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ROUND TABLE
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Monday, November 17, 1986

Morning Session
Moderators:

Chairman John L. Medbery
Joseph E. Reynolds, Jr.

Opening Remarks

Chairman
John L. Medbery

Good morning, Ladies and Gentlemen:

It is a delight to welcome you to the thirty-sixth Annual Meeting of the Fertilizer Industry Round Table. We especially appreciate having you with us during these days of austerity in the fertilizer industry. We have worked hard to prepare a program worthy of your attention and rewarding for the time, money and effort needed to make this journey.

We also extend a warm welcome to our friends from other countries. The Round Table is becoming more and more an international organization. Last year, at the Atlanta meeting, we were hosts to the International Fertilizer Association Technical Committee and had, as members of that group, forty-two visitors representing twenty nations in addition to the U.S.A.

In honor of the IFA members a display of flags of their countries was prepared. Additionally, we had registrants from six more countries. In total, there were eighty-four attendees at our meeting that came from outside the U.S.A. twenty-six foreign lands were represented. The flags of these countries are displayed here this year. They are:

Algeria
Belgium
Brazil
Canada
Columbia
Denmark
Federal Republic of Germany
Finland
France
Greece
Guyana
India
Ireland
Israel
Italy
Jordan
Morocco
Netherlands
Nigeria
Norway
Spain
Sweden
Switzerland
Togo
Tunisia
United Kingdom
United States

If we have registrants from additional countries this year, their flags will be added next year for the 37th Annual Meeting which will be held in New Orleans.

Two years ago, our meeting was held in Baltimore. In his opening remarks, Chairman Harold Blenkhorn, commented on the historic significance of Baltimore to the fertilizer industry. We referred to this city as the cradle of the fertilizer industry in North America. The first fertilizers were produced here in the 1850's and bones, oyster shells, and mineral phosphates were acidulated to make superphosphate in about 1860.

By the time of World War I, there were twenty fertilizer companies operating in Baltimore. The associated industry of manufacturing fertilizer equipment, also flouished here, and many of these fine companies continue to produce quality machinery for the processing of fertilizer products.

Baltimore also was the birthplace of the Round Table. It was here, in the back room of a restaurant, in 1951, that the Round Table had its first meeting. The late Doctor Vincent Sauchelli, who was Director of Agricultural Research for the Davison Chemical Corporation, assembled a small group of local fertilizer chemists and production men for an exchange of ideas and technology. This was the humble beginning of our present day organization.

Today, the Fertilizer Industry Round Table stands as the only forum which addresses the entire spectrum of our industry on a global basis. We play an important role, and hope to improve and expand in the future, as we have in the past.

Outlook for Agriculture and the Fertilizer Industry

Dr. R. E. Wagner, President
Potash & Phosphate Institute

Mark Twain once said, "Don't tell people your problems—80% don't care and the other 20% think you deserve them." I have always felt that is good advice and tried to live by it. But, we have the kinds of problems in this industry and in agriculture today that command our best effort in whatever form that might require.

Because of the time constraint I will restrict most of my remarks to the U.S. perspective . . . but in a global context. Today's international market forces are powerful factors in the U.S. farm economy, which depends so heavily on a continuous flow of exports.

It was in a weak moment early in the year that I had the bad judgment to accept this assignment of keynoting your meeting with the topic, "The Outlook for Agriculture and the Fertilizer Industry." Being of the optimistic variety, I was quite willing to take the chance that things would change enough so that when November 17, 1986 came, I could start things off in an upbeat mode and be perfectly honest . . . which I think keynoters should do. Just the other day as I was searching for some positives, I was told, "Look, you have a choice . . . you can be gloomy or you can lie!"

FEW POSITIVES

You be the judge. Are you better off than you were a year ago or six months ago? Has your market picked up? Has the farm situation improved? Most important, do you see clear signs of turnaround?

I am afraid the answer to all these questions is "no". The great concern is the "no" to the last one. That's different than it has ever been. In the past after being in the tank for so long, we could begin to see signals of better things to come and we had an optimism that it soon would be here.

