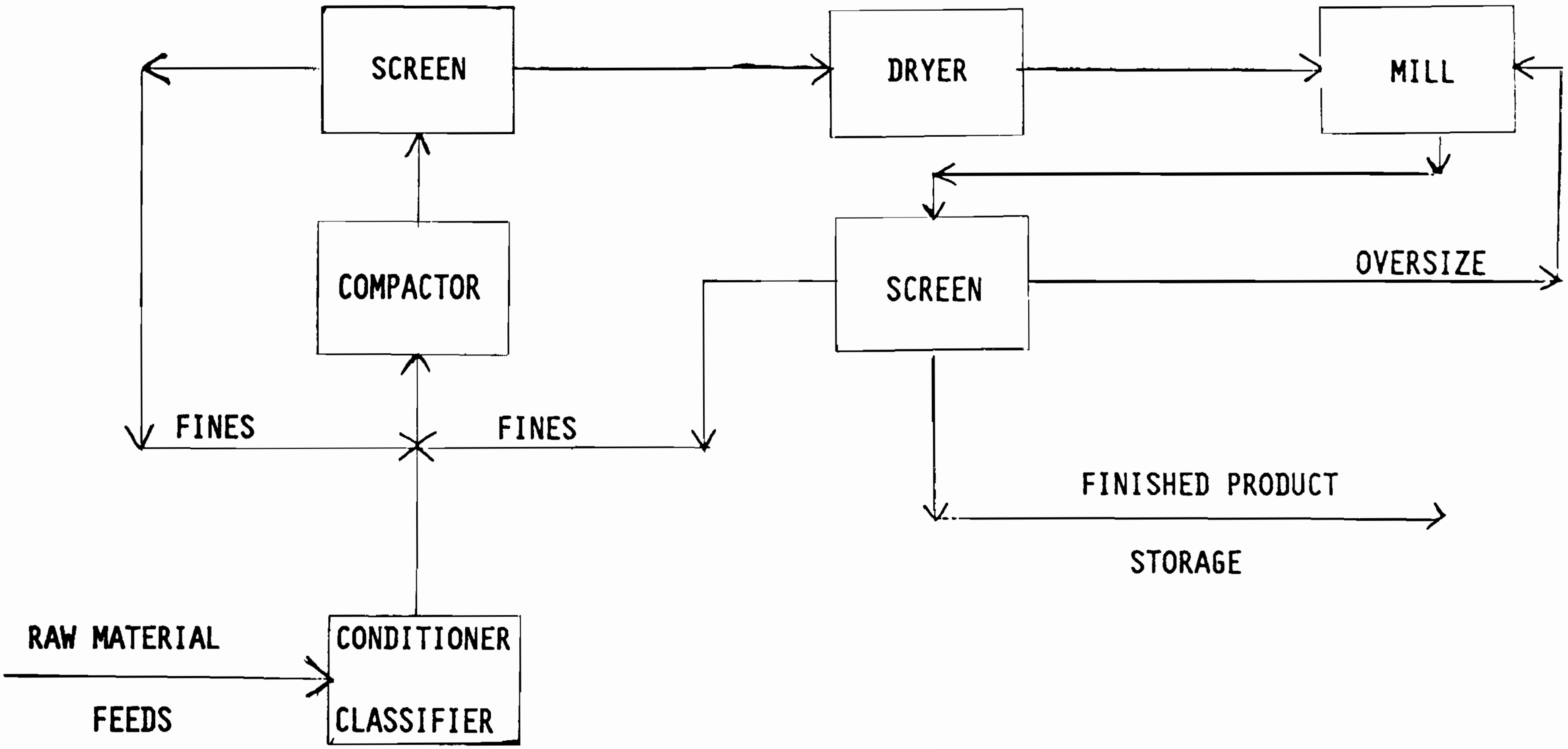
NOTES:
1.) ALL PIPE SHALL BE HASTELLOY C-276
2.) ALL FLANGES SHALL BE 316L STAINLESS STEEL
3.) SMOOTH ELBOW AND STUB END SHALL BE HASTELLOY C-276

DETAILS OF PRESSURE REACTOR
GRANULATION OF AMMONIUM SULFATE

FIGURE III

FIGURE IV

SCHEMATIC FLOW DIAGRAM
FOR THE COMPACTION OF A/S



Effect of Formula Modifications and Additives on Soil Surface Loss of N from UAN Solutions

Harold D. Blenkhorn
Nitrochem Inc.

Surface applied urea-ammonium nitrate (UAN) solutions are subject to volatilization losses of N due to hydrolysis of the urea component, which normally constitutes half of the total N content. The mechanisms of urea decomposition and subsequent loss to the atmosphere are well known and need not be discussed at length. Simply stated, urea is converted to ammonium carbonate by an enzyme which is universally present in the soil. Ammonium carbonate is unstable and hydrolyses to form free ammonia which is lost to the atmosphere. Factors such as soil pH, texture, and organic matter content have considerable effect on the breakdown of ammonium carbonate.

The AN:Urea (N) ratio of 1:1 in a UAN solution is related to the proportions of the two salts which provide maximum solubility. This ratio can be altered to increase the level of AN relative to urea if the total nitrogen content is lowered to maintain the salt-out temperature at the acceptable level of 0°C. With the restriction of a 0°C salt-out temperature, the effect of increased AN levels on total N content are shown in fig. 1. The composition of possible modifications are listed in table 1. It is shown that the AN:Urea ratio can be altered from the usual 50-50 in a 32% solution to 67-33 if the total nitrogen content is lowered to 26%, thus reducing the urea nitrogen content by one-third. Lowering the total N to 24% permits a 50% reduction in urea.

A formula modification which minimizes the urea content of a UAN solution relative to the total N content should obviously result in improved N efficiency from surface application. However, there is a practical limit to which the total N content of a solution can be sacrificed to reduced urea. The efficiency gained from moderately reduced urea might be extended through the use of chemical additives which might inhibit the action of urease and retard the hydrolysis of ammonium carbonate. One possibility is ammonium thiosulphate (ATS) which has been found to exhibit mild urease inhibition (Goos, 1985). The addition of inorganic salts which stabalize ammonium carbonate (Fenn, 1981) may also have a beneficial effect. This paper reports the results of a laboratory study of soil surface NH_3 volatilization losses from solutions containing varying combinations of AN and urea. Also investigated were the added effect of ATS and calcium-magnesium compounds contained as impurities in an alternate source of ammonium nitrate.

TREATMENTS AND N LOSS MEASUREMENTS

The treatments compared in this study are listed in table 6. The designation 0-100, 75-25, etc. indicates % of total N derived respectively from AN and urea. To facilitate accuracy of application, all solutions were made up to a total N content of 10%. Pure sources of AN and urea were used. ATS was added as 60% solution at rates of 1.8 and 3.6% by weight, providing levels of ATS (100% basis) which amount to 10 and 20% of the urea content of a 50-50 solution. These rates become 20 and 40% in the case of the reduced urea in a 75-25 solution.

The alternate source of AN is a liquor recovered in a pollution abatement process. The total salt content of this reclaimed product is composed of about 90% AN, and 10% other soluble salts which are mainly calcium and magnesium compounds plus other minor impurities. The Ca and Mg are largely in the form of nitrates. This product (designated as AqL) was used in certain treatments to provide half of the AN requirement in the formulation.

Procedure for measurement of NH_3 volatilization was adapted from the method described by Fenn and Kissel (1973). Soil was placed in 6.0 cm ID by 8.3 cm tall screw top of jars to a depth of about 1 cm. Application rate of N for all treatments was about 40 mg, corresponding to a surface application rate of 140 Kg/Ha. Treatments were carried out in duplicate. Jars were covered immediately following the application of treatments and connected to a manifold which provided a constant flow of purified, moist air. Air entering the sample jar was passed into 100 ml of 2% boric acid. Volatilized NH_3 was measured by titrating with .05 N H_2SO_4. Daily measurements were taken over a period of ten days.

EXPERIMENT I

N losses from AN-urea combination on five soil types

Nitrogen losses were measured over a period of ten days on five soil types. The pattern of NH_3 volatilization was similar on all soils, reaching a peak in three or four days and receeding to negligible amounts by the tenth day of incubation. (see example, fig.2). Confirming the observations of similar studies, the degree of N loss was greatly influenced by soil type, and was closely related to the clay content (see soil properties, table 4). Losses of N from the 0-100 treatment (pure urea) ranged from 23 to 55% respectively from the heaviest to the lightest soil types over the ten day period.

As might be expected, nitrogen losses were reduced with decreasing levels of urea. The degree of reduction was greater than the reduced urea content of the treatment. N Loss values of each treatment expressed as a percent of the amount of applied urea were progressively lower as the urea content of the solution decreased. (tables 2 & 3, fig. 3). This effect may be partly due to decreased application rates of urea, but may also be associated with the corresponding increase in ammonium nitrate. As shown in table 6, the pH of the solutions used in the experiment decrease with increasing levels of AN. This decrease in pH related to treatments is also reflected in measurements taken on KCL extracts carried out on each soil sample after incubation (table 2). It is probable that increasing amounts of an acid-forming salt in the presence of ammonium carbonate has a retarding effect on the hydrolysis to free ammonia.

EXPERIMENT 2

Effects of ATS and Aquachem Liquor

Treatments 50-50 and 75-25 in combination with three rates of ATS and two sources of AN were compared on St. Sophie and St. Bernard with closely similar results on each soil. Averaged results are given in table 5 and illustrated graphically in figure 4.

The lower level of ATS added to the 50-50 solution prepared from pure A.N. reduced the N loss by 33%. There was no further benefit from the higher ATS level, which in fact, was slightly less effective. The calcium-magnesium salts (amounting to 7% by weight of the urea content) in the AqL treatment reduced N loss by 16%, and slightly enhanced the effect of ATS at both levels, lowering the N loss by a total of 38%.

Confirming the findings of experiment 1, the N loss from a 50-50 solution is reduced by about 60% due to the direct and indirect effect of the reduced urea content of the 75-25 solution. The combined action of ATS and Ca-Mg supplied from AqL extends the reduction in N loss to more than 80%.

SUMMARY

It has been demonstrated by laboratory measurements that a considerable reduction in nitrogen losses from surface application of UAN solutions can be accomplished by altering the usual AN:urea (N) ratio of 50-50 to 75-25. A solution which accomplishes this purpose would be made up of 51.4% of AN and 12.9% urea providing a total N content of 24%. The disadvantage of such an approach is the cost of plant nutrient transportation in comparison with the conventional solutions containing 28, 30 or 32% N. Also, urea is generally a cheaper source of N than ammonium nitrate. There are, however, certain situations where the opposite is true. In this instance, the increased use of AN actually lowers the overall cost of N at the point of manufacture. As shown in table 1, urea can be substantially lowered in solutions such as 260 (0-50-19) or 270 (0-49-21) to provide AN-urea ratios of 67-33 or 63-37. ATS and partial use of aquachem liquor could be used to enhance the nitrogen efficiency of these solutions.

ACKNOWLEDGEMENTS

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The author wishes to express thanks to Dr. A.F. MacKenzie, professor of soil science, for overall guidance of the project, and to Dr. Thamir Al-Kanani, research assistant, who carried out the laboratory work.

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TABLE 1.
Composition of N solutions with varying AN-Urea ratios to provide a salt-out temperature of approximately 0°C.

Total N	% AN	% Urea	AN:Urea ratio	Decrease in Urea as % of Total N
32	45.7	34.3	50 50	
28	47.2	24.6	59 41	18
27	48.6	21.4	63 37	26
26	49.8	18.4	67 33	34
25	50.7	15.5	71 29	42
24	51.4	12.9	75 25	50

TABLE 2.
Effect of AN – urea ratios on soil surface nitrogen losses from five soil types – ranges and averages

		NH_3 – N volatilized after 10 days			
Treatment		% of Total N applied		% of Urea N applied	
AN	Urea	Range	Ave.	Range	Ave.
0	100	22.5 – 54.7	41.2	22.5 – 54.7	41.2
25	75	13.2 – 35.3	26.2	17.7 – 47.2	34.0
50	50	4.8 – 26.0	16.0	9.8 – 52.0	82.0
75	25	2.1 – 8.6	5.5	8.8 – 34.6	22.4

TABLE 3.
Effect of soil type on surface N loss from AN-Urea combinations

	NH_3 – N volatilized after 10 days				
Treatment	% of total N applied	N loss Index	N as % of Urea	pH*	
AN Urea					Soil Type**
0–100	22.5	100	22.5	6.70	Dalhousie
25– 75	13.2	59	17.7	6.42	
50– 50	4.8	21	9.8	6.25	
25– 75	2.1	9	8.8	6.03	
0–100	48.5	100	48.5	6.79	Macdonald
25– 75	31.5	65	42.0	6.58	
50– 50	18.9	39	37.9	6.34	
25– 75	8.6	18	34.6	6.04	
0–100	47.5	100	47.5	6.74	St. Bernard
25– 75	30.4	64	40.3	6.58	
50– 50	19.0	40	38.0	6.40	
25– 75	6.8	14	27.4	6.03	
0–100	32.8	100	32.8	6.61	Chicot
25– 75	17.2	52	23.0	6.43	
50– 50	11.1	34	22.5	6.22	
25– 75	3.8	12	15.5	5.99	
0–100	54.7	100	54.7	5.97	St. Sophie
25– 75	35.3	65	47.2	5.93	
50– 50	26.0	31	52.0	5.88	
25– 75	6.4	12	25.6	5.82	

*Determined on KCL extracts of soil samples after incubation.
**See physical and chemical properties and soils – Table 4.

TABLE 5.
Effect of ammonium nitrate urea ratios, AqL and ATS on soil surface NH_3 losses from St. Sophie sandy loam

Treatment		NH_3 – N volatilized after 10 days	
AN	Urea	% of Total N applied	N Loss Index
50	50	19.7	100
50	50 ATS_1	13.2	67
50	50 ATS_2	14.0	71
50	50 AqL	16.5	84
50	50 AqL ATS_1	12.3	62
50	50 AqL ATS_2	12.5	63
75	25	7.3	37
75	25 ATS_1	5.7	29
75	25 ATS_2	5.1	26
75	25 AqL	6.5	33
75	25 AqL ATS_1	4.1	21
75	25 AqL ATS_2	3.4	17

TABLE 6.
Effect of ingredients on pH of test solutions

N distribution % of total	pH
Test Solutions Experiment 1	
AN Urea	
0–100	8.3
25– 75	6.4
50– 50	6.1
75– 25	5.8
Test Solutions Experiment 2	
50– 50	6.1
50– 50 ATS_1	7.0
50– 50 ATS_2	7.4
50– 50 AqL	5.9
50– 50 AqL ATS_1	7.0
50– 50 AqL ATS_2	7.2
75– 25	5.8
75– 25 ATS_1	6.7
75– 25 ATS_2	7.0
75– 25 AqL	5.5
75– 25 AqL ATS_1	6.7
75– 25 AqL ATS_2	7.0

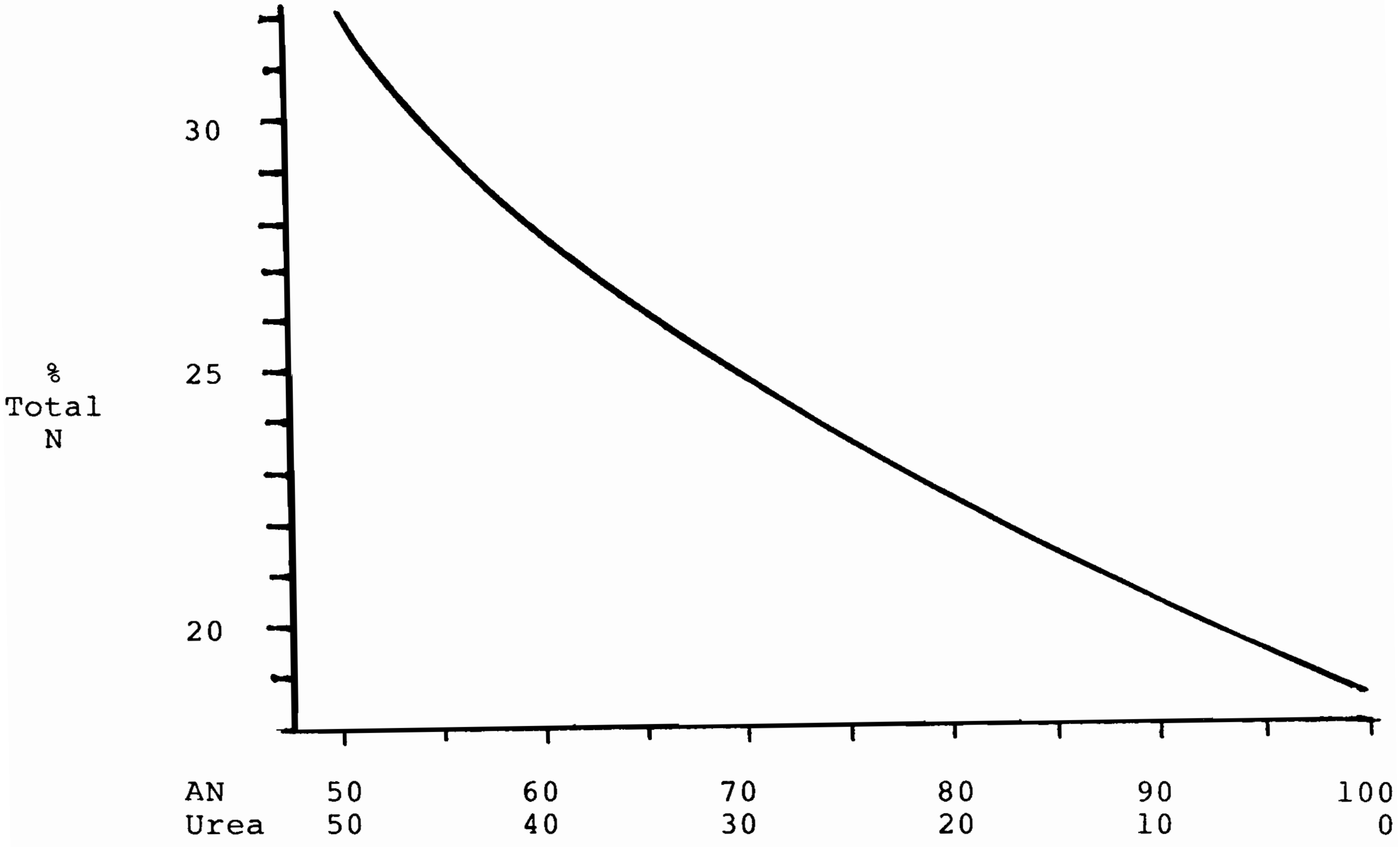
ATSm Ammonium Thiosulphate
AqL Aquachem liquor

TABLE 4.
Physical and chemical properties of soil samples

Soil	Sand	Silt	Clay	Organic matter	pH	P	K	Ca	Mg
Chicot (SCL)	60.7	14.0	25.3	2.36	6.3	16.0	58.0	540	124
Dalhousie (C)	38.9	19.5	41.6	7.20	6.6	12.0	120.0	3000	175
Macdonald (SL)	67.9	13.2	18.9	3.94	6.4	18.0	52.0	800	130
St.Bernard (SCL)	62.7	15.4	21.9	3.83	6.5	9.0	40.0	900	168
St.Sophie (S)	86.2	5.1	8.7	2.53	5.9	32.0	108.0	470	33

C, clay. L, loam. S, sand.

FIGURE 1 COMBINATIONS OF TOTAL N AND AN:UREA (N) RATIOS TO PROVIDE 0°C SALT-OUT TEMPERATURE



N Source distribution % of total N

FIGURE 2 SOIL SURFACE N LOSSES - ST. BERNARD SANDY LOAM

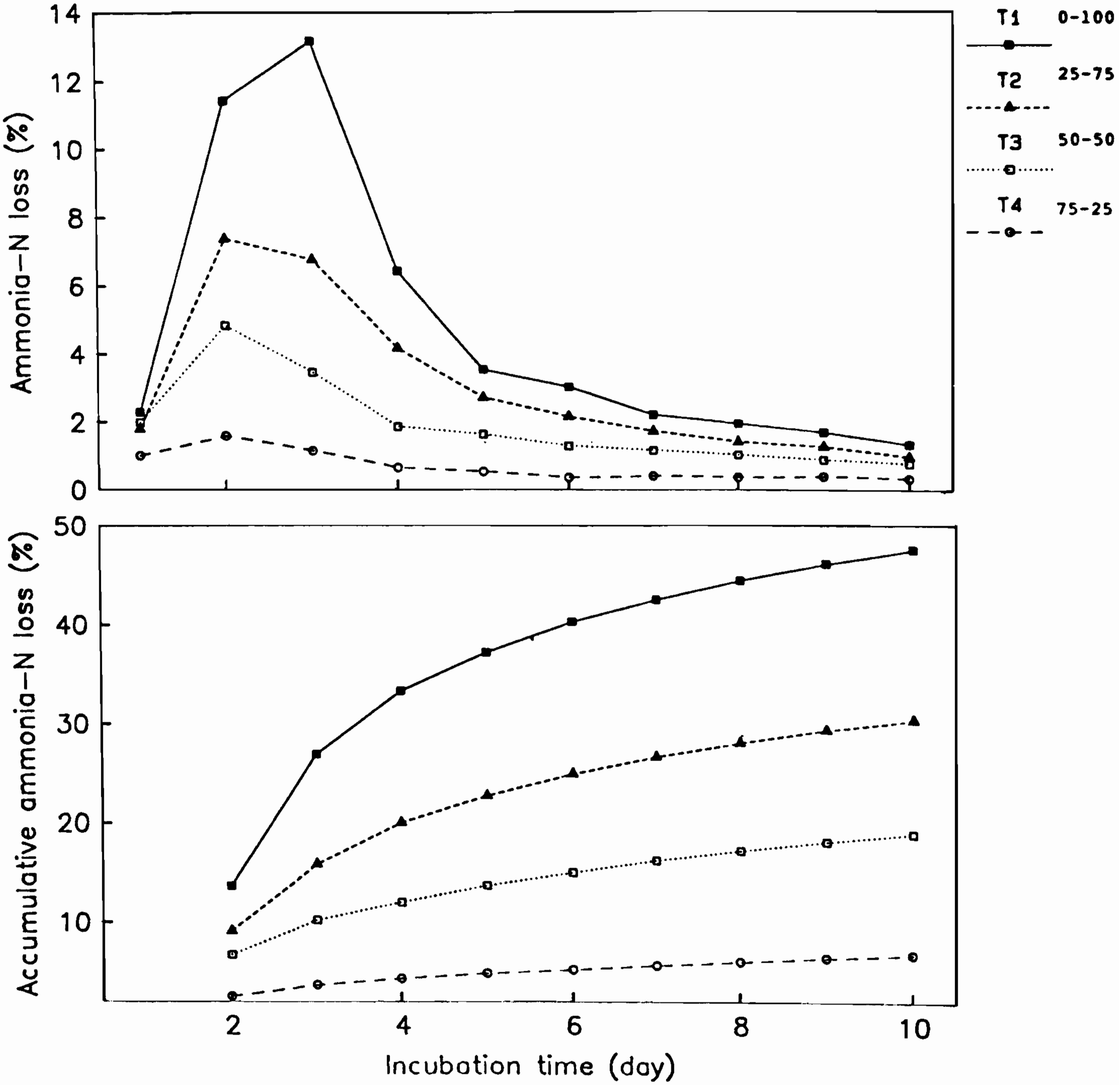
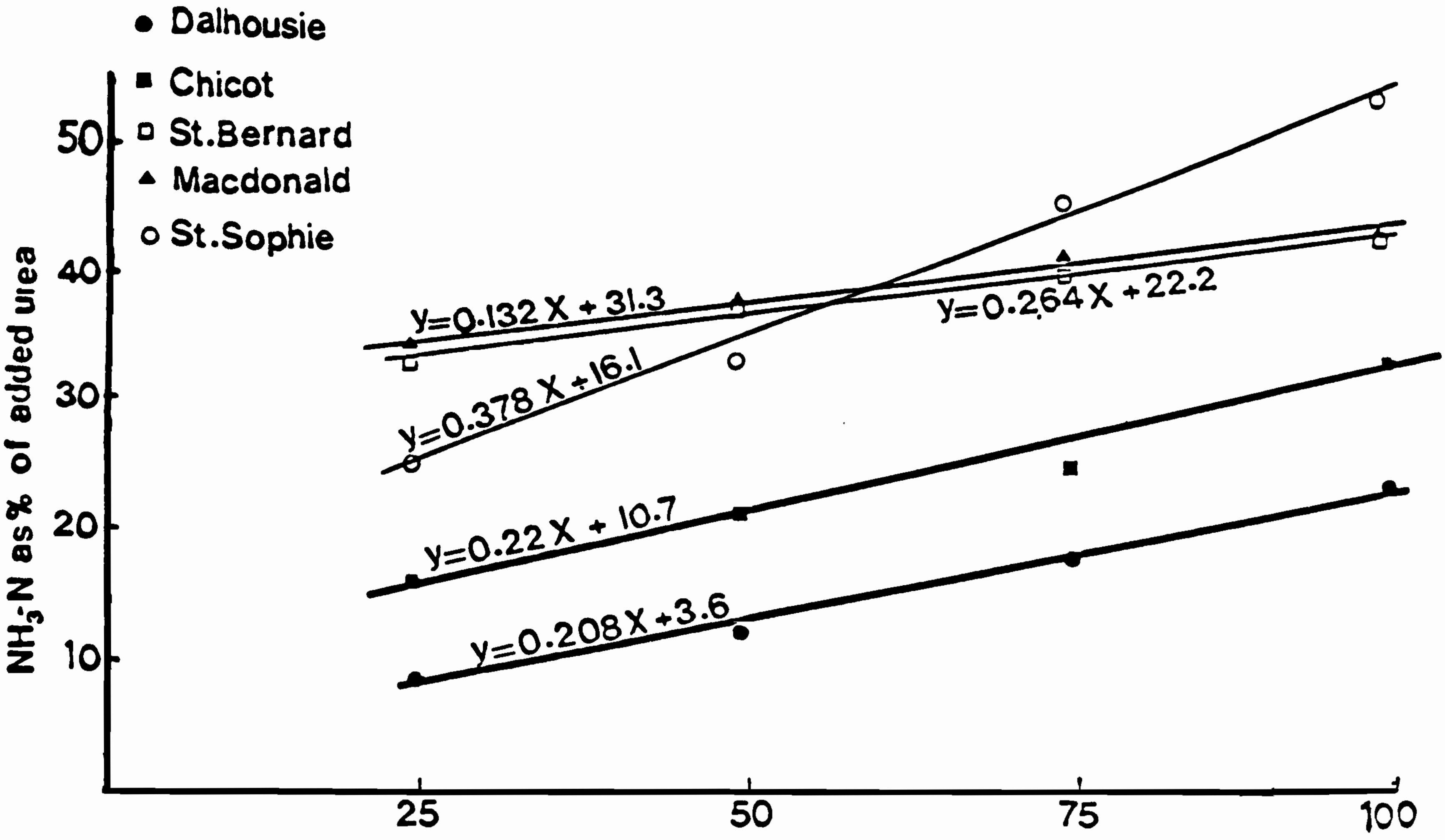
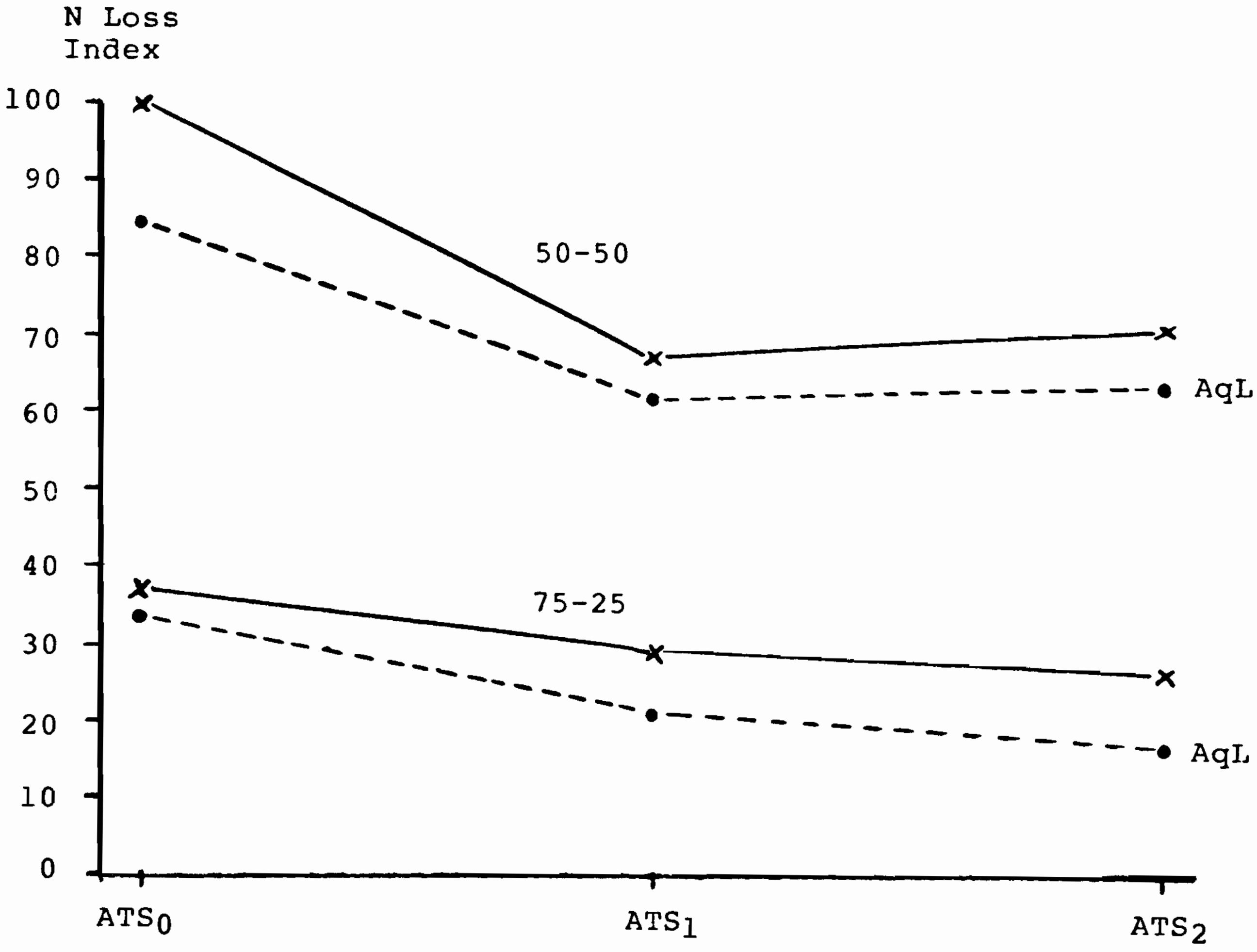


FIGURE 3



LEVELS OF UREA AS % OF TOTAL N

FIGURE 4 EFFECT OF AN-UREA RATIOS, ATS, AND AQUACHEM LIQUOR ON N LOSSES FROM A SANDY LOAM SOIL



Water-Soluble P_2O_5: Some Technical and Marketing Considerations

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INTRODUCTION

Why are we interested in talking about water-soluble P_2O_5? We all know that P_2O_5 is sold in the United States based on its available phosphorus. (You will note that I refuse to use the common terminology of available phosphoric acid or APA.) By definition, available phosphorus means the phosphorus soluble in water and neutral ammonium citrate as determined by a prescribed analytical protocol. Our interest then in water-soluble P_2O_5 stems from international sources, and it pertains to specifications and methods of measurement. Specifically, we are interested because the European Community (EC) requires that all superphosphates be guaranteed to have 93 percent of their declared value as water-soluble P_2O_5.

OEEC COMPILATION OF METHODS

Historically, how have we arrived at this point in water-soluble P_2O_5 specifications? In particular, how did the EC arrive at this juncture? And what about other international specifications? In 1948, the Organization for European Economic Co-operation (OEEC) was constituted and can be considered as a predecessor of the EC. The OEEC had 18 member countries, and the United States and Canada were invited to participate in its work. In 1952, the OEEC Subcommittee on Fertilisers, Fungicides, and Insecticides prepared a comparative study of the methods of analysis for fertilizers that currently were in use. Methods of analysis for nitrogen, phosphorus, and potassium from 14 of the 18 countries were included in the document *Fertilisers—Methods of Analysis in OEEC Countries.* The evaluation of phosphates was nearly all by combined extraction by water and citrate, with the exception of Ireland and the United Kingdom which listed only water-soluble extraction methods. This indicated that these two countries sold phosphates based on water-soluble criteria rather than water plus citrate solubilities. One last comment about the OEEC publication—inside the front cover a preamble is printed that includes the following sentence: "It has been through OEEC that the national recovery programmers of the membered countries have been coordinated so as to ensure the most effective use of American aid." This has a hollow ring after 40 years, and when a much more competitive attitude exists.

AID SPECIFICATION

In the mid-1960s, the U.S. Agency for International Development (AID) requested and received from Congress millions of dollars to provide fertilizer for developing nations. This prompted a need for the development of specifications and designated analytical methodology. On December 15, 1966, some 55 invited persons gathered in the AID offices in Washington to select and negotiate specifications and analytical methods. The group represented AID officials, USDA, TVA, NPFI, AOAC, university staffs, testing laboratories, and fertilizer producers. This initial meeting produced specifications and analytical methods for a very limited number of fertilizer products, and the first printed documents made no mention of water-soluble P_2O_5. Within 18 months, however, new specifications issued by AID did include water-soluble P_2O_5 minimum quantities. These minimum guarantees, shown in table 1 at the end of this paper, have remained essentially unchanged to the present date, even though there have been several revisions of the specifications. Attendees of the meeting in 1966 recall that the water-soluble minimums were established by a consensus of the producers and their ability to meet the guarantees without altering the production procedures in use at that time.

EC SPECIFICATION

In December 1975, the Council of the European Communities adopted a directive establishing mandatory provisions for the composition and definition of fertilizers. If member states adopted these provisions, they could label their fertilizer "EC fertilizer" and could trade their products within the community without hindrance from national regulations. The directive addressed only straight and compound solid fertilizers containing primary plant nutrients. Included in the specifications were five references to water-soluble P_2O_5. These are noted in table 2. Three of these cases referred to superphosphates and required that 93 percent of the declared content be present in a water-soluble form. Subsequently, it has been learned that the percentage of 93 was obtained by averaging the national specifications of all 10 of the countries represented on the council.

As the international fertilizer industry entered the 1980s, we had two sets of arbitrary water-soluble P_2O_5 specifications, neither of which had considered the requirements of the crop being fed nutrients. One was based on what the manufacturer could easily produce and the other was based on an average of previously set specifications, which I dare suggest were based on nonscientific considerations.

AOAC AND EC METHODS OF ANALYSIS

Before I continue this discussion, I feel obligated to direct a few remarks to the difference between the

AOAC and EC methods for determining water-soluble P_2O_5. The EC method prescribes weighing a 5-gram sample into a 500-milliliter flask, adding 450 milliliters of distilled water and rotating or tumbling for 30 minutes, diluting to volume, and analyzing an aliquot of the extractant solution. The AOAC method prescribes weighing a 1-gram sample, placing on a folded filter paper, washing serially until 250 milliliters of filtrate is collected, and analyzing an aliquot of the filtrate. Some years ago in a TVA comparison of the EC and AOAC methods, using triple superphosphate (TSP) and diammonium phosphate (DAP), it was noted that the EC method always yielded slightly higher results than the AOAC method when applied to TSP. The reverse was true when applied to DAP. Some selected results are shown in table 3. When the pH of the sample solutions were measured, they were found to be approximately 3.3 for TSP and 7.5 for DAP. To obtain comparative pH data from the AOAC method, it was necessary to measure the pH of each serially applied small portion of water. The results are shown in table 4. It appears that in the EC method, the free acid in the TSP sample influences the results, giving higher values; and in the DAP sample, the reverse effect was observed. In the AOAC procedure, the contribution by the acid in the TSP and the ammonia in the DAP was considerably less apparent than in the EC method. And after the third or fourth washing, no contribution was evident. As can be seen by the examples, one must be cautious and always define how results were obtained when commenting on water-soluble P_2O_5.

AGRONOMIC CONSIDERATIONS

The fertilizer Institute (TFI) constituted a task force in 1983 to gather information to justify the agronomic requirement for water-soluble P_2O_5. This was to support a bilateral negotiation between the United States Trade Representative and EC. Several scientists made literature searches to accumulate research data to support or deny the need for high water solubility of phosphates. The most comprehensive review was prepared by Dr. George W. Cooke, Honorary Scientist and former Deputy Director, Rothamsted Experimental Station, Harpenden, Herts, United Kingdom. Dr. Cooke examined 36 studies conducted in Europe and the United States between 1951 and 1983 and evaluated all the findings in a very concise, straightforward manner. The conclusions reached by Dr. Cooke (and independently arrived at by the other reviewers) can be summarized as follows:

- The greater part of applied phosphate reacts with soil within a short period, and its value will depend on the solubilities of the products of this reaction.

- There is no evidence that water-soluble phosphates leave residues in the soil that are more useful to crops than are the residues of citrate-soluble phosphates. In fact, there is some evidence to the contrary.

- No more than 20 percent of the amount of phosphate fertilizer applied will be taken up by the first crop grown.

- Finally, there is no indication that scientific evidence exists to support the EC requirement that 93 percent of the citrate-soluble phosphate should be water soluble.

Unfortunately, when negotiations were held in Geneva, Switzerland, in December 1984 and again in October 1985, very little attention was given to the agronomic evidence presented. It was the posture of the EC negotiators that the 93-percent-water-solubility requirement was a labeling issue and not an agronomic or scientific one; that U.S. producers used low-cost sludge acid to produce granular triple superphosphate (GTSP), and they could improve quality if they wanted to by using clean acid; and that the requirement had not penalized the United States because the decrease in sales in Europe was due to economics.

CURRENT AGRONOMIC STUDIES

To further evaluate the role of water solubility of phosphates, cooperative research is being conducted by TVA and Auburn University. The thrust of this work is to separate and identify water-soluble compounds from fertilizers, mix them with varying amounts of reagent-grade monoammonium phosphate (MAP), and test for agronomic response. This work will cover at least a 2-year period and may be extended. The identification and characterization of the insoluble compounds, in addition to controlling the degree of solubility, makes this work unique.

MARKETING CONSIDERATIONS

From the information that has been presented on USAID and EC product specifications, it is obvious that our discussion should center on the water solubility of available P_2O_5 in GTSP that will be consumed in the EC.

As a starting point, we need a brief description of the importance of GTSP as a P_2O_5 source, both in the world and EC marketplace and to U.S. producers. A review of recent trade statistics can lead to the following generalizations:

1. About 29 percent of current U.S. nameplate (47 percent of active) GTSP capacity is exported.
2. About 18 percent of the GTSP that moves in world trade is produced in the United States.
3. In calendar year 1984, the United States supplied about 15 percent of the GTSP imported into the EC but only 0.6 percent in 1987.

4. About 14 percent of the GTSP exported from the United States in calendar year 1984 went to the EC, and this declined to 0.9 percent in 1987.
5. GTSP is the source of about 20 percent of the P_2O_5 imported into the EC.
6. U.S.-produced GTSP averaged about 3.2 percent of the EC's P_2O_5 imports in calendar years 1984 and 1985. This has decreased to about 0.9 percent in calendar years 1986 and 1987.

What happened to the GTSP market in the EC after the enactment of regulations governing the water-soluble P_2O_5 content of GTSP? For the first five or so years of the life of the EC regulations, little, if any, attention was paid to the water-solubility issue. This relaxed attitude continued until the demand for GTSP for use as a direct application fertilizer or as a component of bulk blends began to show growth during the early 1980s. When these "new" uses of GTSP made significant inroads into the West European market, traditional market forces came into play. Then the existing regulations became a part of marketing strategy and buyer leverage.

In review, we note that EC regulations require that GTSP, as a distinct product, must have at least 93 percent of its declared P_2O_5 value in a water-soluble form if it is to be sold as GTSP. *BUT*, and this is an important "BUT," the water-solubility requirement is not defined for GTSP if it is to be used to prepare a blend with a *guaranteed grade* of, for example, 0–23–0—made by blending 500 kilograms of GTSP and 500 kilograms of filler. However, if a blender wants to avoid the risk of a mislabeling penalty arising from segregation problems detected in sampling, he may sell the above mixture as a *custom blend* by guaranteeing that the mixture contains a declared amount of GTSP (500 kilograms) and filler (500 kilograms) per metric ton. In this case, the GTSP must now meet the 93-percent-water-solubility requirement!

Dealers say that they do not want to store a 93-percent-water-soluble GTSP for sale as a direct application GTSP or for use in custom formulated blends and a second GTSP product which has no water-solubility requirements for use in *guaranteed grade* bulk blends. A price concession, however, can greatly reduce or even eliminate this last concern! This is a particularly effective method for obtaining low-cost raw materials for use in preparing *guaranteed grade* blends. Requested price concessions can be quite severe, and, in some cases, U.S. origin GTSP can have its sales value reduced to 83–93ds (89 percent) of the market price of competitive products. This latter situation comes into play when GTSP is in adequate or surplus supply or when market buy-in strategies are at play. A ratcheting downward of product price results when a buyer tells a non-U.S. supplier that he must meet the lowered, and very attractive, U.S. product price. The softening of GTSP prices between 1984 and 1987 reflect this and other pricing pressures. Market prices during 1988 suggest that these pressures are being resisted due to, perhaps, a short supply of product or reduced U.S. participation in the EC market.

Aside from price concessions, there has been a loss of sales of U.S.-produced GTSP to the Federal Republic of Germany (FRG) where buyers have refrained from buying GTSP that does not meet the EC solubility regulations. This is an unfortunate situation because well prepared bulk blends are growing in popularity in the FRG. Some trade statistics may show that 10 to 15 percent of U.S. GTSP sent to Western Europe enters the FRG, but these data do not show that all of this material was enroute to Eastern Europe. A summary of GTSP movement to Western Europe (excluding FRG shipments) during the calendar years 1984 to 1987 and an export price history ($/metric ton, F.O.B. Tampa) during calendar years 1984 to 1988 are shown in tables 5 and 6.

As mentioned previously, offshore customers and some domestic critics incorrectly avow that GTSP is made from "sludge acid" (an unfortunate synonym for "partially clarified acid") and that GTSP is, therefore, a product with low quality and value because it is made from an "inferior" and low-cost raw material. To set the record straight, the ratio of P_2O_5 from acid to P_2O_5 from rock in GTSP increases as the degree of acid clarification decreases. From an accounting viewpoint, the product made from unclarified acid may well have a higher production cost than the product made from fully clarified acid.

The direct effect on the market of the water-solubility issue and the perceived value of raw materials used to produce GTSP is impossible to evaluate. However, it is sufficient to say that these quality factors have been a part of the price history of GTSP during the past 5 years. A review of the median price of U.S.-produced GTSP from 1984 to the present suggests that through 1986 price concessions were possibly made either to accede to pressures exerted by the low-quality school; the water-solubility school; the buy-in school; or the practical choice of "some of the above, all of the above, or none of the above."

From the data in table 6, it can be concluded that from 1984 to 1987, the price of GTSP going into Western Europe from Tampa was about $125/metric ton plus freight plus import duty (about 4.8 percent), and that the U.S. market share shown in table 5 indicates a large drop despite a general decline in the median price of GTSP. This decline in U.S. market share to the EC continues, while the market share figures for product from Turkey, Tunisia, and Morocco show growth. Tunisia and Morocco have significantly recovered market shares from the early 1980s when they were losing to strong competition from established U.S. suppliers and expanding Israeli capacity. Global exports of GTSP from Turkey have shown consistent growth during the period 1983 to 1986, with a 400 to 500 percent growth in shipments to Western Europe during that period.

Northwest African producers bring an additional stress to the market when their production is heavily dedicated to delivering large P_2O_5 tonnages to India (acid and/or DAP) and Russia (GTSP). At the conclusion of these large contracts, product is again available from this source and there is another adjustment. No doubt this pattern will continue.

To stabilize their operations, U.S. producers have either prudently developed other markets or have accepted the role of secondary suppliers to traditional markets.

Data prepared by TFI for the U.S. Trade Representative to use in discussions with the EC in 1984 and 1985 showed that a 93-percent-water-soluble GTSP could not be produced from fully clarified (merchant-grade) phosphoric acid and presently available high-grade Florida phosphate rock (the lowest cost raw material combination). The data show that GTSP's P_2O_5 water solubility is strongly influenced by the total iron content of the product and the process used to produce the GTSP. It is not realistic to expect a relaxation of current water-solubility requirements because farmers and many others in the agricultural community equate nutrient water solubility with product performance and/or quality.

In summary, the technical and political aspects of water-solubility requirements for GTSP have not been resolved and prospects for a solution(s) are not bright. A change in geographic product distribution patterns has allowed U.S. producers to increase export tonnage (a 16.5 percent growth for 1987 shipments versus 1986 shipments of GTSP) despite a decline in volume to the EC. Other data sources suggest there was an 8 percent decline in U.S. exports of GTSP during this period. At the same time, the F.O.B. price of GTSP has shown a strong recovery. During 1986, the F.O.B. Tampa price of GTSP declined from a mid-March high of $143/metric ton to a year-end low of $101/metric ton. In 1987, the F.O.B. Tampa price of GTSP showed good growth to an end-December high of $153/metric ton. And during the last year, the price has continued its growth to an October 1988 high of $163/metric ton.

Despite today's very attractive picture for U.S. GTSP exports, it would be a mistake to think that market pressures have eased or have gone away. Consequently, U.S. marketing and production people need to work more closely than ever to ensure that unwarranted product specifications do not enter the marketplace and that substantive product quality is maintained throughout our industry.

RECOMMENDATIONS

1. Even though it may be market-driven, the fertilizer industry is a chemical industry and supplies a major input to agriculture. It must be directed by competent engineers, chemists, and soil scientists.
2. Fertilizer distribution is controlled by state and national laws throughout the world. Representatives of the industry must get involved and participate in the process of establishing regulations and specifications at all levels. This includes AAPFCO and AOAC in the United States and IFA, ISO, EC, FAO, and others on the international scene.
3. An issue not related to the subject of this paper but perhaps more important to our future is the impact of fertilizers on the environment. This will be our number one issue during the next decade, and we must address it seriously. Regulators will control the use of fertilizer and agrichemicals to protect our groundwater and we must work with them now.

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- Dr. Jim Ransom of NFDC

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- Official Journal of The European Communities 30.1.76, No. L24/21, Council Directive of 18 December 1975
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TABLE 1
Aid Specifications for Water-Soluble P_2O_5

Product	Percent of Available P_2O_5
DAP	85
MAP, granular	85
MAP, run-of-pile	85
GTSP	75
TSP, run-of-pile	75

TABLE 2
EC Specifications for Water-Soluble P_2O_5

Product	Percent of declared Value
Normal superphosphate, >16 percent	93
Concentrated superphosphate, >25 percent	93
Triple superphosphate, >38 percent	93
Partially solubilized rock phosphate, >20 percent	40
NPK, NP, or PK	If >2, must be indicated.

TABLE 3
Percent Water-Soluble P_2O_5 by Indicated Method

Product	EC	AOAC
GTSP	43.57	43.17
GTSP	44.52	44.31
GTSP	42.33	42.16
DAP	43.03	43.92
DAP	45.33	45.86

TABLE 4
pH of Washings from AOAC Water-Soluble P_2O_5 Method

Washing Number	pH of Solution From:	
	DAP	GTSP
1	7.40	3.13
2	7.30	3.50
3	7.06	4.76
4	6.98	5.61
5	6.93	5.97
6	6.88	6.06
7	6.84	6.12
8	6.78	5.99
9	6.85	6.20
10	6.76	5.90
11	6.84	6.18

TABLE 6
GTSP Prices
$/MT, F.O.B. Tampa

Year	Low	High	Median
1984	$117	$142	$130
1985	112	138	125
1986	103	140	121
1987	106	148	127
1988	149	163*	156

*As of October 6, 1988.

TABLE 5
Percent of GTSP Imports Entering Western Europe by Country of Origin

Year	Belgium	Holland	USA*	Morocco	Tunisia	Israel	Turkey
1984	7.7	30.1	13.7	14.0	23.5	10.0	0.9
1985	14.5	24.8	15.7	8.6	22.9	13.0	0.4
1986	11.7	30.8	7.4	7.7	29.2	7.5	5.8
1987	6.8	22.8	0.7	11.0	26.7	17.9	2.9

*Excluding shipments to FRG.

Tuesday, November 15, 1988

Session III
Moderator:

James J. Schultz

Improvements to CFI's Ammonia Converters Utilizing Casale's Internals

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ABSTRACT

In 1986, CF Industries modified the ammonia converters in their four Kellogg 1000 ton ammonia plants utilizing Ammonia Casale's internals to achieve a combined axial-radial flow design. These modifications, coupled with other retrofit projects, reduced the energy consumption of these four plants more than five (5) percent. After more than one and one-half years of operation, the converter performance and energy savings have not deteriorated.

Part I describes the technology, project planning, implementation and results achieved in the four CF Industries plants at Donaldsonville, Louisiana. Part II describes the application of the Casale axial-radial ammonia converter technology to other types of ammonia converters.

PART I

INTRODUCTION

CF Industries operates four nominal 1000 ton per day ammonia plants, designed and built by Kellogg at Donaldsonville, LA. Two of these plants began operation in 1976, and are the so-called "Stretched" 1000 ton plants. They are equipped with air preheat, ten row reformers and other minor modifications which result in a design through-put of 1150 short tons per day. The other two are 1000 ton per day ammonia plants which were placed on stream in 1965 and 1969, and have eight row reformers without air preheat.

Beginning in the late 1970's, CFI began seriously considering major plant improvements directed toward improved energy efficiency. Process computer control and installation of a system for cryogenic recovery of hydrogen and methane from purge gas are examples of the projects placed in service. These improvements functioned merely as additions to the basic process and did not alter the original plant design.

In the early 1980's, imports of low cost ammonia, especially from non-free market economies, and rising feedstock prices, significantly reduced profit margins. It became apparent that for CFI to remain a major domestic manufacturer of nitrogen fertilizer, the efficiency of the production units at Donaldsonville would have to be improved. During this time period, CFI operated its two older, less efficient plants at Donaldsonville, using low costs natural gas provided under a long term contract which was to expire in 1986. The low cost gas could not contractually be used in the newer plants. The high cost of natural gas, and low product prices dictated that the two newer plants, which operated on higher cost feedstock, be shutdown for extended periods in the early 80's. Survival became the incentive to enhance energy efficiency, as the expiration of the low cost gas contract in 1986 approached. The goal of any retrofit project was thus clearly established, as the reduction of energy consumption. When the benefits of any retrofit project could be realized as increased production or reduced energy consumption, we chose the latter.

The capital costs for any retrofit projects undertaken in 1985 and 1986 were expected to be reasonable, due to the low level of orders in the major fabrication shops, and the fierce competition in both the equipment manufacturing and construction sectors. The indications were that the most appropriate timing for installation of retrofit projects would be in the summer and fall of 1986 when the normal low demand for product coincided with the expiration of the low cost feedstock contract.

PLANNING

With the basic timing established, CF began in-house evaluation of several energy saving projects. The projects considered included:

1. Cogeneration
2. Hydraulic turbines in the CO2 removal systems
3. Improved ammonia converters
4. Heat recovery from flue gas

5. Superheated steam burners
6. Upgraded CO2 removal solvents
7. Intermediate temperature shift converters
8. Molecular sieve synthesis gas dryers

These projects were, in some cases, mutually exclusive, and all of them impacted the plants' steam balances. Roger Parrish assisted in the evaluation of these projects and his computer program was used to perform the energy and material balance calculations. The CF Industries' Project group retained Salmon and Associates to make detailed estimates on the more promising projects.

Evaluation of the expected energy savings indicated that the combination of projects with the best rate of return within the capital limitations consisted of the following.

1. Retrofit all four of the existing ammonia converters with the Ammonia Casale combined axial-radial design. Also, included was the revision to the synthesis gas compressor recycle impeller, to accommodate the lower circulation rate.
2. Install feed gas saturator coils for flue gas energy recovery in the two older plants without air preheat.
3. Install new CO2 removal solvents in all four plants, including replacing two cooling tower pump turbines with condensing turbines to achieve a satisfactory steam balance.
4. Install molecular sieve synthesis gas dryers in the two newer plants.

CASALE CONVERTER MODIFICATION

Of the projects selected, only the Casale ammonia converter modification was previously unproven in a Kellogg 1000 ton per day plant. As this is the primary focus of this paper, the reasons for selecting this design, its operation and installation will be discussed in more detail below.

Before selecting this option, various converter configurations were considered including radial flow units, horizontal converters, and combination of one new converter in one plant with the relocation of the surplus converter to parallel operation in another plant. All of these options had internal rates of return lower than we would normally accept. This was primarily because of the high cost of a new converter. Other design modification proposals to the existing converters were considered, but they were not as well developed as Casale's or involved cutting the top off of the existing converter in the field to install new internals. CF was unwilling to accept the risk of successfully rewelding the top on a converter which had been in service for 20 years.

In 1985, Ammonia Casale S.A. approached CF through Process Management Enterprises and presented their proposal for a converter modification which would change the present converter (FIGURE 1-A) from an axial flow unit to one combining axial and radial flow patterns. Their design permitted the utilization of the smaller 1.5 - 3.0 mm catalyst with a significant pressure drop reduction and improved ammonia conversion. The modified converter also provided for an increase in the catalyst volume of approximately 8%. The Casale design involved a complete revision to the basket internals of the existing converters. As the existing pressure shell and most of the existing basket would be reused, the cost of a modification of this type was only a small fraction of a complete new converter. The Casale proposal eliminated the need for new foundations, piling, large transportation costs and long delivery times required for other, new, low energy converters. Casale claimed that the converter could be modified in 21 days. This permitted a reasonable turnaround schedule of 32 days from plant shutdown to completion of catalyst reduction. The first converter modified at Donaldsonville could be completed in eight months from issuing the purchase order, and the remaining three converters could be modified during the next four months. Another advantage of the Casale design was that the only welding to the converter basket required is to the quench pipes and at the bottom of the catalyst drop out nozzle. No problems with nitriding or embrittlement in welding to these basket parts was anticipated because of the weld locations and relatively low operating temperatures.

The Casale proposal was lump sum, turnkey, with the fabrication and installation to be performed by VEW of Austria, a firm with whom we have dealt quite satisfactorily in the past. After carefully reviewing the process and mechanical features of the proposed design, CFI selected the Casale design for modification of all four ammonia converters at Donaldsonville.

In September 1985, funding was authorized to prepare major equipment specifications and obtain pricing on long delivery equipment. Salmon and Associates was retained to prepare these specifications and proceed with the engineering necessary to retrofit the first plant in July, 1986. The CFI Project Engineering Group administered this work, and handled procurement. The process engineering and technical evaluation was performed by the Donaldsonville staff. Final approval on the project was given in late December, 1985, and Salmon and Associates was retained to do the detailed engineering of all parts of the retrofit with the exception of the converter internals, the proprietary portion of the feed gas saturator and the syn gas compressor modification. Process engineering was handled by the Donaldsonville staff. Construction was done by Matthews McCracken Wallace under the supervision of the CFI Projects Group.

AXIAL RADIAL ADVANTAGES AND OPERATION

The Casale modification generally maintains the existing quench converter's configuration of four beds with quenches for inter-bed temperature control. From a process viewpoint, the modification utilizes a combined axial-radial flow system with the largest portion of the flow being radial. (FIGURE I-B) This permits the use of small (1.5–3.0 mm) catalyst. This catalyst has a very high activity and has been used successfully in other high efficiency converter designs. This catalyst has a high pressure drop and is practical only when used in designs where the length of the flow path is limited. A more efficient quench arrangement is incorporated into the system to provide better mixing of the quench gas with the bed effluents.

The operation of the modified converter can best be illustrated by following the process flows on the drawing. (FIGURE 1-B) The primary inlet flow to the converter is into the annular space between the basket and the shell to provide cooling to the shell. The gas then passes through the shell side of the existing converter effluent interchanger. As the feed gas exits the interchanger, it is mixed with the first bed quench flow to control the first bed inlet temperature. A new first bed quench ring is installed closer to the outlet of the converter interchanger to improve mixing and temperature control. Because there is a level of catalyst above the perforated portion of the new outer wall, most of the flow is forced into the center distribution chamber.

The feed gas then flows radially outward through the catalyst. The catalyst is contained between two concentric perforated cylinders covered with an Inconel wire mesh. The gas flows outward through the screen mesh and distribution holes in the new outer wall where it is combined with the quench gas. The quench flow is introduced through holes in the bottom of a circumferential ring which has a rectangular cross section and rests on the top of the new outer wall. The holes in the bottom of the quench header are sized to insure even distribution around the circumference of the basket. Gas shields are installed to prevent cool quench gas from impinging directly on the existing converter basket. The quench gas and the bed outlet flow mix together as they move downward through the annular spaces between the existing basket and the outer wall of the Casale insert. The gas then flows into the space between the bottom of the new floor and the bottom of the old bed. The gas flows both downward through the holes in the existing basket and radially toward the center to the inlet distribution chamber for the next bed. The top three beds function similarly. Most of the gas exiting the third bed, after mixing with the quench gas, flows outward to the annular space between the new outer wall and the existing basket. Thus, in the first three beds, the gas flow is radially outward. In the fourth bed, the flow is radially inward to the center collector. The effluent of the fourth bed then flows upward through the center outlet pipe to the tube side of the converter interchanger.

INSTALLATION

Before the converter could be modified, it was necessary to remove the catalyst. The converter was cooled to 110°F by circulating a heavy H/N ratio with high inerts. The ammonia content in the synthesis loop was also increased to facilitate cooling the converter. The converter was then cooled further with a nitrogen purge and blinded. A continuous nitrogen purge was kept on the converter during catalyst removal. The oxygen content was monitored at all times during the catalyst removal operation as any leak in the vacuum system allowed small quantities of oxygen into the converter. The catalyst temperatures would begin to rise when this occurred and it was necessary to increase the nitrogen purge rate while the leak was located and repaired. The catalyst removal was performed by CAT-TECH, who operated in a very professional and safety conscious manner. After all catalyst was removed, the converter was purged with air until a safe working atmosphere was established.

After the catalyst has been removed from the converter, the intercooler and center outlet pipe are removed. The catalyst basket is then carefully plumbed and the actual internal dimension taken. The center holes in the bottoms of the first three beds were enlarged and the collection manifold at the outlet of the fourth bed was removed. If necessary, the castable refractory was repaired or ground to the original design dimensions to accommodate the prefabricated floor plates. It should be noted that the refractory in all of the four converters at Donaldsonville deviated significantly from the drawings. The bed bottoms are fabricated in pie shaped sections small enough to be brought in through the interchanger opening. The floor plates in the bottom of the fourth bed are fitted into position on top of the refractory and welded together. The pie shaped segments are supported at the center by a plate which is the base of the center collection tube. This plate was supported mechanically by pipe which extends downward into the cool portion of the catalyst drop out pipe where it is welded in position. This was one of the locations where a weld was made to the existing basket. There was little concern for nitriding or hydrogen embrittlement at this location because of the low temperatures. Metallurgical analysis of 321 stainless steel samples from a converter, which had been in service since 1965, exhibited nitriding approximately 0.5 mm deep. Once the floor plates are in place, gussets were welded to the floor plates which extend outward to support the outer wall of the new insert. The tops of the gussets were cut at a constant elevation to insure that the wall sections are plumb. The outer wall sections were then installed so they were equidistant from the center of the basket and have sufficient clearance for thermal expansion between the outside of the outer wall and the existing basket. The bed bottom in the other beds were prefabricated to fit the existing bed bottoms and were supported approximately one (1) inch above the existing bed bottom on radially, oriented square bars. The new bottom segments were positioned and bolted in place to the existing bed bottom before the segments were welded together. The outer wall of the insert was then positioned, concentric with the vessel centerline, and with the correct radial clearance. The wall segments were bolted together and welded to each other and to the bottom of the bed. Because the opening in the new bed bottom at this time was larger than the inlet distributors for the top three beds, it was possible to work on the floors, outer wall sections and quench rings of all the beds simultaneously. The quench rings and center inlet distributors for the top three beds and the central outlet pipe were installed after the outer wall sections are in place. The center inlet distributors were mounted on flat annular rings, which in the O.D. were welded to the new bed bottom and on the I.D. to the center collection pipe. As the new center collection pipe was anchored at the bottom of each of the top three beds, it was necessary to provide expansion bellows between each bed, as well as on the new quench pipes to compensate for differences in thermal expansion. Each catalyst bed was covered with pie shaped segments of Inconel wire mesh on flat bar frames to contain the catalyst and prevent catalyst milling.

CONSTRUCTION TIME

The installation of the Casale insert in all four plants was completed without any major problem. The time required for installation was 22 days for the first converter, although there were several delays caused by bad weather and mechanical problems with the air conditioning unit. The next two converters were completed in 20 calendar days or less. The last converter was revised in 18 days, with the VEW construction crew taking Sundays off. The VEW workmanship was very good.

CATALYST REDUCTION AND START-UP

The catalyst reduction went well although there were some problems in getting the on-line mass spectrometer, the lab wet chemical analysis and the laboratory gas chromatograph to agree on ammonia analysis. In the first three plants, there were interruptions to normal operation at the conclusion of the catalyst reduction because of problems not associated with the converter modification. Only one of the shutdowns was related to the retrofit project. A new balance piston and seal were installed in the high pressure case of the synthesis gas compressor as a part of the recycle impeller modification. This aluminum seal was badly eroded by catalyst dust during the catalyst reduction. This seal was replaced by a stainless steel knife edge labyrinth seal which has shown no signs of deterioration. In the remaining plants, stainless steel honeycomb seals were installed in this application.

CONVERTER MODIFICATION PERFORMANCE

The results achieved at Donaldsonville were quite satisfactory and exceeded our expectations. In the older plants, at production rates of 1170 short tons per day, and normal converter inlet pressures, the pressure drop across the converters and the ammonia conversion fulfilled the Ammonia Casale performance guarantees comfortably. In the two newer plants, the test runs were conducted at 1400 short tons per day. Again, all performance guarantees specified by Ammonia Casale were comfortably satisfied. The performance tests were conducted with 9% inerts to simulate the performance of catalyst near the end of its useful life. The pressure drop in the converter was less than anticipated and the modified compressor wheels had slightly greater capacity than anticipated. It was necessary to throttle the compressor suction to achieve the flows and converter pressure specified for the test run. After the test runs were completed, even more economical operating conditions were established. The actual temperatures, pressure drops and gas analysis are considered company confidential information, and in any case, the expected performance of a Casale modified converter in any other plant must be based on actual operating data from the plant under consideration.

PERFORMANCE OF OTHER RETROFIT PROJECTS

There were no mechanical or process problems with the start-up or operation of the feed gas saturator coil. The coil is capable of lowering the temperature of the stack temperature from above 500°F to below the design of 260°F. One point in the interest of safety should be mentioned. During a subsequent plant start up, stream being fed to the mixed feed coil backed into the saturator coil and condensed. This condensate completely filled the saturator coil outlet separator and went undetected. When gas was introduced, this condensate was pushed through the mixed feed coil and into the reformer. The resulting thermal shock resulted in one reformer tube failure. The installation of a check valve on the saturator coil separator outlet and the installation of more reliable level alarms has solved this problem.

The mole sieves have functioned as designed with no operational problems. The only mechanical problem was a recurring steam leak on the regeneration heater channel gasket. This problem was the result of a piping stress problem and was easily solved. The mole sieves have permitted inlet ammonia concentration of the converter to be reduced below our expectations.

Two different CO2 removal system solvents were installed in the four plants. Both solvents were manufactured by Union Carbide and both used inhibitors requiring air oxidation. Due to corrosion in these systems, these solvents have been replaced with a Union Carbide solvent which does not contain inhibitors requiring air oxidation. Three of the plants' absorbers were corroded to near their minimum allowable wall thickness while in MEA service. Additional wall loss, which occurred while using the air oxidized inhibitors, has necessitated the replacement of the absorbers in three plants. At this writing, the indications are that there is minimal corrosion with the new solvent.

OVERALL PERFORMANCE IMPROVEMENT

Overall, the energy savings for this project have been very satisfactory and represent a reduction in energy consumption per ton of ammonia in excess of 5%. After approximately one and one-half years of operation, no loss of converter performance of energy savings has been observed. These projects in all four plants, including engineering, materials, labor, catalyst, chemicals, overhead, and taxes, were installed for approximately 10% under budget.

The success of this project was the result of the contributions of many groups. The production, maintenance and engineering staff at Donaldsonville worked closely with the design engineers, contractors and with the CF Projects Group, from the concept stage through start-up. All of the outside contractors and design engineering groups did an excellent job.

PART II

The Casale axial-radial ammonia converter technology, which was applied to the Kellogg type converters in the CFI plants as described in PART I, has also been successfully applied to other types of ammonia converters. In Part II, the application of the technology to four different types of ammonia converters is briefly described. The four different types of converters selected to illustrate the application of the technology are:

1. A Topsoe S-100 type converter
2. A TVA type converter
3. An ICI lozenge type converter
4. A BASF type converter

In all of the typical examples selected, the energy savings achieved were comparable to those achieved in the CFI converter modifications. In some instances, converter production capacity was increased in addition to energy savings.

TOPSOE S-100 TYPE CONVERTER

A typical example of the application of the Casale axial-radial technology to a Topsoe S-100 type converter is the modification of the Ruhr-Stickstoff AG (formerly AMH-Chemie) converter in Brunsbuttel, West Germany.

The original converter, as shown schematically in Figure II-A, was a 2-bed quench type cartridge with radial gas distribution. This converter, which utilized small size catalyst, had a design capacity of 1700 metric tons per day.

The Casale modification of this converter, shown in Figure II-B, involved replacement of the original cartridge with a 3-bed, "Piled-Up Baskets" quench type cartridge. The cartridge was designed for small size catalyst (1.5 - 3.0 mm). The gas flow arrangement provided was outward in the first two axial-radial beds and inward in the third bed. Quench rings between the beds were located in the upper part of the annulus between the cartridge wall and the gas outlet distribution wall to obtain efficient gas mixing.

The upper two baskets are easily detachable from the cartridge wall. They are simply seated on top of the other with no sealing requirements. This provides for simple catalyst replacement and maintenance.

The new cartridge was designed for a capacity of 2060 metric tons per day, a 20% increase, in addition to energy savings.

TVA TYPE CONVERTER

A typical example of the application of the Casale axial-radial technology to the TVA type converter is the modification of the 220 metric tons per day plant of NCZ in Kafue, Zambia.

The original converter, as shown schematically in Figure II-C, was a single bed design with axial gas flow and large size catalyst. The catalyst bed contained bayonet-type coiling tubes, which served to cool the catalyst bed and to preheat the inlet feed gas.

The Casale modification of this converter, shown in Figure II-D, involved the replacement of the original cartridge with a 3-bed, "Piled-Up Baskets" quench type cartridge. An outward gas flow was provided for all three axial-radial beds. In other respects, the Casale modification of this converter was similar to the modification provided for the much larger Topsoe S-100 converter described previously.

ICI LOZENGE TYPE CONVERTER

A typical example of the application of the Casale axial-radial technology to the ICI lozenge type converter is the modification of the ICI Plant No. IV converter in Billingham, England.

The original converter, as shown schematically in Figure II-E, was equipped with a lozenge type cartridge containing two quench lozenges. The gas flow was axial and large size catalyst was used. This converter had a design capacity of 1200 metric tons per day.

The Casale modification of this converter, shown in Figure II-F, involved replacement of the original cartridge with a 3-bed, "Piled-Up Baskets" type cartridge, with one quench and one interbed heat exchanger. The gas distribution provided was outward in the first bed, and inward in the second and third axial-radial beds. Small size catalyst was used for this design.

The quench ring between the first and second bed was located in the upper part of the first bed annulus between the cartridge wall and the gas outlet distribution wall. The interbed heat exchanger was located inside the second bed, while a gas-in/gas-out interchanger was located inside the third bed.

To maximize converter space utilization, the first and second bed bottoms were designed with convex shapes.

The first and second beds, as well as the interbed heat exchanger, are easily detachable from the cartridge for simple catalyst replacement and maintenance.

The new cartridge was designed for a capacity of 1450 metric tons per day, a 20% increase, as well as for energy savings.

BASF TYPE CONVERTER

A typical example of the application of the Casale axial-radial technology to a BASF type converter is the modification of the 1200 metric tons per day BASF AG converter in Ludwigshafen, West Germany.

The original converter, as shown schematically in Figure II-G, had a 4-bed quench type cartridge. The gas flow was axial and large size catalyst was utilized. The quench between the beds was achieved with a gas distributor located in a box at the catalyst support grid exit.

The Casale modification of this converter, shown in Figure II-H, changed the flow configuration in all four beds to axial-radial in an outward direction. Small size catalyst (1.5 - 3.0 mm) was employed in the design. The same quench distributors were used, but with an improved design. New parts have been inserted to create the gas inlet and outlet distributors and to seal the bottom of each catalyst bed.

As in the CFI plants, the design objective for the BASF plant was to maintain the existing capacity and to maximize energy savings.

CONCLUSION

These typical examples of the application of the Casale axial-radial ammonia converter technology to achieve energy savings and capacity increases in existing ammonia plants. Each application is custom designed to fit the particular conditions and objectives of the particular plant. The experience of CF Industries in Donaldsonville, Louisiana is typical of what can be achieved in the modification of most types of converters.

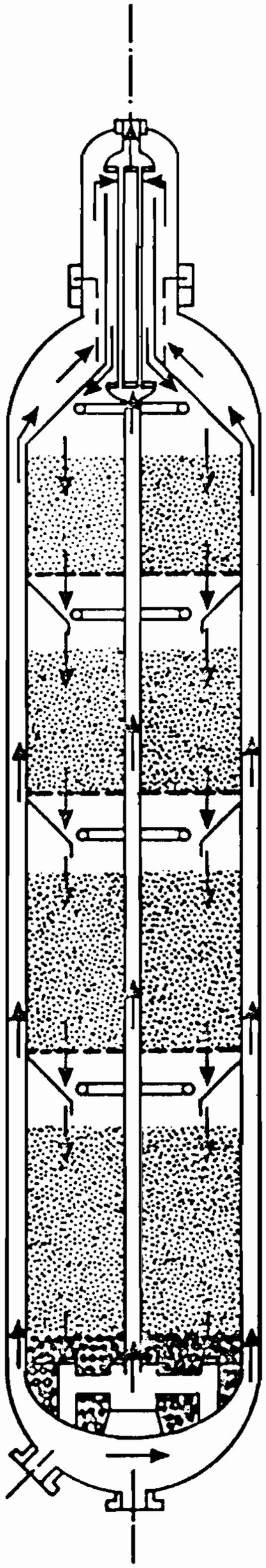


FIG. 1A

ORIGINAL CONVERTER DESIGN

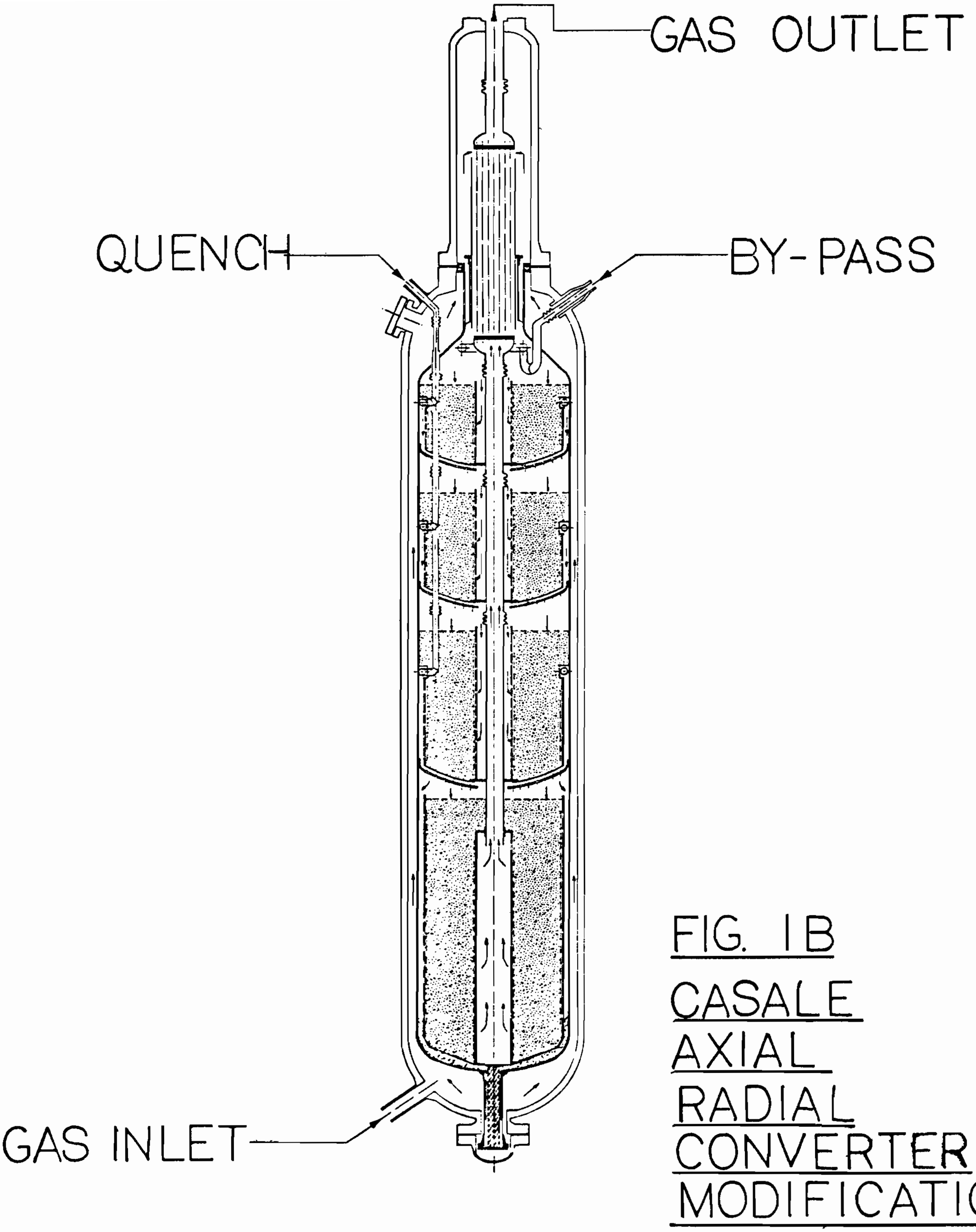
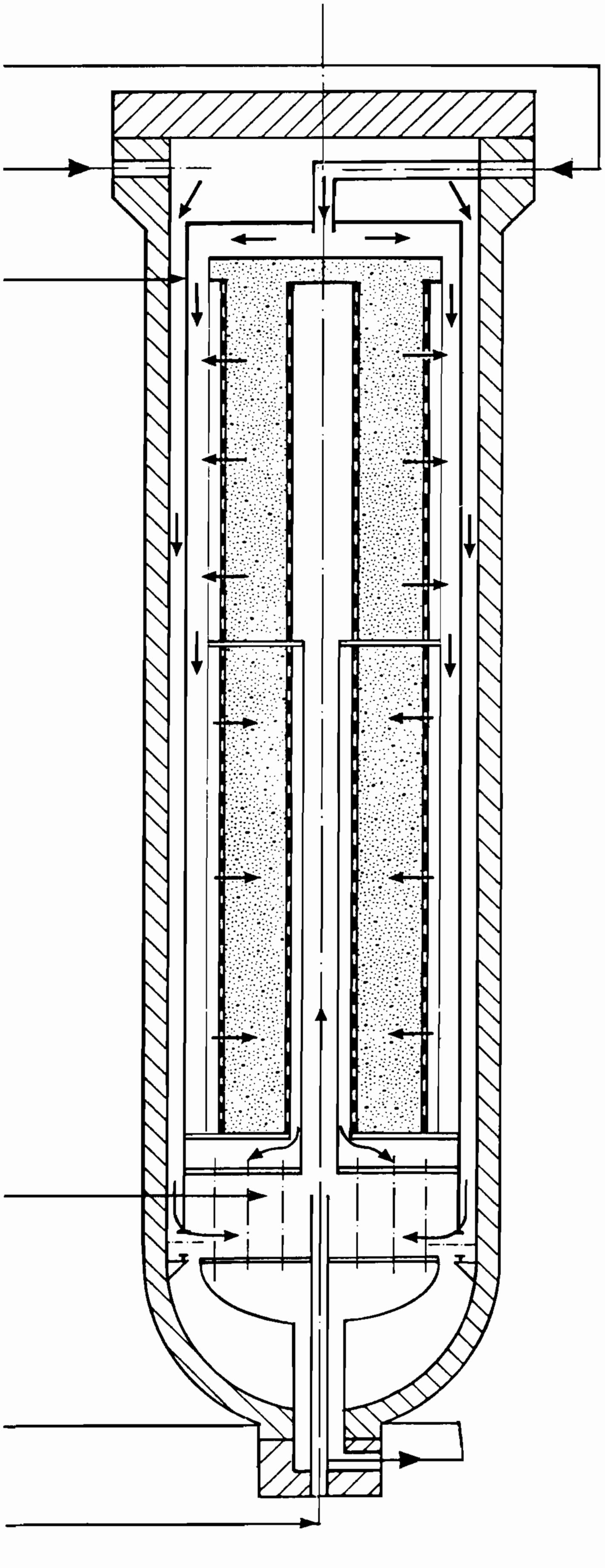


FIG. 1B
CASALE
AXIAL
RADIAL
CONVERTER
MODIFICATION

FIGURE II-A TOPSOE S-100 TYPE CONVERTER



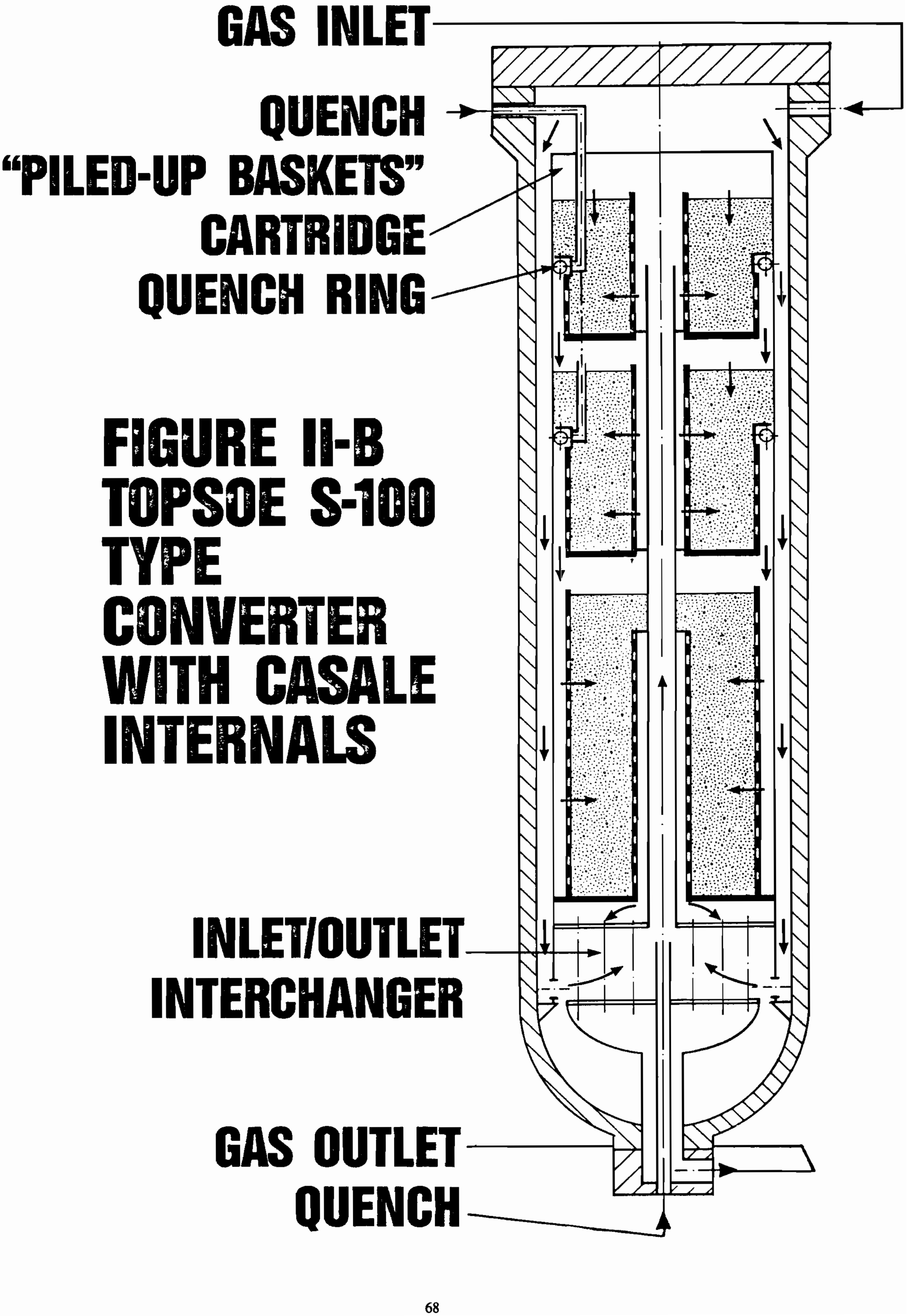


FIGURE II-B
TOPSOE S-100
TYPE
CONVERTER
WITH CASALE
INTERNALS

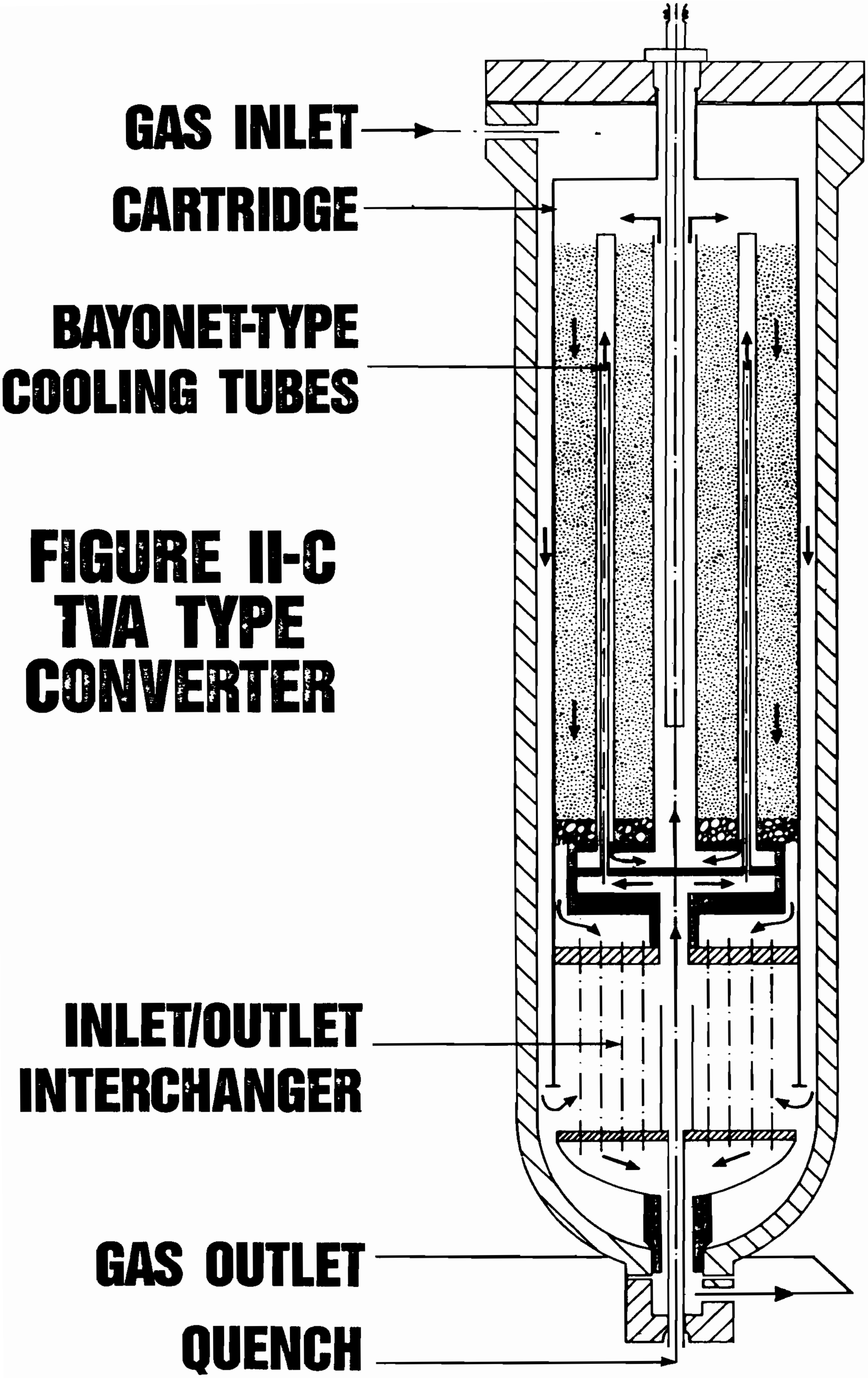


FIGURE II-C
TVA TYPE
CONVERTER

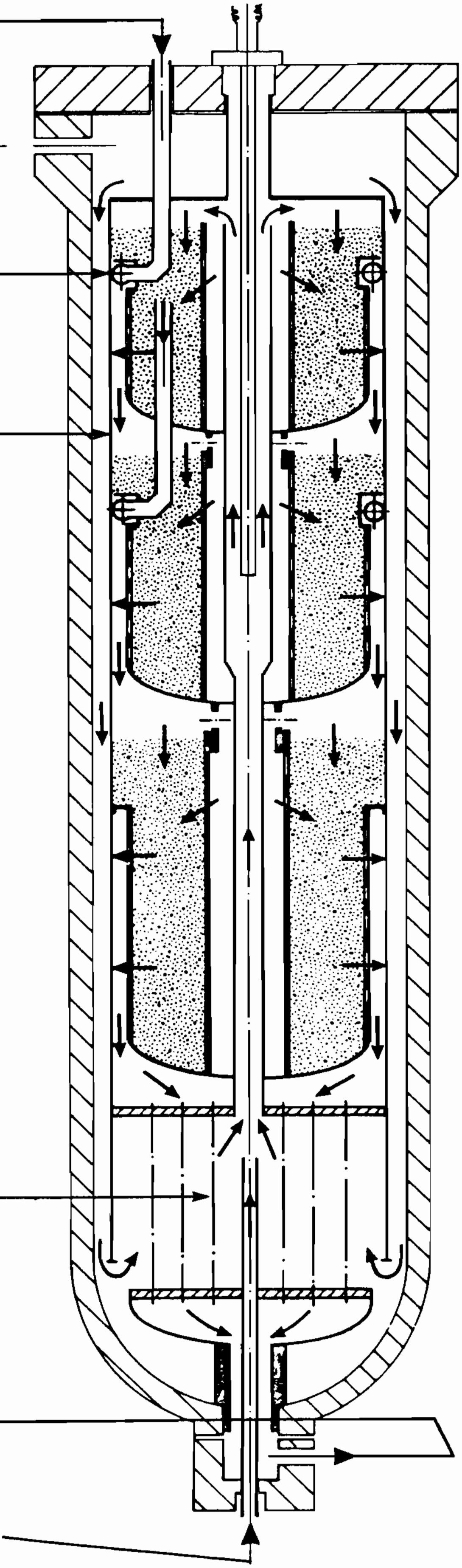


FIGURE II-D
TVA TYPE
CONVERTER
WITH CASALE
INTERNALS

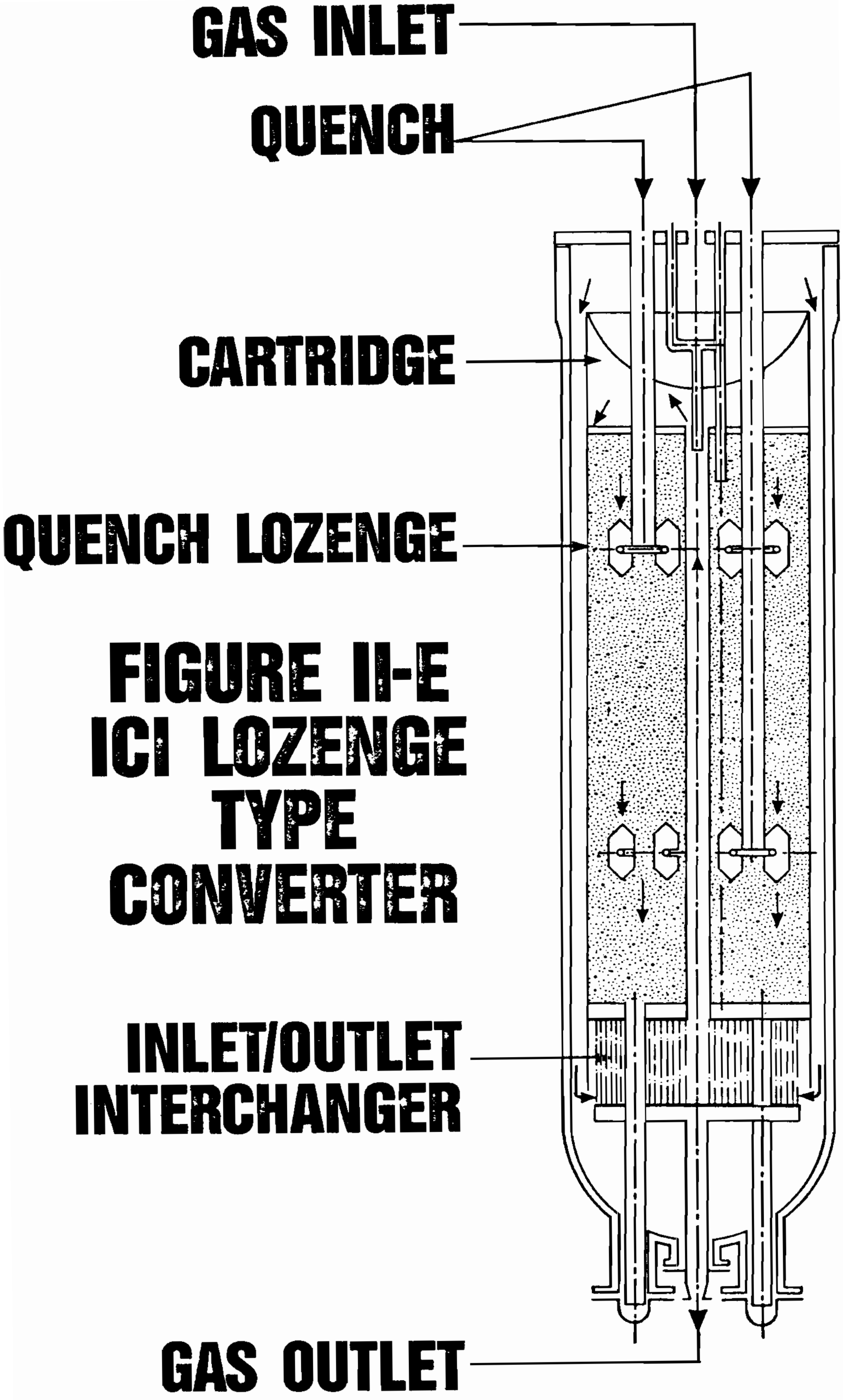


FIGURE II-E
ICI LOZENGE TYPE CONVERTER

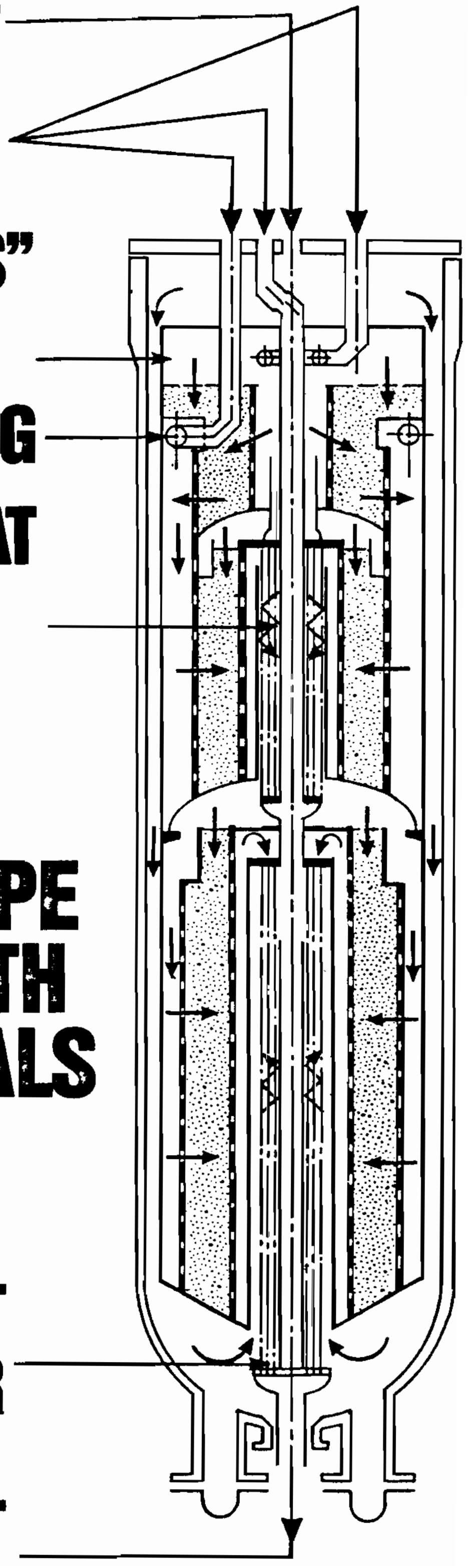


FIGURE II-F
ICI LOZENGE TYPE CONVERTER WITH CASALE INTERNALS

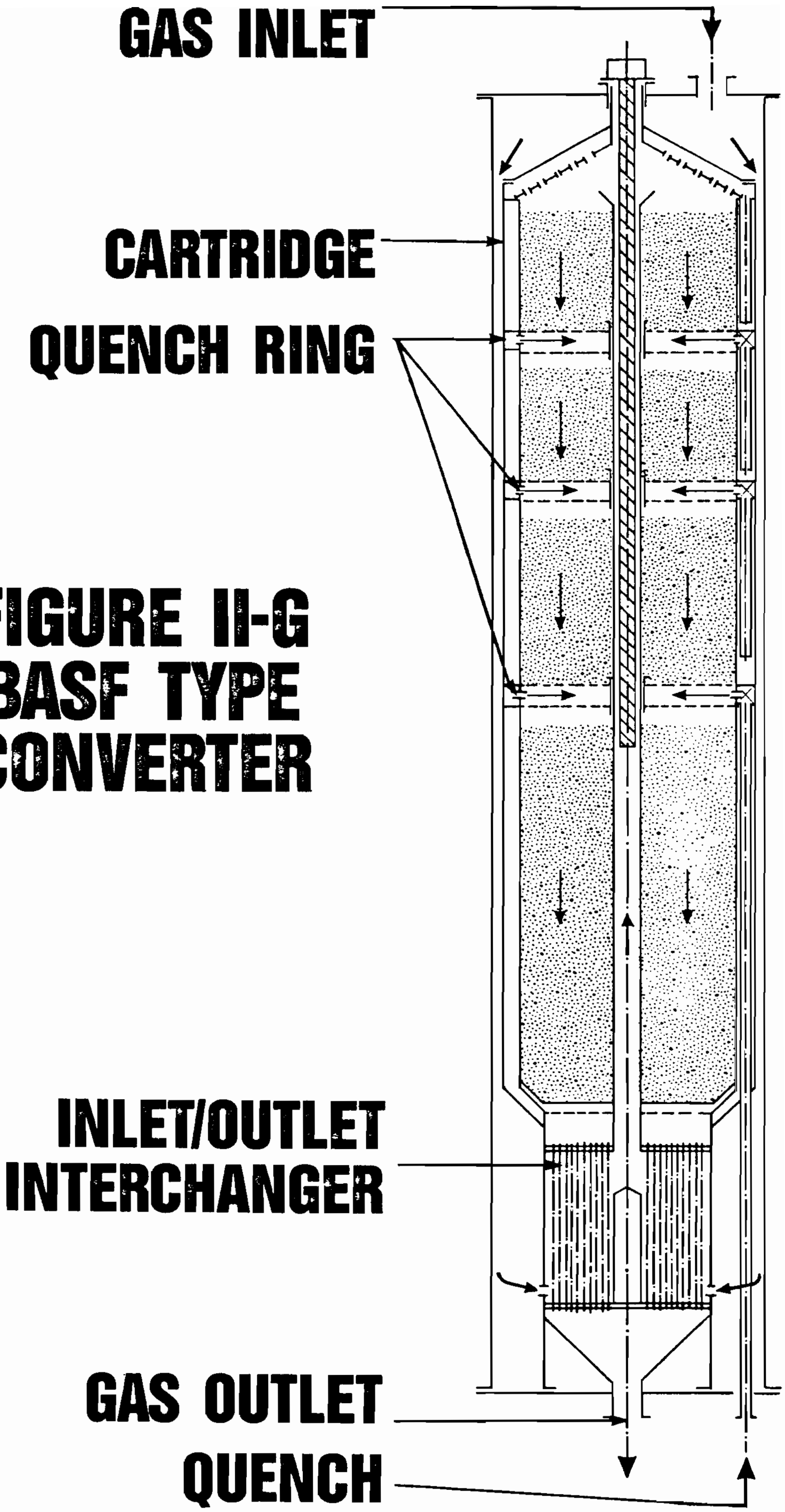


FIGURE II-G
BASF TYPE
CONVERTER

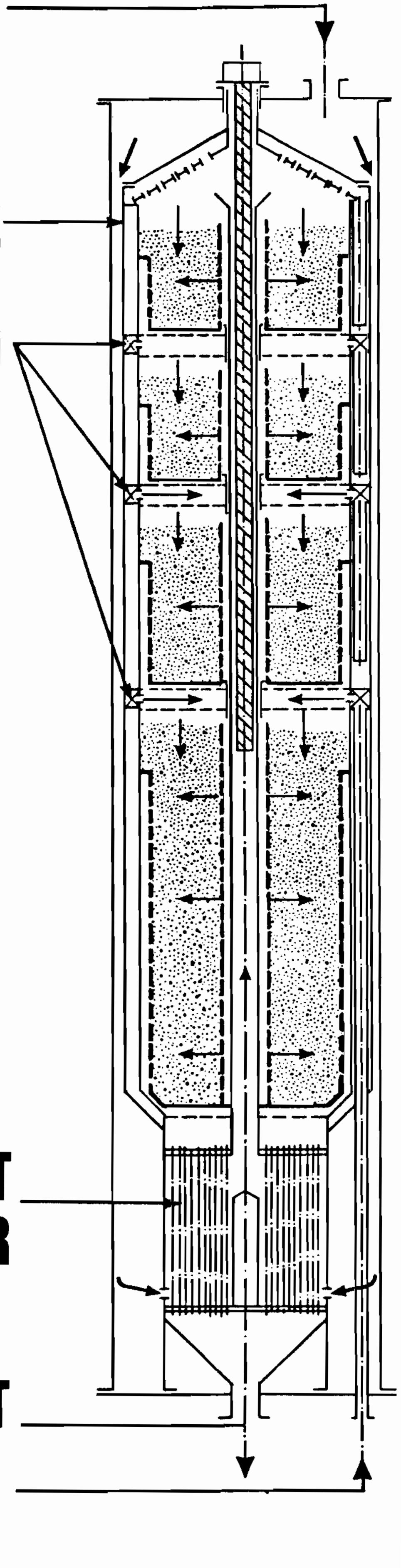


FIGURE II-H
BASF TYPE
CONVERTER
WITH
CASALE
INTERNALS

Modernization of an Agrico Ammonia Converter Via the Kellogg Vertical Split-Flow Basket Modification

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The M. W. Kellogg Company

ABSTRACT

A report on Agrico's ammonia converter basket modification is presented. Various aspects of the retrofit of Agrico's plant No. 2 at the Verdigris, Oklahoma complex are discussed including field construction, analysis of preliminary test data, and final performance after incorporating improved temperature control features.

INTRODUCTION

With the current state of the ammonia market, emphasis has been placed on revamping existing plants with low cost retrofit schemes which provide short payout periods through reduced energy consumption. Of these schemes, one of the most attractive retrofit options is to perform an in-situ revamp of an existing ammonia converter basket to provide increased conversion and reduced pressure drop. Since retrofitting a converter necessarily requires replacement of the existing catalyst charge, the economics are particularly attractive when the retrofit coincides with a scheduled catalyst change-out.

The Agrico Chemical Company's Verdigris, Oklahoma fertilizer complex includes two worldscale ammonia plants built by The M. W. Kellogg Company. Plant No. 1 is a nominal 1000 STPD plant originally started-up in 1975 while plant No. 2 is a nominal 1150 STPD plant brought on stream in 1977. Agrico operates both plants at production rates of 20 to 30% above nameplate capacity. Excellent on-stream factors were highlighted in 1986 when plant No. 2 completed a record setting run of 25 months of continuous ammonia production.

A gradual increase in the plant No. 2 ammonia converter pressure drop was first observed during 1984. The trend continued in 1985, prompting Agrico to begin planning for a turnaround in 1986 to take corrective measures. Since inspecting the converter internals would require unloading the catalyst charge, the decision was made to modernize the converter by performing an in-situ converter retrofit.

In March 1986, after evaluating the three competing proposals, Agrico awarded Kellogg a lump-sum turn-key contract for performing the converter retrofit. External to the converter, the only modification required to realize the energy savings is to install a smaller recycle wheel in the high pressure case of the synthesis gas compressor. This also was included in the scope of the project. The plant No. 2 shutdown was scheduled for the end of August, leaving only 5 months to engineer, procure, fabricate and ship the required equipment to site, as well as the new catalyst charge.

VERTICAL SPLIT-FLOW BASKET MODIFICATION

The Kellogg converter retrofit consists of an in-situ modification of the converter's internal basket which changes the process design from a four bed quench to a two bed, split-flow, intercooled system. Figure 1 compares the flow diagrams for the two designs. As the diagrams show, the quench design requires partial bypassing of feed gas around the catalyst beds for temperature control, while the intercooled design maintains full flow of snythesis gas through the catalyst beds for maximum conversion. This is the principle reason why the intercooled configuration is the preferred design in new, low energy ammonia plants. Note that an internal heat exchanger (intercooler) is used to cool the interbed gas.

For kinetic reasons, the majority of catalyst in an intercooled converter is located in bed two. In the split-flow design, bed two is physically split into two beds operating in parallel. This provides a substantial reduction in pressure drop, allowing the use of small, high activity catalyst. The intercooled design, coupled with the use of small, high activity catalyst provides the increase in ammonia conversion realized by the retrofit, while the split-flow configuration provides the reduction in pressure drop consistent with a low energy design.

The principle components in the retrofit converter are the two new heat exchangers—the feed-effluent exchanger and intercooler. The existing feed-effluent exchanger (interchanger) is replaced since the relatively thin tube walls are subject to damage from nitriding to an extent which cannot be determined until the vessel is opened. Since this exchanger is of a relatively high pressure drop design, replacing it also provides the opportunity for additional energy savings.

Simplified drawings of the four bed quench converter and the two bed split-flow intercooled design achieved through the split-flow basket modification are shown in Figures 2 and 3, respectively. As the drawings show, bed 1 in the modified design is located in place of quench bed 3, bed 2A occupies the space previously held by quench beds 1 and 2 and bed 2B replaces quench bed 4. The support grid for quench bed 1 is removed while the perforated zones of support grids 2 and 3 are blanked-off to form gas partitions. The intercooler is centrally located in bed 2A, below the new feed-effluent exchanger.

FIELD WORK

Houston-based Engineers and Fabricators Company (EFCO) was selected to provide the heat exchangers for the converter retrofit. For the critical field work, CBI Na-Con was selected as the vessel sub-contractor responsible for performing the actual internal modifications, as well as prefabricating various components needed for the retrofit.

In late August 1986, plant No. 2 was shutdown and the ammonia converter catalyst charge was unloaded by the catalyst-handling specialty company, Cat-tech. Subsequent inspection revealed the bottom head of the interchanger was partially collapsed and the center return pipe to the interchanger had come unsealed from the bottom outlet collector. Alumina balls had been gradually entrained up the return pipe, eventually plugging about half of the interchanger tubes, resulting in the excessive pressure drop (Figure 4).

The remaining vessel and internals were found to be in excellent condition. Nitriding levels on the basket internals were as expected for the length of time the vessel had been in service. Ferrite content typically averaged about 10 to 15% on the surface of the support grids where temperatures and nitriding rates are highest, dropping to below 1% after grinding off ⅓₂ to 1⁄16 inch, or 0.8 to 1.6 mm. One quench line flexhose located in the annular space between the pressure shell and basket was found to be damaged. However, this flexhose would not be required in the retrofit configuration.

Field work commenced on September 1, utilizing two crews working 12 hour shifts. The 12 hour shifts were used to provide additional flexibility for coping with any unusual difficulties in the field work on this first converter retrofit. On future projects, 10 hour shifts would typically be scheduled. Kellogg construction supervisors monitored the sub-contractors progress throughout the retrofit to insure quality and schedule would be maintained.

Figures 5A-5D highlight some of the major lifts required during the retrofit. A 150 ton DEMAG crane was used for these lifts. The exchanger pressure shell (bonnet) set the crane requirements.

Modification of the basket internals was completed and final inspection performed 19 days after vessel work began. Modification of the synthesis gas compressor high pressure case was also completed during this time. In general, the actual time required for the various tasks agreed well with construction estimates. On future projects, the field work will be further reduced by increased prefabrication from the vessel subcontractor and revising selected details to further reduce installation time. In particular, the screen seal details will be enhanced to simplify installation of the gas outlet collectors, which required a disproportionate amount of time to complete. With these refinements, a 14 day schedule for the field work appears feasible.