Not much of a positive nature has happened in the current crisis to give us realistic optimism. Yet, we cannot look at it as being hopeless. Indeed, a few things on which we might be able to pin some promise are beginning to stir. Our trade balance seems to be easing. Farm trade improved from its 3-month deficit position. A new survey by the Federal Reserve Bank of Chicago suggests land values could be leveling off. USDA continues to hold to its position that grain exports could increase in 1987 by as much as 20–25%, largely because of falling prices and stepped up export enhancement programs they say. Most important in many respects, maximum economic yield (MEY) agriculture is moving from a promising concept to an on-farm working entity.

NORTH AMERICAN AGRICULTURE THE CLASS ACT

Let's never forget that North American agriculture (U.S. and Canada) still is the class act of the world even though the gap is narrowing. Because of its agriculture the U.S. can spend more of each dollar for things other than food and still eat better than any other nation on earth. Only 16% of disposable income is spent for food versus 34% in the Soviet Union and well over 50% in some other countries. It is the biggest economic sector in our country, constituting 20% of gross national product; 18–20% of all exports; and employing 22 million people on the farm and in related fields.

Unfortunately, these kinds of positives come through as empty and almost ugly platitudes to those who are in deep distress right now, and who are grasping for answers to their immediate problems. It's like the saying goes, "You are lecturing on navigation while the ship goes down."

Let's take a look together, in a little different way perhaps, at some of the things that ail the industry and its farm market even though, like me, you are tired of hearing the gloom. Then, we will move on to explore some of the possible answers. I'll not be dealing with specific supply/demand fertilizer figures since others more qualified will be doing that.

THE SUBSIDY DELUSION

With subsidies a part of U.S. agriculture for over 50 years, farmers have grown up to depend on government help for survival. With this kind of questionable generosity our government has deluded farmers for years into believing they have been making a living. It has bred inefficiencies.

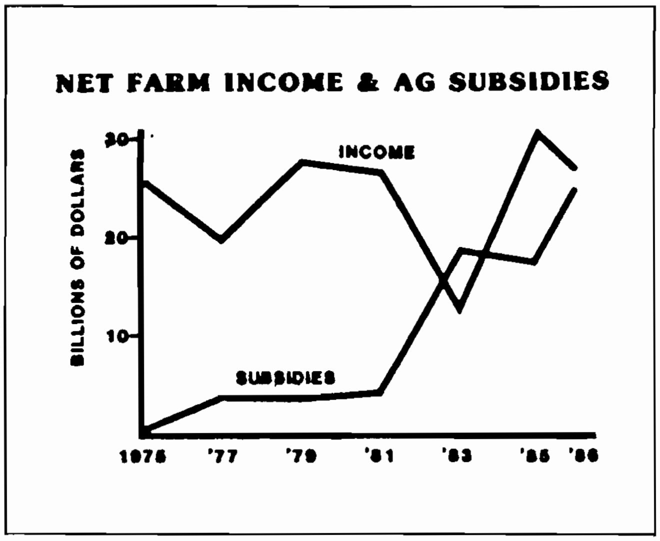
A significant proportion of those in farming still think they are making it pay when, in fact, they are not . . . and it is not just those who are hurting that are being misled. One only has to look at the cash price of corn on major markets today to know how true that is. Only the most efficient can make money with corn at $1.50/bushel or less, and practically none can survive when it drops below $1/bushel as it has done on some markets in the Corn Belt this fall. Realistically, because of subsidies, farmers in the program receive somewhere between the $1.84 loan price and the $3.03 target price in 1986.

How long will the national treasury be capable of providing the current level of $32 billion (the latest estimate) a year for agricultural subsidies, given all the other demands for national defense and social programs? How much longer will the American people and the U.S. Congress put up with it when more realize that some large farm operations have received millions of dollars . . . 22 million in one instance?

SUBSIDIES A NORMAL COST OF DOING BUSINESS?

To put it in the business vernacular, can this sizable outlay continue to be charged off simply as the government's normal cost of doing business in its agricultural division? That's been happening for many years . . . but there are new complications.

The cost burden has skyrocketed out of hand, beginning in 1982. In fact, the latest figures just released show 1986 total agricultural subsidies, which include costs in addition to direct farm payments, will exceed net farm income. Indeed, that is production for the government, not for the market!



The subsidy dilemma is by no means limited to the United States. Country after country the world over is finding the farm subsidy burden too great to bear. The European Economic Community (EEC) countries are perhaps the best example. There is great concern in this community of agriculturally rich countries.