BASF provided the new catalyst charge for the converter. Approximately 2400 CF of catalyst was installed in the modified configuration, which constituted a 6% increase over the original quench converter volume. Pre-reduced catalyst was used for bed 1 to minimize start-up time while oxidized catalyst was installed in beds 2A and 2B. Cat-tech provided loading of the new catalyst charge, which required three days to install. After bolting on the manway covers, the converter was readied for start-up and catalyst reduction.

INITIAL PERFORMANCE AUDIT

In early October, the plant front end was started, catalyst was reduced and the plant reached full production five days after initial start-up. A 24 hour audit of plant performance was conducted in late October. Results of this audit are listed in Table 1, which compares various performance parameters to the targeted design values. As the table shows, both conversion and energy savings were slightly below the targeted values. The observed conversion also resulted in a slightly elevated synthesis loop pressure as indicated by the measured synthesis gas compressor discharge pressure.

During the catalyst reduction phase of the start-up, an anomaly in the temperature profile of the converter was first observed. Thermocouple readings indicated an abnormally large spread in the inlet temperatures to the two parallel beds. Bed 2A was running cooler than bed 2B, which significantly increased the reduction time for bed 2A. After reduction was complete, the temperature spread between the two beds persisted, resulting in higher than desired operating temperatures for bed 2B. Operating away from the optimum inlet temperature resulted in reduced conversion for bed 2B and hence the observed shortfalls in overall converter performance and energy savings.

Two thermocouple assemblies are used to monitor temperatures inside the converter. The assemblies were switched out to check for faulty readings. A radioactive tracer test was also conducted to determine if an internal leak could be the source of the temperature imbalance. Both of these tests proved negative. Elimination of these candidates left the intercooler as the most probable source of the temperature imbalance.

INTERCOOLER FLOW MODELING

The intercooler is principally a longflow exchanger design with cool feed gas on the tubeside and hot bed 1 effluent gas on the shellside (Figure 6). The tube field is annular shaped, with inner and outer boundaries defined by the bed 2B feed pipe and the exchanger shell, respectively. Shellside gas enters the inside bottom of the tube field, flows upwards and splits at the top of the exchanger into the two streams flowing to beds 2A and 2B. Gas flowing to bed 2A exits the tube field at the outer annular boundary while bed 2B feed gas exits through the inner boundary and flows into the bed 2B feed pipe. Because of the longflow design, gas flowing up the inner region of the tube field tends to flow to bed 2B, while gas flowing up the outer region preferentially flows to bed 2A.

Inside the intercooler, the bed 2B feed pipe seals the shellside flow by preventing gas from bypassing the inside of the annular tube field. The shell of the exchanger performs a similar function for the outside of the tube field. During the initial retrofit, the bed 2B feed pipe was supplied and installed by the subcontractor in the field. Required clearances for field installation resulted in an inner seal gap of approximately 1 inch or 25 mm between the OD of the bed 2b feed pipe and the inner row of tubes.

This gap was considered the possible source of the temperature imbalance. If the gap was too large, an excessive amount of gas entering the intercooler would channel up this region, bypass the tube field, and then flow into the bed 2B feed pipe, causing bed 2B to run warmer than bed 2A. In order to quantify the effects of gap size on bed temperatures, the decision was made to create a 3-D flow model of the entire intercooler shellside using the Creare finite difference program FLUENT.

Limitations in the memory available for defining a model's geometry prevented simulating the entire intercooler in one run. The shellside inlet distributor and lower 35% of the tube length were first modeled, and the results then used as input to model the upper 65% of the tube length. Appropriate heat fluxes were specified for the tubes to allow both the radial section flows and temperatures to be predicted.

The tube field was radially split into three sections, with section 1 representing the subject gap (Figure 7). Section 2 contained the inner three tube rows while section 3 defined the outer three tube rows. Note the tube layout causes the radial plane to intersect each tube row differently, giving the appearance of a varying tube width. That is, the width of each tube corresponds to the length of the chord formed by the intersection of the illustrated radial plane with the tube wall. Therefore, only a tube whose centerline is coincident with the radial plane illustrated appears full width.

Results of the simulation are summarized in Table 2. The model indicated more than 30% of the gas was channeling up the gap, bypassing the exchanger tubes. The excessive flow is graphically illustrated by the FLUENT run output for the upper exchanger zone given in Figure 8. The resulting difference between the bed 2A and 2B inlet temperatures predicted by the model correlated well with the temperature spread observed in the field.

After identifying the excessive clearance between the bed 2B feed pipe and the inner tube row as the source of the temperature anomaly, the clearance was reduced in the model to determine the gap size required for balancing the temperatures. A clearance of ¼″ or 6.4 mm was found to balance the bed 2A and 2B inlet temperatures by reducing the section 1 flow to approximately 5% (Table 3). The FLUENT run output for the upper exchanger zone illustrates the balanced shellside flow pattern (Figure 9).

CONVERTER MODELING

Parallel with the intercooler modeling effort, a steady state model of the converter was developed to permit simulating the kinetic and heat transfer characteristics of the exchangers and catalyst beds. In this model, a channeling stream was incorporated into the intercooler module which would pass through the shellside to the bed 2B inlet with no cooling. The model would calculate the size of this stream required to produce a given temperature imbalance.

Simulations of various field data sets typically yielded channeling streams of approximately 20% of the total shellside flow. Since some heat transfer would actually occur in this stream, the true flow required to produce a temperature imbalance would be greater. The results were therefore considered to be consistent with those of the flow modeling effort.

In addition to verifying the results of the flow modeling effort, the converter model was used to evaluate the effects of various proposed modifications. The model showed how the installation of an enhanced feed-effluent exchanger bypass distributor could provide improved temperature control by allowing preferential cooling of either the bed 2A or 2B inlet temperatures.

Results of the modeling efforts indicated the converter temperature profile could be improved by reducing the inner seal gap inside the intercooler and enhancing the distributor design for the feed-effluent exchanger bypass. However, these modifications would require sending the heat exchangers to the shop. Since plant No. 2 was Agrico's most efficient unit, the decision was made to postpone the modifications until after the 1987 spring growing season.

FINAL PERFORMANCE TEST

In July 1987, the plant was shutdown, catalyst unloaded, and the heat exchangers were returned to the EFCO shop in Houston. Inspection of the converter internals revealed them to be in excellent condition after nine months of operation. After installing the new bed 2B feed pipe and bypass distributor, the exchangers were shipped back to site, installed in the converter, and the catalyst charge was loaded.

In mid August, the plant was started and catalyst reduced. A 72 hour test run to evaluate converter performance began on August 31. Results of the test are summarized in Table 4. Note the conversion exceeds the design value while the synthesis loop is actually running below the design pressure, further indicating the improvement in converter performance. Production averaged slightly above design capacity over the 72 hour period.

A test to determine the energy savings was conducted in early October. A savings of 0.91 MM BTU/ST(HHV) or 0.25 MM KCAL/MT(HHV) was determined for the retrofit, corresponding to 125% of the targeted energy savings.

Since passing the performance test, the modified converter has performed without incident at capacities exceeding 104% of design.

CONCLUSIONS

Modification of the intercooler and bypass distributor substantially improved the performance of the modified converter such that conversion and energy savings now exceed design values. Subsequent to the tests, the converter has demonstrated the capability to provide stable operation at capacities substantially above design production. Agrico is pleased with the performance of its modified converter.

TABLE 1

Agrico Plant No. 2 Modified Converter Initial Audit

		Design	Actual
Capacity	(%)	100.0	100.5
Converter Temperature Rise	(°F)	340	325
	(°C)	189	181
NH_3 Concentration Rise	(%)	12.7	12.1
Synthesis Gas Compressor	(psig)	2197	2211
Discharge Pressure	(kg/cm^2g)	154.5	155.5
Energy Savings, HHV	(mm btu/st)	0.73	0.70
	(mm kcal/mt)	0.20	0.19

TABLE 2

Intercooler Flow Model Initial Configuration

Section		1	2	3
Flow Exit Lower Exchanger Zone	(%)	37.1	30.1	32.8
Temperature Exit Lower	(°F)	930	861	836
Exchanger Zone	(°C)	499	461	447
Flow Exit Upper Exchanger Zone	(%)	31.3	35.3	33.4
Temperature Exit Upper	(°F)	839	709	692
Exchanger Zone	(°C)	448	376	367

* Basis: 1 inch (25 mm) inner seal gap

TABLE 3

Intercooler Flow Model Modified Configuration

Section		1	2	3
Flow Exit Lower Exchanger Zone	(%)	5.3	46.2	48.5
Temperature Exit Lower	(°F)	881	892	859
Exchanger Zone	(°C)	472	478	459
Flow Exit Upper Exchanger Zone	(%)	3.4	47.7	48.9
Temperature Exit Upper	(°F)	770	728	756
Exchanger Zone	(°C)	410	387	402

* Basis: ¼ inch (6.4 mm) inner seal gap

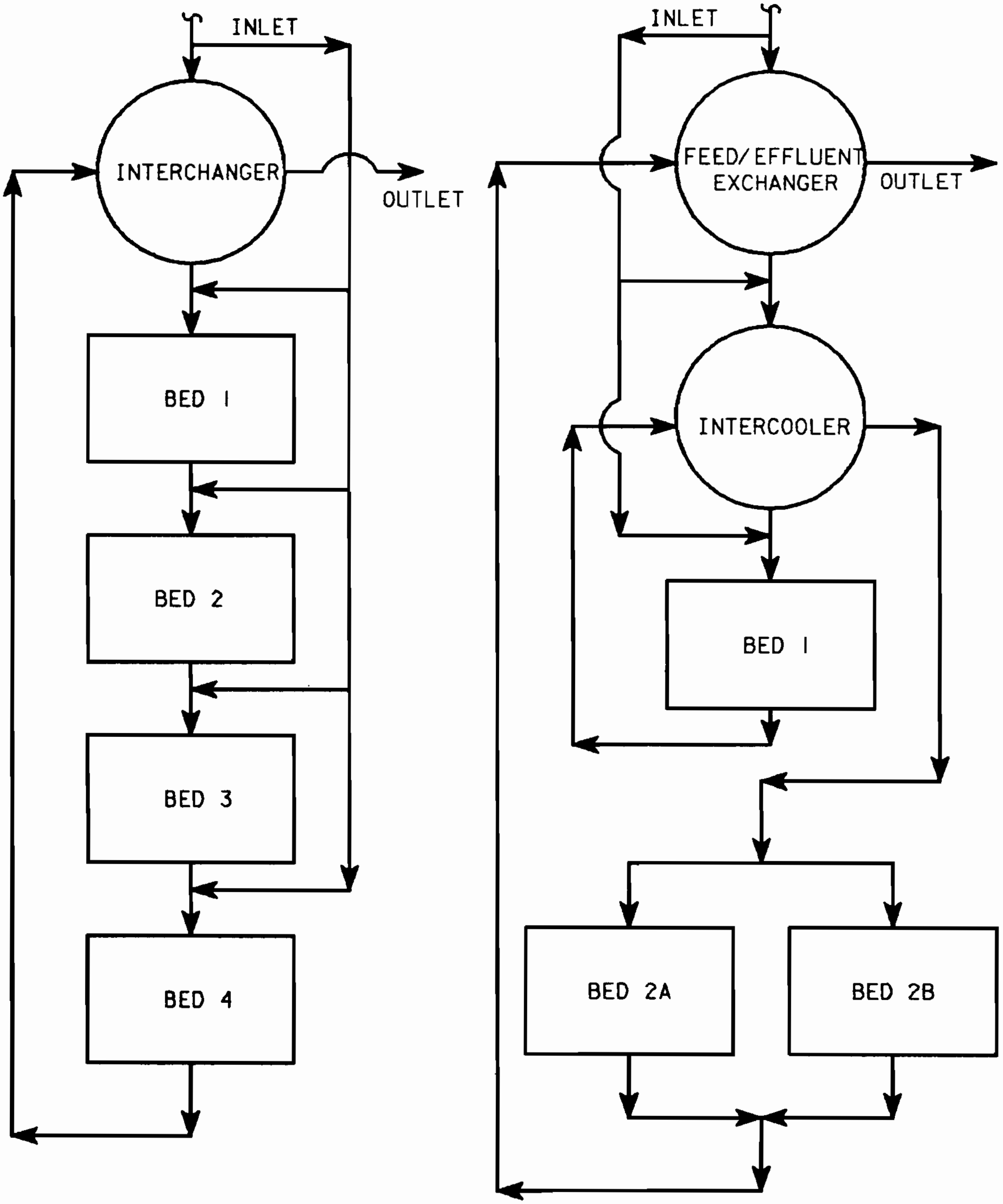
TABLE 4

Agrico Plant No. 2 Modified Converter Final Performance Test

		Design	Actual
Capacity	(%)	100.0	100.6
Converter Temperature Rise	(°F)	340	343
	(°C)	189	191
NH_3 Concentration Rise	(%)	12.7	12.8
Synthesis Gas Compressor	(psig)	2197	2177
Discharge Pressure	(kg/cm^2g)	154.5	153.1
Energy Savings, HHV	(mm btu/st)*	0.73	0.91
	(mm kcal/mt)	0.20	0.25

* Energy savings could not be determined during 72 hour test due to a temporary abnormality in steam system operation. Indicated savings were determined during a subsequent 24 hour test.

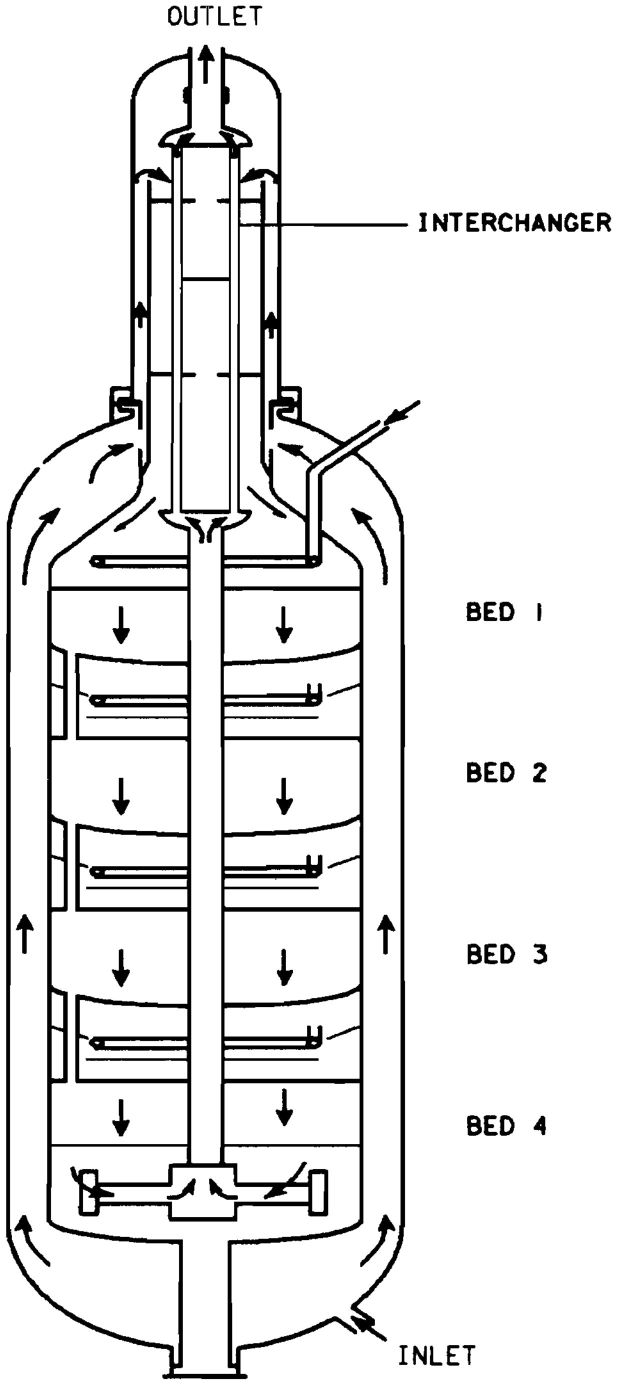
FIGURE I



FOUR BED QUENCH   TWO BED SPLIT-FLOW INTERCOOLED

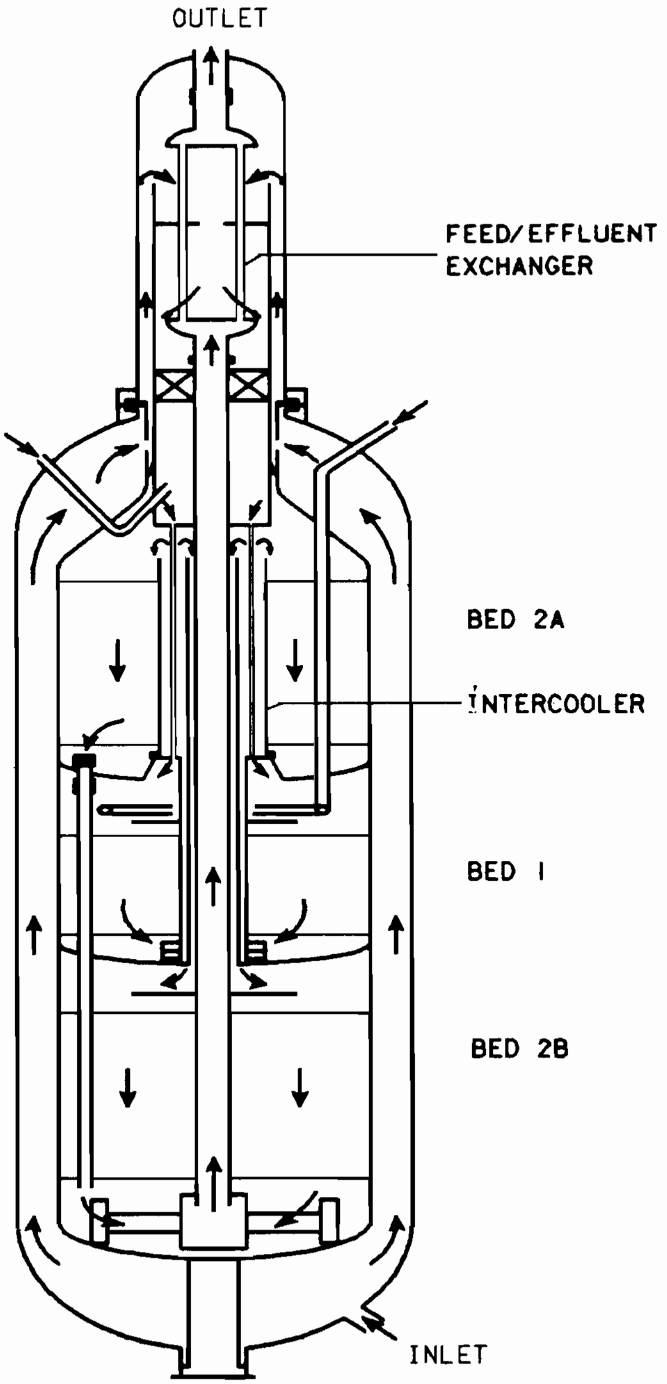
FLOW DIAGRAMS

FIGURE 2



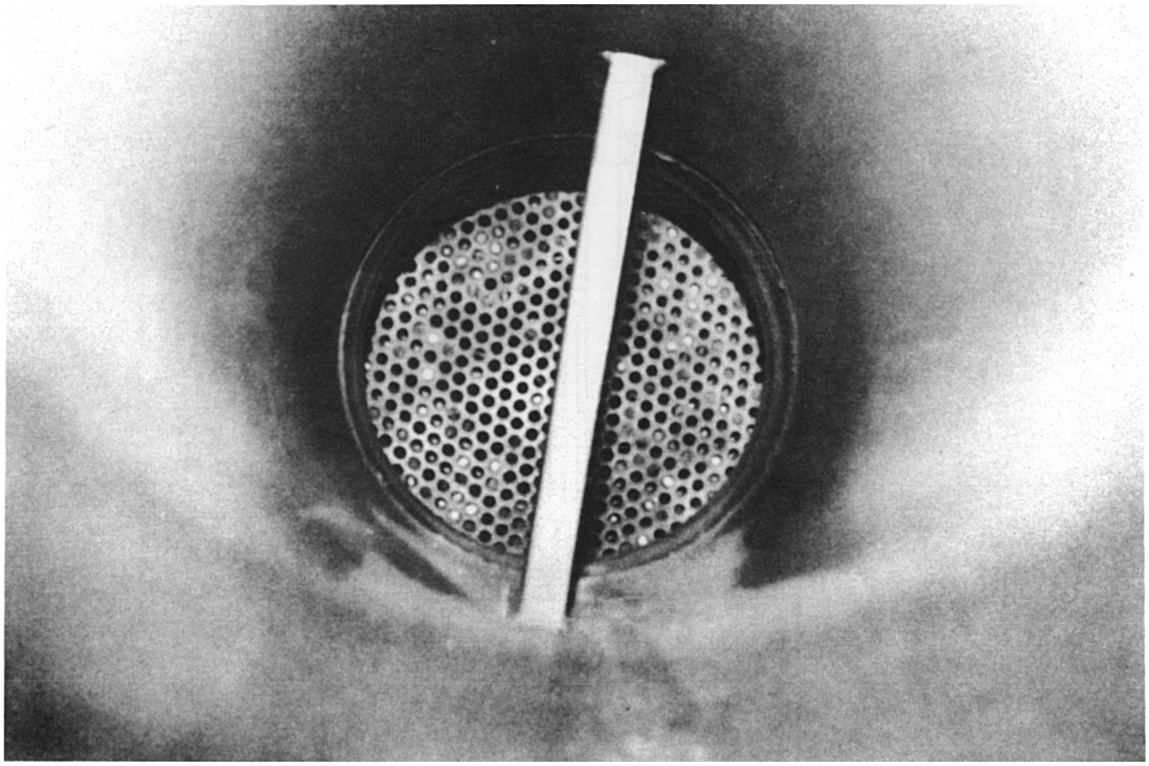
FOUR BED QUENCH CONVERTER

FIGURE 3



TWO BED SPLIT-FLOW INTERCOOLED CONVERTER

FIGURE 4



INTERCHANGER INLET TUBESHEET

PARTIALLY PLUGGED WITH ALUMINA BALLS

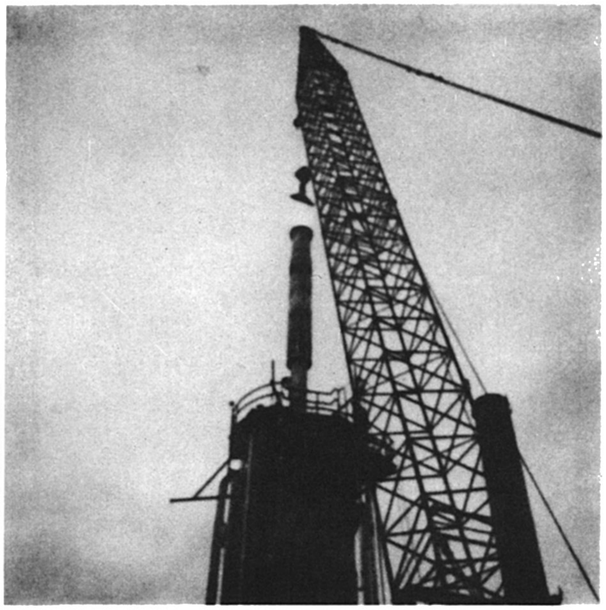


FIG. 5A INTERCOOLER LIFT

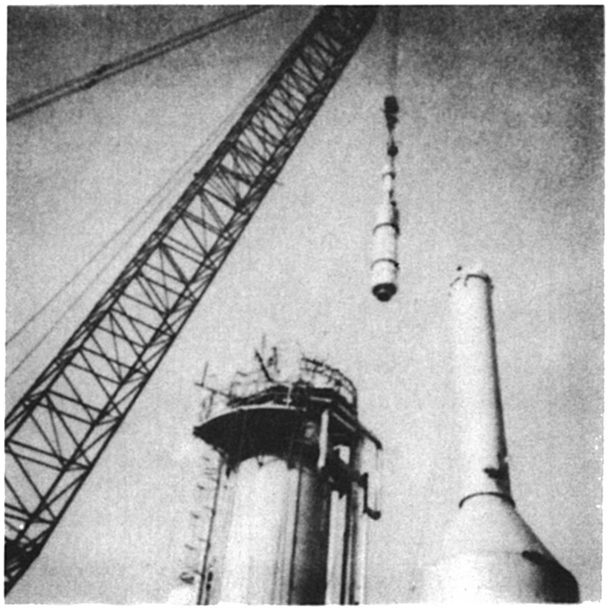


FIG. 5B FEED-EFFLUENT EXCHANGER LIFT

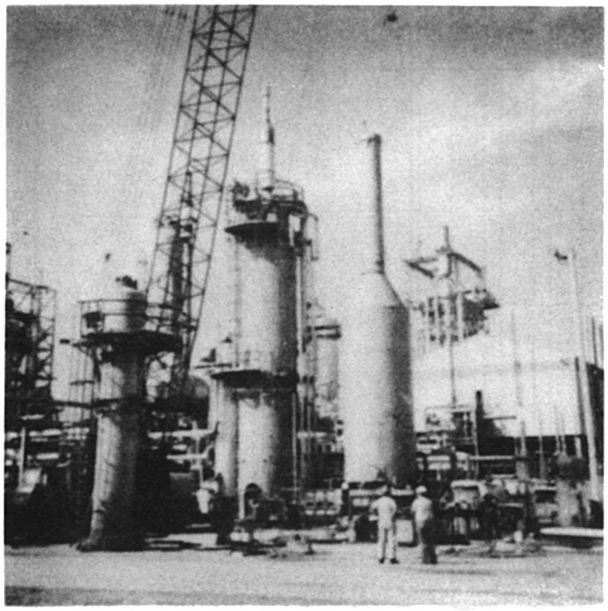


FIG. 5C FEED–EFFLUENT EXCHANGER AFTER INSTALLATION

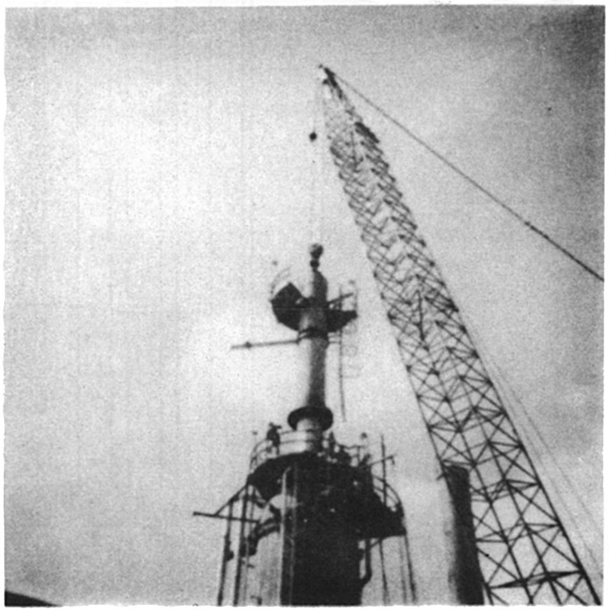
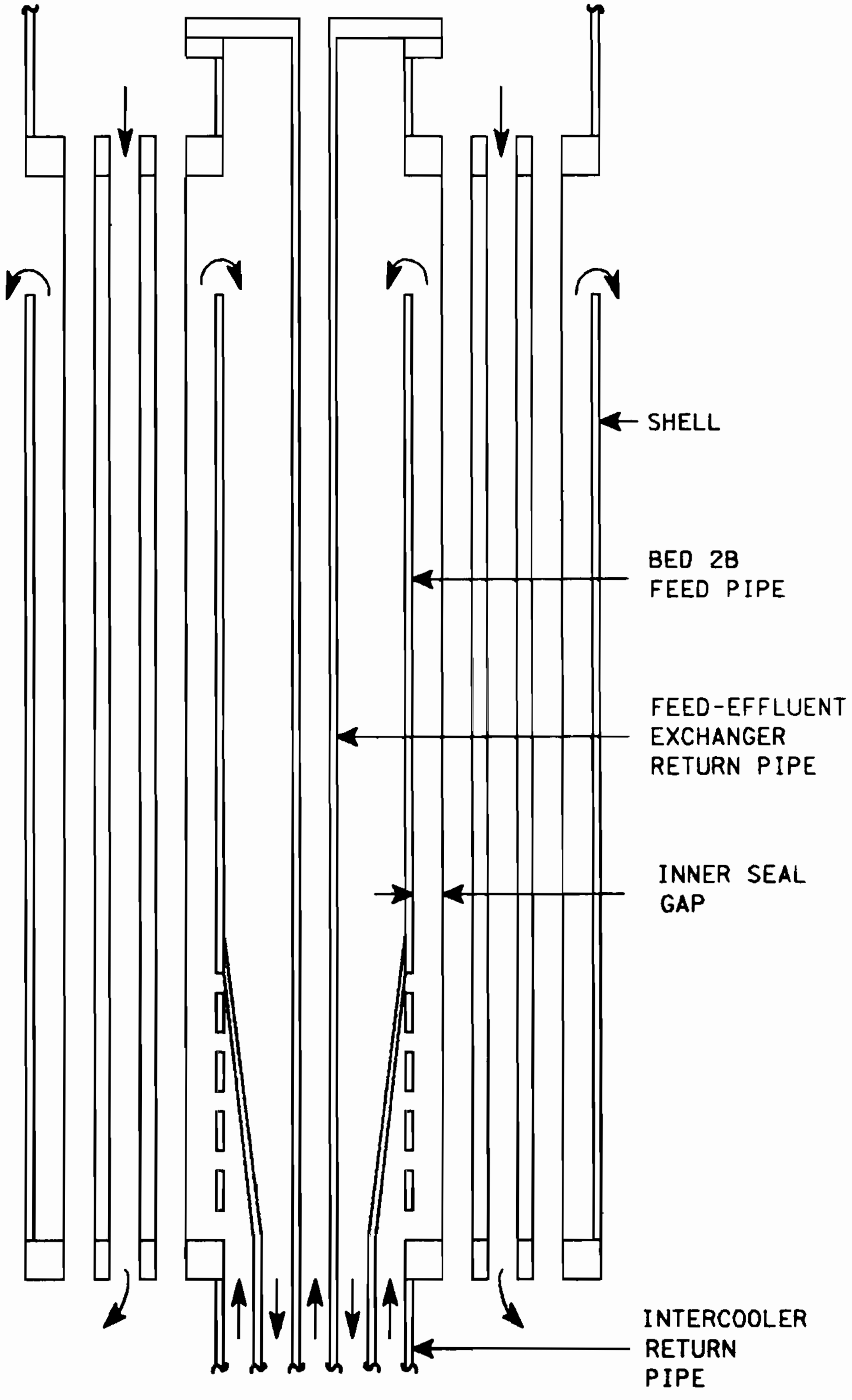


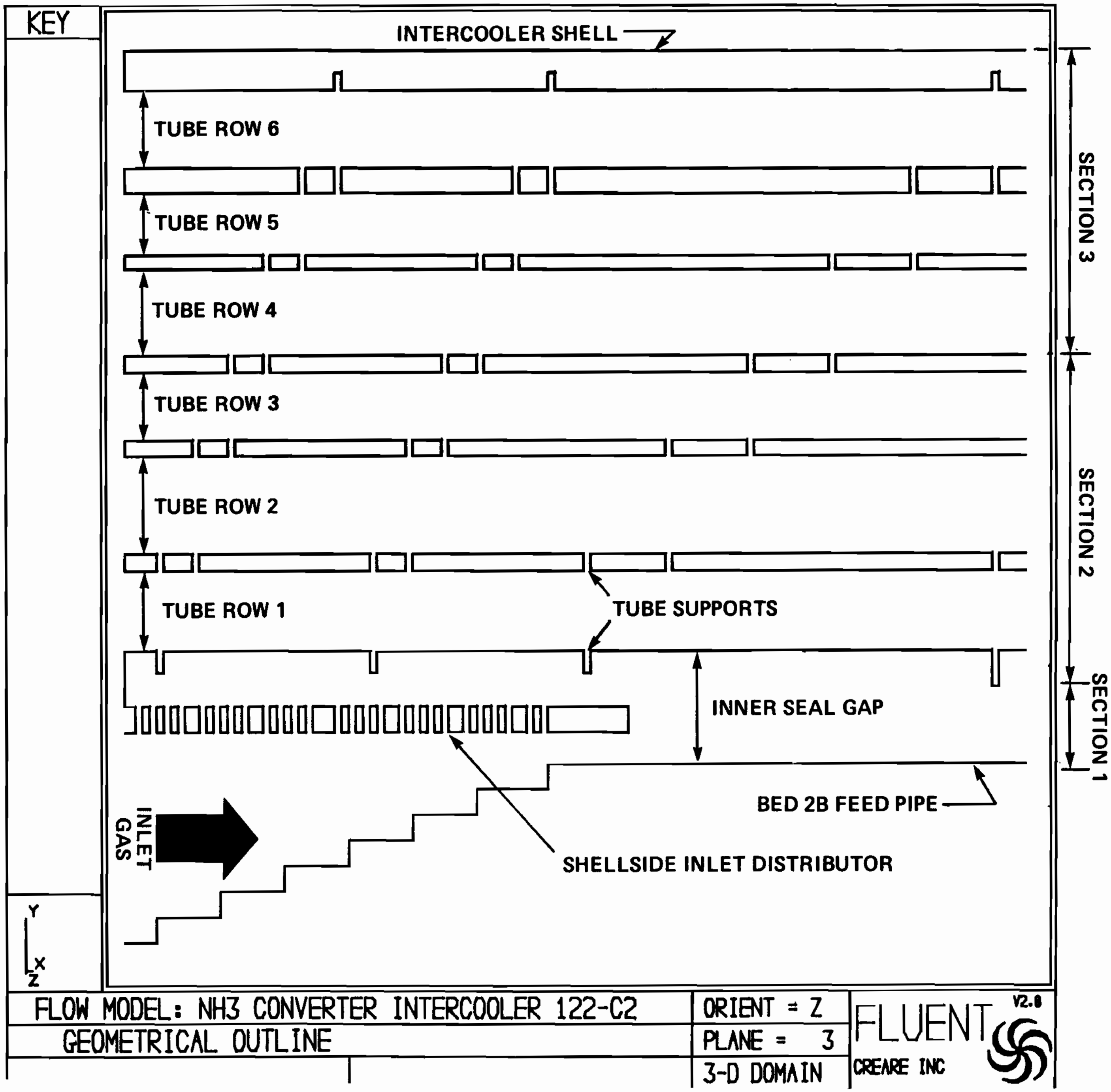
FIG. 5D EXCHANGER PRESSURE SHELL LIFT

FIGURE 6



INTERCOOLER

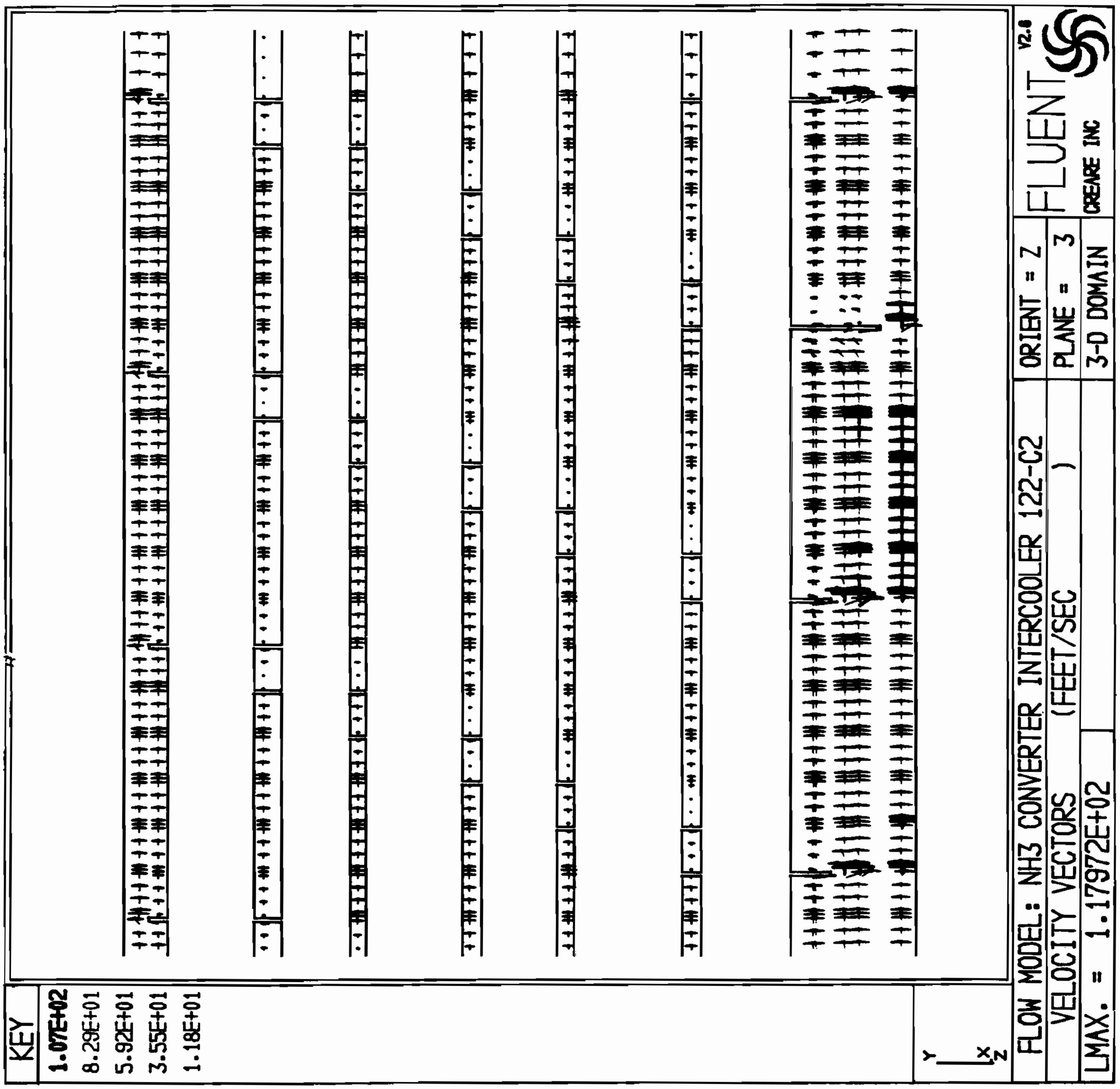
FIGURE 7



FLUENT MODEL FOR INTERCOOLER SHELLSIDE

(LOWER 35%)

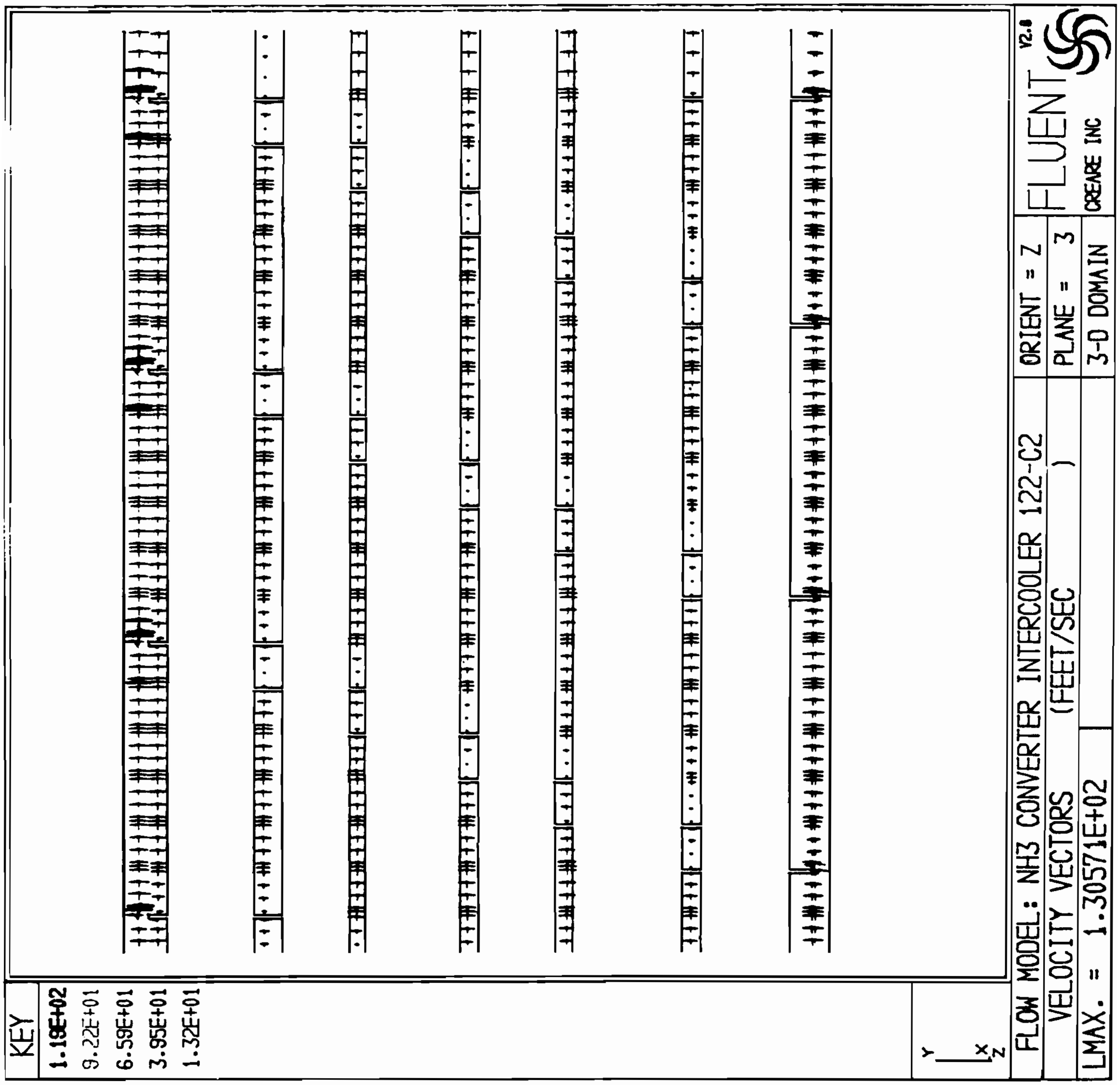
FIGURE 8



FLOW MODEL WITH 1 IN. (25 mm) INNER SEAL GAP

(UPPER 65%)

FIGURE 9



FLOW MODEL WITH 1/4 IN. (6 mm) INNER SEAL GAP

(UPPER 65%)

Cost Reduction Advances in Urea Synthesis Technology

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Toyo Engineering Corp.

Jong Hyun Park
Korea Fertilizer Co., Ltd.

1. *INTRODUCTION*

The ACES Process (Advanced Process for Cost and Energy Saving) is the most energy efficient urea synthesis technology among presently commercially operated urea processes.

Toyo Engineering Corp. (TEC) established the ACES Process in 1981 as a result of almost 3 years pilot plant operation, which included the data collection of the process performances, design and engineering, construction material assurance and plant operabilities.

Currently, two industrially sized urea plants adopting the ACES Process have been in operation.

The first plant was constructed for Korea Fertilizer Co., Ltd. (KFC) with a designed production capacity of 600 MT/D and has been operating since May, 1983.

The second plant was constructed for Union Explosives Rio Tinto S.A. (ERT) of Spain with a designed capacity of 750 MT/D and was put into operation in October, 1988.

Another 1,420 MT/D urea plant for Bangladesh Industrial Development Corp. (BIDC) has been under engineering.

All of these three urea plants are revamped ones by modification of the existing energy insufficient conventional urea plant.

The revamping of the existing urea plants based on the ACES Process results in an increase of the production capacity by 20–50% and energy conservation by 40–50%, depending on the process and equipment used in the existing urea plants.

This paper introduces actual performances of the KFC's ACES Process plant obtained through over 5.5 years plant operation.

2. *BACKGROUND*

KFC had been operating a urea plant, with the production capacity of 1,000 MT/D in two trains constructed by TEC based on the TEC-MTC Total Recycle C Process (TR-C) with the crystal separation-remelting system, since 1967.

KFC was on look out for energy saving urea process technologies to keep down the cost of urea production because of the rise in energy price in early seventies and skyrocketting of the same through the oil crises in mid seventies.

In addition, there was an over-capacity within the country and a weak international market of urea.

Therefore, the urea producers in the country were forced to operate their urea plants at partial loads.

As the demands of liquid ammonia however was strong, the general practice was to operate the ammonia plants at full load with the reduced load of the urea plant.

On the other hand, TEC announced at its Urea Licensee Meeting held in 1980 that its new energy saving urea process would be ready for industrial application in 1981.

After this, through the discussion between KFC and TEC, KFC recognized that the use of the newly developed ACES Process would be the most appropriate technology to implement the project meeting, with two objects of production increase and energy conservation.

A contract for the urea plant revamping of one train was awarded to TEC by KFC in September, 1981.

3. *PROJECT EXECUTION*

3.1 *Production Capacity*

The original urea plant of KFC consisted of two trains of 500 MT/D each as mentioned before but with a common Prilling Tower, and was combined with a Melamine plant by delivering urea melt and accepting off-solution to/from the Melamine plant.

To optimize the overall urea plant economics after completion of the revamping project, KFC with close consultation with TEC, decided to revamp one of two trains using the ACES Process with a 20% increase of the production capacity (from 500 MT/D to 600 MT/D).

The production scheme of the urea plant, before and after revamping, is as shown in Fig. -1.

3.2 *Process Scheme*

For the revamping, the specific equipment of the ACES Process (Reactor, Stripper and No. 1 & 2 Carbamate Condenser) is additionally installed as illustrated in Fig. -2. In the other part of the urea plant, certain modifications to the original equipment were made to meet increased production capacity as described below.

1) Rotating Machines

Following table compares the required capacities of each high pressure rotating machine in the ACES Process with the existing ones of KFC.

	Existing Plant	**Revamped Plant**
	TR-C (500 MT/D)	ACES (600 MT/D)
Ammonia Feed Pump	53 m^3/h	24 m^3/h
Carbamate Pump	39 m^3/h	22 m^3/h
CO_2 Compressor	8,570 Nm^3/h	9,600 Nm^3/h

—Ammonia Feed Pump

In the ACES Process, the required capacity is less than half of that required in the existing plant. Therefore even after the plant capacity is increased by 20%, the number of the operating Ammonia Feed Pump can be reduced from two to one.

—Carbamate Pump (Recycle Solution Pump)

As the quantity of recycle carbamate solution is reduced by about 40% in the ACES Process compared with the existing process, the existing Carbamate Pump (2 + 1) covers the required quantity at 600 MT/D of the plant capacity.

—CO_2 Compressor

Before revamping, the maximum capacity of the CO_2 Compressor had corresponded to 540 MT/D of production. The capacity increase to 600 MT/D was achieved by boaring up the cylinders of the compressor. But it was not necessary to change the electric motor driver as the discharge pressure of the compressor was lowered by 60 Kg/cm^2.

2) Equipment in Down-stream Sections

—Purification and Recovery Section

Because the quantities of residual ammonia and carbon dioxide leaving from the Stripper bottom are far less in the ACES Process than those in the existing process (TR-C) as below, all equipment in the existing purification and recovery sections have sufficient capacity.

	Existing Plant	**Revamped Plant**
	TR-C (500 MT/D)	ACES (600 MT/D)
Urea	600 MT/D	650 MT/D
NH_3	770 MT/D	160 MT/D
CO_2	280 MT/D	170 MT/D

—Crystalization and Finishing Sections

At design stage of the plant revamping, the capacity of the drying system of urea crystals seemed to be the bottleneck at 600 MT/D production, and partial feed of urea solution to the Crystallizer from another train was considered. However, in actual operation, 600 MT/D production could be achieved only with the revamped train.

3.3 *Steam System*

In the complex of KFC, 13 Kg/cm^2G steam generated from the package boilers was distributed to various plants. All rotating machines in the complex were driven by the electric motors and the steam system in the ammonia plant was self balanced. Thus, a new scheme had to be considered to supply steam at 24 Kg/cm^2G required for the Stripper of the ACES Process.

An installation of new package boiler was not considered to be feasible in view point of the investment cost and additional operators requirement.

Then KFC decided to incorporate an additional Waste Heat Boiler to produce steam at 30 Kg/cm^2G at upstream of the existing Waste Heat Boiler producing steam at 13 Kg/cm^2G in the ammonia synthesis loop.

3. *Construction Works*

In order to cut down drastically the pay-out period of the revamping project, the existing urea plant of two trains was operated at full load while the "ACES" loop was under construction on a site close to the existing reactors. The location of the "ACES" loop is shown in Fig. -3. Tie-in works of the existing plant with the "ACES" loop were carried out during annual shutdown of the urea plant in 1982 and thus production was not interrupted during the construction works.

The modification of CO_2 Compressor and the installation of new Waste Heat Boiler in the ammonia plant were also executed during the annual shutdown.

3.5 *Project Schedule*

The revamping project was completed with the time schedule described as below.

Sep. 1981	Contract signed
Apr. 1982	Construction started
Jul. 1982	Annual shut down Tie-in works Modification of CO_2 Compressor Waste Heat Boiler installation
Nov. 1982	Mechanical completion
May 1983	Commissioning
Aug. 1983	Performance test run

4. *PROCESS DESCRIPTION*

A simplified standard process flow scheme of the ACES Process is illustrated in Fig. -4.

As the KFC's ACES Process plant is the revamped one with the maximum utilization of originally existed equipment, the process flow sheet is different from the standard to some extent especially in the finishing section of the plant.

The ACES Process is specifically featured by its synthesis loop structured by one Reactor, one Stripper, two Carbamate Condensers and one Scrubber. All are operated isobarically at 175 Kg/cm^2G. The Reactor runs at 190°C and NH_3/CO_2 molar ratio of 4.

Liquid NH_3 is fed directly to the Reactor by the NH_3 Feed Pump. Gaseous CO_2 compressed by the CO_2 Compressor is mostly sent to the bottom of the

Stripper and a part of CO_2 extracted at an intermediate stage of CO_2 compression is fed to the Low Pressure Decomposer for low pressure CO_2 stripping.

The urea synthesis solution from the Reactor, a mixture of urea, unconverted ammonium carbamate, excess ammonia and water, is led to the top of the Stripper.

The Stripper has two functions. The upper part of the Stripper equipped with the trays separates excess ammonia in the feed urea synthesis solution to ensure effective CO_2 stripping operation at the lower part of the Stripper, that is, the molar ratio of NH_3 to CO_2 is controlled to 3.1 from 4.0 of the feed by direct countercurrent contact of the feed solution with upcoming gas from the lower part of the Stripper.

The urea synthesis solution thus treated in the tray part passes through the falling film heater, where ammonium carbamate and excess ammonia in the solution are decomposed and separated by CO_2 stripping and steam heating.

The overhead gas from the top of the Stripper is introduced to the Carbamate Condensers, two units operated in parallel, where the gaseous mixture is condensed and absorbed into the absorbent solution from the Scrubber and High Pressure Absorber.

The heat formed in the Carbamate Condensers by carbamate formation and ammonia condensation is utilized to generate low pressure steam typically at 5 Kg/cm^2G in the No. 1 Carbamate Condenser and to heat urea solution from the Stripper in the No. 2 Carbamate Condenser after pressure reduction to 16 Kg/cm^2G from 175 Kg/cm^2G.

The non-condensed gaseous mixture and carbamate solution from the Carbamate Condensers are recycled back to the Reactor by its gravity.

The inerts in the synthesis loop are purged to the Scrubber from the top of the Reactor for recovery of NH_3 and CO_2 accompanied with the inerts.

Oxygen in the inerts is used for passivation of the High Pressure Decomposer by introducing the inerts from the Scrubber to the High Pressure Decomposer.

The urea solution leaving from the Stripper with ammonia content of 12 wt.% is further purified in the subsequent High Pressure Decomposer and Low Pressure Decomposer operated at 16 Kg/cm^2G and 2 Kg/cm^2G respectively.

The gaseous mixtures of NH_3 and CO_2 and water vapor separated from the urea synthesis solution through the decomposers are absorbed and condensed in the stepwise absorbers, i.e. the High Pressure Absorber and the Low Pressure Absorber operated at 16 Kg/cm^2G and 2 Kg/cm^2G respectively.

The heat of carbamate formation and ammonia condensation in the High Pressure Absorber is transferred directly to the aqueous urea solution in the concentration section of the urea plant to evaporate water in the urea solution.

The urea solution from the Low Pressure Decomposser is further concentrated up to 95 wt.% for the production of the urea granules or 99.7 wt.% for the production of the urea prills through the Evaporators.

5. *PERFORMANCE RECORDS*

5.1 *Utility Consumptions*

The typical process performances achieved at KFC's ACES Process plant are described as below.

		Existing Plant (TR-C)	**Revamped Plant** (ACES)		
			Design	Nov. '83	Jun. '88
Production	(MT/D)	500	600	630	606
Steam	(MT/MT)	1.38	0.56	0.56	0.55
Power	(kWh/MT)	155	131	128	128

Ammonia consumption was same as before the revamping. Power consumption was reduced by about 700 kWh/h because of lowered synthesis pressure and reduced recycle of liquid ammonia and carbamate solution to the Reactor.

5.2 *Production Records*

Yearly on-stream factors of the ACES Process plant of KFC are reported hereunder.