CUTTING BACK AND LOSING OUT

Distasteful and damaging as the big subsidy bill is, it is not realistic to expect that agriculture would ever be subsidy free. Few farmers can work their way out of this already extended downtime . . . without some government help. Even more important, few can survive by cutting back on inputs . . . the package of inputs, including fertilizer . . . that generate the necessary efficiencies for *low unit cost production*. Cutting back and losing out go hand in hand.

Those whose goal is to be the low cost producers are the ones that are quietly doing well and are among those who in 1986 are making all-time record earnings. This is the group that can say, "Things are not bad if you're good." To be sure, the government is helping to make it possible.

Regrettably, there are some farmers who do not have economic units nor the potential to make them so because of size of operation, marginal soils, poor management, or for whatever reason. It seems hardline to say that these are simply going to have to go, but it is inevitable given the economics of the U.S. and the world potential to produce in the year 1986 and beyond. The choice for some is to continue farming and risk losing their existing equity, or to liquidate now and take the assets.

Perhaps the humanitarian thing to do would be to give small loans to help people get out of the farming business rather than try to maintain a permanent surplus of farmers hopelessly addicted to federal aid. Some suggest something akin to the G.I. bill approach. That's another entire subject which we can't deal with in these few minutes here today.

THE WORST OF BOTH WORLDS

For those who want to continue in the farming business, one of two things or a combination of both has to happen. Either we must find a market for what American farmers produce so well, or there will have to be further acreage reductions. Farmers are now plagued with the worst of both worlds.

You know the sad story on exports . . . from a peak of $44 billion in 1981 to $32 billion in 1985, and still falling in 1986. The United States is becoming a residual supplier in the world market. It is shameful with this country's producing power that we imported more farm produce than we exported for three consecutive months in 1986, the first since 1959. That hurts when the sale of product from one out of three crop acres has been dependent upon exports. Actually, it is closer to one in four now and that is down from two out of five in 1980. No business can lose that much of its market and stay healthy.

We can argue what caused it, but the preoccupation of U.S. agriculture needs to be with how to get those markets back. Pressures to compete internationally will increase substantially in the next five years, according to a recent study of executives of 100 large corporations.

LITTLE MEANINGFUL ACTION ON EXPORTS

Failure to take aggressive and meaningful action at the national policymaking level has contributed in a major way to the disarray in agricultural exports. The promises of the new farm bill, the weakening dollar, and the lowering of interest rates and inflation have been of little help. Some say be patient and give them time. I hope they are right, but let's never forget that we are in a fiercely competitive export business like the world has never known.

Not all the world needs the U.S. now like they used to. And the parts that need us cannot afford us. Former customers are now competitors, like India, China, Thailand, Argentina, Canada, Australia, and others. Recently, Canada added a new dimension by proposing a stiff duty of $1.05 a bushel on U.S. corn imports. The reason? They say it is because American growers are heavily subsidized.

Yes, we have a "market-oriented" farm bill and we have been reminded of that time and again. Not much is going to happen simply because we have a bill on the books that says it ought to happen, or even because some of the economic factors are favorable. Somebody said, "Cows don't give milk; somebody has to take it from them." so it is with markets. Nobody is going to give them to us; we'll have to take them.

It is time to move trade to the top of this country's agenda where it can stand alone with high visibility—not be buried as an add-on to something else. An essential part will be a firm national trade policy with a resolve to enhance America's international competitiveness.

Putting more of the subsidy package, whatever it might continue to be, on the marketing end for export promotion would in many ways be a better way to go than continuing to juggle production in ways that invariably lead to inefficiencies. Even spending some of that money on give-away food to the hungry of the world who can't afford to buy it would be a better option than what we have been doing. Some suggest a system of direct income support for farmers.

MORE ACREAGE CUTS

Yes, our farm markets need a lot of work. The other part of the government action to deal with the farm dilemma, namely, acreage reductions, has been much more aggressive. USDA recently announced a new program to pay farmers not to plant corn and other feed grains on 15% of their land. That comes on top of the 20% farmers must continue to idle next year to be eligible for government price support and income support payments . . . shades of the 1983 PIK year. Acreage cutbacks are an unfortunate but necessary option because of our marketing failure. They send clear signals and open invitations to other countries to plant fence-row to fence-row.

GOOD NEWS . . . MEY AND EFFICIENCY

The good news out of all this is that there are many out there who could introduce the kinds of efficiencies on the farm that would assure their survival without significant government help. Opportunities abound. So do current inefficiencies, of course, as mentioned earlier. I know that firsthand because I have a little operation of my own just getting under way that is fraught with inefficiencies. We will, we must, tighten it up. Fellow operators, I know, will be forced to do the same thing. Many of us just might be surprised at how sloppy we are if we would really put our minds to doing a better job.

In farming in the U.S. or in other parts of the world, or in any business anywhere, the greatest need is to cut *unit* production costs . . . to be a low cost producer. This is the maximum economic yield (MEY) . . . or most efficient yield . . . concept. It is the same concept that you in the fertilizer industry use to position yourselves for survival in these times.

Whether in good times or bad; whether in surpluses or food shortages; whether in developed or developing countries . . . MEY makes sense for the farmer and for the fertilizer producer and dealer alike. High efficiency and *low unit costs* are its trademarks.

MEY is not complex. It is a holistic, high yielding crop production system powered by normal farm inputs. There is no snake oil or magic potion involved. The key is to take fertilizer, pesticides, varieties, and other inputs that farmers should normally be using anyway and put them together in the right amounts at the right times so they can interact in an efficient system. The system manages crop nutrient interactions to make input dollars work harder.

A simple definition of MEY is: that yield which lowers *unit* costs to the point of highest possible net return or profit per acre. MEY gives farmers their best shot at profit and their best buffer against loss.

University of Georgia Economist Dr. William Givan has done extensive budget analysis of farm operations. Here's what he says. "These budgets are reinforcing a point that we have been trying to get across for some time—that average yields and average prices just won't pay the bills for most farming operations. Only operators that can consistently obtain higher than average yields and use skill in marketing their commodities will be able to survive. Cost cutting techniques such as lime or fertilizer reductions are really false economies, and many cost-cut techniques are poor ways for reducing risk."

LOWER UNIT COSTS AND HIGHER PROFITS

The economic impact of increasing yields the MEY way is not fully recognized in most instances. Farmers who are moving toward MEY are among those who are finding out. They know that as their yields increase, fixed costs are spread over more bushels, and total cost per bushel is reduced.

Table 1 shows a simplified example using Purdue University recommendations and estimated production costs of moving soybean yield from 45 to 65 bushels per acre. At the highest level, the farmer is not only producing 20 bushels more on each acre, but his costs for each one of those 65 bushels is $1.68 less. This helps him to make a profit at a lower selling price. It helps to give farm products a competitive edge in world markets.

TABLE 1
Increased Soybean Yields Decrease Unit Costs and Improve Profit Potential. Indiana.

	Soybean Yield Goal		
	45 bu/A	**55 bu/A**	**65 bu/A**
Fert. recommendation	0-50-60	0-70-90	0-80-120
Production cost/A	$287	$297	$306
Production cost/bu	$6.38	$5.40	$4.70

Similar examples can be cited for other crops in any part of the country. Note the case for corn in Illinois (Table 2) and wheat in Georgia (Table 3). These are not unusual situations. They are realistic.

TABLE 2
Increased Corn Yields Reduce Unit Costs and Improve Profit Potential. Illinois.

Corn Yield Goal - bu/A	Total Production Cost/A	Production Cost/bu
120	$363	$3.03
160	$386	$2.41
200	$410	$2.05

TABLE 3
Increased Wheat Yields Decrease Production Cost/bu. Georgia.

Wheat Yield Bu/A	Production Cost/bu
20	$8.40
30	5.47
40	4.25
50	3.52

GA Crop Enterprise Cost Analysis

What about down on the farm? It can be equally impressive. Dr. Harold Reetz of our PPI staff has been working with a central Illinois farmer who is sold on MEY and is moving his operation toward it. When he started in 1978 his corn yields averaged 150 bushels. This year the average was 210 bushels. MEY management reduced the cost per bushel from $1.71 to $1.33 and increased net return per acre by $91.

MEY EVEN IN TIMES OF SURPLUS

A by-product of this route to high efficiency and low unit cost is more production. That's unfortunate in times of surplus. But the alternatives are not good. To encourage yields at less than the maximum economic level is to advocate mediocrity and non-competitive agriculture. To legislate or direct acreage reduction is to openly invite other countries to go fence-row to fence-row production, as we mentioned earlier and which already has happened in too many cases at our expense. Yet, of the two options . . . cut yield or cut acreage . . . the latter is far less damaging.