Year	On-stream Days	Production Rate (%)
1983 (May – Dec.)	152	86.5
1984 (Jan. – Dec.)	313	96.8
1985 (Jan. – Dec.)	327	95.4
1986 (Jan. – Dec.)	318	94.5
1987 (Jan. – Dec.)	333	99.8
1988 (Jan. – Oct.)	285	98.8

The production rates are calculated by:

$$\frac{\text{Actual annual production (MT/Y)}}{\text{Designed capacity (MT/D)} \times \text{On-stream days}} \times 100$$

Relatively lower on-stream factors recorded for 1985 and 1986 were affected by the inventory control of the urea product due to low international market price of urea.

5.3 *Plant Operability*

There is no specific difficulty in maintaining steady plant operation but an automatic analyzer has been installed to control NH_3/CO_2 molar ratio at 4 in the Reactor for optimal operating conditions.

The "ACES" loop allows to retain urea synthesis solution for about 48 hours without fear of the corrosion problem of the construction materials of the equipment because of mild operating conditions under higher NH_3/CO_2 molar ratio of 4 and use of high corrosion resistant materials.

Upset operating condition in the Stripper is absorbed in the High Pressure Decomposer and Absorber operated at 16 Kg/cm^2G.

During the past 5.5 years plant operation since the initial start up of the plant, inside of the equipment of the "ACES" loop has been inspected by KFC and TEC.

No practical corrosion has been observed.

The materials used for the "ACES" loop equipment and the inspection procedures of each equipment are as described below.

Material Specifications

		C(%)	Cr(%)	Ni(%)	Mo(%)
Reactor					
Liner	316L S.S.	0.03	18	14	2.5
Internals	316L S.S.	0.03	18	14	2.5
Stripper					
Liner	R-4	0.03	25	5	2
Tube	DP-3	0.03	25	7	3
Carbamate Condensers					
Liner	R-4	0.03	25	5	2
Tube	DP-3	0.03	25	7	3

R-4 and DP-3 are duplex (ferrite and austenite) type stainless steel.

Inspection of Equipment

	Reactor	Stripper	Carbamate Condensers
Visual inspection	X	X	X
Liner Thickness By Ultrasonic Thickness Gauge	X	X	X
Tube Inside Surface By Fiber Scope		X	X
Tube Outside Surface By Eddy Current Tester			X
Tube Inner Diameter By Bore Gauge		X	
Immersion Test By Test Coupons	X	X	X

6. *PROJECT EVALUATION*

KFC has evaluated that the revamping project has been successful. Although faced with some problems mechanically and process wise at the initial stage of the commissioning, these problems were solved completely and the plant has been operating smoothly. The pay-out period for the project was about two years.

The off-solution from the melamine plant has been treated in either revamped train (ACES) or existing train (TR-C) with less cost impact to the urea production than the original process scheme, which was caused by increased water recycle in the urea plant.

The KFC's fore-thought on optimizing urea production has proved to be quite correct because a number of less efficient urea plants were forced to be shut down under the country's National Production Control Act.

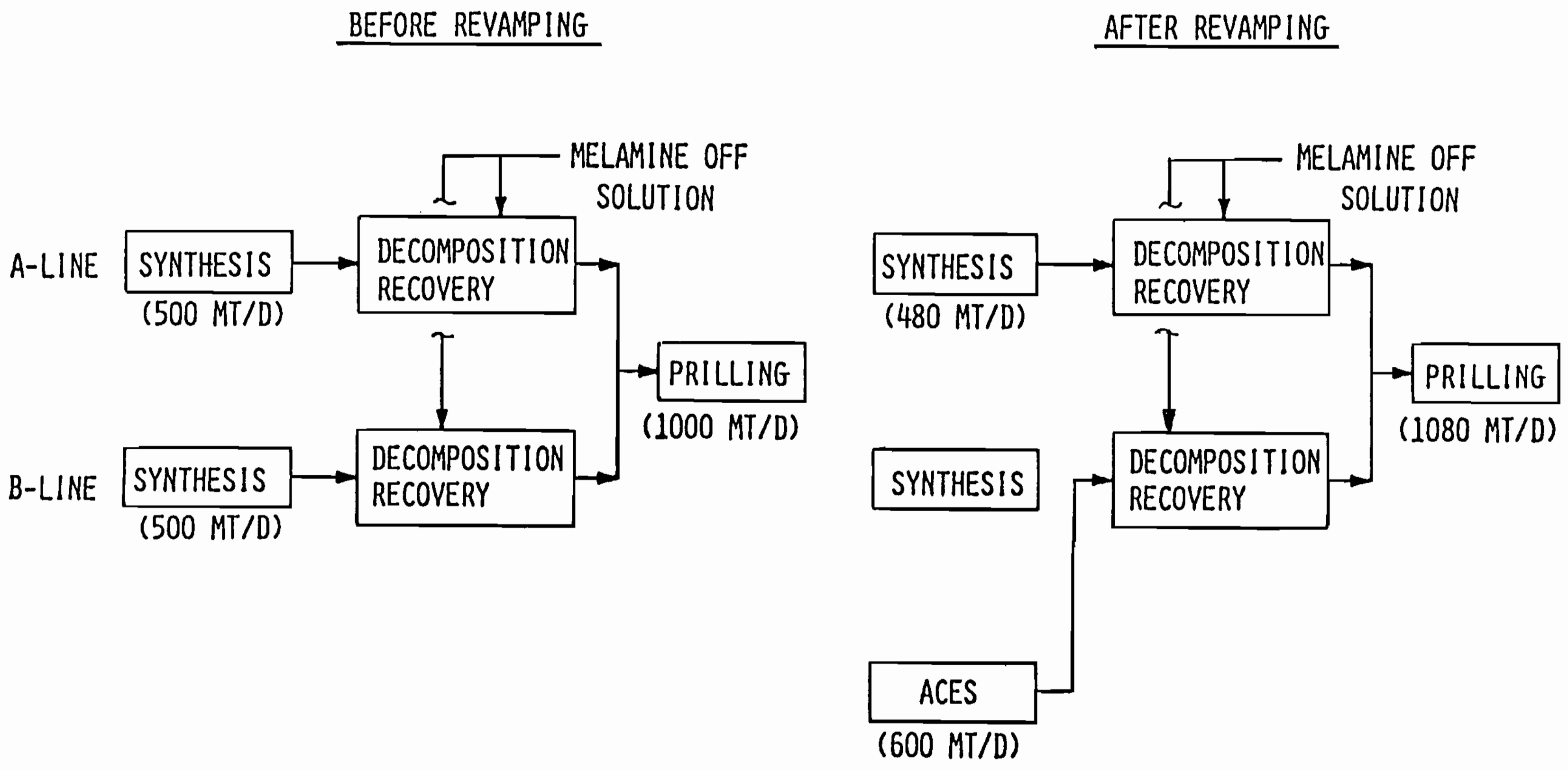


FIG.-1 PRODUCTION SCHEME OF KFC UREA PLANT

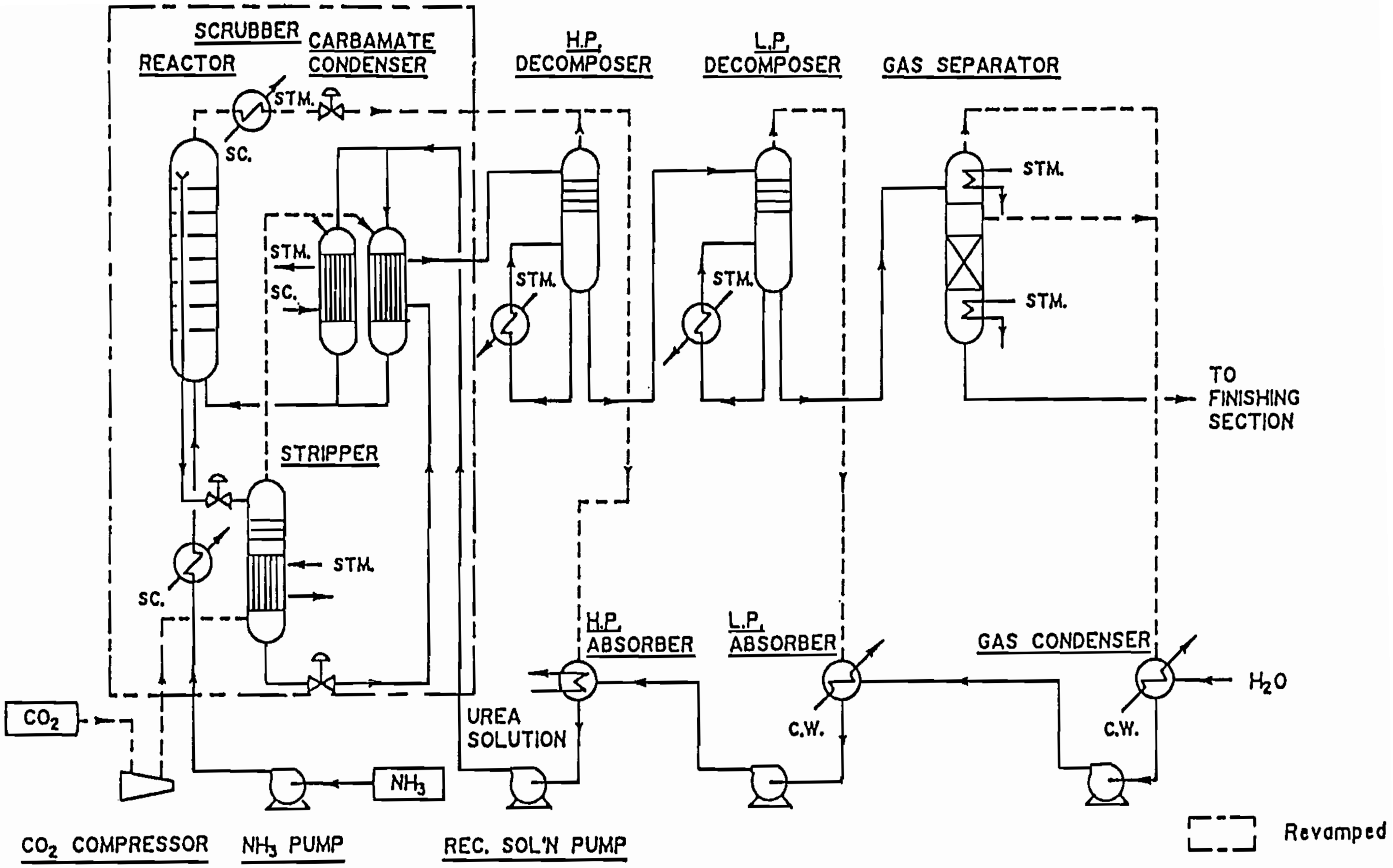


FIG.-2 PROCESS FLOW OF KFC UREA PLANT (ACES PROCESS)

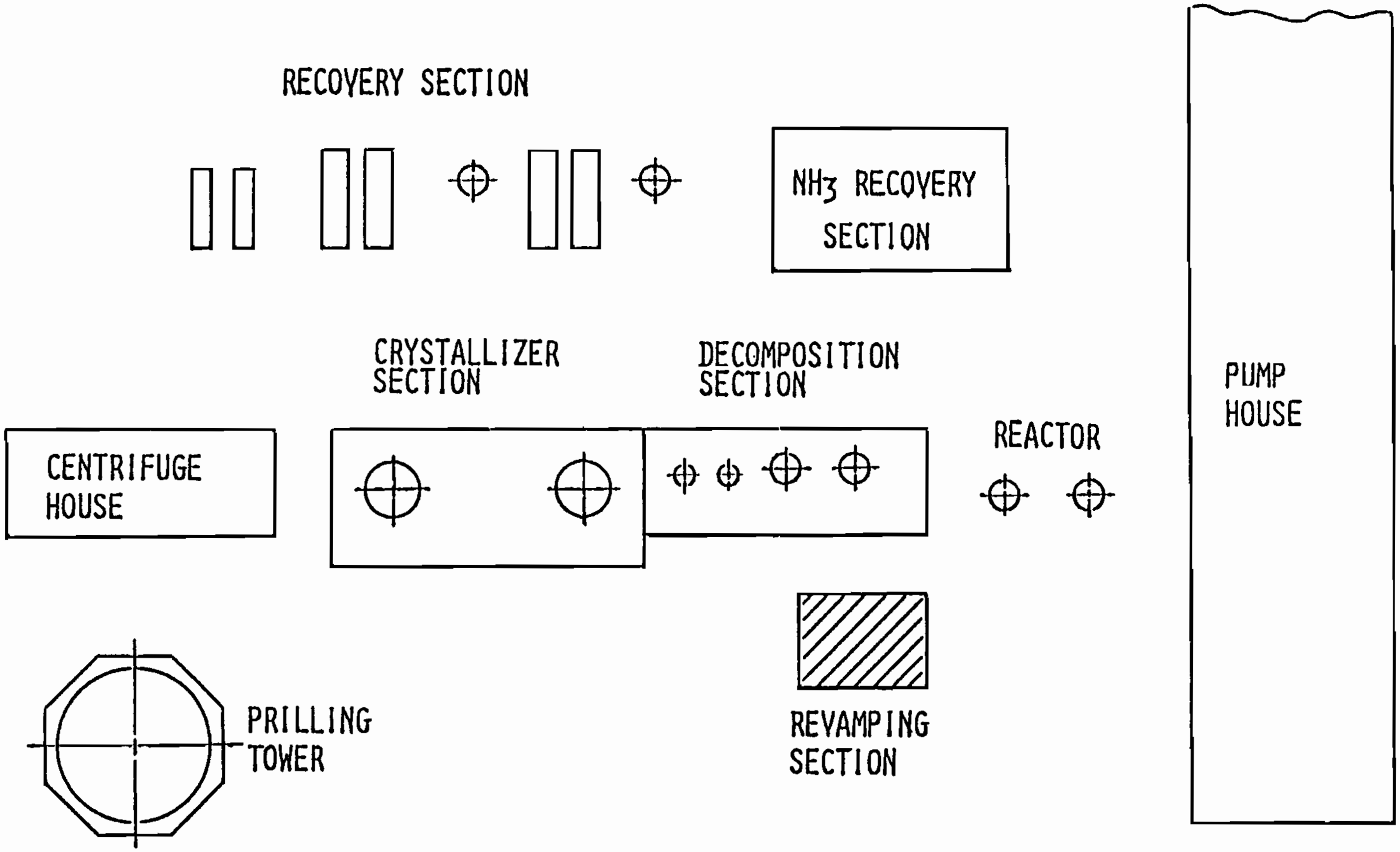


FIG.-3 PLOT PLAN OF KFC UREA PLANT

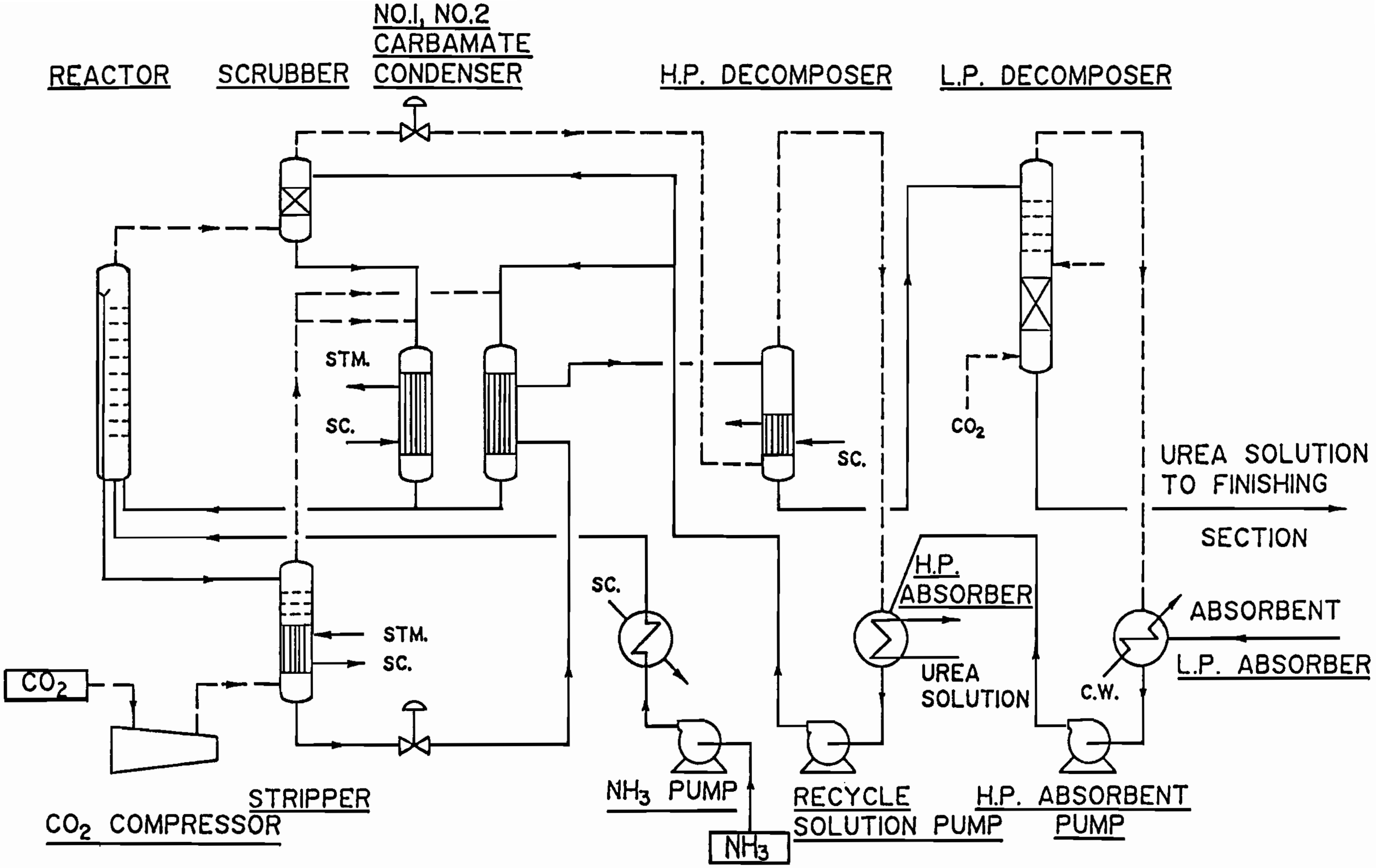


FIG.-4 PROCESS FLOW OF ACES PROCESS

Modernization of Existing Urea Plants

Ivo Mavrovic
Urea Technologies, Inc.

PAPER NOT AVAILABLE AT TIME OF PUBLICATION

Namhae Heat Recovery System Update

John J. Tully, presented by James Shafer
Monsanto Enviro-Chem Systems, Inc.

The purpose of this paper is to discuss the Monsanto Heat Recovery system which was first commercialized for the Namhae Chemical Company sulfuric acid plants in Korea. The HRS is a significant breakthrough in the sulfuric acid process technology in that it recovers energy which was previously lost to the atmosphere by way of cooling towers or sea water.

The topics we will discuss are as follows:

1. History of HRS development leading to Namhae award.
2. Brief description of HRS and how it works.
3. Operation of Namhae after 9 months.
4. Economics of HRS on new and existing plants.

1. *HISTORY*

Before energy crises, when gasoline cost 25 cents a gallon, sulfuric acid plants burning sulfur made about 1.1 to 1.2 lb. steam/lb. acid. About 50–55% of the energy in sulfur was recovered. In the 1980's Monsanto introduced the energy efficient plant in which, with higher SO_2 concentrations, higher steam pressures, and superheat and low temperature economizers we were able to increase steam quality and quantity. This steam was used to produce electric power through turbogeneration. The extra cost of these energy improvements general and a payback of 1–3 years. The energy recovered from sulfur was 65 to 70% vs the older 50–55% standard. Also, steam pressures and superheat increased to 60 bar and 500°C respectively while raising rates to 1.3 lb/lb acid.

Now, the HRS increases steam production by 0.5 lb.lb. of acid to a total of 1.8 lb/lb., although in this case the increase is in the form of 50–150 psig. Thus the energy recovered from sulfur is increased to 90–95% of that available.

Monsanto's research into sulfuric acid corrosion determined that contrary to published data many metals exhibited no increase in corrosion due to higher temperatures in the range of 98.5 to 100% acid. To cut a long story short, we ran a pilot plant at our East St. Louis sulfuric acid plant over a period of 3 years and tested out many metals. The results were excellent, with certain stainless steels able to handle 99% acid at temperatures over 200°C (400°F). Corrosion rates less than 5 mils per year were demonstrated. At the same time, however, the bottom fell out of the U.S. fertilizer industry around 1983–84, and we could not sell a commercial unit in the USA.

However, an opportunity arose at the two train 2700 MTPD plant at Namhae, Korea. Increased pollution laws were forcing them to reduce SO_2 from 2000 ppm to under 500 ppm. After study of IPA alone, IPA with HRS, and ammonia scrub, Namhae heavily favored the IPA/HRS route and Monsanto got the award. A big incentive was government support for energy production projects. The steam generated from the HRS at Namhae would drive a new 9 MW turbogenerator. At power costs of 6.2 cents/KWH, the savings would amount to about $4,600,000 per year. Annual gross savings for sulfur would amount to about 6,600 tons per year, equivalent to 900,000 dollars at $130/ton delivered. Thus total yearly savings would be $5,500,000.

2. *DESCRIPTION OF HRS*

The gas flow diagram (Fig. 1) shows how the HRS was applied to the Namhae plant. As can be seen, the HRS is the interpass tower. Figure 2 shows the details of the acid circulation system. The differences between this and a conventional IPA tower system are—

- SS (Type 310) interpass tower with no brick lining.
- Higher acid recirculation temperatures.
- Boiler instead of acid coolers.
- Improved acid strength control.
- Dilution before the tower in a Monsanto diluter.
- Heat recovery exchangers for acid.
- No cooling water required.

In addition to the improved acid concentration control, we have monitored the corrosion rate to ensure on this first commercial unit that there would be no surprises. There were none. We also developed leak detectors using a leak sound wave principle which have never had the opportunity to detect a leak. We still will continue to supply these extra monitors, however, as quality features.

Also featured in these modifications were—

- Separate 4th pass SS converter.
- Internal modifications to existing converter to handle higher gas strength.
- Monsanto ES mist eliminators.

- Vertical acid pumps by Lewis Pump Co. modified to HRS design.

3. *OPERATIONS AT NAMHAE AFTER 9 MONTHS*

Each 1350 MTPD train was modified in 1987 and started up in November and December of that year. The guarantees were demonstrated within 2 to 3 weeks of each start up, and the results achieved on each train are summarized in the following table.

Guarantees	Plant A	Plant B
Capacity 1350 MTPD	1442	1430
Conversion 500 PPM	208	152
HRS Steam 27.9 MTPH	33.2	30.6
T steam/T Acid 0.5	0.55	0.51

The plant started up with no more than the usual start up problems. For instance, the concentration controller was not calibrated properly in one plant causing us to run at a much more dilute acid for several hours after putting it on automatic control. In fact, we saw some corrosion on a pump impellor and wear rings we pulled which was due to this error. We also had excessive vibration at the diluter due to insufficient support. The vibration has since been stopped. We also had some teflon liner collapse due to vacuum conditions. Part of the liner has been removed because it was found unnecessary and the vacuum condition has been corrected.

Subsequent operation over several months from December to August showed only a few hours downtime due to the HRS, and Namhae had an onstream time of over 99%.

A turnaround of both plants was made at the end of August/early September.

The boiler, pump tank, pumps, piping, distributors, and towers were inspected and found to be very satisfactory. A comparison of corrosion coupon rates after the initial week of startup and corrosion measured by the D-Meter during the September shutdown proved the corrosion rate to be less than 2 mils per year in all areas. On the pumps, no worse corrosion was evident than the usual wear found in standard plants. Since pumping even in standard plants is heavy duty, we would continue to recommend a spare non installed pump and some spare wear rings, etc., as is done in the lower temperature conditions.

Corrosion coupons were checked from time to time during the year. Only those after the diluter showed higher than expected corrosion. This was related to diluter mixing efficiency, but since the pipe at this point was teflon lined no damage was done. We have since improved the mixing by changes made during the shutdown.

Downstream of the HRS, where we commonly use carbon steel ducts and gas to gas heat exchangers, there was evidence of drip acid which attacked the cold interpass gas exchangers. There is always some mist carryover on IPA plants, but heat exchangers generally last 5–10 years. We found attack on the lower part of the cold exchanger tubes such that a few had holes in them which is unacceptable. Monsanto knows the reason for this now and will make modifications to our design to solve this problem. We will also change the arrangement of the ductwork to improve the collection efficiency of any condensation that occurs.

There is no other outstanding problem associated with the HRS. During the plant turnaround, we had potential clients look at the plant and they were generally satisfied.

We have had more recent awards as a result of the good operations at Namhae.

Tessenderlo in Belgium will incorporate HRS in a new 1000 MTPD plant.

Yong Nam Korea has awarded us 2 × 600 MTPD plant modifications to HRS with interpass absorption, and we will also perform an HRS/IPA modification for another client in Korea. These companies have all seen the HRS in action and have gone ahead with HRS as a result.

4. *ECONOMICS OF HRS ON NEW AND EXISTING PLANTS*

The following tables show up to date estimated costs and power capabilities of HRS on new or existing IPA plants. HRS incremental cost is less on a new plant than on an existing IPA plant since it substitutes for the standard interpass tower. The costs do not include power production.

Capacity MTPD	$M New Plant	$M Existing IPA Plant	KWH From HRS
500	1.3	1.7	1.5
1000	1.9	2.6	3.0
1500	2.5	3.4	4.5
2000	3.0	4.0	6.0
2500	3.4	4.5	7.5

The basis of the above table is 11.5% SO_2 gas making 150 psig steam, mid 88 purchase in USA.

Of course, generating power may not be the only reason for buying HRS. Substitution of wasted HP steam by LP steam for evaporators may be a criteria or perhaps cooling water savings, or other fuel saving can make HRS attractive.

On existing single absorption plants, which must be modified to IPA the economics of HRS are even better. Quite often IPA conversions can be accompanied by capacity increases. A recent example studied showed that an original 1500 MTPD plant presently running at 1900 MTPD could be converted to IPA/HRS at 2200 MTPD with a new fourth pass S.S. converter for the following cost:

HRS	4.2 Million
IPA	3.3 Million
Total	7.5 Million

For this the client will get an extra guaranteed capacity of 300 MTPD.

He will also save $1,000,000/year on sulfur
plus generate 3,800,000/year value of extra power
Total $4,800,000 (Existing Turbine)

In another case, a client with a 600 MTPD plant, found that he could supply over half of his fertilizer plants power requirements with HRS/IPA. He estimated return on investment of 14%, whereas with IPA conversion alone, the capital would not be paid out.

Each plant needs to be studied to determine what can be gained by the use of HRS. Whether to pay for a study can best be decided by the operator based on preliminary evaluation of the economics of your operation—an evaluation with which Monsanto Enviro-Chem would be pleased to help.

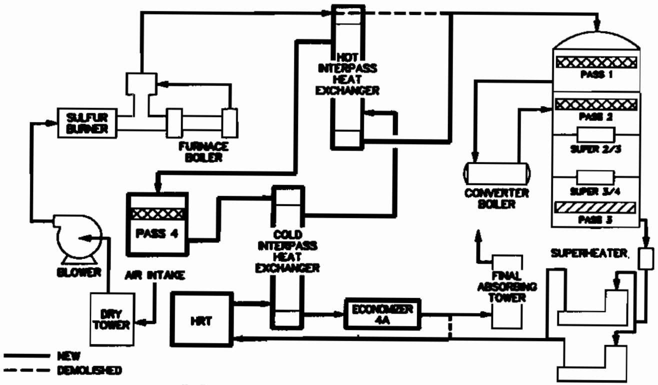


FIGURE 1 — GAS FLOW DIAGRAM

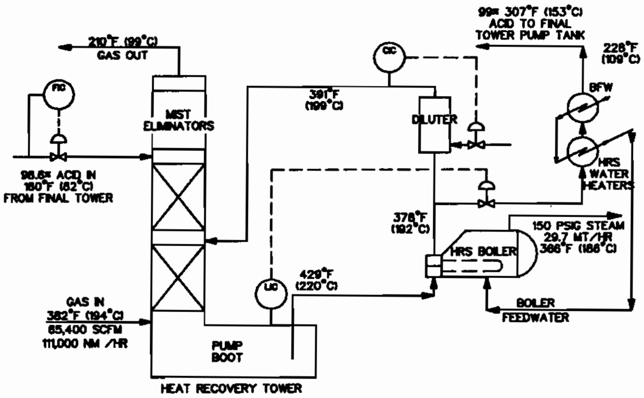


FIGURE 2 — HEAT RECOVERY SYSTEM

Tuesday, November 15, 1988

Session IV
Moderator:
Rodger C. Smith

China Phosphates

Maywood W. Chesson
Jacobs Engineering Group, Inc.

NATIONAL OBJECTIVES

One of China's primary national goals is to increase and sustain agricultural productivity from domestic natural resources. To achieve this objective, high priority has been given to rapid development of mineral resources and chemical industry for manufacturing high analysis fertilizers. Domestic production of fertilizers in the middle 1980's containing at least 2.5 million metric tons of P_2O_5 is predicted to double by the end of this century.

New mechanized phosphate rock and pyrites mines, with efficient beneficiation processes, are being scheduled to supply the additional basic raw materials. High analysis fertilizer plants, employing international state-of-art technology are to supplement existing small, low analysis plants.

Improved transportation networks; highways, railroads, and ports are necessary to distribute raw materials to fertilizer production sites, fertilizers to the agricultural areas, and agricultural products to the consumers. Other agricultural improvements such as additional irrigation, insecticides, and herbicides are important. High priority is given to increase domestic supply and consumption of high analysis P_2O_5 fertilizers to balance the consumption of nitrogen which has grown faster than phosphorous consumption. High priority also is given to developing the domestic supply of potash and improving efficiency of the nitrogen industry.

At the same time of welcoming international fertilizer technology to China, the national government is encouraging free enterprise within China. To stimulate agricultural productivity, farmers now are allowed to profit from hard work and ingenuity. They are the first group of citizens permitted to select their products and after satisfying their quota, sell extra production in free markets. For this they receive extra income (profit) from their customers and public commendations from the government.

To promote large investments in new mines and new fertilizer plants; to encourage consumption of higher cost, higher analysis fertilizers; and to stimulate increased productivity, new pricing policies are necessary. To achieve these objectives without incurring excessive inflation adds another challenge for the national government to face.

BACKGROUND

Phosphates

China is rich with phosphate deposits. The literature contains much information about numerous deposits throughout the country. Figure 1 shows a general band of reported occurrences across China. The highlighted provinces: Yunnan, Hubei, Guizhou, Hunan, and Sichuan are reported to contain the largest and best deposits. Official estimates of China's measured reserves are not available; however, various projections indicate more than 20 billion tons of phosphate resources have been identified. With an average grade of 20% P_2O_5 this represents more than 4 billion tons of P_2O_5 in fertilizers. At an annual consumption rate of 3 million or even 10 million tons of P_2O_5, these deposits are ample for several hundreds of years.

The major phosphate deposits are of the Sinian or lower Cambrian age. Generally the ores are hard, bedded with shale and/or altered limestones and the phosphorites are fine in texture. Most of the ores are associated with carbonates and/or dolomites that require newly developed beneficiation techniques to reduce the MgO and CaO to acceptable levels in the phosphate rock concentrate. The ore grade is relatively high, generally in the range of 15 to 30% P_2O_5.

Phosphate deposit structures are usually complicated by multiple fractures and faults. The beds are generally inclined from a few degrees to as high as 70 degrees. Many deposits are in karst environments where post-structural erosion has produced discontinuous and complicated weathering effects on the ore.

Most of the phosphate deposits are in mountainous areas with elevations up to 3000 meters above sea level. In most cases regional infrastructure in the form of roads, railroads, electricity and water is available but must be extended, for some mining locations, at relatively high costs. Current traffic and demands on these national systems generally are near capacity.

Figure 2 highlights provinces currently producing most of China's phosphate rock. Annual tonnages are reported as high as 12 million tons with grades ranging from 25 to 30% P_2O_5. Only one active beneficiation plant exists. Total national capacity is distributed to the major provinces producing phosphate rock as estimated below:

Yunnan	25% of Total
Hubei	30% of Total
Guizhou	15% of Total
Sichuan	10% of Total
Hunan	10% of Total
Others	10% of Total

Most of the phosphate rock mines produce small annual tonnages. There are four major operations with annual capacities of 1 million or more tons. For many years industrious farmers have mined phosphate rock for their local requirements from ore outcrops, shallow pits and underground audits. Except for the major mines, this local mining has been accomplished manually with very limited equipment.

The rock, without beneficiation, primarily has been converted in local small plants to single superphosphate (SSP) with sulfuric acid from pyrites or smelter gases. In some locations, without nearby pyrites but with other local resources, the rock has been fused to soluble calcium-magnesium phosphate in blast furnaces.

Jiangsu Province has been operating China's first beneficiation plant since 1959 at Jingping Mine. The 9% P_2O_5 ore from an underground mine is ground and subjected to froth flotation to produce concentrate with 30% P_2O_5. Otherwise, only the highest grade ore with P_2O_5 ranging from 25 to 27% has been mined and consumed. Magnesium oxide (MgO), reported in the range of 2.5 to 6.0%, has inhibited development of a phosphoric acid and high analysis fertilizer industry. The manufactured SSP is generally in the range of 12–14% P_2O_5.

Increasing population and growing demands for transportation of all kinds of materials is creating an overwhelming burden on roads, railroads, waterways, and ports. Availability of transportation is a major consideration in selecting locations for new phosphate and pyrites mines as well as fertilizer plants. Difficult compromises will be necessary to balance capital and operating cost of new facilities with the logistics and cost of delivering fertilizer to the soil and agricultural products to the consumers.

Table 1 summarizes the logistics for delivery of 1 ton of DAP to a Shandong farm. This comparison suggests the DAP plant should be at the port nearest to the phosphate and pyrites sources. Obviously there are many other factors and alternatives to be evaluated to determine the best raw material sources to be developed and the best locations for building new fertilizer plants.

Figure 6 shows the phosphate rock source in Yunnan near Kunming. The pyrites source is in southeastern Guangdong. Jinan, in Shandong Province, in the intensive agricultural region, was selected as the center of the DAP consuming area. In Case I, phosphate rock and pyrites are shipped by rail to an assumed DAP plant near Jinan. The DAP is distributed to farms via rail and truck. In Case 2, the assumed DAP plant was located near Zhanjiang Port, in southeastern Quangdong, and DAP is shipped by coastal waters to Qingdao and distributed to farms via rail and truck. In each case ammonia was assumed to be available from regional sources within 500 kilometers.

The purpose of presenting this example is simply to evidence the fact that limited infrastructure can force exploitation of resources nearest the place of consumption even though superior resources exist at other locations within the country.

This hypothetical example also illustrates one of the compelling reasons for de-emphasizing SSP production and placing new investments in high analysis fertilizer plants.

NEW MINES

Yunnan Province

Yunnan Province is considered to have the highest quality deposits in terms of accessibility, mining conditions and ore grade. Some high grade ore (27 to 29% P_2O_5) with 1 to 2% MgO is suitable, without beneficiation, for production of phosphoric acid, TSP, and DAP and is recoverable from open pit mines with quite reasonable stripping ratios. In recent years a third major open pit mine has been developed to increase annual capacity to more than 3 million tons. Yunnan's total production capacity has not been fully utilized because of the great distance to major consuming areas and limited transportation facilities.

New mines in this province are unlikely to be opened until high analysis fertilizer plants are developed in proximity either to the phosphate deposits or to pyrites deposits.

Guizhou Province

A major new mine is in progress for Guizhou Province. The planned capacity is 1.8 million TPY of 35% P_2O_5 concentrate. Large deposits of high grade ore are recoverable from open pit mines. The major development problem is the sharp karst topography that handicaps construction of railroads, roads and layout of beneficiation facilities. The nearest existing railroad at Machangping is about 40 kilometers away from the beneficiation plant site in a straight line. If the railroad were extended to the plant across that terrain it would be 58 kilometers long with many difficult grades, curves, bridges and tunnels. A better alternative is a slurry pipeline about 45 kilometers long to transport concentrate in a fresh water slurry.

The Guizhou Province mine expects to use 10 cubic meter wheel loaders and 85 ton trucks for overburden and ore excavation. The average stripping ratio for 20 years of mining is less than 5.0 tons of waste overburden per ton of ore. Ore haulage will be 1 to 2 kilometers to the primary jaw crusher. Secondary cone crushers followed by ball mills will reduce the ore size to 60% minus 200 mesh (74 micron). The ground ore is to be transported 4 kilometers via slurry pipeline to a multi-stage flotation plant. This slurry pipeline was considered to be superior to truck haulage or belt conveyor in the karst topography.

Table 2 shows the ore and concentrate chemical analysis. Metallurgical efficiency of the flotation process yields a superior quality concentrate with an ore to concentrate ratio of 1.32.

Operating costs for mining, beneficiation, transportation to the railroad, and preparation for shipment with 8% H_2O is approximately \$15 per metric ton of 35% P_2O_5 concentrate. Table 3 shows the Guizhou Province phosphate rock cash operating cost by major cost component. These costs are based on local unit prices for blasting materials, fuel, tires, reagents, labor, electricity, maintenance and administration overhead expenses including personnel housing, transportation, health care and pension.

Capital investments are equal to \$90 per ton of annual capacity of concentrate at a rate of 1.8 M TPY. Machinery and equipment from international sources at larger sizes than those available from domestic sources represent 26% of the total investment. This investment cost, expressed in 1987 US dollars, provides funds for pre-operating expenses, mining, beneficiation and transportation of wet concentrate to the railhead but excludes escalation and interest during construction.

Plans for conversion of the rock to high analysis fertilizers have not been announced but many possibilities may be considered including plants either at Machangping or near Zhanjiang port in proximity to the Guangdong pyrite deposits. Either location is likely to require less freight to deliver fertilizer P_2O_5 to the agricultural areas than shipping rock and pyrites separately.

Hubei Province

The phosphate deposits in Hubei Province are large but not as good as those in Yunnan or Guizhou. However, they are closer to major fertilizer consuming areas and have easy access to existing railroad and highway networks. For many years phosphate rock has been produced in this interior province from weathered ore zones in small open pits that follow the ore outcrops and from small underground mines. Shovels and trucks used in existing open pit mines are of older design and are relatively small compared to current world scales. The mined rock, 25–27% P_2O_5 without beneficiation, has been suitable for SSP production and fused calcium-magnesium phosphate. High dolomite contamination has prevented its use for manufacturing phosphoric acid and high analysis fertilizers.

In recent years, intensive beneficiation research by the Ministry of Chemical Industry Research and Design Institutes has defined and proven a flotation process with excellent reagents which reject 85% of ore MgO with 80% P_2O_5 recovery. Currently an underground mine is nearing completion to produce 1.5 million TPY of high MgO ore. A beneficiation plant employing the newly proven flotation process is included in the project. The entire project has been designed by The Research and Design Institute in Jiangsu Province. This Institute also managed construction of the mine and beneficiation plant.

The beneficiation process requires grinding ore to 95% passing 74 micron. Ore and concentrate qualities are given in Table 4.

The concentrate is to be shipped either wet at 8% moisture or dry via rail to fertilizer plants in adjacent provinces.

Development of another new open pit mine on the same ore body in Hubei is in progress with completion scheduled in 1992. The initial open pit economic boundary is defined by a stripping ratio of 9 tons of waste overburden to 1 ton of ore. Average ore thickness is 10 meters and the average stripping ratio is 4.3 for a 20 year mining plan of 1.5 million TPY of ore. Nearby additional reserves recoverable in open pits and/or underground mines are ample to support expanded production rates for many more years.

The new open pit mine will use 200mm rotary drills for blasting the hard overburden and ore on an initial 5 × 5 meter pattern with 10 meter high benches. Wheel loaders with 10 cubic meter buckets will load 50 ton trucks for waste and ore haulage of less then 2 kilometers. Careful attention is given to control surface water run-off to prevent pollution of streams. Topsoil is to be conserved and placed on contoured waste dumps in mined pits to restore useful lands after mining.

Ore is reduced to 95% passing 74 micron in sequential stages of jaw or cone crushers and ball mills. Clay content in the ore is very small and no waste slimes are rejected in beneficiation. All of the ground ore is subjected to froth flotation and metallurgical efficiency is shown in Figure 4.

This new project has suffered a time schedule delay partially due to incorporating fertilizer plants near the beneficiation plant. The revised project, integrating mining with fertilizer production, will convert the 33.3% P_2O_5, 1.8% MgO concentrate to phosphoric acid and TSP.

The mining investments, including beneficiation, equal \$120 per ton of annual capacity for the 650,000

TPY of concentrate. Higher investment per ton of product capacity, compared to the new Guizhou Province project at $90, is due primarily to lower capacity and to the lower ore grade with 18% P_2O_5 which has an ore to concentrate ratio of 2.3 compared to 1.3 in Guizhou.

Operating costs for the new Hubei open pit mine are higher than the mine in Guizhou for the same reasons. Table 5 shows a cost comparison of these two mines with other world mines.

Another new small mine in Hubei, approximately 200 kilometers east of the mine previously described, with a capacity of 300,000 TPY of 10–12% P_2O_5 ore, is to be expanded. This project is to enlarge the existing open pit mine and beneficiation plant which currently is supplying an adjacent SSP fertilizer plant. Also near the SSP plant is an ammonia plant. The new project will include facilities for production of sulfuric acid from pyrites, phosphoric acid and DAP/MAP and will primarily supply local fertilizer demand. Pyrites will be recovered from the phosphate ore beneficiation plant to supply a portion of the raw material for sulfuric acid production.

For this new small P_2O_5 project, the investment and operating costs exceed those of the larger projects but appears to be economically justified to supply local fertilizer consumption.

OTHER FACTORS INFLUENCING DEVELOPMENTS

Technology

Scientists and engineers employed in China's research, development and design institutes are well trained, quite competent, very careful in reaching conclusions and highly confident of their work. The major disciplines appear to be clearly departmentalized, which may account for difficulties in finding timely solutions to problems involving multi-disciplines. For example, geologists, mining engineers, beneficiation engineers, and civil engineers evidence full responsibility within their respective work areas for completing their assignments according to approved methods and procedures. Deviations from these approved methods or changes in previously accepted conclusions are most difficult and are made only when the resulting benefits are understood and accepted by all of the disciplines. Attaining this acceptance requires patience, determination, and consumes much time.

Acceptance of new methods, equipment, and procedures is being encouraged but is carefully controlled so that later the change will not be abandoned for lack of support when problems are encountered. Also, limited capital compels the nation to continue use of old investments as long as possible. This resistance to change is not limited to China; it evidently is a natural characteristic everywhere.

Pricing Policies

Once the basic decision is made at the highest level of China's National government to sharply increase P_2O_5 consumption and domestic supply, conflicting traditional policies at other government levels become apparent. For example, new high analysis fertilizers cost more in terms of capital investments and operating costs than the existing low quality fertilizers. Traditional fertilizer prices need to be increased without increasing costs of farm products to the consuming public.

Farmers must be induced to accept and trained to properly use the improved products in order to achieve higher agricultural productivity and not suffer higher cost of farm products. New fertilizer pricing and financing policies must be established to support and encourage investments for the additional high analysis fertilizer capacity.

It appears that TSP or DAP producers in China will require selling prices near international prices to economically justify new capital investments. Farmers, accustomed to traditional prices for SSP P_2O_5, probably could not afford to buy TSP at international prices without receiving higher prices for their agricultural products. If the government continuously absorbs the difference between local SSP and imported TSP prices, serious problems develop. Farmers would use the granular, easy-to-handle TSP and the lumpy, dusty SSP would remain in producer's inventory until the producers go bankrupt. The government then would suffer loss of the SSP capacity, become more dependent on imports, and absorb increasing amounts of price support payments probably in various types of farmer subsidies. New pricing policies have to be worked out to accommodate China's plan of expanding P_2O_5 production with high analysis fertilizers and in a manner that will encourage the free enterprise policy without feeding inflation.

To use higher priced raw materials without increasing product prices means that agricultural yields and farming productivity must be increased. In addition to higher quality fertilizer, improved equipment, additional irrigation, new insecticides, new herbicides, and other improved practices are necessary. Technology to provide this agricultural improvement is not now fully in place in China and some must be imported to meet the national policy time schedule. Demands for foreign exchange funds to import agricultural technology must conflict with those for other desired imports. Also funds from internal sources must be carefully allocated to all economic sectors to support the fertilizer investments.

There are pricing policy problems not only for phosphates but for pyrites, freight rates, electricity rates, domestic equipment and so on. The traditional prices in China generally do not reflect real costs including current investment cost.

INTERNAL CONFLICTS

Resolution of difficult national policy conflicts are further complicated by different needs, objectives, interests and political influence of the provinces. These are the same types of conflicts that exist between political sub-divisions in other developed nations. Managing and resolving these problems may be more difficult in China because of its long history and tradition. The resulting compromises may advance some projects faster than others which apparently have superior technical and economic merits.

PHOSPHATE FERTILIZER PLANTS

Rapidly increasing China's domestic capacity for fertilizer P_2O_5, presents many other challenging problems relating to:

1. Process Selection
2. Basic Raw Materials
3. Infrastructure Improvements
4. Capital Investments.

Current fertilizer production is primarily from hundreds of local small SSP plants and a few large SSP production centers. Sulphuric acid primarily is from small units roasting pyrites from many local sources and a few larger mines. Relatively small sulfuric acid tonnage is recovered from local smelter gases. Fertilizer also is produced in many small local plants in the form of fused calcium magnesium slag. All of these production sources need to be improved and sustained to supplement new capacity for high analysis fertilizers now being provided.

The primary new capacity process route appears to be wet-process phosphoric acid with consideration being given to dihydrate, hemi-hydrate, and hemi-dihydrate processes. The fertilizers to be produced from phosphoric acid are likely to be TSP, DAP, MAP and NPK. Projects are underway to utilize all of these processes.

In the interior Shanxi Province an alternative process for fertilizer production is nearing completion. A NITRO-PHOS plant utilizing imported technology with an annual capacity equivalent to approximately 120,000 TPY P_2O_5 will soon start. The process does not require sulfur for producing sulfuric acid to acidulate phosphate rock.

Ammonia is to be produced from coal gasification at the site which is in the vicinity of large coal reserves. Ammonia is converted to nitric acid to acidulate phosphate rock. Phosphate rock is expected to be shipped via rail from the new underground mine 800 kilometers south in Hubei Province. Smaller NITRO-PHOS plants using technology developed in China's research and development centers are reported to be in planning at other locations. NITRO-PHOS may prove to be an economically acceptable route where low cost ammonia is available and the relatively low grades of NPK can be utilized near the production site.

Another alternative route for obtaining fertilizer P_2O_5 is from electric furnace production of elemental phosphorous. Although this technology is not employed in other countries, it may be acceptable in some China locations. Reportedly there are large quantities of uncaptured hydro-electric energy in some regions having hard phosphate rock deposits, which requires no beneficiation. In such situations, where sulfur is not available and other P_2O_5 supply sources are at great distances, this may be economically acceptable for local consumption.

In other countries, economics has promoted the use of wet-process phosphoric acid for fertilizer production and probably will do the same in China. Consequently, the demand for sulfur will rise. With no announced deposits of brimestone, the dependence on pyrites will increase. The national railroad system must be improved to handle this tonnage in addition to the new phosphate rock shipments and fertilizer distributions.

The additional capacity of 2.5 million TPY P_2O_5 predicted to be required by Year 2000 is comparable to the new capacity Morocco has installed at Safi and Jorf Lasfar during the past 10 years. Morocco has constructed new mines in the interior and new railroads to move phosphate rock to the ports at Safi and Jorf Lasfar. Many 500 TPD phosphoric acid plants consuming imported sulfur have been completed. The wet-process phosphoric acid is concentrated to merchant grade acid or converted to DAP, TSP, or NPK and sold in international competitive.

Obviously China has many alternatives to consider. We can wisely assume that all reasonable alternatives, including many not mentioned herein, are being evaluated. China will determine the route to be followed in consideration of all domestic factors. Until their decisions are announced it is very risky to predict how they will increase P_2O_5 domestic supplies by the end of this century.

OPERATING COSTS

Operating costs of fertilizer plants in China, based on traditional pricing policies, have little reason to be much different from those in other countries, assuming efficiencies of raw material consumption is comparable. Phosphate rock and sulfur or pyrites represent the major portion of total phosphoric acid costs. Similarily raw materials in fertilizer products are the major cost items. It is of prime importance to import and install technology and equipment that will provide opportunity for achieving high raw material recoveries. One can safely assume that domestic sourced raw material prices will not exceed world prices and are most likely to be significantly lower.

The cost of processing raw materials to high analysis fertilizer products will be largely dependent on management and operating skills. In the beginning years these skills can not be expected to match those of experienced operators. Carefully planned training is essential to successful use of the new technology and can be provided. From observations of China's existing plants, the worker's dedication to their jobs is apparent. They value dearly their possessions and their work assignment. Their plants are well cared for and last a long time. Labor consumption is high but wages are low. Electric rates are low but pricing policies may change these rates to provide funds for additional capacity. Cost of maintenance and operating supplies, based on traditional domestic prices, are low and serve to offset high cost of importing equipment parts in the early years. Later China likely will manufacture most of the replacement parts.

On-stream time has a major influence on operating cost and can be a serious management problem everywhere in the world. High plant utilization is of course impossible with frequent occurances of empty supply bins or full product storages. China's heavily loaded transportation systems, tendency to minimize inventories, and the normal highly seasonal application of fertilizers suggest that difficulties of moving raw materials and products as required will be one of the largest problems in keeping the plants operating. Low on-stream time inevitably results in higher unit costs.

INVESTMENT COSTS

Capital investments for new fertilizer plants in China may be less than for similar plants in other world countries. The initial relatively large plants for sulfuric acid, phosphoric acid, TSP, DAP/MAP and NPK are expected to require imported technological services and some major equipment items. Detailed engineering following imported process designs can be performed by design engineering groups in China who will incorporate China made process equipment whenever possible. Equipment manufacturers in China are rapidly improving domestic capabilities through joint venture with international manufacturers so that only special items of equipment are to be imported. Domestic sourced equipment traditionally cost much less than international equipment.

Construction materials are generally from domestic sources. Buildings and process structures are commonly designed to use concrete, stone and brick. Shortage of mechanical equipment and little use of prefabricated steel extends the construction time and increases construction labor. Nevertheless, low unit costs of domestic materials and labor results in lower construction costs.

In summary, the total constructed cost of process plants can be expected to be lower than in many other countries but the design and construction time is greatly extended. The cost impact of long implementation periods can be severe if interest expense of accumulated disbursements of a project are considered. Also the cost difference between imported P_2O_5 products and domestically manufactured products during extended implementation periods can be substantial. These considerations have driven more highly industrialized countries to develop procedures and methods which may increase construction costs but reduce the time from project approval to completion. This change due to time value of money is beginning to be recognized in China.

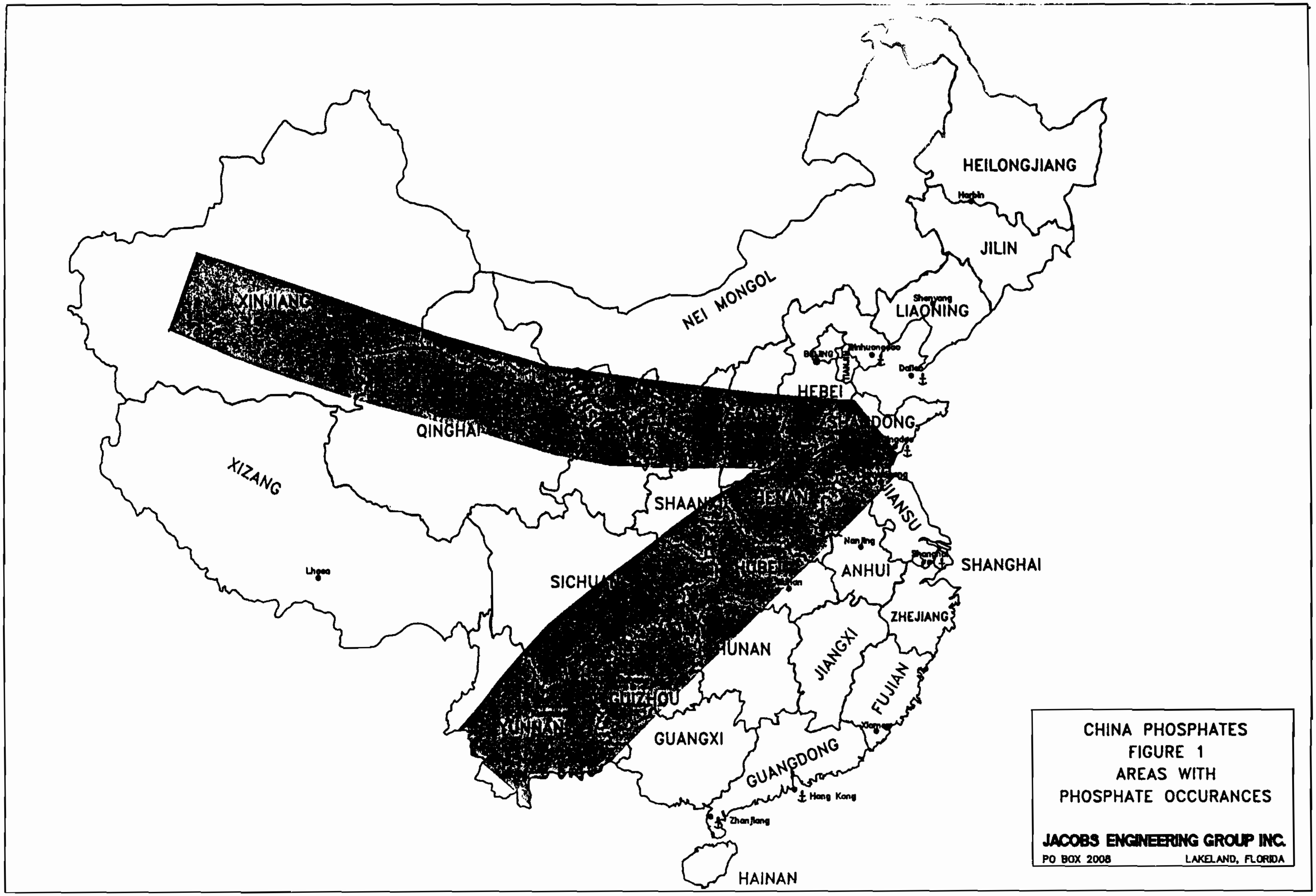
NEW FERTILIZER INVESTMENTS

New capital investments for doubling China's P_2O_5 fertilizer capacity is estimated to be in the range of $1.8 to 2.7 billion. This impressive sum is based on adding 2.5 million TPY P_2O_5 capacity at the investment cost per ton examples shown in Table 6. Mining investments in terms of product P_2O_5 tons, vary according to site and mining conditions; ore and concentrate grades; beneficiation requirements; and production rate. In this illustration, the LOW mining example has higher ore and concentrate grades which offset adverse site and mining conditions. The HIGH mining example has investments savings of about 10% from integration with fertilizer plants at the same location; whereas the LOW example ships phosphate rock concentrates. The number in brackets reflects the fact that only 92% of P_2O_5 in phosphate rock is sold as fertilizer products P_2O_5; therefore the mining investment cost per ton of P_2O_5 delivered to the farmer must be increased to be additive to the fertilizer investment cost.

Fertilizer investments cost per P_2O_5 ton include process plants for sulfuric acid from pyrites, dihydrate phosphoric acid, TSP or DAP plus the required support facilities and local infrastructure. The LOW examples are based on providing 2 process plants of the same sizes as in the HIGH examples to double capacity and realize lower unit investment cost. These examples emphasize the high P_2O_5 investment cost of DAP compared to TSP but does not recognize that DAP has incorporated low cost ammonia not in the TSP. Investments for pyrites production, fertilizer distribution and storage systems, and elements of national infrastructure are not included.

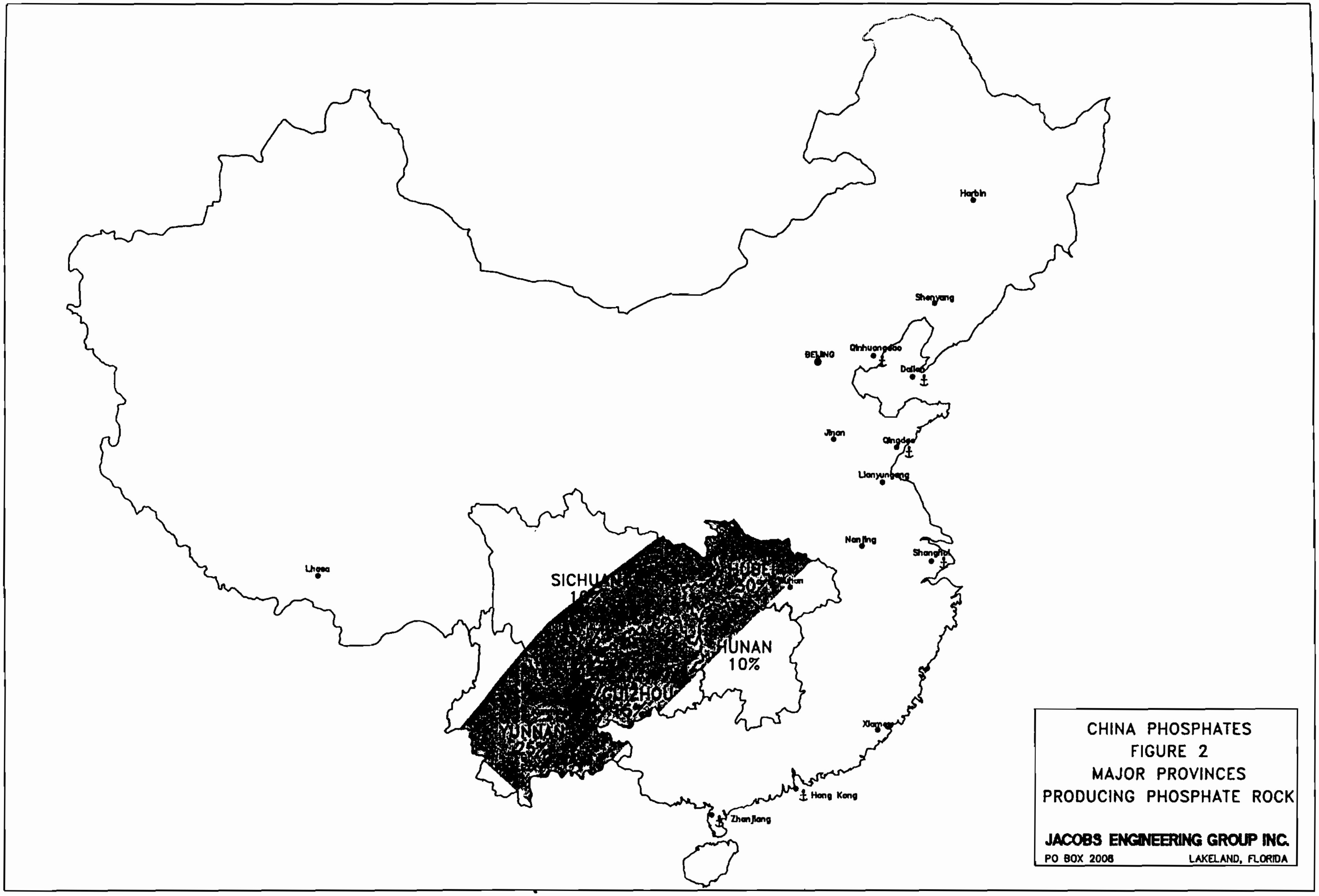
The principle conclusions from these data as shown in Table 7 are:

1. Total investments for producing fertilizer P_2O_5 are about ⅓ for phosphate rock and ⅔ for chemical conversion.
2. TSP has lower P_2O_5 investment cost than DAP.
3. Large fertilizer production centers have lower investment cost per P_2O_5 ton than small centers.



CHINA PHOSPHATES
FIGURE 1
AREAS WITH
PHOSPHATE OCCURANCES

JACOBS ENGINEERING GROUP INC.
PO BOX 2008 LAKELAND, FLORIDA



CHINA PHOSPHATES
FIGURE 2
MAJOR PROVINCES
PRODUCING PHOSPHATE ROCK

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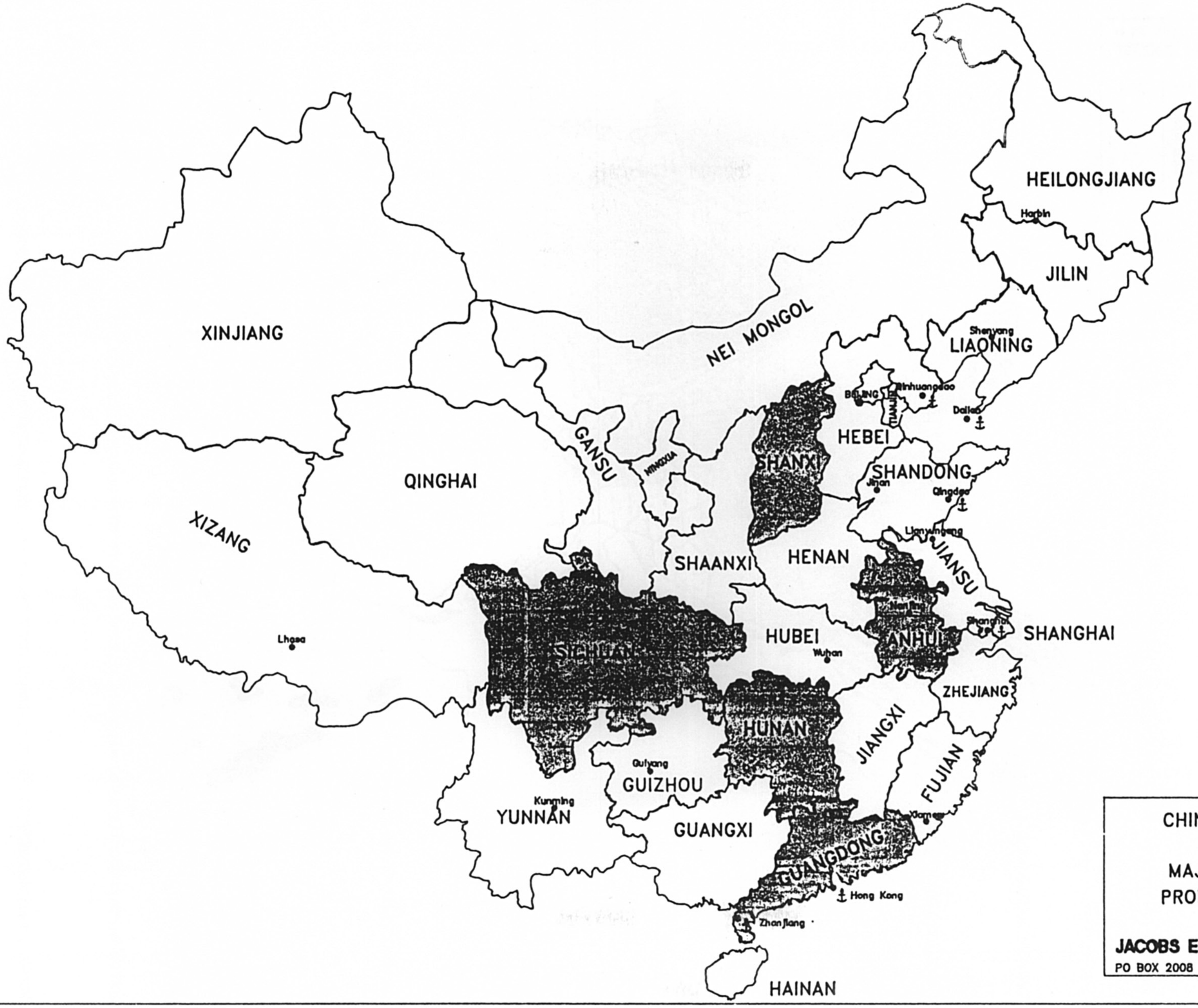

CHINA PHOSPHATES
FIGURE 3
MAJOR PROVINCES
PRODUCING PYRITES

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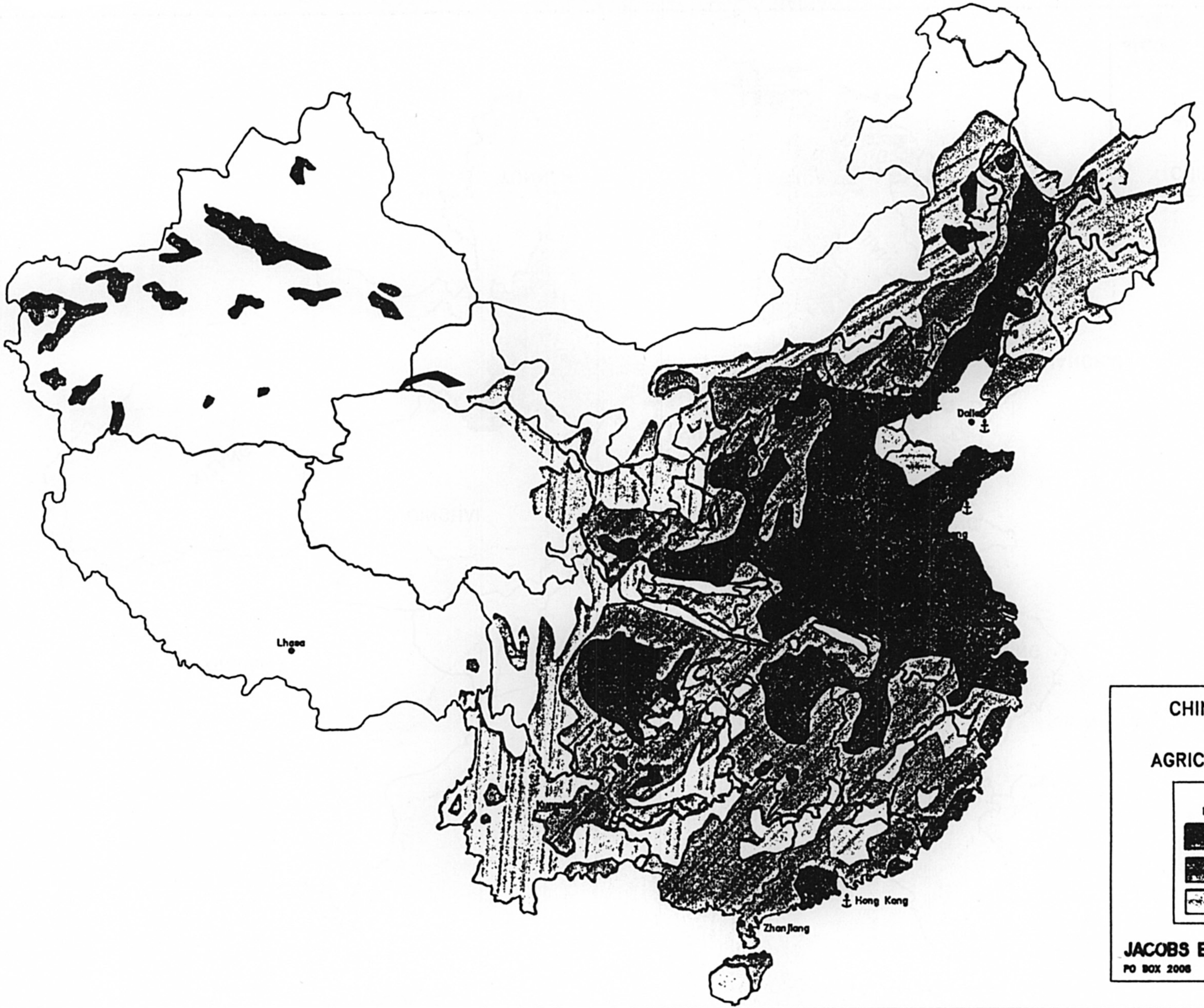

CHINA PHOSPHATES
FIGURE 4
AGRICULTURAL REGIONS

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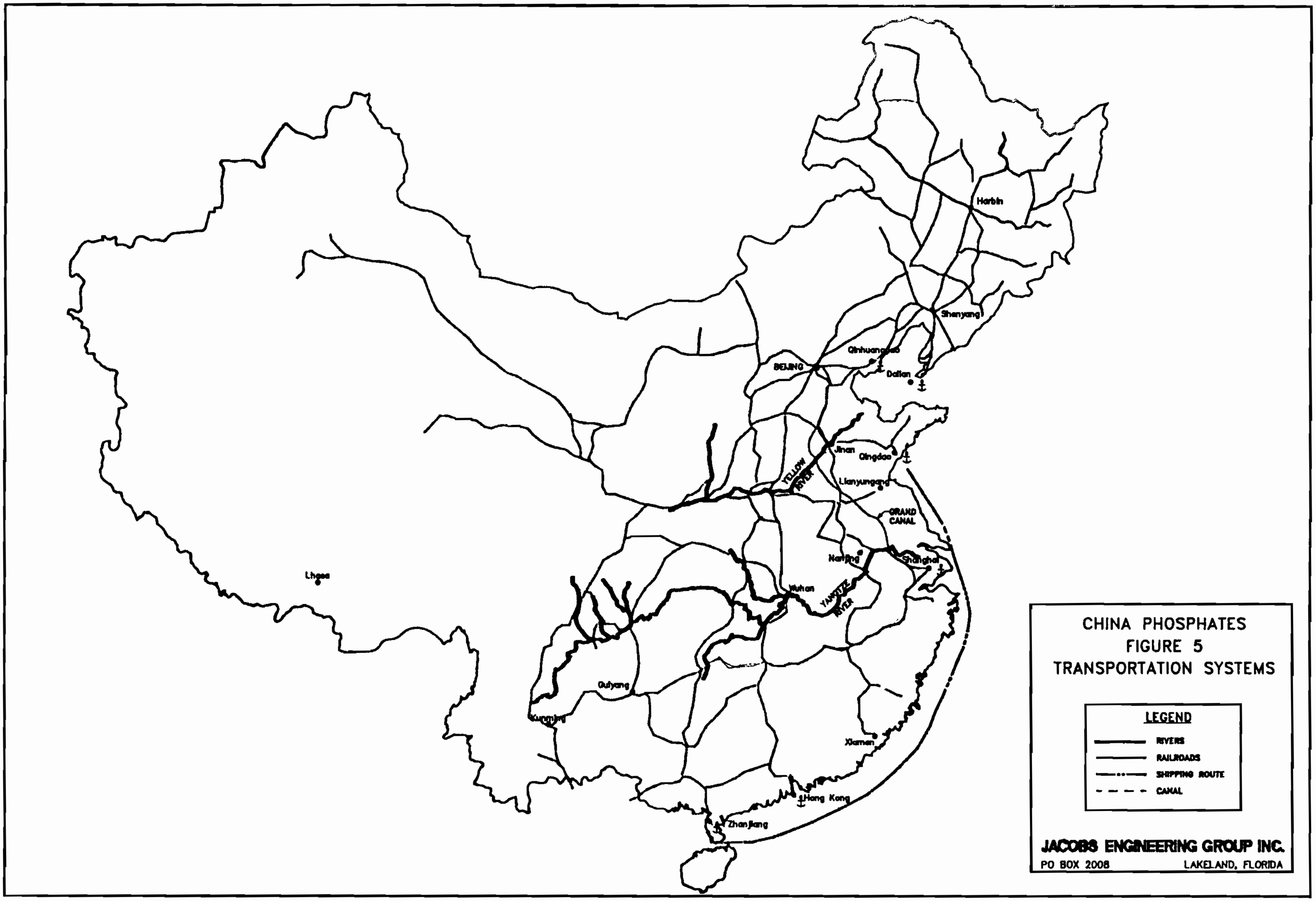

CHINA PHOSPHATES
FIGURE 5
TRANSPORTATION SYSTEMS

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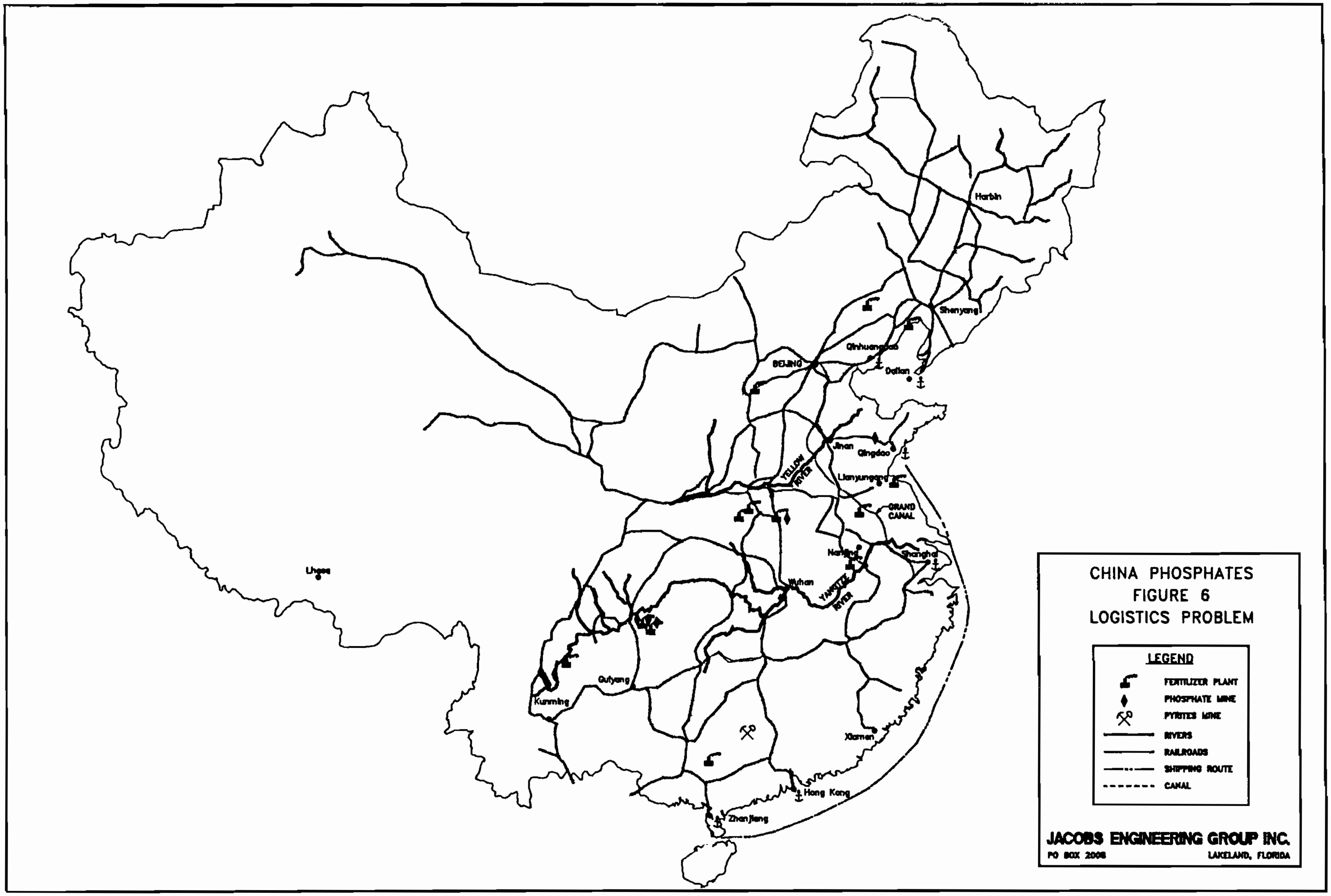

CHINA PHOSPHATES
FIGURE 6
LOGISTICS PROBLEM

TABLE 1
Fertilizer Logistics
Deliver 1 Ton DAP to Farm in Shandong

	Case 1 DAP Plant near Jinan			Case 2 DAP Plant near Zhanjiang		
	T	Km	T-Km	T	Km	T-Km
Rock	1.8	2800	5040	1.8	1500	2700
Pyrites	1.5	2500	3750	1.5	300	450
Ammonia	0.24	500	120	0.24	500	120
DAP	1.0	150	150	1.0	1650	1650
			9060			4920

TABLE 2
Guizhou Province Phosphate
Chemical Analysis

	Dry Weight %	
	Ore	Concentrate
P_2O_5	30	35
CaO	47	49
MgO	4 to 6	1.2
Fe_2O_3 and Al_2O_3	Less than 1.0	Less than 1.0
Ratio CaO: P_2O_5	1.6	1.4
Ratio of Concentration	1.32	1.0

TABLE 3
Guizhou Province Phosphate
Rock Operating Costs

	U.S. Dollars per Ton
Raw Materials and Supplies	5.70
Reagents	1.80
Labor	.75
Electricity	2.10
Maintenance	3.90
Overhead	.75
TOTAL	15.00

TABLE 4
Hubei Province Phosphate
Chemical Analysis

	Dry Weight %	
	Ore	Concentrate
P_2O_5	18.0	33.0
CaO	31.0	45.0
MgO	4.7	1.8
SiO_2	30.0	10.0
Fe_2O_3 and Al_2O_3	3.0	1.0
Ratio CaO:P_2O_5	1.7	1.4
Ratio of Concentration	2.3	1.0

TABLE 5
Comparative Rock Operating Costs
U.S.A. Dollars Per Ton

	Guizhou	Hubei	Morocco	Florida U.S.A.	Western U.S.A.
Raw Materials	5.70	7.00	2.90	0.60	2.30
Reagents	1.80	4.00	0	1.30	0.90
Labor	0.75	1.00	4.00	2.90	2.00
Electricity	2.10	2.30	1.30	2.90	2.60
Maintenance	3.90	4.00	3.80	3.70	2.70
Overhead(1)	0.75	1.20	2.30	4.10	1.50
TOTAL(2)	15.00	19.50	14.40	15.50	12.00
INVESTMENT COST	90	120	106	130	112
P_2O_5%	35	33	31	30	32

(1) Includes Administration, Taxes, Insurance, etc.

(2) Excludes Interest, Depreciation, Reserves Cost Wet Rock at Fertilizer Plant

TABLE 6
Fertilizer Investment Costs
1987 U.S. Dollars $ Per Ton

	High	Low
Mining		
Ore	52	67
Concentrate	120	90
Concentrate P_2O_5	324 (352)	256 (278)
Fertilizer		
TSP P_2O_5	540	459 (2)
DAP P_2O_5	710	604 (2)
Combined (1)		
TSP P_2O_5	892	737
DAP P_2O_5	1062	882

Notes: (1) Combined includes Concentrate P_2O_5 at 92% Recovery

(2) Fertilizer LOW is 85% of HIGH based on 2 optimum sized plants in 1 complex.

TABLE 7
Capital Investments

- Total for 2.5 Million TPY P_2O_5 $1.8 to 2.7 Billion
  - ⅓ Mining
  - ⅔ Chemical Conversion
- TSP Less Than DAP
- Larger Production Centers are Cheaper

Case Study: Blend Plants with High Deficiency Rates

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IMC-Fertilizers, Inc.
Presented by: J. L. Medbery

The Technical Services Department of major fertilizer producers are frequently asked to assist customers with problems in their blending plants. These requests usually result from the blender having received a warning from the regulatory agency of their state. The warnings are occasioned by excessive numbers of deficient samples.

The first step, in response to these requests for aid, is to review all of the reported analysis information and to determine, if possible, the cause of the deficiency. Usually the deficiency is caused by:

Human errors, either in formulation, batching sheet preparation, labeling or misidentification of a material.

Contamination, caused by accidental mixing of two or more materials.

Weighing errors, caused by inaccurate or malfunctioning batch weighing equipment.

Segregation, which results when materials are improperly mixed or they separate during handling following mixing.

Usually the cause of deficiencies cannot be determined without visiting the plant. The balance of this paper will deal with a visit that members of IMC-Fertilizers' Technical Services team made to a company which was experiencing abnormally high deficiency rates.

The company operated several plants, but most of the deficiencies occurred at one location. We did, however, visit five of the plants to identify possible problem areas.

Before visiting the plants, an evening group meeting was held with the plant managers, key hourly employees, and the upper management of the company. During this meeting, the causes and the prevention of deficiencies were discussed. Personnel of IMC-Fertilizers led the program by lecturing, with slides, and by conducting a lively group discussion. Attitudes and concerns of various individuals could, in that way, be revealed. This was helpful during the subsequent plant visits.

The plant visits revealed many conditions that could contribute to deficiencies. Generally, however, housekeeping was excellent and the location managers expressed sincere concern about the deficiencies and welcomed our suggestions.

At one location, materials had flowed through the lower, open section, of the partial bin doors. The materials from adjacent bins were thus in contact with each other and an opportunity for contamination existed. We recommended that the plant install triangular-shaped wing partitions to keep the materials separated.

The materials receiving system consisted of an undertrack conveyor and an elevator. There was no evidence of contamination or accumulated spillage, but the elevator was in need of repair.

The plant uses a blender which meters each material volumetrically into a common auger conveyor where they are mixed and fed to the load-out elevator. The plant manager assured us that he calibrated his feeders on a frequent basis, and that the system was quite accurate. His system is also equipped with a small hopper for minor additions. Impregnation chemicals, when used, are added to the mixing auger.

At another plant we checked the accuracy of the load cell equipped hopper scale in addition to reviewing all of the materials handling procedures. This plant also adds liquid chemicals.

At a third location we were pleased to see good housekeeping and bin labeling in practice. We also devoted time to explaining to the local manager how to back-calculate the formulation represented by a deficient sample. By this method, we were able to show him that segregation had occurred in several samples and we offered suggestions on how to overcome this problem in the future. One key is to prevent coning within the materials bins when they are being filled. A spreader device for the end of the fill pipes was proposed. Also, using well-mixed sizes when withdrawing material for blending was recommended.

At the fourth location we were told that sometimes the inspector draws samples at the mixer discharge, using the sampling cup and that sometimes he collects samples from the loaded vehicle using the D-tube. This was the only plant of the five that we visited that had enough clearance between the discharge lip of the mixer and the conveyor to permit stream cut sampling at this point. Perhaps, however, the small 4-ton mixer discharges too fast for the inspector to make the AOAC-prescribed number of cup passes, especially when small lots are mixed. As no shipping activity was occurring, we had to settle this point by asking the location manager to discuss it with the inspector on his next visit.

The housekeeping, bin labeling, materials handling and other practices were satisfactory. Again, the plant manager was admonished to install anti-coning flow spreaders on the ends of the bin-fill pipes and to mix the sizes as he withdraws material for blending.

The plant with the highest deficiency rate was also the plant with the most tonnage. A concentrated effort was undertaken to determine the source of the problem at this location. The balance of this paper will focus on this activity.

First, an overall inspection of the facility was made. The undertrack receiving system was clean and well maintained. There was no evidence of contamination. The elevator turnhead worked well with no indication of leaking. The bins were filled by long pipes from the elevator, and coning occurred as the bins were filled. Spreader devices were proposed to control this problem. The suggested design is illustrated in Figure 1.

The bin walls showed no signs of leaking and there was no spillage in the aisles.

Housekeeping in the weigh-hopper/blender area was also very good. The blender is an eight-ton size conical-end, tilted axis type. It empties by reversing the rotation.

We checked the flow of material from the weigh-hopper conveyor into the mixer. There was no spillage and the trajectory of the flow carried the material well into the mixer. The rate of transfer into the mixer is about 4 to 5 tons per minute.

The regular impregnation system had been cleaned out and put into storage for the winter; however, we did observe the addition of Treflan by manually pouring the liquid on to the stream of dry material as it was propelled into the mixer by the weigh-hopper conveyor. The liquid chemical was added very carefully and the two volumes matched well.

We investigated the possibility of sampling at the mixer discharge, but the clearances were inadequate for use of the standard cup. We also took note of the flow restriction plates (called choker plates) that had been installed at the mixer outlet. These were required, because, without them, the mixer would empty too fast and overflow the conveyor hopper. In simple terms, the final load-out belt conveyor was too small to accommodate the mixer. The mixer manufacturer gives the discharge rate as 3.5 tons per minute. The 12" wide conveyor is rated at around 2 tons per minute. During tests the 6-ton batches were transferred to the vehicle in 185 seconds, 1.9 tons per minute. We also observed that the feed hopper on the belt contained several cubic feet of blended material until the very end of the discharge cycle. This makes the belt a volumetric conveyor. The implications of this will be discussed later in this paper.

It was also noticed that a thin trickle of fines appeared close to the head drum as the load-out conveyor discharged to a vehicle. Any stream cut sampling at this location would miss these fines. We then had a lip plate made and attached temporarily with vice grip pliers, for sampling to be done that day. It was subsequently welded in place.

The first test consisted of a sampling method comparison. We were aided in this work by two inspectors provided by the state. A 2.5-ton load of 16-20-4-4 sulfur was being shipped. The inspectors first collected a sample using the stream cut method at the discharge of the truck-loading conveyor. Next, the load was sampled using the D-tube method. The two samples were individually mixed by riffling and recombining and then divided into two portions. One portion of each sample was forwarded to the state laboratory by the inspectors and one portion was analyzed by a commercial laboratory. Table 1 gives the results of these comparisons. The stream cut samples tested within state tolerance ranges. The D-tube sample would be graded as deficient, based on the commercial laboratory Nitrogen analysis. (Allowance, 0.67).

The state inspectors also sampled the materials in the plant bins. They used the D-tube in accordance with AOAC procedures. The bins were also sampled by the IMC-F personnel using the D-tube in the prescribed manner. The state laboratory analyzed the samples taken by the inspectors. The IMC-F samples were subjected to sieve testing, on site, and were then sent to a commercial laboratory for chemical analysis.

Table 2 gives the results of the chemical analysis. Monoammonium phosphate (MAP) 11-52-0 was sampled twice; reported as MAP-1 and MAP-2. MAP-2 represents three truckloads delivered on the following day which was noticeably smaller in size than the MAP sampled on the prior day. MAP-2 tests slightly lower in nitrogen.

Table 2 also gives the size data on the materials sampled in the bins and as used in the subsequent blender tests. Please note that the large MAP, MAP-1, was used in blender test A, and that the large DAP, DAP-2 was used in blender test B. DAP-2 came from an 100-ton rail car that was unloaded after the first bin samples had been taken and the sampling methods comparison tests had been completed. Unfortunately, we did not obtain a chemical analysis on DAP-2. Also, note the large size variation between MAP-1 and MAP-2 and between DAP-1 and DAP-2. Both samples of MAP came from one warehouse and possibly represent variations caused by coning in that storage situation or in prior handling. We were not able to determine if the DAP samples came from separate sources, but DAP-1 was in the center of the bin, directly under the fill pipe and consequently was thought to contain fines concentrated there by the coning effect.

Two tests were undertaken for the purpose of determining the mixing characteristics of the blender when the available materials are used. These are identified hereafter as Blender Test-A and Blender Test-B. The size variations of the materials used in these tests are depicted graphically as Figure 2.

Blender Test A involved both stream cut sampling and D-tube sampling of a 6-ton lot of 17.8-17.6-15.7-6.1. Elemental sulfur, chelates of copper manganese and zinc, and Treflan "Pro-5" were all included in the blend. Table 3 gives the formula for this product. It also gives the calculated analysis of the final product, based on the materials analysis provided by the two laboratories.

Also shown is the mathematical average of 11-stream cut samples and the analysis of a composite sample made from portions of all 11 stream cut samples. After the spreader truck was loaded, D-tube cores were taken in the AOAC-prescribed manner. No effort was made to level the load as the vehicle was filled. There are significant differences in the final analysis of the product based on the three methods for determining these values.

Table 4 gives the chemical analysis of the 11 stream cut samples taken at 15-second intervals. The composite sample, made out of portions of each stream cut is also reported, as is the D-Tube sample, a composite of 10 cores.

The D-tube sample reflects low N and APA and high K20 and sulfur. This data infers that the sampling pattern for core removal may not overcome the natural tendency for fines to accumulate at the center of a conical pile in a spreader body.

Table 4 also gives mean values, median values, standard deviation and coefficient of variation for nitrogen, phosphate, potash and sulfur for the 11 stream cut samples.

Figure 3 is a graphical presentation of the Nitrogen value in each of the Test-A stream cut samples. It is consistently higher than the guarantee except in the last samples.

Figure 4 depicts the P205 analysis in each of the 11 stream cut samples. The values are very high in the first cuts and then they drop off in a fairly uniform manner. The last 5 cuts are below guarantee in P205.

Figure 5 shows that the K20 analysis follows a pattern; almost a reciprocal of the P205 behavior. The first cuts are low, but they progressivley build and the final 5 cuts are higher than the guarantee.

Figure 6 is a combination graph of all 3 nutrients plotted at the 15-second intervals represented by the 11 stream cut samples. It is only during the middle part of the discharge cycle that the individual stream cuts come close to meeting guarantee. As mentioned before, only the nitrogen analysis remains fairly consistent throughout the entire cycle.

Blender Test-B was performed on a six-ton lot of 21-21-5-5 sulfur. The nominal formula is given in Table 5. The expected true analysis of the product, based on the state laboratory analysis of the materials and the commercial laboratory analysis of the materials is calculated. The average of the 12 stream cut samples is given too, as is the chemical analysis of the composited sample made up of the 12 individual stream cut samples. No D-tube core samples were taken.

Table 6 gives the chemical analysis on each of the 12 stream cut samples. The analysis of the composited sample is also given. The calculated value of the mean, median, standard deviation and coefficient of variation is indicated.

The analysis of Nitrogen in the stream cut samples is depicted graphically in Figure 7. As in Blender Test A, the Nitrogen remains fairly consistent throughout the cycle, but in Test-B, is low at the very beginning and at the very end.

The graph for P205, Figure 8, shows the extremely high values in the first stream cuts and a steady reduction thereafter with the last 6 cuts being substantially below guarantee.

Figure 9 represents the K20 analysis in the stream cut samples. The first 6 are below guarantee and the final 5 are over guarantee. This conforms to the pattern seen earlier in Blender Test-A.

A combination graph, showing all three nutrient analyses on one chart, plotted against time at 15-second intervals, is given as Figure 10. This shows a pattern similar to that of Test-A. Phosphate is high in the first stream cuts and gradually falls off, ending up low in the final stream cuts. Potash shows a reverse pattern while Nitrogen stays uniform. The coefficients of variation for the nutrients in the tests reflect this lack of uniformity:

	Coefficient of Variation			
	N	P2O5	K2O	S
Test-A	7.8	24.4	26.1	23.1
Test-B	8.3	30.0	43.0	37.2

As stated before, the receiving hopper on the load-out belt was always at least half-full during the discharge cycle. The outlet from the hopper was narrowed to avoid over-flowing the belt. This made it a volumetrically-controlled feeder. For this reason, the volume of each sample taken as a stream cut, remained the same throughout the discharge period. The weight of material in each cut would vary; however, proportional to the density of the materials represented in that particular sample.

The volume of each stream cut sample was about 76 cubic inches. This was mixed by riffling and recombining and then split into 2-38 cubic inch portions. One was sent to the laboratory for chemical analysis. The other was poured into a large container to be part of the composited sample. The entire composite sample was mixed by repeated riffling and recombining before it was reduced by riffling to the conventional sample quantity of about 38 cubic inches.

In Table 7, the quantity of each material represented by the chemical analysis of stream cut samples 3-B and 9-B has been calculated. The density factor for each material contained in the sample is then applied. By this method, the weight of the material contained in 38 cubic inches of sample, can be calculated. For example, sample 3-B which analyzed 22.45-27.97-2.32-3.17 was calculated to contain 1.310 lbs. of material. Sample 9-B which analyzed 22.15-17.07-6.08-6.77 was calculated to contain 1.489 lbs. of material.

This density variation between samples of equal volume explains why the composited sample analysis is different from the average (mean) value of all of the individual stream cut samples. For example, the mean value of the 12 stream cuts of Test-B was: 21.51-21.43-4.80-5.60. The composite sample analysis was: 20.13-21.67-5.42-5.91. The composite sample contains less of the low density material, Urea, and more of the high density material, Sul-Po-Mag. The net effect, to the blender operator, is that bias was introduced which could result in a deficiency penalty on Nitrogen.

The implication of the above is that non-uniformity as represented by samples, cannot be distinguished from a true deficiency. Almost all sampling procedures have a built-in bias when the materials being sampled are non-uniform in size and the blending equipment in use is incapable of overcoming this.

Stream cut samples must be taken at frequent, exactly timed intervals. They must be taken at the end of conveyors with no up-stream restrictions so that the volume caught by each pass of the cup reflects the actual discharge volume from the mixer at a given moment of time.

Because these conditions are seldom obtained in actual blend plants, the next best thing is to eliminate the non-uniformity.

In the case presented, materials varied in size to the limits of the recommended 10% of the average size guide number. For example, in Blender Test-B, the SGN number values for the materials were:

Urea	240
DAP	245
SPM	200
Dolomite	200
Average	221

Average + 10% = 243
Average − 10% = 199

It is our conclusion that the non-uniformity exhibited in the samples was caused by the classification effect of the restricted discharge on the mixer and exaggerated by the density effect attributable to the belt hopper.

CONCLUSIONS AND RECOMMENDATIONS

The severe segregation, or separation, noted in the belt discharge stream cut samples indicates that the mixer discharges more large particles during the first part of the emptying process. Rotary drums are known to classify materials, by sizes, when the materials are retained in the drum. The data strongly suggests that this behavior is also occurring in the conical-end, tilted-axis mixer that was tested. When operated in the reverse rotation, discharging mode, with the choker plates in place, the material cannot discharge freely. Classification then occurs.

The first recommendation was to replace the 12″ wide load-out belt with a 24″ model that can carry the full discharge surge of the mixer. The choker plates should then be removed. The mixer will then discharge a 6-ton batch in 103 seconds, rather than 185 seconds. (3.5 tons per min., per mixer manufacturer).

The operators mentioned to us that although this mixer is rated at 8-tons capacity, they had observed poor mixing when batches over 6-tons were mixed. Our recommendation was that batch sizes be limited to 6-tons or less, at least until tests at higher loadings can be made.

Because coning and segregation occurs in the bins that are filled by long pipes coming from a tall receiving elevator, it was recommended that stream splitters be installed on the down-turned ends of these pipes. While coning cannot be completely eliminated, it is hoped that numerous small cones of approximately equal volume and composition will be formed, rather than one large cone.

It was also proposed that the loader drivers should select materials of mixed sizes when reclaiming from storage bins, and, as much as possible, stir together materials with the loader bucket to ensure uniformity.

Supplier specification sheets should be consulted as to Size Guide Number to ensure compatibly-sized materials for use in blends.

Test sieves should be used to check materials in storage for size compatibility and to verify sizes on incoming shipments.

Encourage the collection of samples by the stream cutting method; however, this should only be done if it can be done safely and without bias caused by mechanical limitations.

Flexible chutes or load-spreader devices should be installed at the end of load-out conveyors to minimize coning in transport vehicles. This will contribute to reducing bias or error in D-tube core sampling.

Additional recommendations included:

1. Completely clean up the unloading area after each receipt of a material.
2. Check for leaks and possible contamination at elevators, belts, bulkheads, etc.
3. Make sure that load-out systems, mixers, hoppers, etc. are completely empty after each shipment.
4. Acquire digital weight indicators for more accurate batch weighing. Retain existing dial heads for back-up in event of circuit board failure.
5. Use a riffle, riffle pans, D-tube, test sieves, etc. to continually check materials and blends.
6. Ask state inspector to split his sample so that a portion can be held at the plant for use in event of a disputed penalty.
7. Refer to the TFI "Bulk Blend Quality Control Manual", a copy of which was provided to each location. It was strongly urged that the company put into effect a training program for all employees. The TFI manual is suitable as a text.

8. Inform all plant managers immediately whenever a deficient sample is reported, regardless of location cited. Ask that location manager to investigate and report promptly as to his findings on the cause of the deficiency. Discuss these reports in the employee meetings.
9. Consider an incentive plan with awards given to the location with the best quality record.
10. Management must respond quickly to suggestions for improvement from employees, state authorities, outside technical personnel. Management must exhibit leadership and commitment toward improvement of quality.

As Churchill was reported to have said, "I am easily pleased with the very best." It is management's responsibility, through the proper use of materials, people and equipment, to ensure that their customers receive blends of the very best quality.

Sales and marketing success are totally dependent upon the performance of the production operation.

TABLE 1
Analysis and Size Data on Blend 16-20-4-4

Formula

Material	**Lbs./t.**	**N**	**P2O5**	**K2O**	**S**
DAP	870	156	400		
UREA	357	164			
SPM	364			80	80
Dolo.	409				
	2000	320	400	80	80
Nutrient percent:		16.0	20.0	4.0	4.0
"Found" Analysis					
State Lab.					
(CUP)		16.10	22.31	4.04	N.A.
(D-TUBE)		15.39	21.34	4.52	N.A.
(CUP)		15.96	22.07	3.87	4.97
(D-TUBE)		14.97	19.57	4.42	5.31

Size Data

Retained on Tyler Mesh

	+6	**+8**	**+10**	**+14**	**+20**	**−20**	**SGN**
BLEND	2.5	25.2	67.9	87.9	94.6	5.4	195
Materials Proportioned							
(Sizes, Table 2)							
DAP (.435)	.61	6.18	26.14	38.80	42.54	—	78.3
UREA (.179)	.39	9.55	17.08	17.61	17.74	—	43.0
SPM (.182	1.67	5.75	12.63	16.73	17.47	—	36.4
Dolo. (.204)	.67	7.53	12.40	15.91	17.83	—	40.8
TOTAL (1.000)	3.34	29.01	68.25	89.05	95.58	4.42	198.5

TABLE 2
Chemical Analysis

	N	P	K	S
DAP-1	18	46	0	
STATE	17.81	46.62		
COMMERCIAL	17.34	46.33		
MAP-1	11	52	0	
STATE	11.22	51.18		
COMMERCIAL	11.23	51.78		
MAP-2	11	52	0	
COMMERCIAL	10.89	51.77		
UREA	46	0	0	
STATE	45.62			
COMMERCIAL	44.79			
MOP	0	0	60	
STATE			59.57	
COMMERCIAL			59.17	
SPM	0	0	22	22
STATE			22.57	23.06
COMMERCIAL			22.06	22.62

Size Data

Cumulative Percent Retained
Tyler Mesh

	+6	+8	+10	+14	+20	−20	SGN
MAP-1	20.9	84.0	99.1	100.1	—	—	285
MAP-2	2.7	26.4	61.3	85.0	95.7	4.3	195
GMOP	19.4	57.0	86.3	96.0	97.2	2.8	250
UREA	2.2	53.4	95.4	98.4	99.1	0.9	240
DAP-1	1.4	14.2	60.1	89.2	97.8	2.2	180
DAP-2	13.7	54.3	76.2	95.7	99.6	0.4	245
SPM-1	11.3	34.5	66.7	90.8	96.8	3.2	200
SPM-2	9.2	31.6	69.4	91.9	96.0	4.0	200
DOLO	3.3	36.9	60.8	78.0	87.4	12.6	200

Notes: DAP-1 and SPM-2 used in Sampling Methods Comparison Test
MAP-1 used in Blender Test A
DAP-2 used in Blender Test B

TABLE 3
Formulas Used For Mixer Test – A

NOMINAL FORMULA
19.69-19.39-17.29 (without additives)
17.8-17.6-15.7-6.1 (with additives)

		Lbs.	N	APA	K2O	S	Cu	Mn	Zn	Treflan
Urea	46-0-0	616	283.36							
MAP	11-52-0	678	74.58	352.56						
MOP	0-0-60	524			314.4					
Sulfur	0-0-0-90	136				122.4				
Copper Chelate, 5% Cu		3					.15			
Mang. Chelate, 8% Mn		12						.96		
Zinc Chelate, 10% Zn		31							3.1	
		2000								
Added 8 lbs. Treflan "Pro-5" @ 50% conc.		8								4.0
Total Batch Weight		2008	357.94	352.56	314.4	122.4	.15	.96	3.1	4.0
			17.83	17.56	15.66	6.10	.0075	.048	.154	.19

Actual Formula—Based on Materials Analysis (State Lab.)
17.8-17.3-15.6

		Lbs.	N	APA	K2O
Urea	45.62-0-0	616	281.02		
MAP	11.22-51.18-0	678	76.07	347.00	
MOP	0-0-59.57	524			312.15
	Others	190			
		2008	357.09	347.00	312.15
			17.78	17.28	15.55

Actual Formula—Based on Materials Analysis (Commercial Lab.)
17.5-17.5-15.4

		Lbs.	N	APA	K2O
Urea	44.79-0-0	616	275.91		
MAP	11.23-51.78-0	678	76.14	351.07	
MOP	0-0-59.17	524			310.05
	Others	190			
		2008	352.05	351.07	310.05
			17.53	17.48	15.44

Found Values—A & L Lab.

	N	APA	K2O	S	Cu	Mn	Zn	Treflan
Average of 11 Stream Cuts:	17.84	18.55	15.14	6.92	——	——	——	——
Composite: 11 Stream Cuts:	16.66*	18.07	17.14	7.46	——	0.052	0.20	0.20
Composite: 10 D-Tube Cores:	16.89*	16.40*	18.03	7.28	——	0.071	0.21	0.22

Deficient

AAPFCO Allowances
Nitrogen Guarantee 17.8, 0.70 units
Phosphate Guarantee 17.5, 0.71 units

TABLE 4
Chemical Analysis of Group-A Stream Cut Samples
FERTILIZER REPORT

Sample ID:	Nitrogen: %	Total Phosphate: %	Potash: %	Sulfur: %	Manganese: %	Zinc: %	Treflan
GROUP A							
1-a	18.70	24.87	10.73	4.67			
2-a	19.06	24.90	10.18	4.29			
3-a	19.30	23.87	10.18	5.37			
4-a	18.22	20.93	12.06	6.28			
5-a	18.79	19.40	14.16	6.38			
6-a	17.20	17.90	15.15	8.59			
7-a	19.57	14.77	16.37	7.52			
8-a	15.69	16.07	18.69	7.98			
9-a	17.34	13.37	19.46	8.41			
10-a	16.59	14.90	19.02	8.06			
11-a	15.83	13.10	20.57	8.59			
12-a	16.66	18.07	17.14	7.46	0.052	0.20	0.20
13-a	16.89	16.40	18.03	7.28	0.071	0.21	0.22
Mean (1-11)	17.845	18.553	15.143	6.922			
Std. Deviation	1.389	4.535	3.955	1.602			
Coef. Variation %	7.8	24.4	26.1	23.1			
Median	18.22	17.90	15.15	7.52			

1a thru 11a Individual Stream Cuts, 15 sec. Intervals
12a Composited Sample, 11 Stream Cuts
13a D-Tube, AOAC Procedure; Composite of 10 Cores

TABLE 5
Formulas Used for Mixer Test B
21-21-5-5

		lbs.	N	APA	K2O	S
			Nominal Formula			
Urea	46-0-0	556	255.76			
DAP	18-46-0	913	164.34	419.98		
SPM	0-0-22-22	455				
Limestone	——	76			100.0	100.0
		2000	420.1	419.98	100.1	100.1
			21.0	21.0	5.0	5.0
			Actual Formula—Based on MTLS. Anal. (State)			
Urea	45.62-0-0	556	253.65			
DAP	17.81-46.62-0	913	162.61	425.64		
SPM	0-0-22.57-23.06	455			102.69	104.92
Limestone	——	76				
		2000	416.26	425.64	102.69	104.92
			20.81	21.28	5.13	5.25
			Actual Formula—Based on MTLS. Anal. (Commercial)			
Urea	44.79	556	249.03			
DAP	17.34-46.33-0	913	158.31	422.99		
SPM	0-0-22.02-22.62	455			100.19	102.92
Limestone	——	76				
		2000	407.34	422.99	100.19	102.92
			20.37	21.25	5.01	5.15
			Found Values—Commercial Lab.			
	Average of 12 Stream Cuts:		21.51	21.43	4.80	5.60
	Composite: 12 Stream Cuts:		20.13	21.67	5.42	5.91
	Composite: 10 D-Tube Cores:			None Taken		

TABLE 6
Chemical Analysis of Test—B Stream Cut Samples

FERTILIZER REPORT

Sample ID:	Nitrogen: %	Total Phosphate: %	Potash: %	Sulfur: %
GROUP B				
1-b	19.73	31.03	2.65	3.58
2-b	20.45	31.87	2.21	3.26
3-b	22.45	27.97	2.32	3.17
4-b	20.98	25.80	3.65	4.63
5-b	22.36	23.17	3.98	4.81
6-b	24.12	21.10	3.65	4.02
7-b	23.05	18.87	4.87	5.39
8-b	21.69	16.30	6.41	6.89
9-b	22.15	17.07	6.08	6.77
10-b	23.40	14.97	5.75	6.61
11-b	19.75	15.03	7.63	8.60
12-b	17.94	14.03	8.40	9.51
13-b	20.13	21.67	5.42	5.91
Mean (1-12)	21.506	21.434	4.800	5.603
Std Deviation	1.789	6.435	2.065	2.087
Coef. Variation %	8.3	30.0	43.0	37.2
Median	21.69	18.87	3.98	4.81

1b thru 12b Individual Stream Cuts, 15 sec. Intervals

13b Composited Sample, 12 Stream Cuts

TABLE 7
Density Effects

Typical Sample, Stream Cut, after 50%
Reduction by Riffling
Volume 4½″ × 2½ × 3⅜ = 38 cubic in.
= 0.022 cubic ft.