Clearly, cutting production is *not* a matter of doing less than an optimum job. That cuts profitability. It *is* a matter of acreage diversion. Marginal and erosive lands should be in conservation reserve. Where to stop beyond that is the real question. Obviously, fewer acres in production can have drastic consequences for the fertilizer industry. One has only to recall the disastrous 1983 PIK year to be convinced.

MEY AND ACREAGE REDUCTION

We in PPI with Dr. David Dibb's leadership have been doing an analysis of what some of the consequences would be of further corn acreage reductions from the 1986 base. Take a look at Table 4 and you will see that they are substantial. Actually, the indicated drop in projected PK use is likely more severe than the real situation would be. The assumption used was that there would be no increase in per-acre rates of fertilizer on the reduced acreage. That's not necessarily true, although in recent times increased per-acre usage on fewer acres has been less than in the past. Whatever the true figures, total fertilizer consumption will drop with acreage cutbacks.

TABLE 4
Effect of Corn Acreage Reduction on P_2O_5 and K_2O Use With Current Management.

	(1000 tons)		
	1986 acres	20% less	40% less
P_2O_5	1,796	1,437	1,078
K_2O	2,279	1,823	1,368

MEY can have a significant moderating effect on these unfavorable consequences if adopted by more farmers. Some of these are illustrated in Table 5, assuming all farmers adopted the system. That, of course, is not a realistic assumption for now, but it is a goal to work toward. In any case, MEY offers probably the best insurance available against the potentially debilitating effects of taking acres out of production.

TABLE 5
Effect of Corn Acreage Reductions on P_2O_5 and K_2O Use With MEY Management.

	(1000 tons)		
	Current Mgmt. on 1986 acres	MEY 20% less	Management 40% less
P_2O_5	1,796	2,348	1,761
K_2O	2,279	3,039	2,279

The interesting and significant thing is that both P and K consumption holds firm even in the 40% acreage reduction scenario. That's significant . . . extremely meaningful. And that's a major reason, along with its cost effectiveness for farmers, that MEY deserves your and my special attention and the strong commitment of lenders and other investors in agriculture, particularly in these times. We need to find ways to get more farmers on to the program.

Yield per acre increases dramatically with MEY, and cost per bushel drops appreciably (Table 6). Per-acre profit increases as does total farm income. MEY is an efficiency program. The alternatives to efficiency are not good.

Obviously, total production increases with MEY, unless there are acreage reductions. Under the 40% reduction scenario production actually declines by more than a billion bushels.

TABLE 6
Effect of MEY Management on Costs, Returns, and Production with Reduced Corn Acreage.

	Current Mgmt. on 1986 acres	MEY 20% less	Management 40% less
Av. yield bu/A	120	165	175
Cost/bu	$2.50	$2.12	$2.08
Profit/A	($0)	$63	$74
Net return (million)	($0)	$3,464	$3,046
Production (million bu)	8,288	9,117	7,253

MEY A PROTECTOR OF THE ENVIRONMENT

Fortunately, MEY is consistent with measures needed for water quality protection and other environmental concerns. MEY is not just high yield. It is a high yield system with provision for efficient use of nutrients and for the building and conservation of our valuable soil resources. Any who might proclaim that with MEY we expend or deteriorate soils for the sake of export sales so other nations may conserve theirs simply do not understand the MEY concept.

Agricultural chemicals are an essential ingredient in the MEY system. This does not please the environmentalists, so vocal in the press today, even though the system calls for their use based squarely on amount and balance needed for efficient crop production and protection. To outlaw chemicals and other technology, as some are advocating on the grounds that they create "agonizing problems," is to commit to agricultural obsolescence.

In a recent speech Novel Prize winner Dr. Norman E. Borlaug said, "This group of critics leaves the impression that the world is being poisoned out of existence by the use of agricultural chemicals. This opinion defies the facts. The truth is that many more people are living a more enjoyable, pleasant and longer life than any previous generation. It is my belief that agricultural chemicals are absolutely necessary to feed today's population of 5 billion, and which is increasing currently at the rate of 82 million per year."