Typical Density of Blending Materials

Material	lbs./cu.ft.	Density	lbs. in 0.022 cu. ft.
Water	62.4	1.00	1.373
DAP	56.5	.905	1.242
MAP	62.0	.993	1.363
UREA	48.0	.769	1.056
MOP	64.0	1.026	1.408
SPM	94.0	1.506	2.067
Dolomite	87.0	1.394	1.914

Weight of 0.022 cu. ft. stream cut samples
Based on analysis of samples

Sample 3-B (22.45 - 27.97 - 2.32 - 3.17)

Material	Pct. in sample	Wgt. in sample, lbs.
DAP	59.2	.735
UREA	25.9	.274
SPM	10.5	.217
Dolo.	4.4	.084
TOTAL	100.0	1.310

Sample 9-B (22.15 - 17.07 - 6.08 - 6.77)

Material	Pct. in sample	Wgt. in sample, lbs.
DAP	31.9	.396
UREA	30.7	.324
SPM	34.6	.715
Dolo.	2.8	.054
TOTAL	100.0	1.489

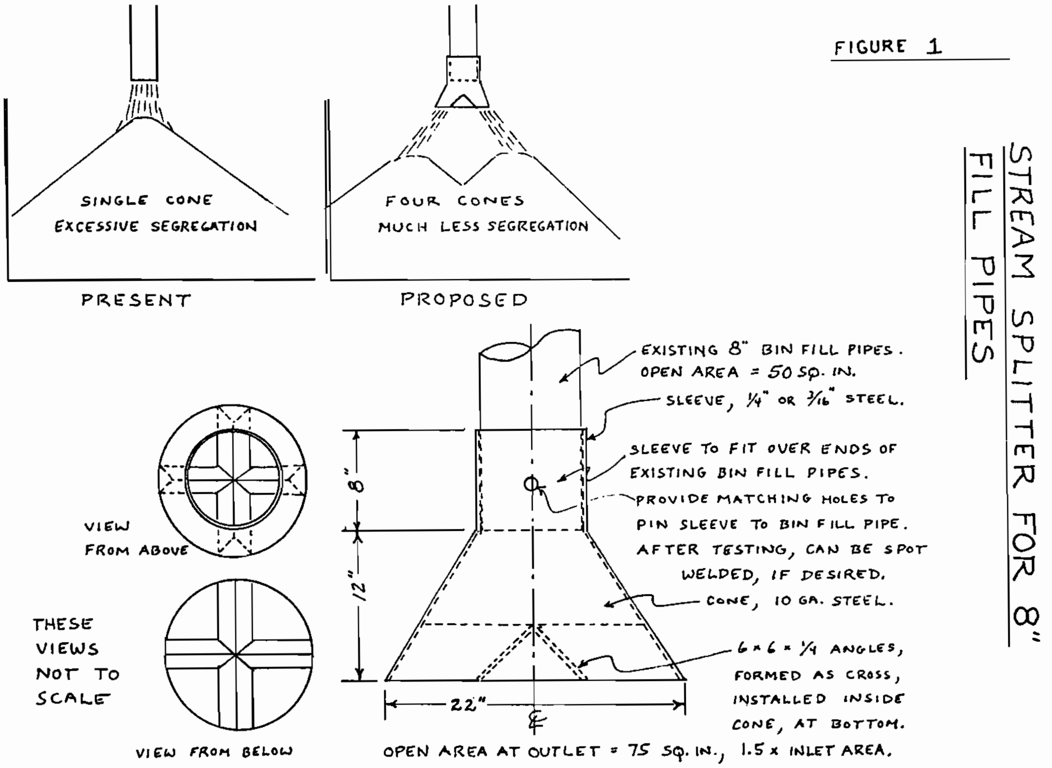
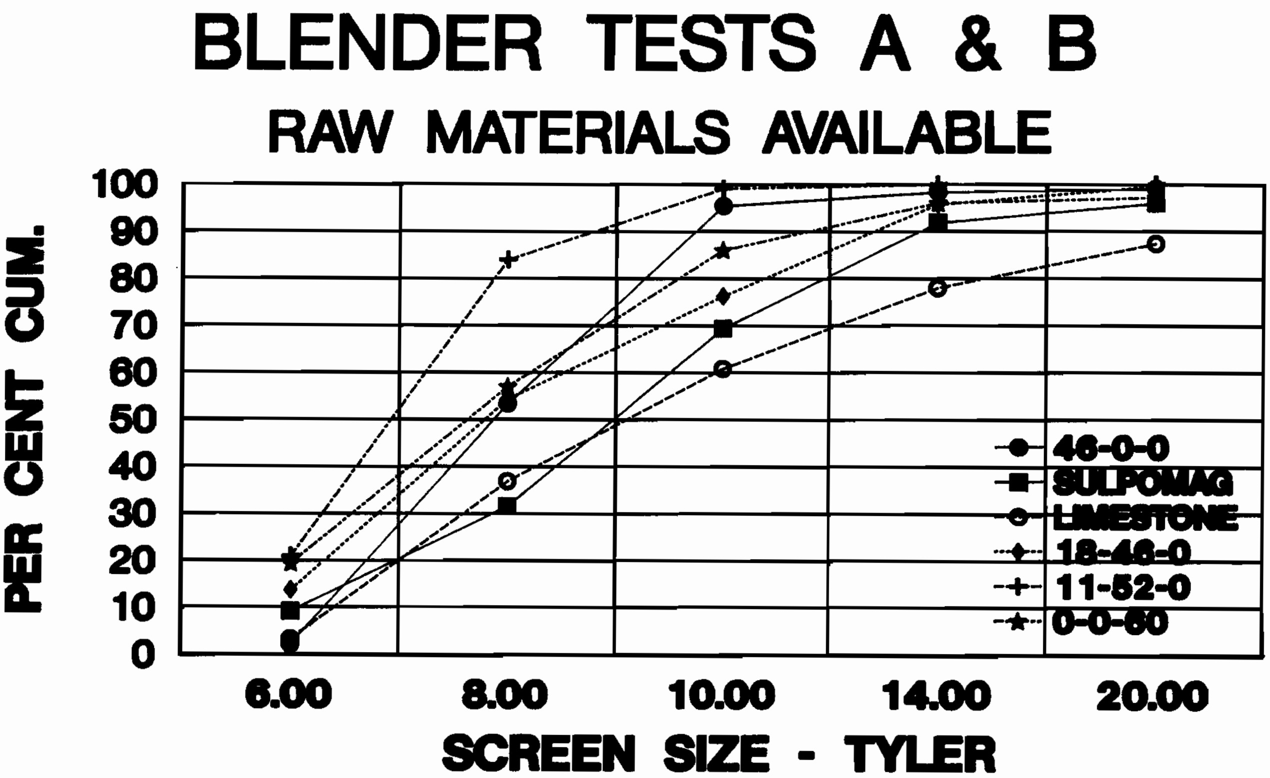


FIGURE 1

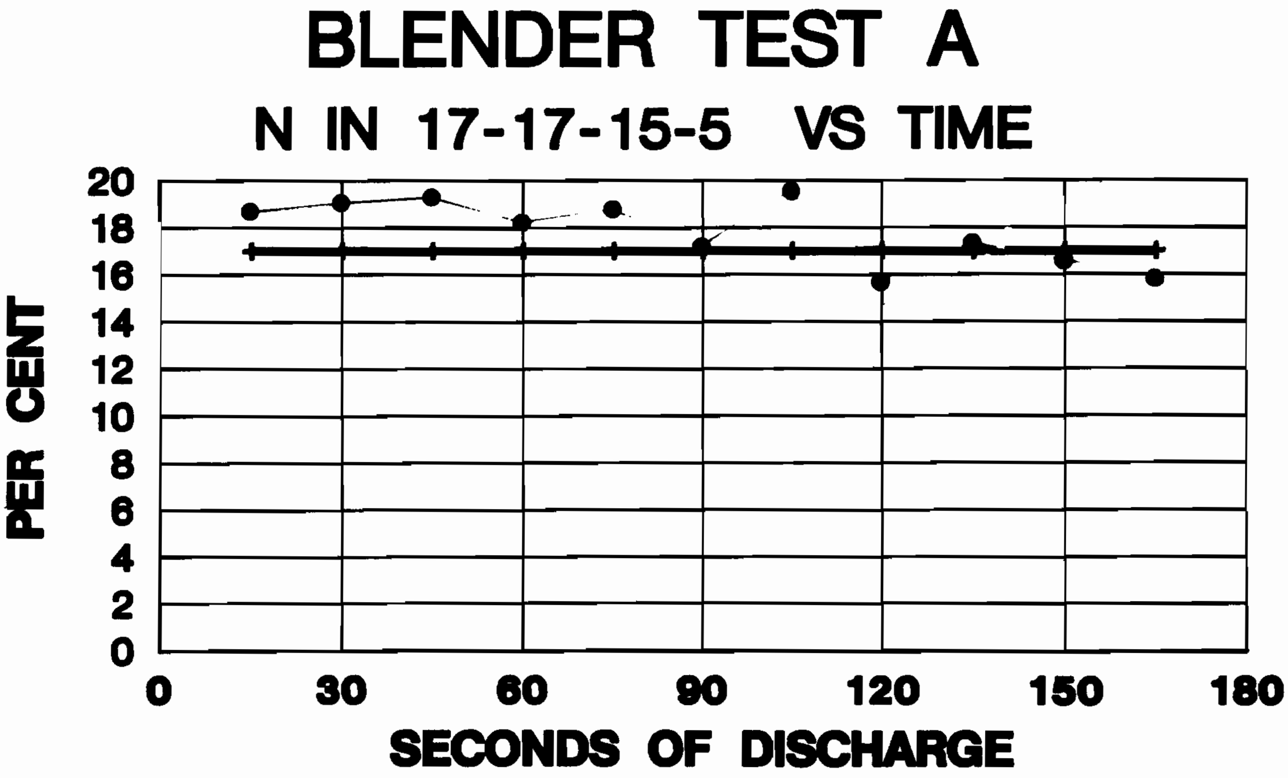
STREAM SPLITTER FOR 8" FILL PIPES

Figure 2


BLENDER TESTS A & B

RAW MATERIALS AVAILABLE

Figure 3


BLENDER TEST A

N IN 17-17-15-5 VS TIME

Figure 4

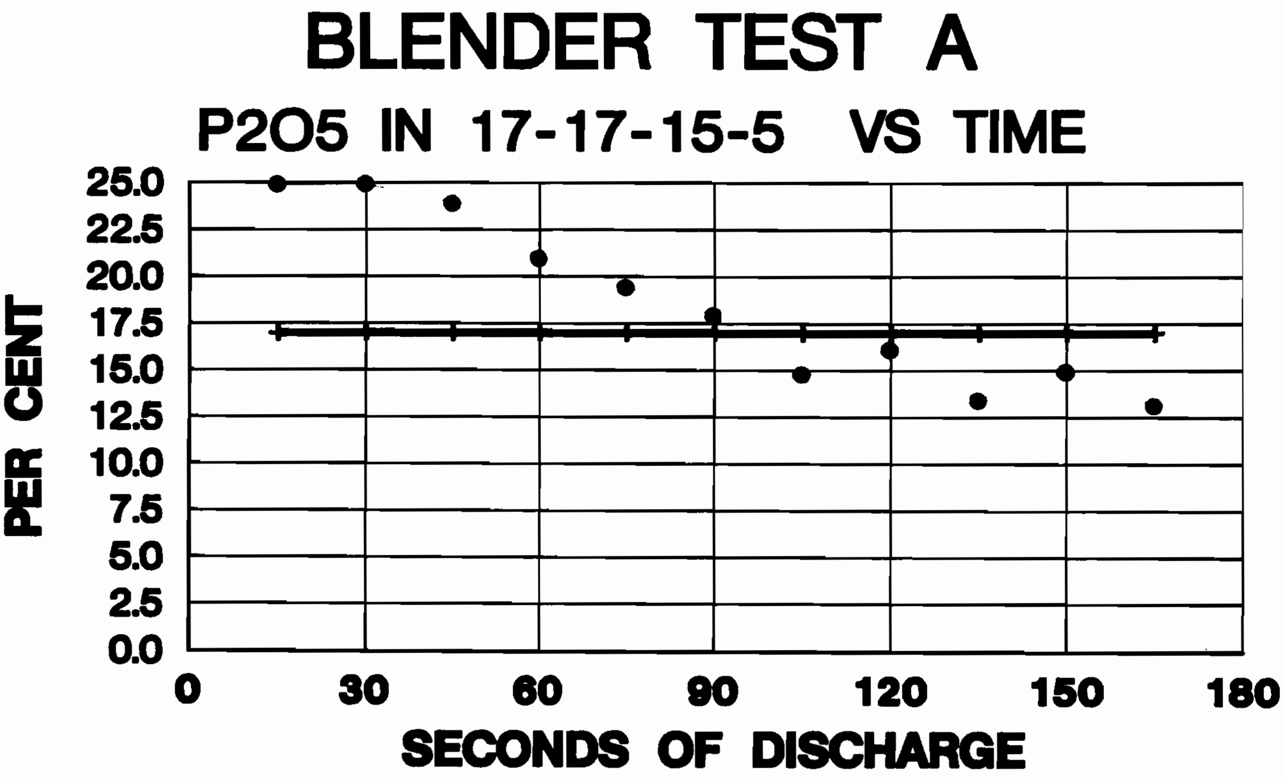


Figure 5

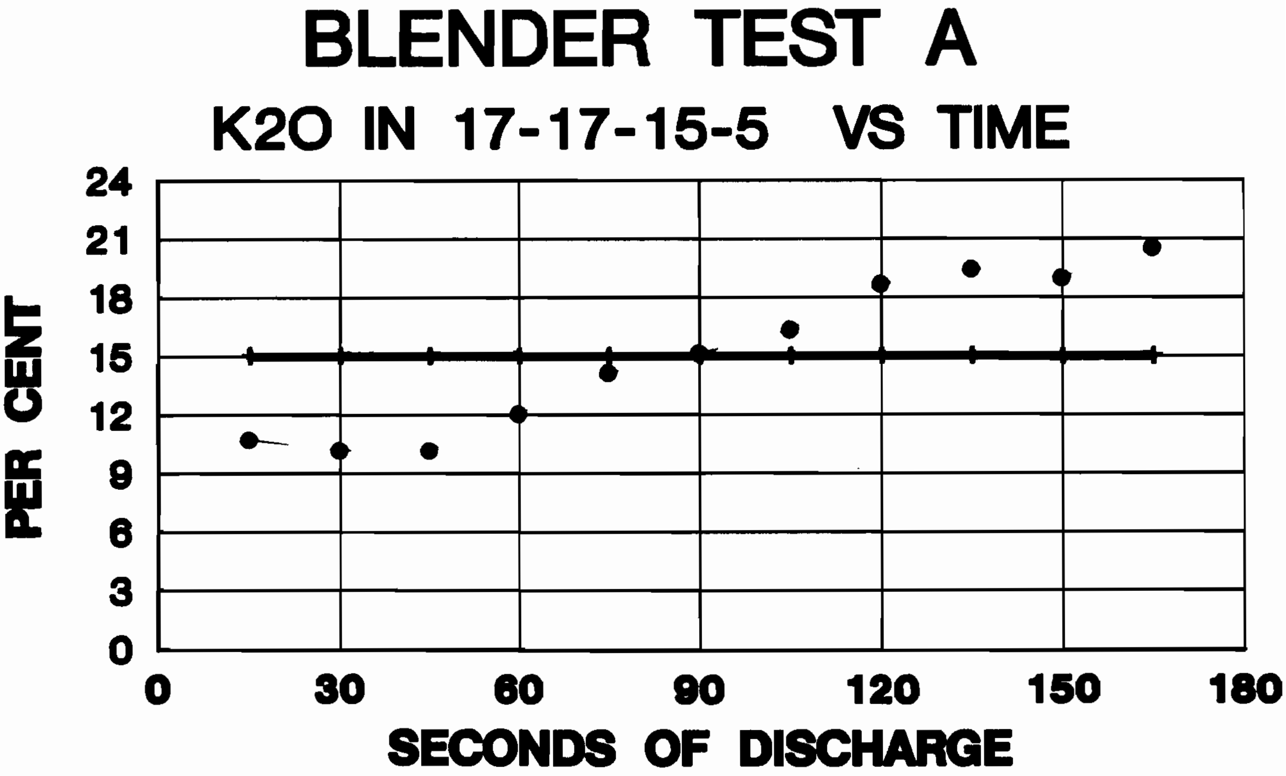


FIG. 6

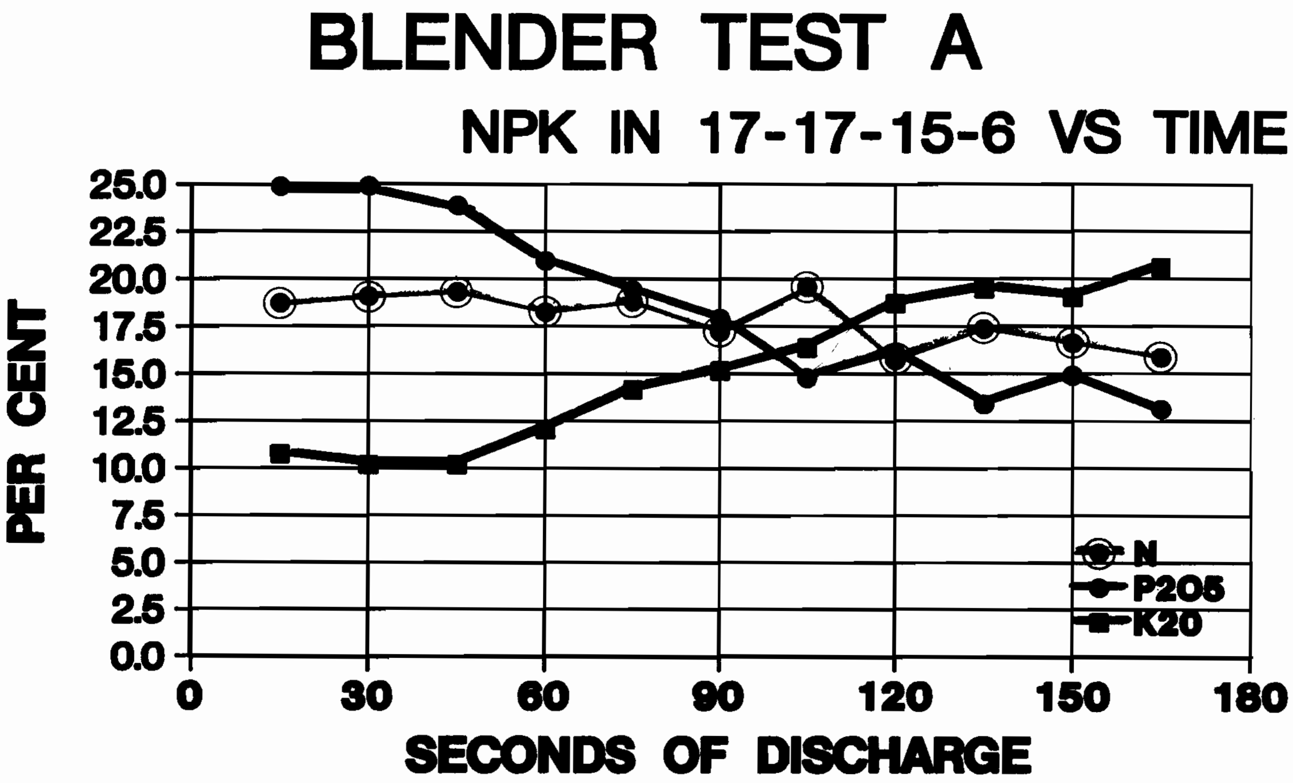


Figure 7

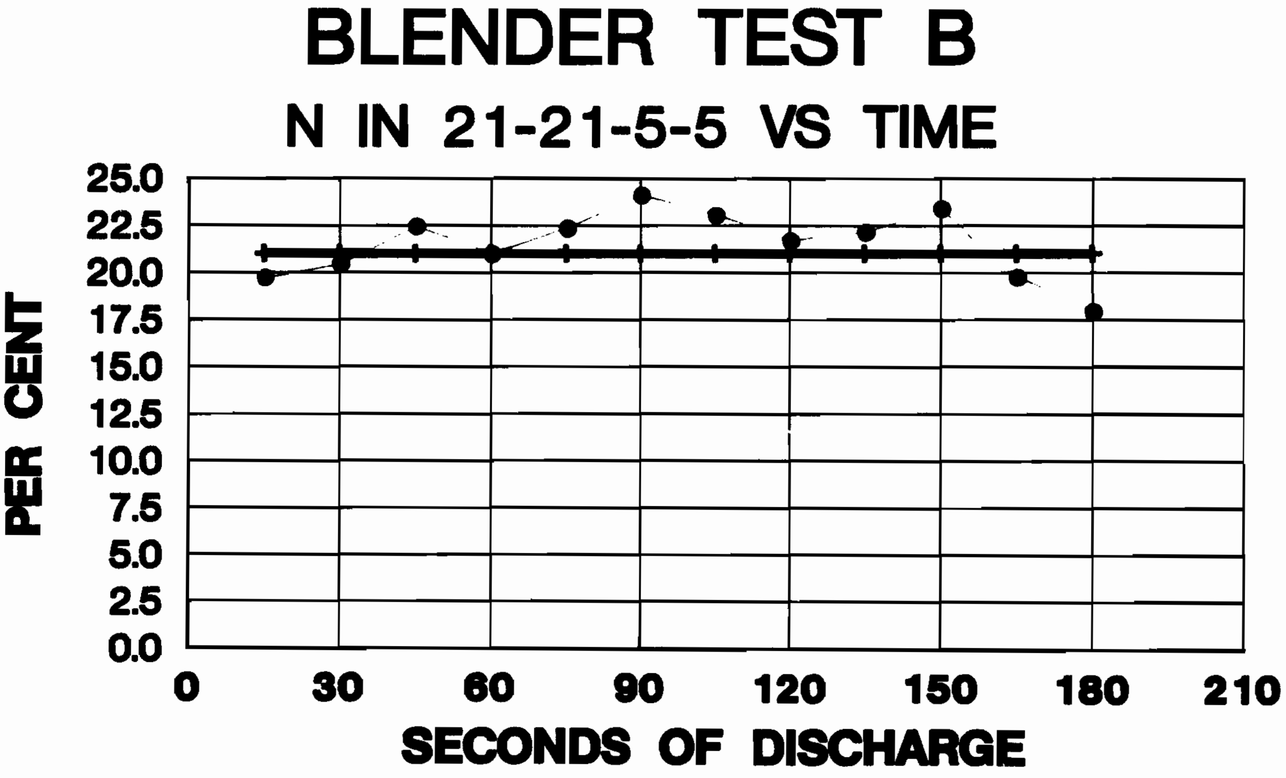


Figure 8

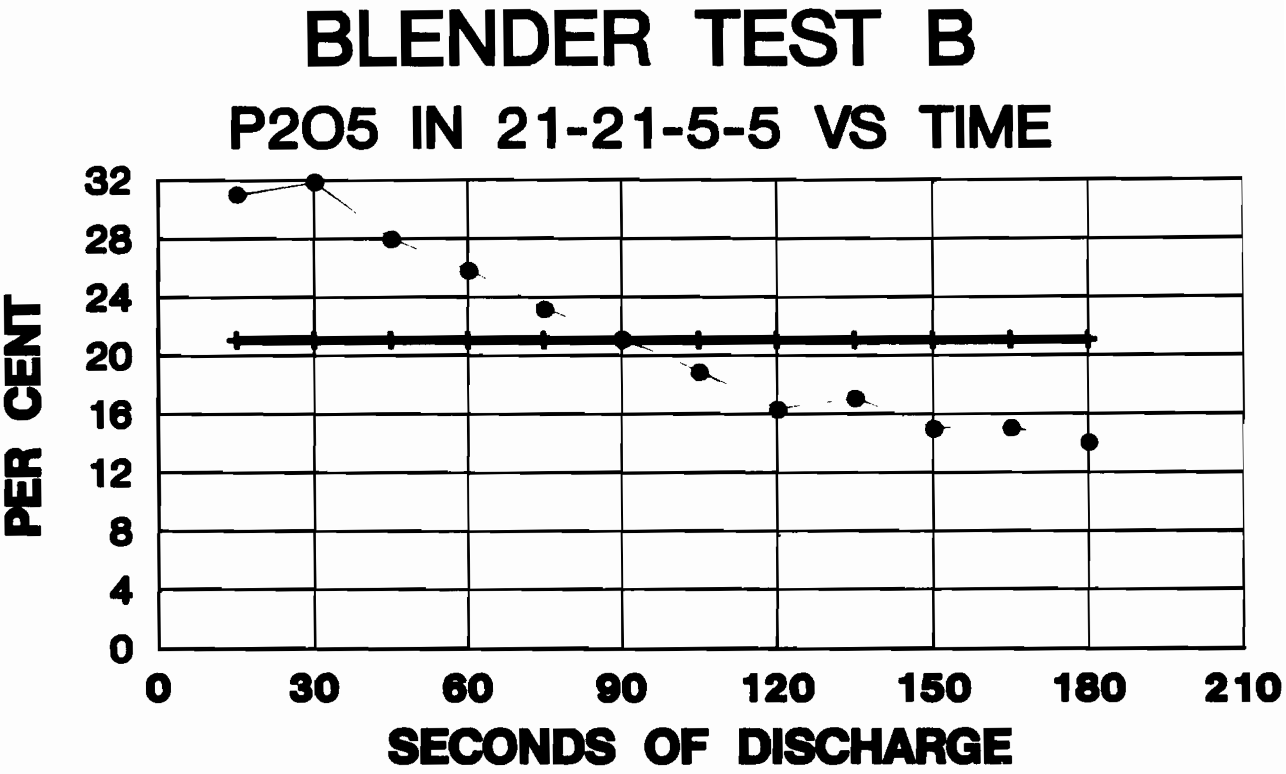


Figure 9

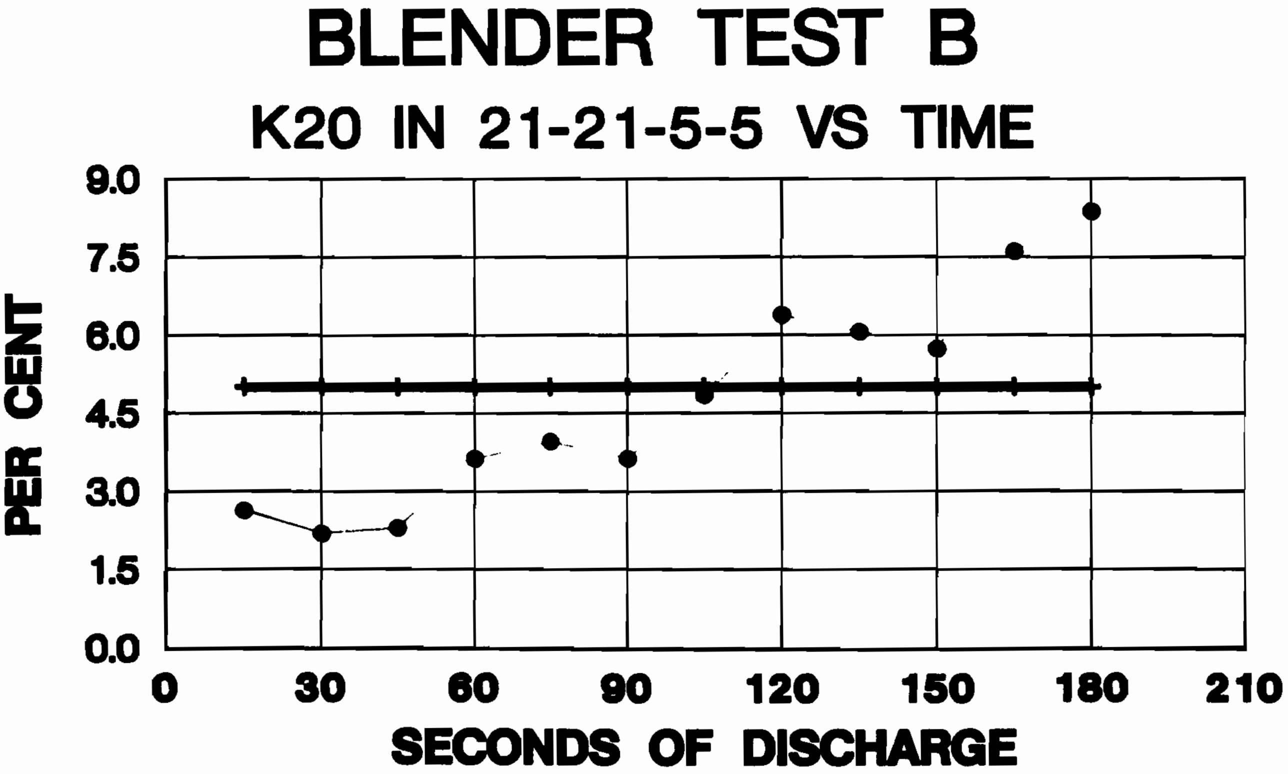
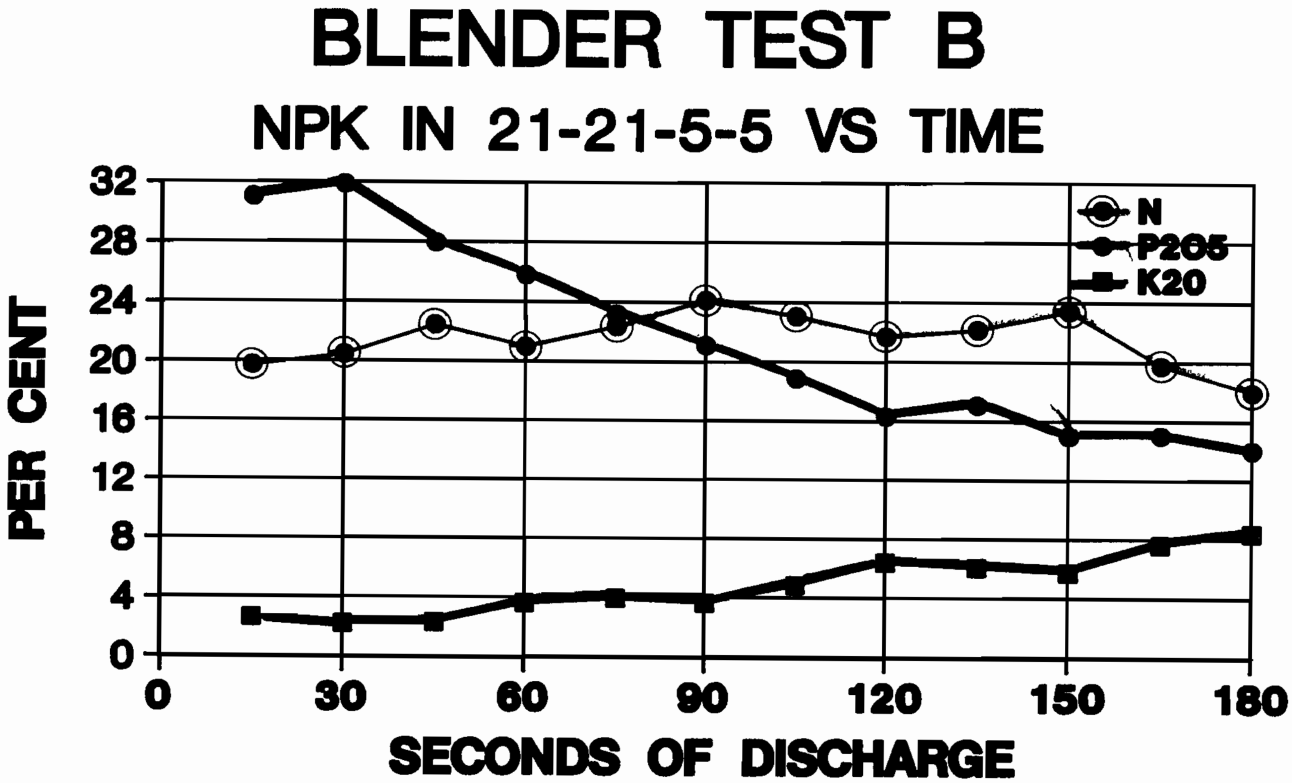


FIG. 10



Canadian Fertilizer Quality Assurance Program

C. D. Crober

Agriculture Canada

I would like to thank the Round Table for inviting our department to attend and address your annual meeting. I am honored to be here among such a large number of knowledgeable industry representatives.

My purpose here today is to explain what the new Canadian Fertilizer Quality Assurance Program is all about.

The aim of this program, not unlike the aims of the Round Table organization, is to improve the quality of fertilizer products manufactured, sold and used in Canada.

I will begin with the why's and how's for the program's development. Agriculture Canada, under the authority of the Fertilizers Act and Regulations, traditionally monitored all fertilizer products in the marketplace and tested samples to verify that the guarantees for Nitrogen, Phosphate and Potash were being met.

Dramatic growth occurred in the volume of sales of fertilizer products especially in Western Canada, where the number of bulk blending plants has increased some 600% since 1971. The number of fertilizer products offered for sale in Canada also increased dramatically during this period. Agriculture Canada was not able to keep up the level of inspections and testing.

As a result, the quality of fertilizers began to noticeably decline.

(Figure 1)

For these reasons, a review committee was set up in 1987 consisting of Agriculture Canada and the six fertilizer associations in Canada (CFI—Canadian Fertilizer Institute, AFI—Atlantic Fertilizer Institute, QFMA—Quebec Fertilizer Manufacturers Association, FIO—The Fertilizer Institute of Ontario Inc., WCFA—Western Canada Fertilizer Association, and WFCD—Western Fertilizer and Chemical Dealers Association). These groups worked together to ensure the program was mutually beneficial. Through these concerted efforts, the CFQAP—Canadian Fertilizer Quality Assurance Program was created. This year has been a trial year for both the industry and Agriculture Canada to adjust to the new program.

(Figure 2)

The key elements of the CFQAP—Canadian Fertilizer Quality Assurance Program are as follows:

1. Participation in the program is voluntary.
2. Samples are taken by each individual fertil-

izer producer using approved methods and equipment.
3. Samples are sent to accredited laboratories for analysis and results are forwarded to Agriculture Canada.
4. Agriculture Canada assigns each individual plant a rating.
5. All ratings are published for general distribution to the public.

1. *Participation in the program is voluntary*

Participation is open to all single ingredient manufacturers (domestic or importers) such as those producing urea, potash or ammonium phosphate and all commercial blenders of bulk and/or packaged fertilizers. This first stage of the program has been directed at these producers but as the program advances, manufacturers and/or responsible packagers of speciality fertilizer including greenhouse, home and garden, golf course products, and fertilizer importers who are marketing their products in Canada will also be involved in this program. In order for a company to participate, an agreement form is required by Agriculture Canada.

2. *Samples are taken by each individual fertilizer producer using approved methods and equipment.*

Participating companies are required to take a minimum number of quality assurance samples based on their annual volume of production. The samples taken should be representative of the plant's production in terms of season of production (spring/fall), product types (grade VS another grade) and packaging (bulk or bagged). Minimum number of samples are required though we do encourage participants to take more, in order to better portray their performance.

(Figure 3)

Minimum sampling levels for Basic and Blended Materials

The number of samples to be taken is based on a statistically valid plan that was developed by means of a survey of the industry.

Previously, the fertilizer program was biased toward poorer performing producers so the results painted an even poorer compliance rate for the industry. The intent of the program is to provide accurate and unbiased industry compliance information. In order to obtain accurate sampling results, it is of the utmost importance that proper sampling procedures are followed. Proper sampling procedures to be followed and diagrams of sampling equipment required were sent to all manufacturers and blenders this spring. Agriculture Canada inspectors are also available to demonstrate sampling procedures and provide short term loans of equipment.

This trial year allowed each plant to obtain proper sampling equipment and practice sampling techniques to iron out any difficulties they may encounter before the results are actually published.

3. *Samples are sent to accredited laboratories for analysis and results are forwarded to Agriculture Canada.*

All samples are forwarded to an accredited laboratory for analysis. This year there were no accredited laboratories, thus companies had the opportunity to shop around and choose the labs they wished to send their samples to. By next year, the operational year, only those labs that are accredited may be used by manufacturers.

Any laboratory, either private, industry or public, wanting to be accredited by Agriculture Canada must forward its request to the Feed and Fertilizer Division in Ottawa. Our department's policy on accreditation of foreign laboratories has not been finalized.* Laboratory Services Division of Agriculture Canada has developed a Laboratory Accreditation and Audit Protocol (LAAP) to verify the laboratories capability to provide quality test data. The labs applying for accreditation must meet certain criteria in order to become accredited. All information, including a copy of the protocol is available on request.

Once labs are accredited, they will continue to be audited and must successfully participate in the Maqruder check sample program developed for each specific test. This way, Agriculture Canada can be assured of accurate results.

Each year, before November 30th, laboratories are required to send sample results to our offices in Ottawa.

4. *Agriculture Canada assigns each individual plant a rating.*

Based on the analysis results submitted by accredited laboratories and on any samples taken by Agriculture Canada, each manufacturer/blender location is designated a AAA, AA, A, B, C, or F rating. Basic fertilizer materials and blended materials are rated separately. I will briefly describe the way in which we establish a rating. I will not spend much time on the mathematics of the rating as my friend from UCO will be spending more time on this in his talk.

Basic fertilizer products are assessed according to current investigational allowances. Samples will be in compliance if the results of analysis do not exceed these tolerances (accommodating unavoidable variation associated with sampling and analysis) set by Agriculture Canada.

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*Our preference is to recognize equivalent foreign laboratory accreditation schemes under our new program. For example, in the United States the Association of Official Analytical Chemists (AOAC) would be a logical organization to provide such an accreditation service.

(Figure 4)

Fertilizer Materials

Nutrient Items	Guaranteed Minimum Amount %	Permitted Tolerances Not to Exceed a Deficiency of
1. Total Nitrogen (N)	0.1 to 8.0	0.3% of the Fertilizer
	8.1 to 18.0	0.4% of the Fertilizer
	18.1 and up	0.5% of the Fertilizer
2. Available Phosphoric Acid (P205)	0.1 to 8.0	0.3% of the Fertilizer
	8.1 to 18.0	0.4% of the Fertilizer
	18.1 and up	0.5% of the Fertilizer
3. Soluble Potash (K20)	0.1 to 8.0	0.3% of the Fertilizer
	8.1 to 18.0	0.4% of the Fertilizer
	18.1 and up	0.7% of the Fertilizer

AAA – 95.1% or more of samples in compliance
AA – 85.1–95% of samples in compliance
A – 75.1–85% of samples in compliance
B – 65.1–75% of samples in compliance
C – 50.1–65% of samples in compliance
F – less than 50% of samples in compliance

Blended materials ratings will be based on the commercial value (measured by the CNL (combined nutrient level), and the accuracy of plant nutrient ratio (measured by the RC1 (Ratio Compliance Index)). The product of those two factors is known as the QCI (Quality Control Index) and the average for all samples is used to determine the plant rating.

Plant food in excess of the guaranteed ratio is adjusted to the guarantee so that there is no penalty for overformulating. A computer program has been developed that will generate the rating for each plant when the analysis results are inputed. The plant rating intervals for the blended materials are shown in Figure 5.

(Figure 5)

Plant Rating Intervals

The Plant Rating Intervals for the QCI are as follows:

Ratings	**OCI Range**
AAA	100 – 99.51
AA	99.5 – 98.51
A	98.5 – 96.51
B	96.5 – 92.51
C	92.5 – 84.51
F	84.5

5. *All ratings are published for general distribution to the public*

By March 1st each year, the ratings will be published in the "The Canadian Fertilizer Quality Assurance Report". This report will appear in Agriculture Canada, Provincial and possibly the individual Fertilizer Institutes newsletters. It will be accessible to all interested persons, i.e., media, producers, and/or general public.

Participants and non-participants will be noted separately in the report. It will be made clear that non-participants do not have an approved quality assurance program. Agriculture Canada will sample non-participants but it may not be at a sampling level that would be representative of their production. Non-participants will be given every opportunity to join the program at any time. It will also be noted in the publication the number of samples the rating was based on and that they were taken by Agriculture Canada inspectors.

(Figure 6)

A certificate will be issued by Agriculture Canada to each participant that indicates participation in a quality control program along with the manufacturer's rating

Since 1988 was only a trial year there will be no publication of results. Each plant will be sent their ratings in order to confirm the results and to see exactly how their plant rated. This enables the plant to correct its mistakes before next years publication.

Agriculture Canada's Responsibilities in the Control over the Program

Agriculture Canada inspectors will sample non-participants. However the sampling intensity will be low and will not be randomized, usually directed sampling. Non-participants having poor performance and displaying no effort to correct this situation (i.e. development of a quality assurance program) will be subject to corrective actions by our department, such as product detention and prosecution.

Participants will be audited to ensure proper sampling procedures are being followed and to inspect the company's facilities and check their sales and supply records. Random samples will also be taken during our audit visits.

Plants found to be departing from the basic principles of the program will be given every opportunity to correct their problems. Failure to do so may result in court action. We do expect that the industry to a large extent will be their own watch dogs in this program and will report any discrepancies to Agriculture Canada.

Benefits

The CFQAP—Canadian Fertilizer Quality Assurance Program has many benefits for many people. It benefits all groups that are concerned about fertilizer quality, namely the consumer, Industry and governments.

The *consumer* benefits from knowing they are purchasing quality, safe and properly labelled products. They also have more information available to them before they purchase fertilizer products.

Industry participants benefit by having better control of product quality. Money could be saved if errors made in over formulating were corrected and product compliance records properly represent the company's capability to blend fertilizers. With more laboratories involved in testing, results will come back much quicker so action to correct problems can be taken. Participants will further benefit from having their rating published (providing it is good!).

Government saves in laboratory resources and therefore has more resources to concentrate on health, safety and regulatory issues and will have a clearer picture as to the compliance of the industry.

Program Update

Some of the analytical results we have received to-date from participants in the program have indicated manufacturing problems. This may be telling some companies that their blending has not been as accurate as they had always thought.

Now that I have explained the mechanics of the program I would like to spend some time showing the progress of the program this year.

(Figure 7)

As of November 1, 1988, 68% of the blenders have now joined the program. 15% have not been visited by our inspectors due to other commodity responsibilities. 10% have indicated they will join the program (but have not done so as of November 1, 1988) 7% are negative or indifferent to the program. We expect that with greater visibility and increased knowledge of the program that most manufacturers will join the program.

It should be noted that in regions where industry meetings have been held outlining the new program and where our inspectors have made visits seem to be enjoying the highest level of participation. For this reason we appreciate opportunities such as this to deliver our message.

Conclusion

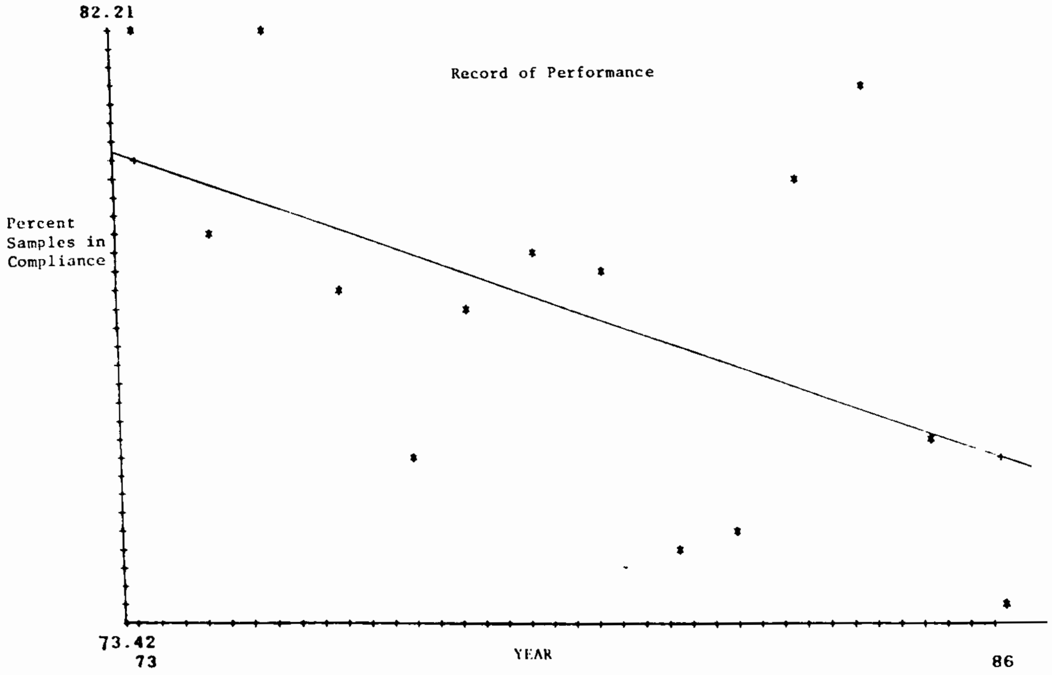
Many companies today are already involved in quality assurance programs to monitor their production. This program recognizes these efforts by publicly honoring their performance in a published document. Any blenders/manufacturers that are doing a good job should have nothing to hide, and should not be afraid to join this program.

We have great aspirations for this program.

In order for the program to be successful, we require 90% participation. This will allow our inspectors the time to effectively audit participants and sample non-participants. To date, we have 68% participation and there are signs of positive movement towards the program which we believe will continue.

I hope I have given you a clear picture of how our new Program works. Please feel free to ask any questions that you may have and again I would like to thank you for this opportunity to speak to you about the CFQAP—Canadian Fertilizer Quality Assurance Program.

Thank you for your kind attention.