AN ABILITY TO COMPETE IN A LOW-PRICE ECONOMY

If you were to ask me how many farmers are already doing MEY, I would have to say no more than 10 to 15%. That is remarkable, though, given the fact that only in the past couple of years has there been a concerted effort to implement the research findings. Until very recently PPI and its Foundation for Agronomic Research (FAR) have emphasized research. Now the emphasis is on getting farmers to use it. It is most encouraging that more and more fertilizer producers and dealers are making MEY the centerpiece of their marketing program.

Someone described a fanatic as one who redoubles his efforts once he has lost sight of his objectivity. I hope it's not that way with me on MEY, but I just can't emphasize enough how important it is.

Whether we like it or not, farmers and fertilizer producers are going to have to learn to compete in a low price economy. Those who make the commitment to low unit cost production rather than waiting for price to bail them out will be the wiser. There simply is too much production both of grain and fertilizer . . . actual and potential . . . overhanging the market for it to be otherwise. The Soviets announced recently that they expect this year's grain crop to be the largest in 8 years. U.S. authorities concur. Another of our major markets closing in on us.

In view of loss of markets, acreage reductions, and advice from so many sides including the "sustainable agriculture" group to cut back on fertilizer, P and K consumption has held up remarkably well. Too bad price has not done so well. With the cutback attitude so prevalent, PPI's traditional role in some areas has been modified to an emphasis on market protection as opposed to market development. The challenge is to hold current recommendations which are under considerable pressure.

With consumption holding as well as it has under severe adversity, I believe it speaks well for the future . . . especially if you and I are determined to make MEY more of a factor. It can be that ray of hope that turns to a bright light at the end of the economic tunnel for farmers and the fertilizer industry alike.

For sure there will always be an agriculture that requires a fertilizer industry. It needs to be a disciplined industry and one that identifies with an agronomic education and market development program. Sound agronomy sells.

The real question is: Who will be the survivors? Farmers who are MEY minded and who are MEY activists will be among them. So will you of the industry who practice the principles of MEY in your operations and are realistic in your market appraisal.

Nitrogen Outlook

Presented by
J.W. Brown
Managing Director
Canadian Fertilizer Institute

The nitrogen fertilizer industry is currently experiencing one of its deepest cyclinal downturns worldwide, economics weakness in the world agricultural sector, declining world trade for cereals and feed grains, excessive supplies of nutrients, plant closures, near record crop production with resulting high grain inventories and low farm commodity prices are all contributing factors.

The past year has been a difficult one for world producers and traders in nitrogen fertilizers. World production of nitrogen increased 9% in 1984/85 compared to a 5% increase in world consumption. For the fertilizer year 1986, world production of nitrogen is forecast to increase by 2% whereas world consumption is forecast to be marginally below last year.

CHANGING WORLD SUPPLY—DEMAND PICTURE

Western Europe, traditionally a net exporter of nitrogen, was a net importer in 1985 and is forecast to be a net importer again this year. The cost/price squeeze on production of anhydrous ammonia in Western Europe has resulted in a 3.8% decline in production in 1985 and a further decline is indicated again this year.

Japan and Korea were likewise caught in the cost/price squeeze on ammonia production. As a result both Japan and Korea had lower production in 1985 compared to 1984. Production is down another 10% this year. Nitrogen exports from both Japan and Korea are less than half of what they were in 1980.

India's production of anhydrous ammonia was 6.7% higher in 1985 than 1984 and based on data for the first six months of 1986 is up an additional 12% this year. India's urea imports have declined sharply from 3.7 million tonnes in 1985 to 2.8 million tonnes in 1986 with a further decline is being projected for 1987.

Pakistan and Bangladesh showed the same general trends as India with production from their own plants increasing more rapidly than consumption. Indonesia, likewise, had a remarkable increase in production in both 1985 and again this year.

Brazil has reduced its imports significantly from the early eighties. The decline was due to continuing economic problems at home and increased domestic supply.

PEOPLES REPUBLIC OF CHINA

China's production of fertilizer nitrogen in 1985 was 12.2 million nutrient tonnes, 10% above the previous year. Reported consumption however, increased 10% to 14.8 million nutrient tonnes. Imports in 1985 were 2.6 million nutrient tonnes. Imports in 1986 are considerably lower due to a reported adjustment of abnormally high inventories.

COUNTRIES WITH INCREASED EXPORT

Eastern Europe and the U.S.S.R are taking an increasing share of total world traded nitrogen markets. Consumption within the region has grown from 10.8 million tonnes of nitrogen in 1975 to 15.4 million tonnes in 1985. Exports of nitrogen during the same period have increased from 1.7 million nutrient tonnes to 6.2 million nutrient tonnes. In 1985 the Eastern Bloc countries accounted for approximately 30% of the world nitrogen trade.

U.S. SITUATION

In the 1986 fertilizer year, ammonia production of approximately 14.9 million tons was down 12% from the previous year; the second lowest level since 1970. This reduced supply came about due to a 5% reduction in domestic fertilizer use and a 36% decline in nitrogen exports. In total, fertilizer demand for domestic consumption and exports declined by approximately 1.8 million nutrient tons or 2.2 million tons ammonia equivalent. Imports, on the other hand, increased by 13.4% or 491 thousand tons nitrogen.

CANADA

Canadian production of anhydrous ammonia increased 11% during the 1986 fertilizer year to 3.82 million tonnes. Domestic consumption of fertilizer nitrogen decreased by 2% to 1.23 million nutrient tonnes, while exports mainly to U.S. markets were about the same as the previous year at 1.51 million nutrient tonnes.

WORLD OUTLOOK 1986/87

World consumption of fertilizer nitrogen, after a flat year in 1986 is forecast to increase by 2.4% in 1987 to 71.83 million nutrient tonnes.

All of the increased consumption, however, is forecast to take place in the developing and centrally planned economies.

U.S. OUTLOOK 1986/87

Demand

U.S. demand for agricultural nitrogen is forecast to decline further this year. A drop in planted corn acreage from 77 million acres in 1986 to 65 to 68 million acres in 1987 will be the largest contributing factor to reduced demand. The planted wheat acreage, likewise, is forecast to decline from 72 to 68 million acres. These two crops account for approximately 67% of total U.S. agricultural nitrogen demand.

Exports

U.S. exports of nitrogen declined by 36% in 1985/86 compared to the previous year or about 1.2 million nutrient tons. The decline was due in most part to greatly reduced shipments of ammonia (−29%) urea (−48%) and D.A.P. (−46%). Increased offshore demand for D.A.P. and M.A.P. will likely increase nitrogen moving to international markets during the current fertilizer year whereas, ammonia and urea exports are likely to remain at or below current levels.

Supply

In 1986, U.S. ammonia production was the second lowest since 1970 (14.9 million tons). This sharp decline in output is extending into the current fertilizer year due largely to a further decrease in domestic demand and very low selling prices for all nitrogen materials. Natural gas costs are coming down but not enough to counterbalance the lower selling prices for ammonia and other nitrogen materials. Current trends indicate that U.S. ammonia production will decline another 10 to 12% this year. Production of nitrogen derivatives will likewise be lower.

Imports

Imports of fertilizer nitrogen increased by 11% in 1985/86 due entirely to a 56% increase in urea imports. Ammonia imports were down marginally (−5%) from the previous year. The current world glut in urea has resulted in a prolonged period of very depressed prices which are continuing into the current fertilizer year. An anticipated pick up in world nitrogen demand combined with scaled down production particularly in West Europe, will tighten the supply somewhat and should strengthen prices in the future.

U.S. ammonia imports have been running at approximately 2.8 million tonnes and are likely to continue at about the same level this year. Imports from Canada have increased whereas imports from Mexico, Trinidad and the U.S.S.R. have decreased.

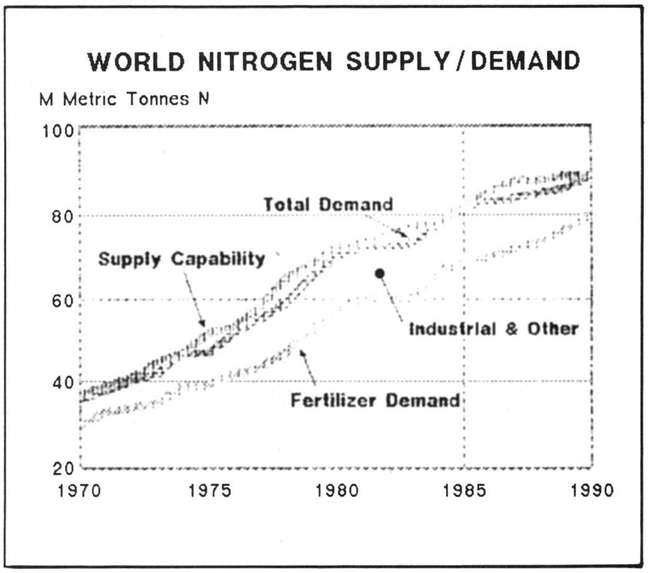
U.S. imports of nitrogen should remain at 4.2 million nutrient tonnes during the current fertilizer year. Additional imports of ammonia could originate in Canada where three new ammonia plants (650 tonnes capacity) are coming into production this year.