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REGRESSION EQUATION

  INTERCEPT= 106.51182417583    SLOPE= -.35854945054948

  r = -.5202    r squared =  .2706
```

(Figure 1)

The Key Elements of the CFQAP

- Participation in the program is voluntary.
- Samples are taken by each individual fertilizer producer using approved methods and equipment.
- Samples are sent to accredited laboratories for analysis and results are forwarded to Agriculture Canada.
- Agriculture Canada assigns each individual plant a rating.
- All ratings are published for general distribution to the public.

(Figure 2)

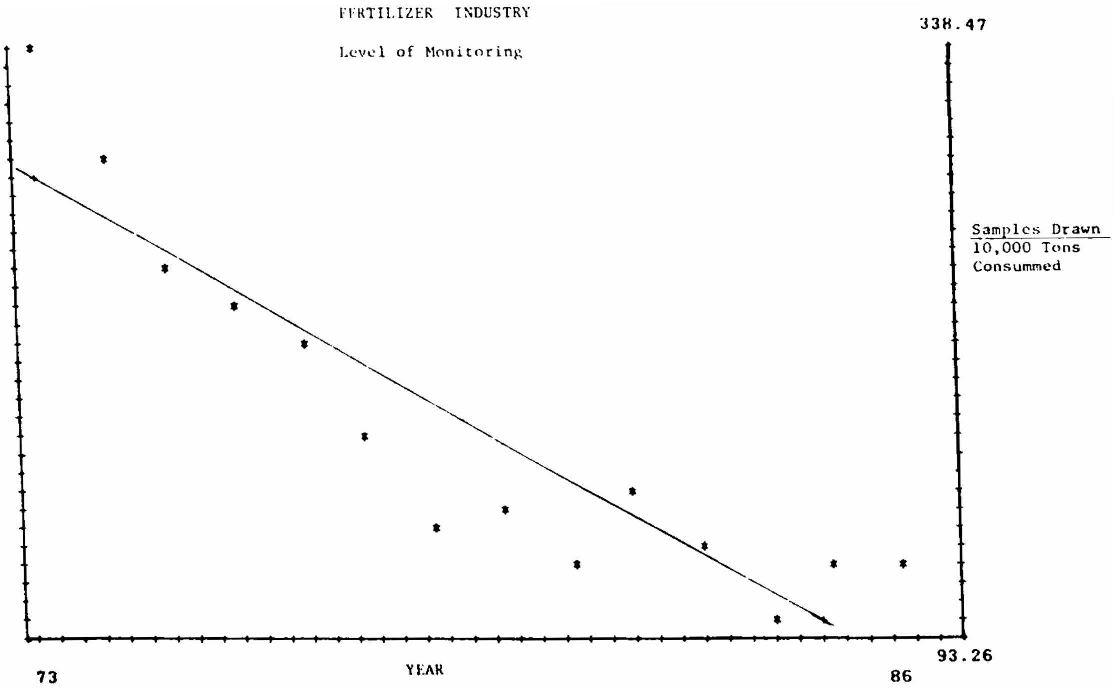
MINIMUM SAMPLING LEVEL FOR BASIC MATERIALS

ANNUAL PRODUCTION (TONNES)	SAMPLES PER YEAR
Small (0 to 50,000 T/yr)	3
Medium (50,001 - 120,000 T/yr)	5
Large (over 120,000 T/yr)	8

MINIMUM SAMPLING LEVEL FOR BLENDED PRODUCTS

ANNUAL PRODUCTION (TONNES)	SAMPLES/YEAR
Small (up to 600 T/yr)	3
Medium (601 - 4800 T/yr)	5
Large (over 4800 T/yr)	8

(Figure 3)



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REGRESSION EQUATION
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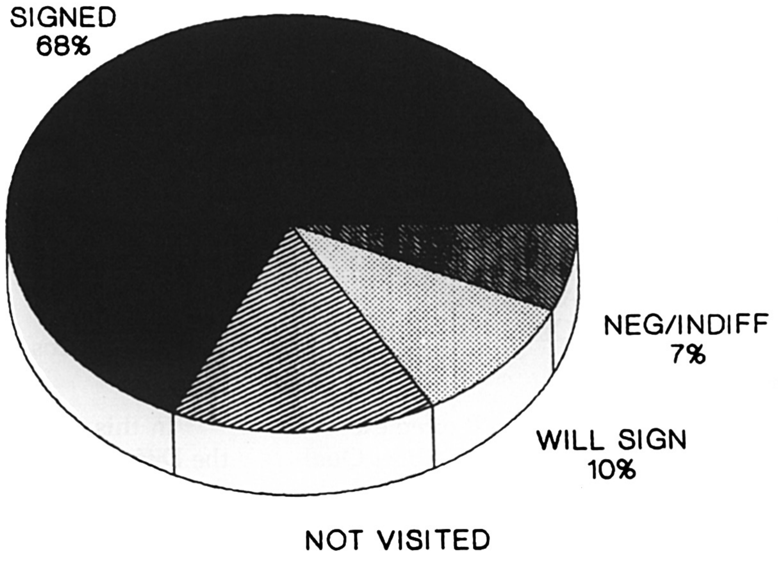
(Figure 6)

NATIONAL STATISTICS
NOVEMBER 1, 1988



(Figure 7)

Measures of Quality in Fertilizer Blending

Jean Cheval and Paul Branconnier
United Co-operatives of Ontario

A SATISFACTORY FERTILIZER MUST PROVIDE:

1. FULL VALUE FOR THE PRICE PAID,
2. THE PLANT FOODS IN THE DESIRED RATIO.

THE COMMERCIAL VALUE IS MEASURED BY THE COMBINED NUTRIENT LEVEL (CNL).

THE PLANT FOOD RATIO IS MEASURED BY THE RATIO COMPLIANCE INDEX (RCI).

THE OVERALL QUALITY IS MEASURED BY THE QUALITY CONTROL INDEX (QCI).

The Combined Nutrient Level has been used by Agriculture Canada for 19 years. We, in UCO, developed some time ago the other two measures to compare the performance of our blenders in a fair and equitable manner. Agriculture Canada and the Canadian Fertilizer Institute have now formally adopted these two measures of quality (ref. 1).

Our Quality Control begins with the guarantees and the actual analysis of the fertilizer sample. The N,P,K values are reduced to two independent measures, CNL and RCI. These in turn are combined to produce one single quality index, QCI. Blenders can be ranked by the average of their QCI's.

We will, in this paper, examine in detail the mathematics of these measures of quality as they apply to the Canadian Fertilizer Quality Assurance Program.

THE COMBINED NUTRIENT LEVEL

The Combined Nutrient Level measures the commercial, or relative, value of the fertilizer. In Canada, the unit of Nitrogen is deemed to be worth 2.5 times the unit of soluble Potash (K_2O), and the unit of A.P.A. 2.0 times the unit of soluble Potash. We can express this calculation in the following formula:

$$\text{CNL} = \frac{100\,(2.5\text{ fN} + 2\text{fP} + \text{fK})}{2.5\text{ gN} + 2\text{gP} + \text{gK}}$$

where:
N stands for Nitrogen,
P stands for avail. Phosphoric Acid (APA),
K stands for soluble Potash (K_2O),
and the prefix "f" for "found",
the prefix "g" for "guaranteed".

CNL is expressed as a percentage. It often exceeds the guaranteed 100%. In the Canadian Fertilizer Quality Assurance Program, however, CNL values greater than 100% are adjusted down to the 100% guarantee for the calculation of the Quality Control Index.

For example a guaranteed 19–19–19 must have a content of:
$2.5 \times 19.0 + 2 \times 19.0 + 19.0 = 104.5$ CNL points.
A found analysis of 19.5 – 19.3 – 19.5 means $2.5 \times 19.5 + 2 \times 19.3 + 19.5 = 106.85$ CNL points, and therefore, a CNL of 102.2%.
A found analysis of 18.1 – 17.5 – 21.1 means $2.5 + 18.1 + 2 + 17.5 + 21.1 = 101.35$ CNL points, and therefore, a CNL of 97.0%.

THE RATIO COMPLIANCE INDEX

The Ratio Compliance Index measures the performance of the plant food ratio. It expresses, in one single number, how close the plant food ratio in the actual analysis is to the plant food ratio defined by the guaranteed analysis. When the plant food ratio is exactly the same in both the guaranteed analysis and the found analysis the resulting RCI is 100%.

To measure the RCI we rely on a trigonometric approach. In a 3-dimension space, where one axis is the Nitrogen scale, the second axis the A.P.A. scale and the third axis the soluble Potash scale, the guarantees define a vector of length G (Fig.1).

It is easy to demonstrate that:

$$G^2 = N^2 + P^2 + K^2$$

where:
G^2 is the square of the value G,
N^2 the square of the guaranteed Nitrogen,
P^2 the square of the guaranteed A.P.A.
K^2 the square of the guaranteed Potash.

The "found" values (actual analysis) will define a vector of length F (Fig.1). F^2 will be calculated by summing the squares of the found values for N, P, and K. For the purpose of the Quality Assurance Program, these found values which are above guarantee are adjusted down to guarantee before calculating F^2.

The two vectors create a specific plane, in which they are the two sides of a triangle (Fig.2). The third side is called D. The square of the length D is between corresponding guaranteed and adjusted found values.

For any oblique angled triangle the law of cosines states:

$$a^2 = b^2 + c^2 - 2bc \cos A.$$

We transform and restate this formula to:

$$\cos\,(\text{D.A.}) = \frac{G^2 + F^2 - D^2}{2GF}$$

In this formula, cos (D.A.) stands for "cosine of the Difference Angle". The Difference Angle (D.A.) is the angle opposite the side D and consequently adjacent to the sides G and F.

The Difference Angle measures the deviation between the two plant nutrient ratios. It can take any value between 0 and 90 degrees.

Its value can be zero if the two vectors representing the ratios are coincident (they have exactly the same orientation, although they may be of different lengths).

The Difference Angle cannot be any greater than a right angle because there is no such thing as a negative guarantee or a negative found value.

A right angle measures 90 degrees, or 100 grads. The calculation of the Ratio Compliance Index is simplified when the Difference Angle is measured in grads. The Ratio Compliance Index can be seen as the complement of the Difference Angle:

$$\text{RCI} + \text{D.A.} = 100 \text{ grads}$$

therefore: $\text{RCI} = 100 - \text{D.A.}$ (in grads).

An inexpensive calculator with trigonometric functions, such as Texas Instruments T132, easily converts the cosine of the Difference Angle to the angle itself (expressed in grads). With the instrument in the GRAD mode and the cosine value in the display, you need to push only two keys ("2nd" and "cos") to obtain the Difference Angle in grads. Subtract D.A. from 100 and, there on the display, is the Ratio Compliance Index you are looking for.

A micro-computer will do the work in a flash. Which ever instrument you choose, you can follow the ten (easy ?) steps listed in appendix A.

It is almost inconceivable today that someone would want to go through the RCI calculations with pencil, paper and trigonometric tables. If you choose to go that route, it is very likely that the trig tables will give you the Difference Angle in degrees and minutes. Remember to convert to grads before continuing with the procedure.

RCI tables can be printed for a number of standard analyses (Fig. 3). Consider for instance a guaranteed 8–32–16. If one lot analyzes 7–32–14, the table tells us that the Ratio Compliance Index is 96.5% (it is not exactly the required 1–4–2 ratio). If another lot analyzes 7–28–14, which is exactly the required 1–4–2 ratio, quite rightly the table reads 100% RCI.

THE QUALITY CONTROL INDEX

The Quality Control Index of a sample is a measure of the quality performance for the purpose of the Canadian Fertilizer Quality Assurance Program. The Quality Control Index is obtained by multiplying CNL by RCI. It is expressed as a percentage.

QCI will never exceed 100%, since:

—by definition, RCI will be between 0 and 100% and

—CNL will be adjusted down to 100% if its value is greater than 100%.

An example of calculation can be found in appendix B. You may determine that the lab results seem to indicate a weighing error. Possibly so, but segregation is in our experience the most likely cause. In fact, we have statistical evidence that the Mixing Quality Index (a measure of size variation combining SGN and Uniformity Index of the materials) is a reliable predictor of the Ratio Compliance Index.

The SGN manual of the Canadian Fertilizer Institute contains a section on the Mixing Quality Index. We have reprinted here, as appendix C, the definition and our favorite application method. This will at the same time correct a printing error that occurred in the proceedings of 1986, in the standard deviation formula (ref.2).

The example of appendix B looked like too much Potash and too little DAP. Consequently the CNL was below 100%. If the sample had too much DAP and too little Potash the CNL would rate over 100%. You can now appreciate that, at equal RCI's, the blenders with high CNL's will rate higher on the QCI scale.

The problem of ranking and rating blenders was driven home when we were confronted with the following situation: Two plants had each 10 samples in the record. Under the old rules Plant A would have rated 30% deficient. For this reason the manager was properly "chewed out" by his boss. Yet the average CNL was above 100% and the three deficiencies were just below the tolerance. Plant B would have had no deficiency whatsoever. The manager felt this was a perfect record and wanted a raise "for his efforts". However, the average CNL was below guarantee, most samples showed poor control and several barely missed being classified deficient. Intuitively we knew plant A had performed better than B. The QCI average confirmed this feeling. The manager of plant A got an apology and a pat on the back. The manager of Plant B is still trying to understand what happened.

THE RATING SCALE

Statistical analysis of a large number of samples had shown a Poisson distribution of the location average QCI. Following this analysis a simple geometric progression, with a first term of 0.5 and a common ratio of 2, was selected for the intervals of the rating scale:

Interval	QCI range	Rating
0.5	100.0–99.51	AAA
1.0	99.5–98.51	AA
2.0	98.5–96.51	A
4.0	96.5–92.51	B
8.0	92.5–84.51	C
—	below 84.50	F

With this rating scale the "A" group neatly straddled the mode of the distribution. All other selection criteria were also met.

SUMMARY

The SGN concept, a system of material identification, was introduced in 1981 to help the blenders in the selection of size compatible materials, thereby reducing segregation and improving chemical quality (ref.3). AAPFCO and TFI now support the use of SGN (ref.4).

The measures of quality we describe in this paper are particularly well suited to the needs of the Fertilizer Industry in North America. The last forty years have seen nothing less than a revolution in manufacturing and distribution. Maybe the time has come to adapt our process of Quality Control for the next forty years.

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Appendix A

The Ratio Compliance Index of the Quality Assurance Program in 10 Easy Steps

This method is designed for a pocket calculator with trigonometric functions.

1. Sum up the squares of the guarantees and record the value G^2.
2. Find the square root of the value G^2 and record it as G.
3. Compare found (actual) and guaranteed values. Adjust down to guarantee those found values that are greater than the corresponding guarantees.
4. Sum up the squares of the adjusted found values and record the value F^2.
5. Find the square root of the value F^2 and record it as F.
6. Find the differences between guarantees and corresponding adjusted found values.
7. Sum up the squares of the differences and record the value D^2.
8. Find the cosine of the Difference Angle:

   $\cos(\text{D.A.}) = (G^2 + F^2 - D^2)/2GF$
9. The Difference Angle is measured in grads to simplify calculations. With the calculator in the GRAD mode, the $\cos^{-1}$ key will calculate the smallest angle whose cosine is in the display:

   $\text{D.A.} = \cos^{-1}((G^2 + F^2 - D^2)/2GF)$
10. The Ratio Compliance Index is:

    $\text{RCI} = 100 - \text{D.A.}$ (in grads)

Appendix B

The Quality Control Index of the Quality Assurance Program — A Calculation Example —

You have sold a 50/50 blend of DAP 18-46-0 and Muriate 0-0-61. You have guaranteed 9.0-23.0-30.5 and the lab reports 8.7-22.2-31.6.

Calculate CNL:

$$\frac{(2.5 \times 8.7) + (2 \times 22.2) + 31.6}{(2.5 \times 9.0) + (2 \times 23.0) + 30.5} = \frac{97.75}{99} = 98.7\%$$

Calculate RCI:

1. $G^2 = 9.0^2 + 23.0^2 + 30.5^2 = 1540.25$
2. $G = \sqrt{1540.25} = 39.24601891$
3. N found = 8.7, no adjustment required
   P found = 22.2, no adjustment required
   K found = 31.6, adjust to guarantee: 30.5
4. $F^2 = 8.7^2 + 22.2^2 + 30.5^2 = 1498.78$
5. $F = \sqrt{1498.78} = 38.71408013$
6. $N = 9.0 - 8.7 = 0.3$
   $P = 23.0 - 22.2 = 0.8$
   $K = 30.5 - 30.5 = 0$
7. $D^2 = 0.3^2 + 0.8^2 + O^2 = 0.73$
8. $G^2 + F^2 - D^2 = 1540.25 + 1498.78 - 0.73 = 3038.3$
   $2GF = 2 \times 39.246 \times 38.714 = 3038.739288$
   $\cos(\text{D.A.}) = \frac{3038.3}{3038.7393} = 0.999855433$
9. D.A. = 1.0825 grads = 1.1
10. RCI = 100 − 1.1 = 98.9%

Calculate QCI:

CNL = 98.7%
RCI = 98.9%
QCI = 98.7% × 98.9% = 97.6%

Appendix C

The Mixing Quality Index

A method has been devised which combines, in one single quality index, statistical information on the SGN values and the UI values of the materials used together (or to be used together). The mixing quality index (MQI) is calculated by subtracting the coefficients of variation (CV) from 1.0. In mathematical form:

MQI = 1.0 − CV of SGN's − CV of UI's

The closer this MQI is to 1.0 the better chance of good quality control performance.

Consider, for example, the case of the blender mixing together the following four materials:

	Mat. 1	Mat. 2	Mat. 3	Mat. 4	Average
SGN	230	225	215	190	215.0
UI	44	44	40	36	41.0

First, the operator will calculate the standard deviation fo the SGN's using the formula:

$$SD = \sqrt{\frac{\Sigma X^2 - (\Sigma X)^2/N}{N - 1}}$$

The calculations go like this:

N	X	X^2
1	230	52900
2	225	50625
3	215	46225
4	190	36100
	$\Sigma X = 862$	ΣX^2 185850

$$(\Sigma X)^2 = 860 \times 860 = 739600$$

$$SD = \sqrt{\frac{185850 - 739600/4}{4 - 1}} = 17.795$$

To obtain the coefficient of variation of SGN's, the standard deviation, 17.795, is divided by the average, 2115.0, giving a CV of .08.

Now the operator will calculate the standard deviation of the UI's using the same formula as before,

$$SD = \sqrt{\frac{\Sigma X^2 - (\Sigma X)^2/N}{N - 1}}$$

The calculations go like this:

N	X	X^2
1	44	1936
2	44	1936
3	40	1600
4	36	1296
	$\Sigma X = 164$	ΣX^2 6768

$$(\Sigma X)^2 = 164 \times 164 = 26896$$

$$SD = \sqrt{\frac{6768 - 26896/4}{4 - 1}} = 3.830$$

To obtain the coefficient of variation of UI's, the standard deviation, 3.83, is divided by the average, 41.0, giving a CV of .09.

Therefore, the calculated MQI for these four materials is:

$$MQI = 1.0 - .08 - .09 = .83$$

The Mixing Quality Index has been found to be a good predictor for the Ratio Compliance Index. With good equipment and operating staff, and as long as you formulate without overage, the four materials described in this example should give you about 94% RCI.

Update on Ground-Water Legislation Affecting Agriculture—1987–1988

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Until recently, Federal environmental protection programs have focused mainly on pollution derived from the urban, industrial, and transportation sectors of U.S. society. Focus was, e.g., on municipal and industrial wastes, sewage, and emissions from combustion operations and motorized vehicles. Now, increasing attention is being focused on agriculture, particularly on agricultural chemicals as potential contaminants of surface and ground waters. Historically, agriculture has been exempted from many mandatory pollution control requirements found in environmental protection laws. Point source control requirements for irrigation return flows and feedlots with less than 1000 animals are examples of such exemptions found in the 1977 amendments to the Clean Water Act that will no longer be allowed.

In the late 1960s, Congress decided that regulatory control of industrial pollution could be achieved nationally through uniform technological control requirements. But this approach is inappropriate for agriculture because, from an environmental point of view, agriculture differs from manufacturing in two important respects. First, industrial pollutants are mainly waste products while pollutants resulting from agriculture may be derived in part from agricultural chemicals that are used to benefit crop production. Agricultural chemicals are not wastes to be discarded but are farm inputs to be considered, I think, on the basis of potential public benefit and risk. Second, the pollutant potential of farm inputs is highly site-specific, so that uniform control technologies are not practicable.

Because of these differences and because the practices of agriculture themselves exert environmental control, an approach other than that taken for manufacturing is being taken to control ground-water contamination from agricultural sources. This approach combines the water quality goals and requirements given in the Clean Water Act [administered by the U.S. Environmental Protection Agency (EPA)] with soil conservation programs administered by the U.S. Department of Agriculture's Soil Conservation Service and Agricultural Stabilization and Conservation Service. These programs call for voluntary adoption by farmers of "best management practices" (BMPs).

Congress, however, has been unwilling to leave ground-water protection solely to the discretion of the agricultural sector. It began, with the passage of the Clean Water Act Amendments of 1987, the process of giving states the predominant role of developing their own respective ground-water protection strategies and giving EPA, rather than the Department of Agriculture, a mandate to provide guidance and oversight on the Federal level.

In addition, the 1986 amendments to the Safe Drinking Water Act (SDWA), combined with the provisions of the 1987 Clean Water Act (CWA), form a statutory link between drinking water supplies and substances that when applied to land may leach to ground water. Thus, agricultural chemical use is tied by law to drinking water quality by way of ground water. Provisions in these two pieces of legislation also link potential pollutant sources from agriculture (e.g., agricultural chemicals, animal manures, and sewage disposed on land) to previous legislation, specifically the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Resource Conservation and Recovery Act (RCRA), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Legislation introduced during the 100th Congress seeks to link the SDWA and CWA to provisions found in 10 pieces of previously enacted legislation.

Most states have begun developing and implementing their respective ground-water protection strategies and some have codified them into law. During 1986 and 1987, at least 11 states passed comprehensive ground-water protection or environmental quality legislation that makes specific reference to storage or use of agricultural chemicals. About 40 states now have some type of ground-water legislation that includes some aspect of agricultural chemical storage, handling, disposal, or use. More than a dozen major ground-water protection bills and several minor ones that could affect future agricultural chemical use were considered by the U.S. Congress during 1987 and 1988.

Of these, H. R. 791, the National Ground Water Contamination Research Act, has received by far the most attention. The language of the initial bill introduced January 28, 1987, by Representative Gjedenson (D-CT) is identical to H. R. 5526, passed by the House on September 22, 1986, but which failed to move through the Senate because of the deliberations over ground-water amendments to FIFRA. Interest in a comprehensive Federal program for ground-water protection intensified following a report by the Environmental and Energy Study Institute that confirmed that ground-water contamination was a serious national problem that required immediate Congressional action. The longstanding question of which agency was to take the lead now needed to be answered. The Gjedenson bill authorized a ground-water assessment program under the auspices of the U.S. Geological Survey (USGS). Several legislators were concerned that the bill as introduced would infringe on the responsibilities of the U.S. EPA, particularly regarding its research activities. As a consequence, during 1987 and 1988, H. R. 791 assimilated language from the following bills: H. R. 3676, Water Resources Activities of Geological Survey; H. R. 2253, Ground Water Research, Development, and Demonstration Act; and H. R. 3069, Agricultural Nitrogen Management Act of 1987. The latter resulted largely from the efforts of The Fertilizer Institute. Also introduced to the Senate as S. 1696, H. R. 3069 sought to establish a national education program aimed at the farmer, urging adoption of best management practices for nitrogen to minimize ground-water contamination. The bill recognized the importance of the fertilizer dealer to farmer education.

Meanwhile, the Senate was considering S. 20 (Moynihan, D-NY) which, with Amendment 178 became S. 1105, Ground Water Research Act of 1987, (Burdick, D-ND). Among related bills were S. 513, S. 1419, and H. R. 963. The bills S. 20 and H. R. 963 authorized states to set ambient ground-water standards, develop ground-water management strategies, and create protection programs. EPA would administer the Act, with USGS assuming joint consultation authority.

The House passed H. R. 791 by yes-nay vote of 359–15 on December 1, 1987, and referred the bill to the Senate Committee on Environment and Public Works. The bill passed the Senate on October 7, 1988, but with major amendments carrying many of the provisions of S. 2091 (Durenburger, R-MN), an omnibus bill that collected major portions of the Senate bills listed above. These Senate amendments during the closing days of the 100th Congress overwhelmed the legislative process. As a result, Congress failed to pass any of the above ground-water protection legislation.

What do these actions forecast for action by the 101st Congress during 1989? House passage of H. R. 791 with minimal opposition and recent Senate action suggest the passage of some form of Federal ground-water protection legislation is probable. However, because as many as 15 subcommittees in the House alone may have input into such legislation and because House and Senate approaches to ground-water protection appear to differ philosophically, any bill probably will travel a tortuous path before final enactment. My judgment is that the House discussions, unlike those of the Senate, point less to setting the framework for restrictive legislation and more to establishing mechanisms for increased monitoring of ground waters, collection and dissemination of available information, and fostering interaction among EPA, USGS, USDA, and other governmental organizations.

Provisions of H. R. 791 as passed by the Senate that are of particular interest to agriculture include: funds for the Agricultural Research Service (USDA/ARS) to report on the effects on ground-water of irrigation and pesticide use; surveys of major sources of ground-water contamination, including fertilizers; assessing the effects of nitrates and nitrosamines in ground water; and the farmer educational program on best management practices included in H. R. 3069, to be developed by the Secretary of Agriculture.

Two major philosophical tenets inherent in the

Senate amendments to H. R. 791 (included in provisions of S. 2091) that merit considerable discussion are: (i) All ground water is potential drinking water; aquifers may not be classified on the basis of differential use; and (ii) The quality of any ground-water resource may not be allowed to decrease but must be maintained at or enhanced above its current quality; nondegradation of ground water is a national goal.

These tenets, if adopted into law, would cause administrative and regulatory difficulties for Federal oversight agencies. For example, most states now classify their ground waters according to use. About 30 per cent of U.S. ground waters currently cannot meet drinking water standards in all respects. The EPA strategic plan for ground-water protection against pesticide contamination itself is based on allowable limits of contamination.

How stringent the control requirements for fertilizer will be will depend in part on the resolution of these issues.

EPA has developed a "Proposed Agricultural Chemicals in Ground Water Strategic Plan." This plan is a strategy only for pesticides. Fertilizers are to be addressed later but probably not before Federal ground-water legislation is passed that will require the development of and provide guidelines for a fertilizer strategy. However, when required, EPA probably will follow, insofar as possible, the general approach taken with pesticides. This approach includes establishing maximum contaminant levels, or MCLs, in waters for fertilizers and fertilizer-derived constituents. As with pesticides, fertilizers probably will be regulated on a site-specific basis. For pesticides, EPA will allow states to decide whether a particular chemical may or may not be used in a specific area based on that area's vulnerability to ground-water contamination by that pesticide. Similarly, nitrogen fertilizer use may be controlled within a state area if that area is highly susceptible to nitrate leaching. Thus, in Nebraska, fall application of nitrogen fertilizer is not permitted, and split applications in the spring are encouraged in all of the 24 natural resource districts of Nebraska that have average well-water concentrations exceeding 12.5 mg of nitrate-nitrogen per liter. A third similarity in approach is that best management practices on the farm will be advocated for both pesticides and fertilizers, with EPA and the individual states sharing responsibilities for managing their use. EPA will continue to take broad actions on pesticide use and disposal affecting ground-water contamination. It may take similar actions with fertilizers. States, I think, will decide how, where, and to what extent a pesticide or fertilizer can be used. Manufacturers also can expect to have increased responsibilities, e.g., increasing technical support for farmers and helping to monitor ground-water contamination.

Certain differences between pesticides and fertilizers will affect the specific regulatory control of each by EPA and states. Fertilizers differ from pesticides in that the contaminant to which they may contribute in part may also be derived from other sources. For example, nitrate nitrogen, for which the maximum contaminant level in drinking water is 10 mg/L, can be derived from soil, plant residues, animal manures, urban and industrial wastes, irrigation waters, precipitation, and biologically fixed atmospheric nitrogen. The relative contribution of each potential source to the total contaminant level often is difficult to precisely quantify, albeit sometimes valid estimates can be made where particular sources predominate. Several potential sources of toxic heavy metal (e.g., beryllium, cadmium, mercury, and lead) contamination of drinking water supplies also are present in or added to agricultural soils; these sources include crop residues, animal manures, sewage, and fertilizers. Heavy metals may be present in fertilizers as impurities derived from a raw material used in manufacture e.g., phosphate rock.

EPA could require best available technologies to be used in fertilizer manufacture to decrease the level of impurities. This approach currently is under discussion for phosphatic fertilizers in Denmark and The Netherlands. However, the permissible level in fertilizer from an environmental point of view would be a complex function of fertilizer application rate, potential of the heavy metals to leach to ground water or move horizontally to surface waters, and their propensity to be stabilized by soil constituents. Action by EPA for some regulatory control of heavy metals in fertilizers is not imminent but may be accelerated depending on the current discussions about California's Proposition 65 and how many States pass legislation similar to that passed in California. Proposition 65 states that "no person in the course of doing business shall knowingly and intentionally expose any individual to a chemical known to the State to cause cancer or reproductive toxicity without first giving clear and reasonable warning to such individual," except as spelled out in another section of the law. On October 27, 1988, 29 chemicals that were listed as toxic came under the law's provision prohibiting discharge of listed chemicals into drinking water ("No person doing business shall knowingly discharge a chemical on this list into water or on land, if the chemical might pass into drinking waters"). Arsenic, cadmium, and lead are included among these chemicals, all of which elements may be present as impurities in fertilizer. The regulations regarding this aspect of Proposition 65 are still being formulated and exemptions to the law are being considered; but in its strictest interpretation, the law currently forbids application of many phosphatic fertilizers to some lands.

Further directives for EPA to address the heavy metal content of fertilizers may stem from language that was used in S. 1105 and S. 2091. In these bills, USDA would be required to oversee a survey of the heavy metal content of all fertilizers used on and off the farm. The bills do not specify the protocols for such a survey nor indicate how the information should be used, but the language indicates that some legislators are concerned with the possible impact of fertilizer use on the heavy metal content of drinking water.

Future water quality legislation reasonably can be expected to permit differential treatment of aquifers and continue to adopt the concepts of negligible risk and maximum contaminant level, rather than the concept of zero risk, and will not classify all ground water as potential sources of drinking water. Where it is possible to eliminate a contaminant which may be present in water at a potentially toxic level because a suitable alternative is available to use of the chemical which gives rise to the toxic contaminant, then such action may be taken. Such an approach is not possible for plant nutrients because they cannot be eliminated. Some substitution of nutrient sources can be done, such as legume nitrogen for fertilizer nitrogen. Regulations, rules, and guidelines can be written concerning the manner in which nutrients are used, or measures can be taken to reduce the amount of nutrient used in a vulnerable land area. But complete elimination of any nutrient from a productive agricultural system is not possible, regardless of whether that system is to be sustained in an economically, highly productive state or in a low input state.

Because there is natural leakage of nutrient, especially nitrogen, from the system, since one cannot eliminate entirely the horizontal movement of soil, soil constituents, and soil amendments to surface waters, the best that we can do is to minimize the amount of leakage, and minimize the amounts of horizontal movement by applying the best management practices (BMPs) that we have at our disposal. But these BMPs should be responsive to environmental as well as economic and production concerns.

Clearly, agriculture must share the responsibility of reducing ground-water contamination. The many bills before the U.S. Congress and State legislatures that implicate agricultural practices give a certain indication that agriculture, along with other segments of society, will be required to do its part in assuring that both public and private drinking water supplies, in particular, and U.S. ground-water resources, in general, will have the highest quality possible consistent with overall national policies, economic health, and crop production needs.

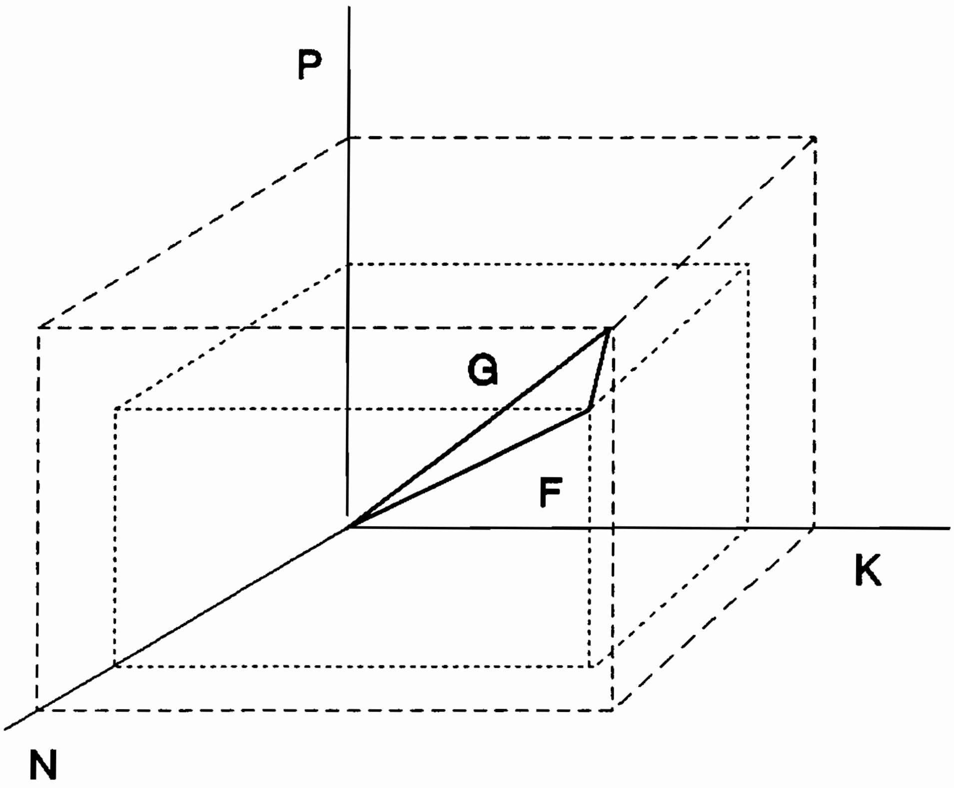


FIG. 1 THE DIFFERENCE ANGLE IN A X-X-X GRADE

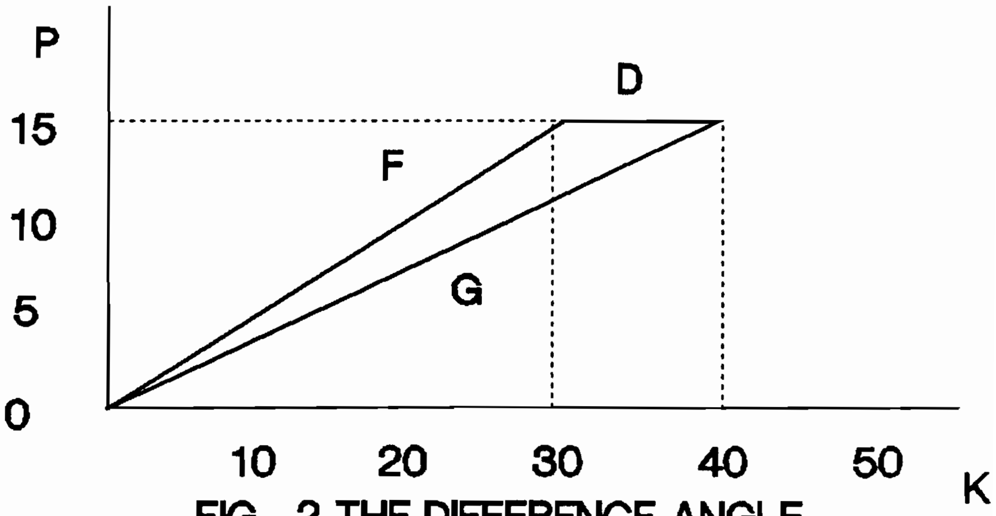


FIG. 2 THE DIFFERENCE ANGLE IN A 0-X-X GRADE

FIGURE 3 - TYPICAL RCI TABLE

FOR 8-32-16 GUARANTEED
WHEN ACTUAL VALUES ARE AS BELOW

N = 8

K \ P	32.0	31.0	30.0	29.0	28.0	27.0	26.0	25.0
16.0	100.0	99.1	98.2	97.3	96.3	95.2	94.1	92.9
15.0	98.4	99.0	99.1	98.5	97.6	96.6	95.5	94.4
14.0	96.8	97.5	98.0	98.3	98.1	97.5	96.6	95.6
13.0	95.1	95.8	96.4	96.9	97.2	97.2	96.9	96.3
12.0	93.5	94.1	94.6	95.2	95.7	96.0	96.1	96.0
11.0	91.7	92.3	92.9	93.4	93.9	94.4	94.7	94.9
10.0	90.0	90.5	91.0	91.6	92.1	92.5	92.9	93.3
9.0	88.2	88.7	89.2	89.7	90.1	90.6	91.0	91.4

N = 7

K \ P	32.0	31.0	30.0	29.0	28.0	27.0	26.0	25.0
16.0	98.3	98.4	98.0	97.4	96.5	95.6	94.5	93.4
15.0	97.8	98.5	99.1	99.0	98.2	97.3	96.3	95.1
14.0	96.5	97.3	98.2	99.1	100.0	99.0	98.0	96.8
13.0	95.0	95.8	96.5	97.4	98.2	98.9	99.0	98.2
12.0	93.4	94.1	94.8	95.6	96.3	97.1	97.7	98.0
11.0	91.7	92.3	93.0	93.7	94.4	95.1	95.8	96.4
10.0	90.0	90.6	91.2	91.8	92.5	93.1	93.8	94.4
9.0	88.2	88.7	89.3	89.9	90.5	91.1	91.7	92.3

N = 6

K \ P	32.0	31.0	30.0	29.0	28.0	27.0	26.0	25.0
16.0	96.6	96.7	96.7	96.4	95.8	95.1	94.3	93.3
15.0	96.3	96.9	97.3	97.4	97.2	96.8	96.0	95.1
14.0	95.5	96.2	96.9	97.6	98.1	98.2	97.7	97.0
13.0	94.3	95.0	95.8	96.6	97.5	98.3	99.0	98.8
12.0	92.8	93.6	94.3	95.1	96.0	96.9	97.9	98.9
11.0	91.3	91.9	92.7	93.4	94.2	95.1	96.0	96.9
10.0	89.6	90.2	90.9	91.6	92.4	93.2	94.0	94.8
9.0	87.9	88.5	89.1	89.7	90.4	91.1	91.9	92.7

N = 5

K \ P	32.0	31.0	30.0	29.0	28.0	27.0	26.0	25.0
16.0	94.8	95.0	95.0	94.9	94.5	94.0	93.4	92.6
15.0	94.7	95.1	95.4	95.6	95.6	95.3	94.9	94.2
14.0	94.1	94.7	95.2	95.7	96.1	96.3	96.2	95.8
13.0	93.1	93.8	94.5	95.1	95.8	96.4	96.8	97.0
12.0	91.9	92.6	93.3	94.0	94.8	95.6	96.4	97.2
11.0	90.5	91.2	91.9	92.6	93.4	94.2	95.1	96.1
10.0	88.9	89.6	90.3	91.0	91.7	92.5	93.4	94.3
9.0	87.3	87.9	88.5	89.2	89.9	90.7	91.5	92.3

N = 4

K \ P	32.0	31.0	30.0	29.0	28.0	27.0	26.0	25.0
16.0	93.1	93.2	93.2	93.2	92.9	92.6	92.1	91.4
15.0	93.0	93.3	93.6	93.7	93.7	93.6	93.3	92.8
14.0	92.5	93.0	93.4	93.8	94.1	94.2	94.2	94.1
13.0	91.7	92.3	92.9	93.4	93.9	94.4	94.7	94.9
12.0	90.7	91.3	91.9	92.6	93.2	93.9	94.5	95.0
11.0	89.4	90.1	90.7	91.4	92.1	92.8	93.6	94.3
10.0	88.0	88.6	89.3	89.9	90.7	91.4	92.2	93.0
9.0	86.5	87.1	87.7	88.3	89.0	89.7	90.5	91.4

N = 3

K \ P	32.0	31.0	30.0	29.0	28.0	27.0	26.0	25.0
16.0	91.3	91.4	91.4	91.4	91.2	90.9	90.5	89.9
15.0	91.2	91.5	91.7	91.8	91.8	91.7	91.5	91.1
14.0	90.9	91.2	91.6	91.9	92.1	92.2	92.2	92.1
13.0	90.2	90.7	91.1	91.6	92.0	92.3	92.5	92.7
12.0	89.3	89.8	90.4	90.9	91.4	91.9	92.4	92.8
11.0	88.2	88.7	89.3	89.9	90.5	91.1	91.7	92.3
10.0	86.9	87.5	88.0	88.6	89.3	89.9	90.6	91.3
9.0	85.5	86.0	86.6	87.2	87.8	88.5	89.2	89.9

N = 2

K \ P	32.0	31.0	30.0	29.0	28.0	27.0	26.0	25.0
16.0	89.6	89.6	89.6	89.5	89.3	89.1	88.7	88.2
15.0	89.5	89.7	89.8	89.9	89.8	89.7	89.5	89.2
14.0	89.1	89.4	89.7	89.9	90.1	90.1	90.1	90.0
13.0	88.6	89.0	89.3	89.6	89.9	90.2	90.4	90.5
12.0	87.8	88.2	88.7	89.1	89.5	89.9	90.2	90.5
11.0	86.8	87.3	87.7	88.2	88.7	89.2	89.7	90.2
10.0	85.6	86.1	86.6	87.1	87.7	88.2	88.8	89.3
9.0	84.3	84.8	85.3	85.8	86.4	86.9	87.5	88.2

N = 1

K \ P	32.0	31.0	30.0	29.0	28.0	27.0	26.0	25.0
16.0	87.8	87.8	87.8	87.6	87.5	87.2	86.9	86.4
15.0	87.7	87.8	87.9	87.9	87.9	87.7	87.5	87.2
14.0	87.4	87.6	87.8	87.9	88.0	88.1	88.0	87.9
13.0	86.9	87.2	87.5	87.7	87.9	88.1	88.2	88.2
12.0	86.2	86.5	86.9	87.2	87.5	87.8	88.1	88.2
11.0	85.3	85.7	86.1	86.5	86.8	87.2	87.6	87.9
10.0	84.2	84.6	85.0	85.5	85.9	86.4	86.8	87.2
9.0	83.0	83.4	83.8	84.3	84.7	85.2	85.7	86.2

Wednesday, November 16, 1988

Session V
Moderator:
John Renneburg

NEW WAVE PEST CONTROL OPTIONS FOR THE 1990's

John L. Hellman
University of Maryland

The 1990's will offer us some major changes in the availability and the variety of pest control options. Some of the old favorites will be rapidly lost to us due to public opinion or EPA regulations. The new wave of public outcry due to environmental contamination problems and fear for personal safety will greatly impact our industry. As I view the next 10–15 years, these are the new waves of the future in terms of insect control options.

A. Chlorinated hydrocarbons (organochlorine insecticides).

Very stable insecticides, both chemically and biologically. Stored in the fat of animals. Very toxic to a broad spectrum of animals; only moderately toxic to mammals.

DDT
Methoxychlor
Kelthane
Lindane (BHC, HCH)
Chlordane
Dieldrin
Kepone

In general this class of insecticides is no longer available because of EPA and industry decisions to withdraw them from the market. They were considered excessive high risks to wildlife, environment and human health. Many species of insects are now moderately to highly resistant to these compounds.

B. OPs (Organophosphate insecticide)

These compounds are relatively short-lived; metabolized in biological systems and degraded in the environment. Generally very toxic to insects, but some are specific to certain groups of insects. Very toxic to mammals, with some exceptions. Some are systemic and highly water soluble.

Malathion
Cygon
Diazinon
Triumph
Mocap
Dylox/Proxol
Orthene
Dursban
Oftanol
Dasanit
Nemacur

C. Carbamates

Properties are generally similar to those of the organophosphorus insecticides, except that they are generally somewhat less toxic to mammals. Several degrade to products which are more toxic than the original compound.

Carbaryl
Baygon
Turcam
Mesurol
Methomyl
Temik
Oxamyl

Today both the OP and carbamate classes are the most widely used compounds and will likely maintain this status into the foreseeable future. Problems with resistance, pest resurgence and environmental concerns will increase that need for alternative control strategies. One new major concern in both the agricultural, ornamental and turf industries will be the problem of enhanced microbial degradation. Because microbes rapidly biodegrade soil insecticides, this problem will severely limit the repeated use of these compounds.

D. Plant derivatives (botanical insecticides)

These naturally occurring materials are isolated from plants. Historically these compounds are relatively expensive, sometimes not readily available but are relatively safe to mammals (except nicotine). They have a specialized nitch in insect control.

Nicotine
Rotenone
Sabadilla
Ryania
Pyrethrins
* NEEM

This Botanical class may offer several future compounds but today only pyrethrin, rotenone and NEEM look promising.

NEEM or Margosa tree, *Azadirachta indica* A. Juss. is native to India but grows throughout Indo-Malaysia, and tropical Africa. Recent introductions into the Caribbean and southern Florida may provide close sources of the raw seed extracts for United States uses.

Historically NEEM has been used for centuries in India in soaps and toothpaste. The seed extract is also used to treat skin diseases, sores, ringworms and rheumatism. These same extracts have both repellency and insecticidal properties. The NEEM insecticide has activity against locusts, Japanese beetles, mosquitoes, leafminers, stored product insects and cockroaches to mention a few. Soil drench applications appear to be taken up by plants and translocated to the leaf tissues.

I envision NEEM as the new botanical find of the century for the United States market.

E. Pyrethroids

This new class of insecticide evolved from the search to discover a cheap source of synthetic pyrethrins. Natural pyrethrins are expensive and short-lived in the environment. The new synthetic pyrethroid compounds developed are generally very stable, broad spectrum and biologically very active at very low concentrations. They also have low mammalian toxicity for improved safety. The first compounds (resmethrin) developed for the indoor market decomposed fairly rapidly on exposure to air and sunlight. The next generation in the 1970's included fenvalerate (Pydrin) and permethrin (Ambush, Pounce and Pramex). These compounds were very photostable and would last 7–8 days on foliage. Indoors these same materials remained active for 6–8 weeks or more. The third wave included:

cypermethrin (Ammo, Cymbush)
fenpropathrin
flucythrinate (Payoff)
fluvalinate (Mavrik)
decamethrin (Decis)
cyfluthrin (Baythroid, Tempo)
fenpropathrin (Danitol)

These compounds are a significant improvement over the previous generations. Some materials in the group have longer residual activity, others are consid ered "easy" on bees, and more importantly, some possess soil activity against grubs.

F. IGR (Insect Growth Regulators)

The first agricultural insecticides such as sulfur, heavy metals, and flourine compounds were stomach poisons. Where as the synthetic organophosphates, carbamates and chlorinated hydrocarbons developed in the 1940's–1980's were nerve poisons and killed through either contact or stomach activity.

The next new generation of insecticide (biorational compounds) mimic natural compounds in their mode of action. The IGRs alter growth and development of insects. They specifically affect embryonic development, nymphal or larval metamorphosis and may cause sterility in adult insects. *Adult insects aren't* killed by IGR compounds, only immatures are affected.

These compounds have very great biological activity. In some instances only a few molecules can interfere with the insect molting process.

Unfortunately many of these compounds are broad range and may cause severe mortality to non-target beneficial insects and aquatic arthropods important to food chains.

In addition to the environmental concerns, industry acceptance will be slow because of the "Birth Control" aspects of the mode of action. They only kill the immatures after a moderately long period of time. The insect may not die until it molts a week after exposure. Over the years the "Immediate kill" factor exhibited by the use OPs, carbamates and the new pyrethroids is an insecticide characteristic the public has been conditioned to expect. The aspects of IGRs not killing adult insects and the immatures living a few days after treatment will be a hard IPM concept to sell our clientele.

The public outcry over the use of dimilin for gypsy moth control is another example of public mistrust of new pest control concepts.

Fortunately, Methoprene, another IGR introduced into the market in 1975 is virtually non-toxic to humans and other warm blooded animals. The following compounds look promising for use in the 1990's:

Methoprene: (precor, altoid, apex, kubut, diacon)
Kinoprene: (enstar)
Dimilin
Trigard
Fenoxycarb

G. Microbials

To date four major classes of organisms have had successful applications in the biological control of insect pests.

1) Bacteria
  Bacillus thuringiensis (only caterpillars)
    Thuricide
    Dipel
    Biotrol
    Bugtime
    Bactospeine
  Bacillus thuringiensis israelensis (fly larvae, mosquito & blackfly larvae)
    Teknor
    Sok Bt
    Bactimos
  Bacillus popilliae (mainly Japanese beetle grubs)
    Doom
    Attack

2) Viruses
  Gypcheck (only gypsy moth)

3) Nematodes
  Neoaplectrana carpocapsae
  Steinernema feltiae (Biosis)
  Heterorhabditis heliothidis (Biosis)
  Heterorhabditis HP88 (Biosis)

4) Fungus
  Beauveria sp.

Bacillus thuringiensis (BT)

Bt is a spore-forming bacterium that occurs naturally in many types of US soils. The B.t. is capable of producing a protein crystal which is toxic to certain groups of insects, depending on the strain of bacterium involved.

Presently B.t. is marketed under the brand names Thuricide, Dipel, Bugtime, Biotrol, Bactospeine. These products kill only caterpillars. The formulated product that is mixed with water and sprayed contains both bacterial spores and the protein toxin. When a caterpillar ingests this product, the toxin destroys the gut wall thus killing the insect. The toxin is the important element of this biocontrol agent. The toxin often causes immediate cessation of feeding even though the caterpillars appear to live on for another several days.

The important thing to remember about Bt is that it must be used much like a pesticide; sprayed each time a pest population requires control. This material is ideal in IPM programs because it does not directly interfere with the possible buildup of beneficial organisms or other minor pests that might be present. It may at times encourage the buildup of other biocontrol agents.

The major use by volume of Bt at present is in the control of vegetable pests, gypsy moth and spruce budworm. It has particular value in urban areas since there is relatively no obJection to drift such as occurs when synthetic pesticides are used. Due to the ability to mass produce this agent, the future looks good for IPM.

Bacillus thuringiensis israelensis (B.t.i.)

This new bacterium strain is a special selected strain that controls fly larvae. Trade names such as Teknar, Sok B.t. and Bactimos are formulations with this new strain and can be used to control mosquito larvae, blackfly larvae and certain mushroom and greenhouse fly pests. Even newer strains are being developed to control beetle larvae on vegetable and ornamentals. These B.t. beetle strains are now being tested (1988-89) for white grub and soil insect control.

The future uses of B.t. looks good as a tool in IPM programs. The human safety factor, natural orgins and the development of special strains to control specific insects makes the B.t. option a viable alternative to the nerve toxin insecticides.

Milky Disease. *Bacillus papilliae & B. lentimorbus*

The use of this bacterium in the 1940s was a great success story for classical biological control. Reductions of the Japanese beetle grub population in many communities are still maintained well below damage thresholds 40 years after the spore dust was applied. In fact other annual white grub species are now replacing the Japanese beetle as the primary grub pest in these same communities. New strains that can control chafers and a new manufacturing process promise to increase the use and decrease the price of milky disease.

Viruses. At present very few virus products are available for commercial insect control. The general public's negative view of releasing viruses into the environment will greatly inhibit the production and marketing of these control agents.

Nematodes. Several natural occurring species can now be mass produced for insect control. These living nematodes are broad spectrum, typically kill within 48 hours, reproduce and spread to other hosts, safe to non arthropod animals and are applied with standard insecticide equipment.

When the efficacy is compared to insecticides, the data do vary somewhat depending on environmental conditions at the time of spraying, but on the average they provide acceptable control of selected pests. The important turf and ornamental markets will welcome this new alternative to the standard insecticide usage.

The concept of using nematodes to control insects has been demonstrated even before the advent of synthetic insecticides. However, the one major hinderance to commercial production and widespread use of these microscopic worms has been lack of mass production and packaging technology. Recently a company in California called Biosis has made major strides in providing the industry with a quality nematode product. The new product will be sold under the trade name Biosafe.

These selected strains of naturally occurring nematodes in the genera *steinernema* and *heterorhabditis* look very promising to date.

Fungus. Fungal agents such as *Beauveria* sp. are widely used in Europe, Russia and China for agricultural and forest insect control.

However, their use in the United States has taken a back seat to development of synthetic insecticides. Generally their success is greatly dependent on the environmental conditions at sites of application. Narrow ranges in required optimal temperature and humidity are limiting factors in the widespread use of fungal agents outdoors in turf, agronomic crops and forestry systems. However, renewed interest and the problem of resistance to insecticide may revive the market for *Beauveria* products in the United States.

Oils and Soaps

Even before the advent of the synthetic insecticides, both soaps and oils were known to suppress and control a wide range of insect pests. Today Safer's Insecticidal Soap and the new highly refined light, non-sulfur horticultural (Sun) oils have replaced the OP's and carbamate insecticides in many traditional use patterns, particularly in the urban tree care and ornamental markets. These products will continue to penetrate into the market over the next 10–15 years.

In closing, several new classes of pesticides and biocontrol agents are now riding a wave of public acceptance. It is important to remember in the 1990's when competing in high waves, you can either miss the boat and drown or ride high and enjoy the new view from on top the new waves. Your challenge will be to find the best marketing vehicle to take advantage of the new pest control technology.

CHANGING TIMES FOR INTERNATIONAL FREIGHT

Jan E. Jakubowski
Continental Grain Company

At the outset of my talk, let me first take you on a quick trip down memory lane to give you an idea on how the international shipping industry has changed. Of course, I will be concentrating on the free market segment of the industry rather than the liner side, however, there will be some correlation. When I first entered this business as a cadet at the U.S. merchant Marine academy in 1958, the shipping world consisted primarily of tweendeck ships, of the Liberty and Victory class and T-2 tankers. All remnants of the 2nd World War. Newer dry cargo ships being built, primarily in European yards, were tweendeck ships. There were a smatering of ore carriers and a new type of ship was commencing its entry into the market place called the container ship, but in general the fleet consisted of small, flexible ships.

I recall while sailing, and later while working for Continental Grain, having to grain fit these tweendeckers with enough lumber to construct a small house. As the 60's progressed we began to see the principle of economies of scale take effect, with ships getting bigger and more specialized. The self-trimming bulkcarrier started to replace the tweendecker and the art of grain-fitting began to be lost as it became too expensive. Containerization was maturing and larger and larger tankers were being constructed. Flexibility was being lost.

In addition, another change was occurring which reflected the fact that the industrial revolution was alive and well and continuing to move westward, with Mother Steel still leading the way. Steel, being labor and cost intensive, was forcing the ship building industry to turn to the Far East. As we entered the 70's ship's became larger and more specialized, car carriers and Ro-Ro's entered the scene. Ship's prices fostered by attractive financing and the disolution of fixed exchange rates brought about a rash of ship building. And with it, the pattern continued with more specialized and larger vessels. For the speculator it was getting too expensive to order small ships. This pattern continues today, particularly regarding small ships.

All during this period energy was playing a role. At first, no one paid too much attention to this issue. The cost was relatively stable and inexpensive. about $15/18 per ton. The world chugged merrily along. Then in the early 1970's the roof fell in and before the decade was over fuel cost had risen to $150/ton, as OPEC became a dominant force. New economical ships were needed to reduce the amount of oil burned. Coal was being looked upon as a viable inexpensive alternative for heating and electricity. One study in particular came out from a prominent U.S. institution of higher learning which said, by the year 2000 the world would need 1000, 100,000 tonners to carry the coal that would be needed. And what did any self.respecting ship owner do. He jumped in and built and built. By this time a second Far Eastern country was competing for the owners/builders money and by about 1982 the stage was set for one of the worst shipping depressions since the phoenicians set sail. Bearing in mind that the freight market is rather simplistic in nature, i.e. it is supply and demand orientated, and there was too many ships to lift too few cargoes.

This brings us to today where after an intensive scrapping initiative and reduced order books, the market has recovered and matters are beginning to stabilize. However, when the dust settles certain patterns will still be continuing, i.e. the trend towards building bigger and more specialized ships. Through this period of time, one thing has remained fairly constant. That is, of all the dry bulk commodities, iron ore, coal and grain, in that order, make up close to 50% of the demand for dry bulk, free market ships. Furthermore, while grain represents only about 15% of the overall market, it basically controls the spot traded market. The trend in the coal and iron ore trades is to use the larger capsize ships, whereas in grain the work horse is perceived as the panamax ship, but handysize ships are also a significant factor. Presently, a capsize vessel costs about $35 million, a panamax about $25 million and a decent handysize, around 30,000 tons, about $20 million. The capesize will basically only be built against a meaningful time charter or contract of affreightment. The handysize will prove to be too expensive to be built by speculators. Consequently, they will turn their sights to the panamax, risking that this will be the next generation of ships to be over built. It will also mean that the handysize and smaller general purpose type vessels will be built by government backed entities or by owners with a special, high paying trade in mind, with few built for the free market. Meanwhile, it must be recognized that while the overall world fleet is aging, the smaller tonnage is doing so, more rapidly and will increase, percentage wise, the least over the next several years. Bearing in mind that the freight market, on a rate basis, for a ton of cargo will be normally geared to the second hand value of ships and not the new building prices, except on an occasional basis in a very bullish market. Therefore, for the shipowner, who is a speculator, comparing his ability to earn a fair return on his investment, will build the panamax at about $25 million before he will order a handysize vessels at about $20 to $22 million, unless that segment of the market drastically increases.

While my specialty is grain, Continental also functions as an owner and time chartered owner. We use our tonnage as a hedge of our freight short position. That is to say we do not dedicate our ships to our own business, quite the contrary, we trade freight as a commodity. Namely, we trade our ships any where in the world, loading whatever cargo (without impairing the safety of the crew and ship) which achieves the greatest possible per diem return. At the same we trade our cargo requirements to obtain the lowest possible rate. Sometimes the two come together, however, from experience this occurs only about 10% of the time. It is because of this dual function we have had some experience in the phosphate rock and fertilizer business, in addition to acting as a broker for our Contichen Division. Because of this relationship, I am aware that the trade is more geared to the smaller category of tonnage. While the use of increased sized ships has occurred, this growth does not appear to be, or will be, keeping step with the rapid growth of the size of vessels as we enter the 1990's. The overall age of the existing fleet is about 10 years old with the oldest segment in the smaller category. Furthermore, while the size of the fleet, dead weight wise, has been relatively stagnant over the last couple of years at about 194 million tons, the number of vessels has declined from about 4900 ships to about 4700.

As a freightman, admittedly specialized in grain, this would appear to be a critical issue which is facing the phosphate rock and fertilizer industry as well as the rest of the demand side of what is termed the minor bulks, as we approach the next decade. Of course if this happens uniformally to the industry, then buyers will have to adjust to the reality of potentially higher freight cost, or alternative, be faced with the possibility of the bigger problem of adjusting storage, distribution and port facilities at both the load and discharge side.

Another development which is occurring, that to some degree may assist in overcoming the problems of size trends and construction costs of smaller vessels, is the change in ship financing to meet the challenges of higher cost and the demise of traditional means of ship financing. I consider great strides are being made out of necessity because the traditional manner of playing with the banks money as close to a 100% as possible is becoming a thing of the past. The international banking community took quite a hit in the now ending depression, with their worldwide shipping debt not quite at par with the debt of the Third World, but not far behind. Shrinking asset values and poor cash flows forced these banks to proceed with massive foreclosures, making them large shipowners in that terrible market.

Vows of never again and insistence that the shipbuyer increase his equity participation has fostered a new breed of shipowner. One that has commenced drawing on syndicated money and stock schemes to come up with the cash in order to increase the owners equity. While this may have some draw backs from an investors point of view, I do believe that by this manner of financing the daily cost of the vessel i.e. the operating cost and debt service, will assist owners to more readily face the realities of the market place.

This method of buying ships is bringing new faces, a new breed of owner to the market. This may bring some discomfort to many of you who tend to recognize the old guard and therefore have some apprehension about dealing with these new faces. I can appreciate this concern and therefore give you a little hint. Look to who is the operator. He may or should be recognizable. Chances are in such a venture the operator will be different from the owner.

In these changing times and with volatility in the freight market, one has to be concerned with how to deal with the everyday risks of being short or long freight. Not all charterers or owners for that matter, have the exposure or the expertise to deal with the traditional ways of hedging freight as a commodity by having time charter vessels or contracts of affreightment. Even the ability to deal with time charter has lead to additional risks of fluctuating oil prices and foreign exchange exposure in port charges etc. About 3 years ago, a new vehicle entered the scene called freight futures. I am certain a good number of you have heard of Biffex and equally certain that many here are skeptical of this trading tool, or don't see its benefits in the fertilizer trade, or in dealing with small vessels. While I firmly believe in the concept and have successfully used futures to assist in managing our freight risk, especially in the deferred position, I can understand apprehension of others, particularly those who consider this market grain led and influenced.

For those of you who are unfamiliar with this market, let me briefly explain. The BFI or the Baltic Freight Index, until November 4, was comprised of the index of 13 routes, each weighted differently percentagewise. The first 3 routes are the major grain routes for panamax vessels and make up 45% of the BFI. It should be noted that these routes have the most influence on the overall spot market. On November 4th, one route was eliminated, namely the pig iron route from Vitoria to China. Other routes are comprised of coal, petcoke, phosphate rock (from casablanca and aqaba to west cost india) and iron ore. You will note that not only is grain heavily weighted but big ship routes are also more prevalent. While I am convinced that sufficient correlation exists for the handysize business such as for fertilizer, I will agree that additional studies required to make this tool sufficiently attractive to all potential users. In particular, an allowance for short term time charter on a round voyage basis, should be included in this index.

There is a committee of several London brokers who supply rates on a daily basis, in order for the index to be determined. This constitutes the cash market and is separate from Biffex, where the actual futures are traded for the various positions. This has been designed to afford a professional approach which is expected to be above reproach. I am convinced that to date, this is the case. I would urge all here dealing in the international freight market to become educated in this area in order to help better manage their positions.

You have been most kind and patient by indulging me this time and I would like to close before I perhaps bore you any further. I first, however, would like to briefly summarize the 3 issues which I consider will be significant over the next few years, and hope you will investigate them further in order to better manage your freight risks.

1) The trend towards larger less flexible ships.
2) The changes in the method of financing the purchase of ships which will influence who the owners of the future will be and the cost structure of freight.
3) The use of freight futures as a tool of growing importance to assist in the management of your freight risks.

Thank you for your kind attention.

"WHAT'S AHEAD FOR THE U.S. BARGE INDUSTRY"

Thomas M. Torretti
Consolidated Grain and Barge Company

The U.S. Barge industry has gone through a series of ups and downs over the past 10 years. From the mid to late 70's most barge lines were able to generate good returns on their operations. Grain exports during that time were a key factor along with lower operating costs. Backhaul commodities such as salt, coal, fertilizer, etc. and a generally good agricultural sector also contributed. By the late 70's into the early 80's, a building boom occurred in the industry. With the tax advantages for new equipment, investors of all sorts were waiting in line to participate. Shortly after the building boom stopped, we found ourselves in an oversupplied status. With the grain embargo of 1980, coupled with too many barges, life became a real struggle. Transportation prices dropped to levels that were break even at best.

From 1982 to Mid-1986 the barge industry had a tough time. Small operators were forced to close their doors. Competition remained fierce. Shippers couldn't believe how barge lines were able to move customer products at such depressed prices. The Maritime Administration, who at the time of the building boom loaned investors money, were repossessing barges. By late 1986, to early 1987 there were some acquisitions made by larger barge lines of smaller ones. Covered hopper barges were turned into open hopper barges, due to the age of the covers. Those covered barges were not replaced. The Maritime Administration started selling off their repossessed barges at auction. Active purchasing by barge lines increased the value of barges built during the late 70's early 80's, while they improved their respective fleets. Grain exports have been good, fertilizer movements have increased, coal consumption both domestic and export has been on the rise, ores and alloys for the steel industry has been tremendous and other commodities that move on the inland waterway system have improved. I think that the barge industry has become healthier within the last 2 years and although we face challenges with Mother Nature on an ongoing basis, we have become wiser, more efficient, and we value our respective fleets far greater than we have in the past. The industry is on its way back.

Let us take a trip back in time to see what has developed over the past 10–15 years in the barge industry with respect to total numbers of covered hopper barges, barge values, numbers of barge operators, acquisitions of smaller barge lines by larger ones, what percentage of the covered hopper barge fleet in controlled by the 5 largest barge lines and what the future holds for us.

As the barge inventory (Exhibit 1) shows, the total covered hopper fleet as of July 1987 was 10,580, although, I think that total is closer to 9500. Quite often barge lines will charter their barges to other barge lines and when totaling up their respective fleets, there may be a double accounting of equipment. The average age of the covered hopper fleet is approximately 11 years old. The life expectancy of a covered barge, if maintained correctly, is approximately 20 years. The covers at that point in a barge's life may be sold for scrap and if the hull is in good condition may operate another 5 years in the open hopper trade.

The value of covered barges constructed in the late 70's early 80's have been up and down like a yo-yo. Covered hopper barges topped out in early 1982 at approximately $325,000 to $330,000. Those same barges today are worth between $180–193,000. It was not so long ago that those barges could have been purchased for under $100,000. The price of new covered hopper barges today range from $240,000 to $280,000 dependent on the amount of the order and the respective shipyard and types of covers.

The number of covered barge operators (Exhibit 3) went from 32 in 1975 to a high of 53 in 1983. As of 1987 there were 36 operators and that number will diminish by the end of 1988. There will possibly be more acquisitions, and outright sales of barge lines within the next 2 to 5 years. We will start looking like an airline industry if these types of things continue. It will also make our industry stronger because the fleet will be in the hands of efficient operators who have weathered the storm we plodded through in the early to mid 80's.

Within the last 5 years there has been quite a few changes that took place in the barge industry. In 1985 Ohio River Company bought Federal Barge Lines which increased their covered hopper fleet from 225 to 680. In 1984 Ingram Barge Line purchased from U.S. Steel, Ohio Barge Line, increasing their covered hopper fleet from 0 to 270. This particular acquisition involved more open top barges than covered barges. In 1987 American River Transportation Company (ADM) acquired, on a management basis 425 barges with Agri-Trans (CF Industries) and 227 barges with Trinity Industries. In 1988 Artco acquired Wisconsin Barge Line with 511 barges (21 of which were open tops). This gives Artco a covered hopper fleet of 1816 plus barges. Also in 1988 American Commercial Barge Line acquired Sioux City New Orleans barge line with 17 barges which increased their covered hopper fleet to 1300. The old saying the "bigger get bigger" holds true here. The above numbers are as close to being accurate as the last published barge inventory survey.

As we look at the 5 largest covered hopper barge lines (Exhibit 4) since 1975, we can see how some remained constant (to a slight increase) while others jumped by leaps and bounds. Companies who were fortunate enough to have capital to invest in acquiring barge lines or investor barges are probably thankful for it today. With the price of used equipment coming back in value, these investments have turned out to be good.

What's in store for the barge industry in 1989? The drought of 1988 was a devastating blow to barge lines. The American Waterways Operators, our industry spokesman, reported losses during the summer months of $150–200 million for barge operators. Low water, draft restrictions, groundings, blockages were the causes. The Corps of Engineers and Coast Guard did a tremendous job in keeping the river open. We face the same sort of problems in the first half of 1989. With no measurable precipitation and below normal water levels, navigation could become hazardous to our wallet. Ice will definitely be a problem. Dredging will continue where it is needed and if Mother Nature doesn't give us a lot of snow cover this winter, next spring could be the instant replay of summer of 1988.

Aside from the potential navigating problems, the future looks bright. Grain exports should continue to increase. Domestic coal movement should be good since utilities have burned a lot of inventory due to the hot summer and potentially severe winter. Fertilizer movement by barge should be up over 1988. All other commodities will continue to increase their presence on the water. New covered equipment could be built within the next 2 years. Towboat power is sufficient and hopefully the price of diesel fuel will remain at its present levels. Barge values should remain firm. I feel our industry is on the 3rd rung of a 10 rung ladder. As long as the agricultural sector prospers so will both the barge industry and fertilizer industry. I just pray that Mother Nature will be nice to us all.

Barge Profile By Year: **Exhibit 1**

Year	Covered	Open	Total
1987	10,580	5,552	16,132
1986	10,902	5,065	15,967
1985	11,450	5,872	17,322
1984	11,488	5,668	17,156
1983	11,467	5,582	17,049
1982	11,294	5,918	17,212
1981	10,284	4,737	15,021
1980	N/A	N/A	N/A
1979	8,541	4,196	12,737
1978	6,812	2,710	9,522
1977	6,819	2,511	9,330
1976	6,452	2,284	8,763
1975	6,121	2,158	8,266

**As provided by Cargo Carriers Inc.

Exhibit 2
History of Hopper Barge Construction
1955-1986

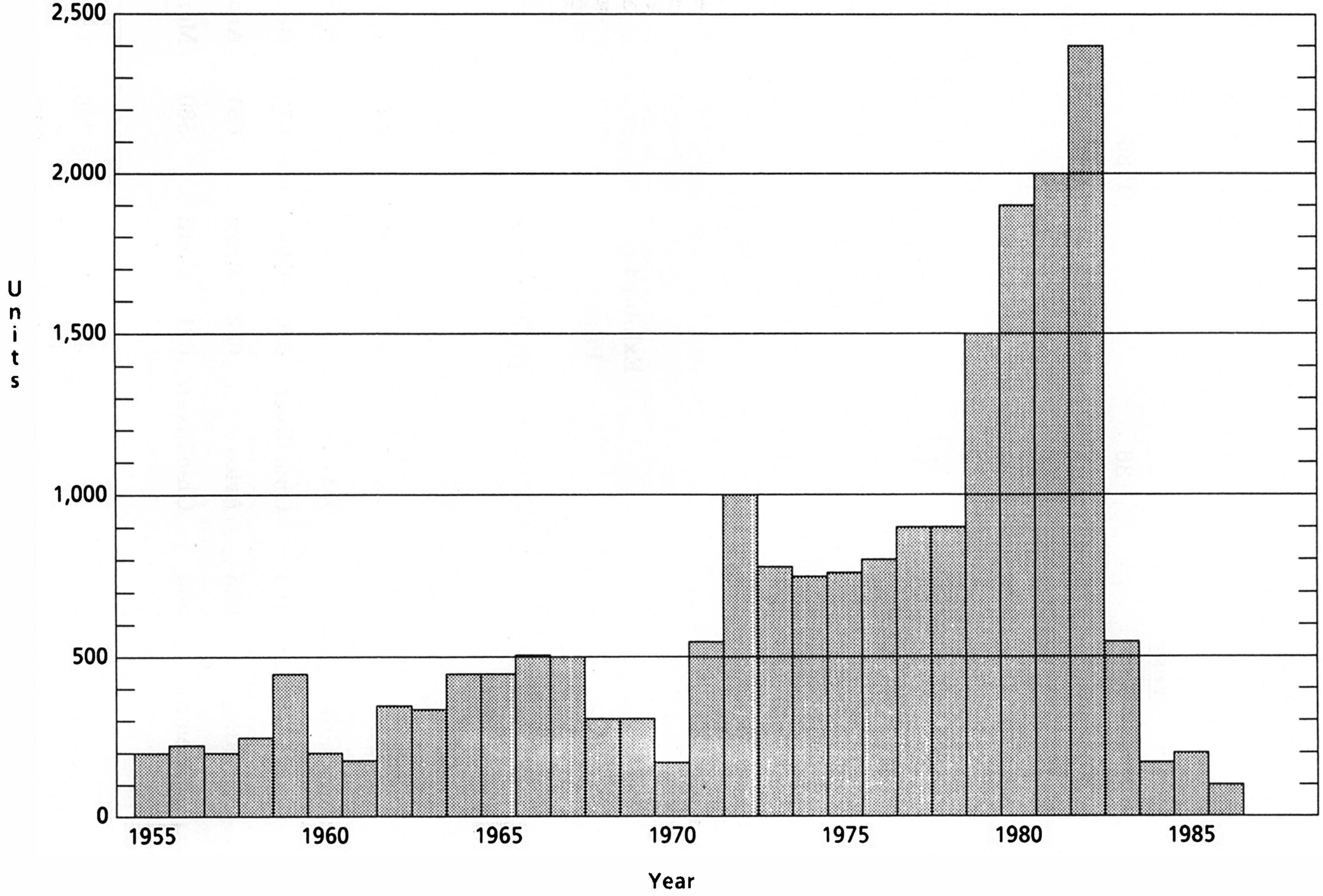


Exhibit 3

#OF BARGE OPERATORS BY YEAR:

Year	Covered		
1987	36	1980	N/A
1986	40	1979	39
1985	50	1978	43
1984	48	1977	34
1983	N/A	1976	31
1982	53	1975	32
1981	49		

Exhibit 4

Page 1

FIVE LARGEST COVERED BARGE LINES:

1987		1986		1985		1984	
Artco	1326	ACBL	1021	ACBL	937	Valley	932
ACBL	1150	VAlley	702	Valley	913	ACBL	921
Ohio River	653	Ohio River	680	Ohio River	675	Ohio River	697
Valley	625	Artco	652	Artco	661	Artco	670
Memco	563	Ohio River	621	Conti	580	Memco	575
Total	4,317	Total	3,676	Total	3,766	Total	3,795
% of Total	41%		34%		33%		33%

Exhibit 4

Page 2

1983		1982		1981		1979	
		ACBL	940	ACBL	1046	Valley	931
		CGB	800	CGB	690	ACBL	833
		Valley	717	Federal	531	Federal	546
		Artco	566	Valley	525	Dravo	544
		Wisconsin	523	Wisconsin	468	CGB	500
Total		Total	3,546	Total	3,260	Total	3,354
% of Total			31%		32%		39%

1978		1977		1976		1975	
ACBL	758	ACBL	657	ACBL	647	ACBL	638
Valley	522	Valley	558	Wisconsin	450	Wisconsin	450
Federal	513	Wisconsin	450	Valley	441	Valley	446
Wisconsin	450	Artco	351	Dravo	357	Dravo	369
Riverway	390	Dravo	350	Artco	351	Artco	342
Total	2,633	Total	2,366	Total	2,246	Total	2,245
% of Total	39%		35%		34%		37%

RAIL UPDATE

John R. Flournoy

CSX Transportation

To start with let me thank Jim Brown and PCA for inviting me here. We at CSX are always happy to participate at these types of functions. We certainly enjoy our association with the fertilizer industry.

At the outset what I'd like to do is review the changes going on at CSX in transportation and storage of fertilizer materials. To start with, let me say that fertilizer is important to CSX. We received, in 1987, about $275 million worth of revenue and this year expect to do about $295 million. In doing so we will handle over 500,000 carloads of fertilizer and related products. At CSX we have a renewed focus on our core business.

What we refer to as our core business is rail transportation. You might have read some of the recent divestitures that we are looking at, such as the gas transmission line and also the resorts. That's back to the focus on basics and the focus on the railroad. To illustrate, in 1988 and 1989 we expect to spend over $400 million on equipment repair programs and car acquisitions. These include repair programs on the three types of cars that are unique to our Bone Valley, Florida operations—the rotary covered hopper cars that go through our Rockport facility, the rotary gons which are used primarily at Agrico's Big Ben facility, and also the wet rock hoppers.

In addition to that, we will be acquiring, and have started receiving, 2,000 new jumbo covered hopper cars. These cars are used both in fertilizer and grain services. We will be repairing, in 1988 and 1989, approximately 4,000 bad ordered jumbo covered hopper cars and also repairing in 1989 approximately 1,600 small cube covered hopper cars which are used in dry rock service, among other products. We will also be acquiring 50 new locomotives at a cost of $1.2 million.

Since deregulation at CSX, we have attempted to move from tariff base rates—the old way of doing business, to what we refer to as market based rates. These rates reflect the dynamics of the marketplace, the competition that exists today, also product prices, product sourcing, and generally whatever we at CSX have to do to get the business. Our objective in this evolution is, of course, to be competitive, more competitive than we have been in the past, to offer the best value to our customer, to be flexible, and surprisingly for a railroad, to be easy to do business with.

What I want to cover is not going to be technical, but our general marketing strategy, focusing on DAP movements, potash, and urea.

This strategy being the packages that we are trying to offer our customer—we define our customer as either a producer; a receiver; and also a broker and trader. The package that we offer is designed to provide flexibility in providing alternate means of moving the product to reflect the customer's particular needs. And, in doing so, I want to try to illustrate some of the programs that we have to offer.

Some of this will be geared to Florida producers and to domestic sourcing, wherever it happens to be. The first of these packages is our Rockport facility in Tampa, FL. At that facility, we handle dry rock and also chemical products, DAP MAP and Triple. Rockport is the only non-producer owned port facility in Tampa and is one that, from our perspective, offers the producer the flexibility to take a product and move it across the Gulf or for export. We have a facility that can accommodate both. The slide reflects the growth in tonnage that we have experienced at Rockport since 1986 and what we are estimating to do in 1989. As you can see tonnage levels have grown from about 4.7 million tons in 1986 to a projected 6.5 million tons in 1989. We're on a pace this year that will do somewhere around 6 million tons so that 1988 numbers are conservative.

If on the other hand, you are not looking at moving the product across the Gulf, the package that we have to offer is what we refer to as our "corn belt program" or as a variation of that multiple product "round trip facilities." The corn belt program format is a dry phosphate program that's based on Florida origins. I might add that this program is being expanded to include Texas Gulf at Lee Creek as an origin. The destinations are Illinois, Ohio, Indiana, and Michigan. Those four states comprise the largest consumption of DAP. More corn grows in that area than any other grouping of states that we are aware of.

The program is not based upon tariff rates but on zip code rates and what we've done is published rates from Florida based upon 3 digits zip codes. This four page document is our corn belt tariff, which encompasses one page printed on both sides of rates to Ohio, Indiana, Illinois, and Michigan. For those of you who are familiar with railroad tariffs, and I'm not, the railroad tariffs that would move the product from Florida to these same states would encompass somewhere in the neighborhood of 4–5 inches and in general be unintelligible.

The zip code tariff is based upon 3 digit zips and covers a fairly large area. For example, the zip code encompassing southwestern Ohio, which would include Cincinnati, is 452 and within the 452 zip code area there would be a rate that would be applicable out of Florida.

The corn belt program also provides for local and interchange applications in that you take the rate that CSX has provided you and interchange with another carrier at whatever gateway the connecting carrier wishes to use. You can add a switch change onto that rate which provides a great deal of flexibility. The corn belt program, the 4601 tariff, is an annual publication and the rates that are contained in that publication are fixed for a year's period of time. You know what the rate level is, it's not subject to any increase whatsoever.

So, it gives your sales representative a known quantity that they can go out and sell with.

The 4601, our zip code tariff, also provides contract flexibility in that if you, as we like to say, bellie up to the bar, with tons—whether that's 20,000 tons or 200,000 tons, we can provide allowances off of that tariff for tonnage commitments. There is also an opportunity for off demand rates to encourage the year-round movement of fertilizer, which is something that is very important to us.

As we move through these programs that we have to offer, the corn belt is really the key and the building block for the other types of programs. The benefits of the programs are competitive rail direct rates. And, by competitive, I mean competitive versus the cost of transporting product across the Gulf and moving it up through the river system. No offense to the previous speaker because we do have barge lines as well.

We provide individualized or tailored incentives depending upon the particular needs of the producer and the receiver. If you know the zip code of the user of the fertilizer, you have a rate. It's nothing more than that.

Accurate billing is also important and this program, in simplifying the pricing and getting away from tariffs, provides us with that opportunity. All of our transportation contracts are confidential. We don't talk, other people may. And, again as I mentioned, this is predictable pricing in that these rates are fixed for the term of the tariff, which is a one year period starting September 1 and expiring August 31.

Tied into the corn belt program is what we refer to as our off-line program. In the past, CSX or its predecessor, the Seaboard, moved very little fertilizer or related product west of the Mississippi River. That's all changed given the demise of the interior producing plants. So, we have worked out again, zip code pricing arrangements with our western connecting carriers, for example, the Burlington Northern, and also programs with the SOO and the CNW to provide zip code pricing into the territories served by those railroads. Again, this is done on a contract form. In the case of the Burlington Northern, we have published a zip code tariff. We expect to be publishing similar tariffs with the SOO and CNW, providing rates on a through basis that are competitive with the existing river system.

Within the corn belt territory, the program is being expanded to include Conrail, Norfolk Southern, and the myriad of shortlines that have developed as railroads themselves downsize and sell off spur lines and feeder lines. So you have a program that encompasses the primary corn growing area, simplified in a three-digit format either published or through contract and competitive with the existing system.

A variation of the zip code program is what we refer to as our round trip program dealing with grain elevators and the movement of fertilizer and grain. This is a program that is geared to improving the utilization of our equipment and making us even more competitive. The basic round trip program involves the movement of fertilizer from Florida ultimately from Lee Creek as well, in fifteen car blocks from the production facility. We will use Florida as an example here.

The fifteen car block of fertilizer would move into a multi-product facility which is really nothing more than a grain elevator that can receive, unload, and store fertilizer. Taking that fifteen car block, the facility unloads it, cleans the car, reloads it with grain, and than releases that block of grain cars back to CSX for shipment. In this case, moving on established grain rates to locations at or near the next fertilizer, generally in the State of Florida, occasionally South Georgia.

The CSX grain business has been primarily poultry or feed mill oriented and as a result what seems like hundreds of feed mills capable of receiving either unit train or fifteen car lots has sprung up in the South. These chickens eat copious quantities of grain and provide a steady source of cars that we can tie into the fertilizer program.

The format is really pretty simple. It's built off of the corn belt program, the 4601 tariff. The grain again moves at the existing grain rates; the incentive is on the fertilizer side; and the additional allowance that we provide is tailored to that program.

These types of contracts, because of the nature of trying to establish a different fertilizer structure than exists today, are multi-year terms with requirements for tonnage guarantees for the producer and also some guarantees on our part as to the rate level. We also, as part of this contract, provide facility development cost incentives to encourage the elevator to build additional track and conveying devices to handle the fertilizer that does not normally move through the facility.

The benefits of the program are improved equipment utilization. You significantly eliminate the empty miles that a car moves to pick up its next load and that's a savings to CSX that we pass on. It also improves equipment availability particularly for the grain elevator that can now receive fertilizer. It improves transit time because you're not hunting for empties and the cars are moving in fifteen-car blocks. It provides an opportunity for us to expand the market and to develop an infrastructure where the actual fertilizer is consumed. Growing up in Cincinnati, I know that there are fertilizer warehouses along the Ohio River; but, I can assure you that no corn is grown in downtown Cincinnati.

The round trip reload program provides us the ability to offer competitive rates which key on what we envision the CSX rail network to be in the 1990's. And, it provides an opportunity to have incentives to clean cars which is a benefit in the improvement of equipment utilization. These round trip reload centers will also be expanded not only to hand DAP related products but also potash and urea. That's something that

I'll touch on, as they are envisioned to be multi-product facilities. I might add that we have seven of these facilities underway now in Ohio, Indiana, Illinois, and Michigan, and five more that are under development.

If on the other hand you don't want to take the product to Rockport to move it across the Gulf, and you don't want to ship rail direct into the interior, we have another program for you. And this is our rail-barge package tied into the movement of fertilizer, again from Florida to New Orleans. This is a slide of the Turner Marine facility in New Orleans. We move well in excess of 300,000 tons of fertilizer annually through this facility, by rail, and transfer it into barges for interior movement. The Turner facility has some storage capability in handling product to New Orleans and then provides us with equipment that we can use on a backhaul basis for potash and urea that come into New Orleans and then would move into the southeast. We have the equipment there that we can tie in on backhaul shipments.

This program as I say is a rail barge program. It is part of the expansion of CSX into transportation areas other than rail. We are the owners of American Commercial Barge Line and we have what we at CSX refer to as a one-stop shipping program, where you the shipper receive one bill for the movement of the product through Turner and on into American Commercial Barge Lines. The program is also available for other barge lines as well depending upon the needs of the shipper and the economics of what they're trying to do. Many people use ACBL, many people don't. In general, about half the tonnage moves on our own barge line, about half moves on others. But again the program provides flexibility in that we have a transportation arrangement that can meet the particular needs.

Since we're talking about ports, there's another port program that exists at CSX as well. And that's an import program tied to the coastal ports. What we have established and are in the process of expanding is again zip-code rates. We're big on zip-code rates at CSX. Zip-code rates to the CSX area from all of the coastal ports—Mobil, New Orleans, Brunswick, Savannah, Baltimore, Norfolk, and Wilmington. This is again geared toward potash and urea. To use Mobile as an example, a considerable amount of grain terminates in the Mobile area. By having a program out of Mobile for potash and urea, we can then do backhaul rates in grain cars and encourage the movement of potash and urea related products through Mobile.

The objective of the program is to provide competitive rates from a variety of ports. The importer or user of the product has the flexibility in being able to determine which port they wish to go through and to be able to work their best deal through ports. It provides access to a wider market with again market base prices and enables them to sell in rail car quantity versus barge loads and for CSX, provides us with improved covered hopper utilization.

This graph depicts the relative growth that we have experienced or are projecting in our fertilizer covered hopper business. Since 1986 we've been projecting about a 15% growth until about 1990. In reality, we've been exceeding that running somewhere close to 20% and we'll do about 20% growth for 1988 and are looking at trying to duplicate that again in 1989.

The focus of these programs is to provide improved quality in the transportation services we're trying to offer. CSX is very big on quality. We, like a lot of the people we do business with, have instituted quality programs, looking to continuously improve the product and the service that we offer—to work closely with our customers to recognize their needs, and what the market-place dictates.

These programs offer the benefits of being able to ship in smaller quantities, provide less handling, less product shrink, improved product quality and less likelihood of contamination. For us it provides improved car utilization, improved car supply and provides year round delivery.

Slides unavailable at time of publication.

"WHAT'S AHEAD FOR THE U.S. TRUCKING INDUSTRY"

Jim Fisher

Cargill Transportation Services, Inc.

As with all services in a free society, the marketplace rules. It is clearly the same for the trucking industry in the United States.

Since deregulation of the trucking industry in 1980, caused primarily by marketplace demand, competition between carriers has been ferocious. Shippers have been able to reduce rates to all-time lows. This was attributable to the mass flood of new authorized carriers entering the marketplace. Many of these new carriers sought quick fame and fortune which caused the demise of some of the old-line carriers. Quickly, the more poorly-managed new carriers also began to go by the wayside. As is always the case, the marketplace is bringing into line the number of players that will be eligible to play.

The marketplace is not only controlled by supply and demand but also by trends within those confines of supply and demand. Past scenarios, for the most part, have been the stockpiling of raw materials and "Get It Here When You Can" attitudes. Today's marketplace, which requires "Just in Time" service, is more interested in quality of service and will soon become a nearly paperless environment.

Change? Absolutely! There will, no doubt, be many remarkable changes in the future. Our world and our society are constantly changing, and our industries must be able and willing to change with those needs.

To predict what the future holds in the trucking industry is possible only in generalities; it is impossible in specifics. Let me attempt to generalize as much as I can.

First, it is my belief that we have now found the lowest levels of truck rates. In fact, it is my belief, we will begin to see upward cost adjustments in carrier rates. Of course, there will always be those smaller carriers who will reduce rates in order to get business; only to later find that, with those lower rates, they cannot be profitable. Also there will be those geographic locations that will continue to recognize lower than average rates, again, because of supply and demand. For the most part, I believe you will see a rise in overall truck transportation costs of about ten percent from present levels.

It is truly interesting to be asked to look into the future of your industry and speak about what you see. If you asked ten different people to do what I am doing, you would no doubt get ten different answers; however, I would surmise that several answers would correlate very well.

The topics I have selected to speak about are *Rail-To-Truck Synergies, Dedicated Contract Carriage*, and *Electronic Data Interchange*. Although there are other numerous topics such as Truck and Trailer Technology, Regional Carriers vs. Long-Haul Carriers, and more, I believe the three topics I have chosen are already at our doorstep and about to make a name for themselves. Let us see if you agree with my conclusions.

RAIL-TO-TRUCK SYNERGIES

Rail-to-truck transfers are not new. We have had TOFC capabilities for many years. This, of course, is where after loading the trailer with a tractor, you deliver the trailer to a railroad ramp; put it on a flat car and transport it to the destination; pick it up again with a tractor and deliver the trailer to its destined customer.

Beyond this well-known version of rail-to-truck transfers has emerged the capability to transport dry bulk and liquid bulk long distances by rail, transload to a truck, and deliver to customers who may not have rail-siding availability. This is even being accomplished with food-grade material. It is truly a cost-effective method, and one that I believe you will see much more of in the future. Several of the larger bulk carriers have already made a financial commitment to the growth of this industry, and I believe that over the next several years you will see more carrier competition in this marketplace, which will bring more competitive rates.

Let us look at a potential example of utilizing this method in order to expand your marketshare. Assume that you supply a dry fertilizer to the marketplace and that your producing facility is in Florida. The only feasible way that you can penetrate a market in Wisconsin is if your customer has rail siding. You could never penetrate this market by truck from Florida; the cost would be out of line with your competition.

Here is the proverbial "what if": what if you could rail to a point near your customer in Wisconsin, hire a local carrier to transfer your material from the rail car to a truck, and deliver it to your customer? All of a sudden you have a new marketplace. You can enjoy the low cost of rail transport for long hauls and truck transport for the short hauls.

This is an amazing marketing tool and, in my opinion, is underutilized by a large margin. Perhaps the reason for this underutilization is that many people do not quite understand it, haven't explored it thoroughly, or just don't have the expertise to make it competitive. For those that don't, I suggest they learn quickly how to use it, or they will find their own customer base eroding away to their competition.

For those of you who have packaged freight, it is my belief that there is also a future coming that will make you more competitive in more distant markets.

Although the railroads have not put a great deal of energy or money into TOFC recently, I have to believe that they will soon. Dedicated Sprint Trains of TOFC, long distances, will have to come in order for the railroads to compete with long-haul over-the-road carriers.

When this does come to fruition, the railroads will not put all of the long-distance cross-country carriers out of business, but they will certainly limit the field. As of this time, we are beginning to see this type of service offered in five hundred to one thousand mile ranges between key geographic points by the railroads. It won't be that long before the railroads will be long-haul competitors with truck lines.

DEDICATED CONTRACT CARRIAGE

Dedicated Contract Carriage is very near and dear to me because it is a major portion of my present business at Cargill.

The best way I can describe Dedicated Contract Carriage is to say that it is like having a proprietary fleet without having the liability.

For those of you who have proprietary fleets, think about it. Very possibly for the same cost, or lower cost, you could enjoy the advantages of a proprietary fleet without assuming the liability for it.

What is the potential liability of a proprietary fleet in the trucking industry? The potential cost is astronomical. Typically it does not do much for the name of your company when a picture of your truck hits either the front page of the newspaper or the six o'clock news with pictures of mangled machinery and injured citizens.

I have always strongly believed that if you are a shipper, do what you do best, SHIP. If you want to be a carrier, then be an expert at it; don't do it as a hobby or to save a few dollars.

As it will be much easier for me to best describe Dedicated Contract Carriage to you from knowledge of my own business, I hope that this will not offend you, and I would recommend that you weigh my comments for one-sidedness.

To give you an example of the interest in this type of carriage, let me tell you that my company has never actively attempted to sell this service to anyone; yet, we have multiple opportunities offered to us monthly. In fact, at present, we have several opportunities available to us that we have not had sufficient time to investigate properly.

Dedicated Contract Carriage has to meet two specific criteria before it can be successfully implemented. First, it must create a win/win situation, not a win/break-even or a win/lose situation. It must work equally well for both parties: be profitable for the one entity, cost effective for the other entity, and provide the total quality needs of both parties.

Second, it must form a partnership relationship, not a customer-vendor relationship. This is probably the most difficult to overcome. As this has never in the past been a standard in the business, it is very difficult for a shipper to view its carrier as a business partner.

In our business, we have actually extended this service for several customers and become their traffic department. Sound amazing? Actually what we have found is that this has been very successful. Typically, traffic departments at shipper locations tend to be more of an administrative function than a profit center that is concerned about cost.

If there is a down side to Dedicated Contract Carriage, we have not yet discovered it, but expect it would be in the area of losing touch with the competitive-carrier market. We always warn our customers about this and tell them that someone from their organization needs to keep a finger on the pulse of the marketplace.

If you are one of those who might be interested in Dedicated Contract Carriage, my suggestion is you find several potential vendors of this service and discuss some options with them. I do not think you will be disappointed.

ELECTRONIC DATA INTERCHANGE

Last, I have chosen to speak about Electronic Data Interchange or EDI, if you will.

Although having been around for several years now, it is still in its true infancy. For those who are not at all familiar with EDI, it is a way to exchange information by electronic means, primarily computers.

We are all faced in our businesses with unbelievable amounts of paperwork. Our society is born, lives and dies with paperwork. Nowhere is it more prevalent than in the shipping business. We have manifests, bills of lading, delivery receipts, invoices, payables, ...

Why? Because that is the way it has always been. The future is saying, "We don't need all of this paper; there is a better way and EDI is that better way." If you don't believe it can work, ask Proctor and Gamble, or call Ford Motor Company or General Motors. They will tell you it works. In fact, they may tell you that if you do not have EDI capability, you cannot do business with them.

This is a major change in the way we do business. It will be viewed initially, by most, as an expensive pain in the neck that has to be tolerated. Once they implement EDI in their business, they will begin to wonder why they had not implemented it a long time ago.

Let me caution you; EDI is truly in its infancy at this point. It has a long way to go, but it is like a mutant. It is growing very rapidly and will be standing in front of you soon, more refined and more user-friendly.

For those of you who think that incorporating EDI into your business is at least ten years out, think again. Think in terms of two to five years. It won't be long and you will find that without EDI capability, you will begin to lose marketshare to your competitors who have EDI capability.

EDI will move across this country and the world quickly, and for those that attempt to avoid it, they will find themselves in a very precarious predicament.

In the shipping business, there are several major vendors that offer this service. Although certainly not all of them, the apparent majors are Kleinschmidt, McDonnell-Douglas, and General Electric, not necessarily in that order.

Just in the past two months, there have been major breakthroughs in this technology such as gateways that allow the user access to other users of different vendors. This was a major step forward; whereas, prior to this, if your EDI supplier was GE and your customer was served by McDonnell-Douglas, one of you had to get the others' vendor service to allow communication among yourselves.

Invoicing and payable can now be done electronically. Amazing capabilities. Think of the potential reductions in overhead costs that can be attained. Tremendous promise for the future. My suggestion is that if you don't know much about EDI, you should get to know about it.

In closing, let me say that the future of the trucking industry in this country will change as our marketplace changes. The players will change.
The old ways of doing things will be replaced by the new ways of doing things. But where there will be product to ship to a consumer, there will be a truck to get it there.

As for what we can do about all of this, I believe we need to be the good business people that we are. We need to stay abreast of the changes in our industry and implement them in ways that make our businesses successful. If we are unwilling to change, we will see our competition take our business away, and we will no longer be recognized as good business people and leaders in our industries.

We need to be innovators of our industry, unafraid to try new methods, and open new territories. In short, **WE NEED TO DO OUR JOB.**

Warehousing in the United States from the Potash Producer's Viewpoint

Paul O. Warner
Potash Company of America

It is a challenge to address such a knowledgeable group about an issue that has had such a fundamental impact on our industry. I'll be telling you much that you already know, but I hope I can provide a useful perspective on this vital topic.

While the warehousing phenomenon has not been confined to potash, by any means, I believe that potash provides the clearest example of how innovative distribution modes can change the whole method of marketing a commodity.

We at PCA have put together a brief outline of what we believe are the most important elements of the warehousing picture, finishing up with some comments about the current situation and what might come next.

In 1980, in-market warehousing was hardly a factor for potash producers. But starting about that time, and until the last couple of years, we saw a steady proliferation of new facilities. In many cases, existing warehouse space, designed for other purposes, was leased by producers for the storage of potash.

Figure 1, for five key consuming states, shows how many warehouses Canadian producers had established by 1984, and how the number had increased by 1987. Ohio and Iowa were clearly where the early developments took place, but Illinois and Indiana saw greater relative expansion—in terms of number of locations—after 1984.

Figure 2 graphs the same growth in the same states, but measured in tonnage capacity rather than number of locations. The picture is slightly different. Ohio warehouses—roughly 20 of them in 1987—averaged about 20,000 tons capacity. The average Illinois warehouse is about half that size. The difference—of course—is the logistics of supplying by Great Lakes vessel (in Ohio) versus barge or unit train (in Illinois).

Before talking about the reasons for the warehousing boom, I would like to make an important point. All booms must come to an end, and the warehousing expansion boom is clearly over. We believe that the saturation point has been reached—and unfortunately—passed.

I'd like to quote from a document which illustrates the point more clearly than any other public study I know of. As part of the Antidumping suit initiated against Canadian producers last year, the staff of the U.S. International Trade Commission—in Washington—prepared an excellent analysis of the potash business. It was based on a compulsory questionnaire completed by producers and importers. This "prehearing brief"—done by Jim McClure and Cynthia Traynor of the ITC—was never used by the Commission because the case was suspended; but it provides some key insights into this and other issues. Let me read from it.

> Importers of potassium chloride from Canada responding to the Commission's questionnaires owned or leased *157 warehouses* with a capacity of slightly over *2.0 million short tons.* [. . .] PCS, IMC, Cominco, and Kalium, *with 117 warehouses,* had a storage capacity of nearly *1.6 million short tons.* Of these warehouses, 88 were located in the major consuming states in the upper midwest and 20 were located in the southeast.

Think about that—*two million tons of warehouse capacity!* In a ten million ton U.S. market, where Canadian producers might sell eight million tons in a good year, we as an industry owned or leased two million tons of storage space. That means that for every *four tons* of Canadian potash sold in the United States, by whatever mode, to wherever in the country, somebody had to lease or buy *one ton* of storage capacity for a year. The whole thing got out of hand.

That doesn't mean it was a bad idea in the first place. It started as an excellent tool by which producers, railroads and major consumers tried to gain an advantage over their competitors.

The economics of lake vessels, river barges and unit trains—relative to single car shipments—resulted in much lower freight costs for those producers who acquired warehouses.

The railroads serving the U.S. from Canada gained better utilization of their hopper car fleets (allowing them to eliminate care shortages, while providing better service at lower cost). As economics improved to the east and the south, Canadian producers gained market share from offshore and U.S. producers—allowing Canadian railroads to increase their shipping volumes.

Oversaturation happened when almost everyone got on the bandwagon. The producers who had been on the cutting edge were not able to sustain their initial advantage, because their strategy was easier to copy than they had originally thought.

Perhaps the big losers were the U.S. producers. I'd like to quote again (at greater length) from that ITC report.

> [. . .] Canadian producers developed, much more extensively than U.S. producers, shipping mode combinations involving unit trains to ship large volumes of product cheaply and quickly to the major consuming areas of the United States.

To accommodate such large shipments and to overcome substantial rail abandonments, potassium chloride producers began obtaining warehouses in the major U.S. markets. Expansion of warehousing into the midwestern and southeastern markets of the United States, almost exclusively by the Canadian potassium chloride producers, extended geographically the competitive impact of these low-cost, high-volume transportation modes. As a result, marketing of potassium chloride in the United States shifted to a regional warehouse-based distribution system.

> [. . .]
> By 1984 the Canadian potassium chloride producers had achieved *significant freight cost advantages vis-a-vis the U.S. potassium chloride producers* [. . .].

Potash buyers close to the new warehouses got their first experience of "just in time" potash delivery. Inventory levels at fertilizer plants could be reduced without the former worries about running out in the peak season. Carrying costs—for the buyers—were reduced. With reliability of supply always a major concern, some buyers regarded a full warehouse—with a long-term lease—as tangible proof that the producer was committed to that market.

In terms of product quality, the new system had both bad and good points. Multiple handlings, on and off barges, vessels and trucks, sometimes caused product to break down. On the other hand, it was no longer necessary, as it sometimes was before, to store potash outside to ensure availability during seasonal peaks.

As the seller's market of 1980 turned into a buyer's market in subsequent years, most of the freight savings developed by the producers were ultimately passed on to the buyers.

In 1980, it was only a slight oversimplification to say that the potash *producer's* responsibility was to get the product into a hopper car. The rest was up to the buyer.

By 1987, it was only a slight oversimplification to say that the potash *buyer's* responsibility was to have truck and driver at the local warehouse on time. The rest was up to the producer.

When I spoke earlier about the fundamental impact of warehousing on our industry, this was primarily what I meant. The burden and risk of getting potash to the market—the logistics, the inventory, the carrying costs—once borne almost exclusively by the buyer, are now borne almost exclusively by the seller.

With producers offering their product to buyers—not just FOB the minesite—but at no fewer than 157 geographic locations in the market, the pricing structure became far more complex than before. The whole task of understanding the market—of gathering market intelligence and of responding appropriately to market developments—became far more difficult. In some cases, this increased complexity contributed to the increased price volatility of the mid-1980's.

It appears now that the warehouse network has entered the downsizing phase. Alternatives are available—in some parts of the country—which appear to have economics equal to or better than producer-leased warehouses. I'm referring to opportunities to fan single cars off unit trains—to re-ship cars from strategically located hold tracks—to make vessel sales at "end of ship's tackle"—to direct transfer from vessel to rail cars. In many cases—where a warehouse is the best strategic option—the buyer is sharing greater responsibility for warehousing.

Which brings me to my conclusion. Is warehousing the ultimate selling tool some of us once thought it was? Is it the miserable burden it sometimes seemed like? Is it the salvation or the ruin of the potash industry?

The answer to all of these is—of course—"No". But in combination with other distribution modes, warehousing is a key element in any balanced distribution network.

Its growth has often seemed like a very mixed blessing from the potash producer's viewpoint. But the advantages of warehousing—in terms of reliability and cost-effectiveness—have made very real and significant contributions to the American fertilizer industry.

FIGURE 1

Warehouse/Distribution Facilities
Canadian Potash Producers

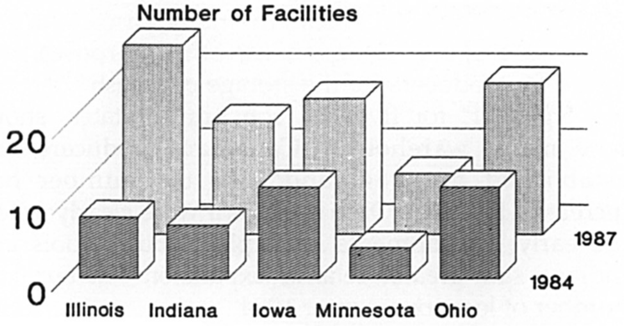
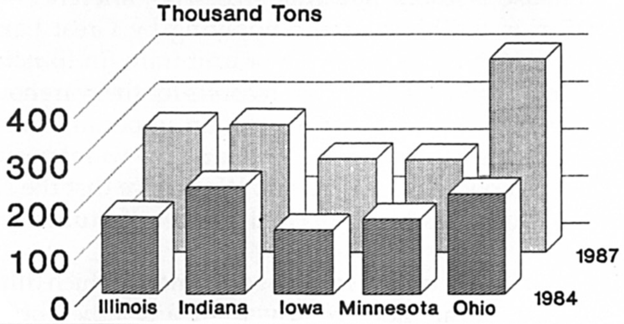


FIGURE 2

Warehouse/Distribution Capacity
Canadian Potash Producers



Clear Span Bulk Storage

Jack L. Brunk
Dome Systems Corp.—Div. Porter Grain

Thank you inviting me to address you today. I'd like to introduce you to a relatively new type of storage structure which has been used extensively in the U.S. for the past few years.

The design provides an economical, watertight structure of incredible strength. The structure can take a variety of shapes and sizes. The shapes most commonly used for fertilizer storage are the hemisphere and the barrel building.

The construction consists of an airform, a 28-oz. PVC coated polyester membrane, which can become the exterior surface or be removed in favor of an industrial grade coating. Inside the airform is a layer of seamless insulating foam (1 or 3 inches thick) followed by reinforcing steel bar and 6 to 12 inches of high strength concrete. The result is a clearspan structure impervious to thermal shock, high wind and interior and exterior loading; able to be sealed airtight and dehumidified for storage of urea or other hygroscopic materials.

The construction time for foundation, shell and floor is approximately seven to ten weeks and the floor can be concrete or, if soil bearing pressures are poor, asphalt or soil cement.

The concern for fines created from material free falling to the floor below is eliminated through the use of "soft drop" spouting which lowers the product to within 10 or 12 feet of the floor and allows the storage pile to build with material drops no greater than 8 to 10 ft.

This slide sequence shows the step by step construction of the dome beginning with:

SLIDE #____ The construction of the foundation and floor.

SLIDE #____ Then we spread the airform over the foundation. You will notice the rebar has already been placed on the floor in piles and covered.

SLIDE #____ Next we inflate the airform using a centrifugal fan.

SLIDE #____ This shows the air inlet and air lock for personnel access.

SLIDE #____ The next step in the process is to apply the insulating foam.

SLIDE #____ This is done in multiple passes achieving a desired thickness of from 1″ to 4″ depending on the final use of the dome and local climate.

SLIDE #____ After the foam is applied, the reinforcing steel is laced into place. Rebar sizes range from #3 to #9 depending on the stresses created at different heights in the dome. The heavier rebar is used when the dome is to act as a dry bulk or liquid storage structure.

SLIDE #____ Finally, the shotcrete is sprayed on in thicknesses generally ranging from 4″ at the top to 10″ at the base, but in some specific applications the base area thickness can be 24″.
The strength characteristics exhibited by the dome is a result of the double curved surface and the materials of construction.

SLIDE #____ The domes ability to withstand large internal loads is exhibited by this loader working along the outer wall of a salt storage dome.

Now I'd like to show you some of our projects recently completed and a couple still being worked on.

SLIDE #____ TEXASGULF CHEMICAL CO., Weeping Water, Nebraska 1:142-ft. diameter insulated concrete dome having a capacity of 16,300-tons of 60-pcf material whose angle of repose is 30 degrees. (Dicalcium Phosphate)
This system loads product to the dome and unloads using the same inclined conveyor. There are six (6) belt conveyors under the building going to an industrial elevator that runs vertically through the building, returning product to the incline conveyor.
This was a turnkey project by DOME SYSTEMS CORPORATION. At the time of construction, this was the largest dome in the U.S.

SLIDE #____ THE ANDERSONS, Champaign, Illinois
2:133-ft. diameter insulated concrete domes having a capacity of 14,000-tons each of 60 pcf material whose angle of repose is 30 degrees. (Potash and DAP)
Also included is a 60-ft. × 80-ft. pole type building for direct loading of trucks by end loader.

SLIDE #____ THE ANDERSONS, Redkey Terminal, Dunkirk, Indiana
2:140-ft. diameter insulated concrete domes having a capacity of 18,000-tons each of 60-pcf material whose angle of repose is 30 degrees. (Potash and DAP)
Also included is a wood frame loadout building for direct loading of trucks by end loader.

SLIDE #____ THE ANDERSONS, Maumee, Ohio
1:93-ft. diameter insulated concrete dome having a capacity of 5,000-tons of 60-pcf material whose angle of repose is 30 degrees. (Diammonium Phosphate)
In the foreground is an "A" frame building that had a history of leaking and shingle problems. DOME SYSTEMS CORPORATION, repaired this building using the ure-

thane foam and elastomeric coating process. This photo shows the repair in progress.

SLIDE #____ THE ANDERSONS, Port of Toledo, Toledo, Ohio

3:140-ft. diameter insulated concrete domes having a capacity of 18,500-tons each of 60-pcf material whose angle of repose is 30 degrees. (Potash, DAP, Urea)

Also included are two wood frame loadout buildings for direct loadings of trucks by end loader. Domes are loaded directly from a self-unloading ship at a rate of 3,000-tons per hour. Material is reclaimed by end loader and loaded directly into trucks.

This is a turnkey project by DOME SYSTEMS CORPORATION.

SLIDE #____ NORTH BEND TERMINAL CO., North Bend, Ohio

4:90-ft. diameter insulated concrete domes having a capacity of 5,000-tons each of 60-pcf material whose angle of repose is 30 degrees. (Di-phos, Mono-phos, Urea, Potash)

This is a turnkey project by DOME SYSTEMS CORPORATION.

SLIDE #____ CARGILL, INC., New Madrid, Missouri

2:93-ft. diameter insulated concrete domes having a capacity of 5,000-tons each of 60-pcf material whose angle of repose is 30 degrees. (Potash, Urea)

SLIDE #____ UNITED STATES STEEL, Crystal City, Missouri

1:118:ft. diameter insulated concrete dome having a capacity of 11,000-tons of 60-pcf material whose angle of repose is 30 degrees. Nitrate storage.

SLIDE #____ CARGILL, INC., Florence, Illinois

2:108-ft. diameter insulated concrete domes having a capacity of 8,000-tons of 60-pcf material whose angle of repose is 30 degrees. (Urea, Potash) Modified in 1986 for grain.

At the time of the photo this project was not complete. There is a truck loadout building and conveyors to load buildings not installed until later.

SLIDE #____ PILLSBURY COMPANY, Huron, Ohio

1:133-ft. diameter insulated concrete dome having a capacity of 14,000-tons of 60-pcf material whose angle of repose is 30 degrees. (Potash)

Also included is a wood frame loadout building and automatic reclaim systems for loadout to rail or truck. Domes are loaded directly from a self-unloading ship at a rate of 3,000-tons per hour.

Knockouts have been provided at four locations around the base for later addition of aeration to allow the dome to alternately store grain or fertilizer.

SLIDE #____ NAPLES TERMINAL CO., Naples, Illinois

6:110-ft. diameter insulated concrete domes having a capacity of 10,000-tons each of 60-pcf material whose angle of repose is 30 degrees. (Potash, Urea, Coal)

SLIDE #____ Exterior coatings which are durable, self-cleaning and have esthetic value find application in many of the commercial applications. When using a coating, the airform is usually removed first.

SLIDE #____ The size of the openings in the dome can be tailored to any need. Also, durable watertight skylights can be used to eliminate the need for costly artificial lighting in many cases.

Some of our clients want a dual use dome to store fertilizer or grain. Storing grain requires an aeration system. Therefore block-outs are built into the dome wall so aeration can be added when needed or taken out and the openings sealed-up again when storing fertilizer.

Environmental conditioning is usually straight forward and the use of air conditioning, vacuum systems or pressurization with an inert gas gives added elements of application to the airtight dome.

The dome shape can carry sizable exterior loads. Proper design to avoid "punch through" is usually all that is necessary. Conveyor supports are usually well off center of the dome and can apply loads of 20 to 25 kips. Anchoring into 4500-psi concrete containing an abundance of 60-psi rebar just beneath the surface is best done by planning ahead.

SLIDE #____ Transfer towers for supporting fill conveyors are generally close to the center of the dome and we have projects carrying loads up to 70 kips on the top of the dome.

Loads caused by happenstance are usually the result of operator error such as material spills during filling. We have domes in operation which have been accidently loaded with up to 60-tons of material on the upper exterior surface.

Restrictive site areas due to existing structures, overhead obstructions and/or property line restrictions can be accommodated in many instances through the use of a little ingenuity in defining the shape of the storage structure.

If site area is a concern, many times a simple hemisphere or a low profile dome can't be used. The use of a straight wall section under a dome may allow for the required capacity in a smaller diameter. This was the situation recently at a Minnesota river terminal. Existing facilities, traffic patterns and a high voltage power line presented quite a challenge. Design attempts using rectangular shapes failed to meet either the tons required, the economics and/or the 18-ft. power line clearance required. We saw an opportunity to meet the customers need if we could build a small diameter dome under the power line and a second but larger dome away from the line. The width restriction however did not allow us to get enough tonnage in a hemisphere. The solution was to construct a cylindrical section with a hemispherical dome on top of it. Economics required an all air placed approach rather than double forming the cylinder wall and then putting a dome on top of it. Also, the top of the opening for loadout equipment entry occurred close to the top of the cylindrical section which would have given us a steel placement problem had we used the formed and poured method.

So we constructed an airform containing both the cylindrical section and the hemisphere. After adjusting some of our normal procedures to compensate for the stresses in the cylindrical section, we felt confident and proceeded.

SLIDE #____ The result was this 122-ft. diameter hemisphere on a 14-ft. high cylinder giving us an overall height of 75-ft. and a capacity of 16,000-tons of 60-pcf product having a 30 degree angle of repose. The shape of the dome is good and we learned enough to be quite confident in applying a straight wall section and multiple shape airforms to future industrial applications. This installation uses our soft fill system to minimize breakage in the 75-ft. high dome.

For dome foundations we like to see 2000-psf bearing capability or higher, however we have built domes on 1400-psf, and in one case as poor as 850-psf. Our concern is rarely the dome integrity. Usually a dome with proper foundation design will not have a problem, however, the floor is a problem and requires special consideration. Since the floor carries the product load, and most applications are single point fill, the floor sees a load per square foot which increases to a maximum at the center of the dome. On poor soils this results in a dished effect as differential settlement occurs. Therefore we usually recommend soil cement or asphalt as a floor material crowned in the center in an attempt to predict the amount of settling at the middle of the dome. After the soil has stabilized a finish course can be added.

I hope this look at the airform shaped, insulated concrete shell has given you an insight into a more economical method of achieving watertight, high strength storage. We are currently constructing shells of 263-ft. diameter × 131-ft. high and are now offering an airform in the shape of a silo. Although the silo shape was developed primarily for cement storage it is available for agricultural use as well.

Slides unavailable at time of publication.

FINANCIAL STATEMENT

October 31, 1987 to November 10, 1988

Cash Balance—October 31, 1987		22,297.99	
Income—October 31, 1987 to November 10, 1988			
Registration Fees 1987 Meeting	9,050.00		
Sale of Proceedings	2,015.89		
Registration Fees—1988 Meeting and Cocktail Party Receipts	14,470.00		
Total Receipts October 31, 1987 to November 10, 1988		25,535.89	
Total Funds Available October 31, 1987 to November 10, 1988			$47,833.88
Disbursements—October 31, 1987 to November 10, 1988			
1987 Meeting Expense (Incl. Cocktail Party)	7,801.12		
Misc. Expense—Postage, Stationery, etc.	206.64		
1987 Proceedings (Incl. Postage, etc.)	10,380.28		
Directors Meetings	1,607.55		
Advertising	214.20		
1988 Meeting—Preliminary Expenses	5,010.89		
Total Disbursements October 31, 1987 to November 10, 1988			$25,220.68
Cash Balance—November 10, 1988			$22,613.20

Respectfully submitted,

PAUL J. PROSSER, JR.
Secretary/Treasurer