Summary

The 1985/86 fertilizer year was another year of declining production, consumption and exports. Current trends indicate a further decline in production and consumption this year with a possible increase in nitrogen exports.

Agriculture is facing a severe over capacity crisis that will force nitrogen fertilizer demand downward until agricultural commodity markets begin to improve.

Nitrogen supply will be adequate to meet agricultural requirements in light of forecast demand decreases. Rapid changes in world trade, sources of supply and domestic capacity utilization will be common in the industry as it reacts to changing supply/demand conditions. The market during the next few years will be a classic example of supply/demand relationship as prices respond to international market developments for both the agricultural and fertilizer industries.



WORLD FERTILIZER STATISTICS
(Million Metric Tons of N)

	1984	1985	% Change
Production	67.83	74.26	+9.5
Imports	15.11	16.30	+7.9
Exports	13.74	16.44	+19.7
Consumption	67.13	70.51	+5.0

PROJECTED WORLD PRODUCTION AND CONSUMPTION FERTILIZER NITROGEN
1985/86 vs 1986/87

	1985/86 (Millions of Metric Tons N)	1986/87 (Millions of Metric Tons N)	% Change
Production	73.49	75.67	+3.0
Consumption	70.16	71.83	+2.4
Balance	3.33	3.84	

Source: FAO/UNIDO Fertilizer Work Group—June 1986

U.S. NITROGEN SUPPLY-DEMAND BALANCE 1986 AND PROJECTED 1987 (Thousands of Short Tons)

	1986	1987
Domestic production	12,198	11,000
Producers beginning inv.	1,461	1,830
Imports	4,142	4,000
Total agricultural cons.	10,928	10,380
Exports	2,046	2,300
Producers ending inv.	1,830	1,220
Industrial use conversion and down stream losses	2,997	2,930

CANADIAN NITROGEN SUPPLY-DEMAND BALANCE 1986 AND PROJECTED 1987 (Thousands of Metric Tons)

	1986	1987
Domestic production	3,129	3,160
Producers beginning inv.	114	276
Imports	180	200
Total agricultural cons.	1,220	1,250
Exports	1,510	1,600
Producers ending inv.	276	350
Industrial use conversion and down stream losses	417	436

U.S. NITROGEN—EXPORTS AND IMPORTS JULY TO JUNE 1985 vs 1986 (Thousands of Short Tons)(N)

	1985	1986	% Change
Exports	3,200.2	2,046.2	−36.1
Imports	3,678.1	4,142.1	+11.2

U.S. IMPORTS UREA—JULY TO JUNE 1985 vs 1986 (Thousands of Short Tons)

	1985	1986
Canada	879.3	1,021.3
Netherlands	130.7	180.1
Venezuela	11.5	27.2
Soviet Union	357.1	706.5
Quator	13.8	113.6
Romania	346.6	410.0
German Dominion Republic	44.6	200.6
Others	98.1	445.4
Total	1,989.7	3,104.7

Source: U.S.D.C.

U.S. EXPORTS AND IMPORTS OF NITROGEN 1970 TO 1986 FERTILIZER YEARS (Nitrogen Short Tons)

	Imports	Exports
1970–71	929	1,077
1971–72	843	1,032
1972–73	882	1,508
1973–74	1,068	1,269
1974–75	1,198	1,115
1975–76	1,218	1,239
1976–77	1,842	1,251
1977–78	1,857	1,798
1978–79	2,240	2,467
1979–80	2,565	2,642
1980–81	2,454	3,088
1981–82	2,531	2,498
1982–83	2,654	2,037
1983–84	3,940	2,082
1984–85	3,651	3,200
1985–86	4,142	2,046

U.S. ANHYDROUS AMMONIA EXPORTS & IMPORTS DURING FERTILIZER YEARS 1974–1986 (Thousands of Short Tons)

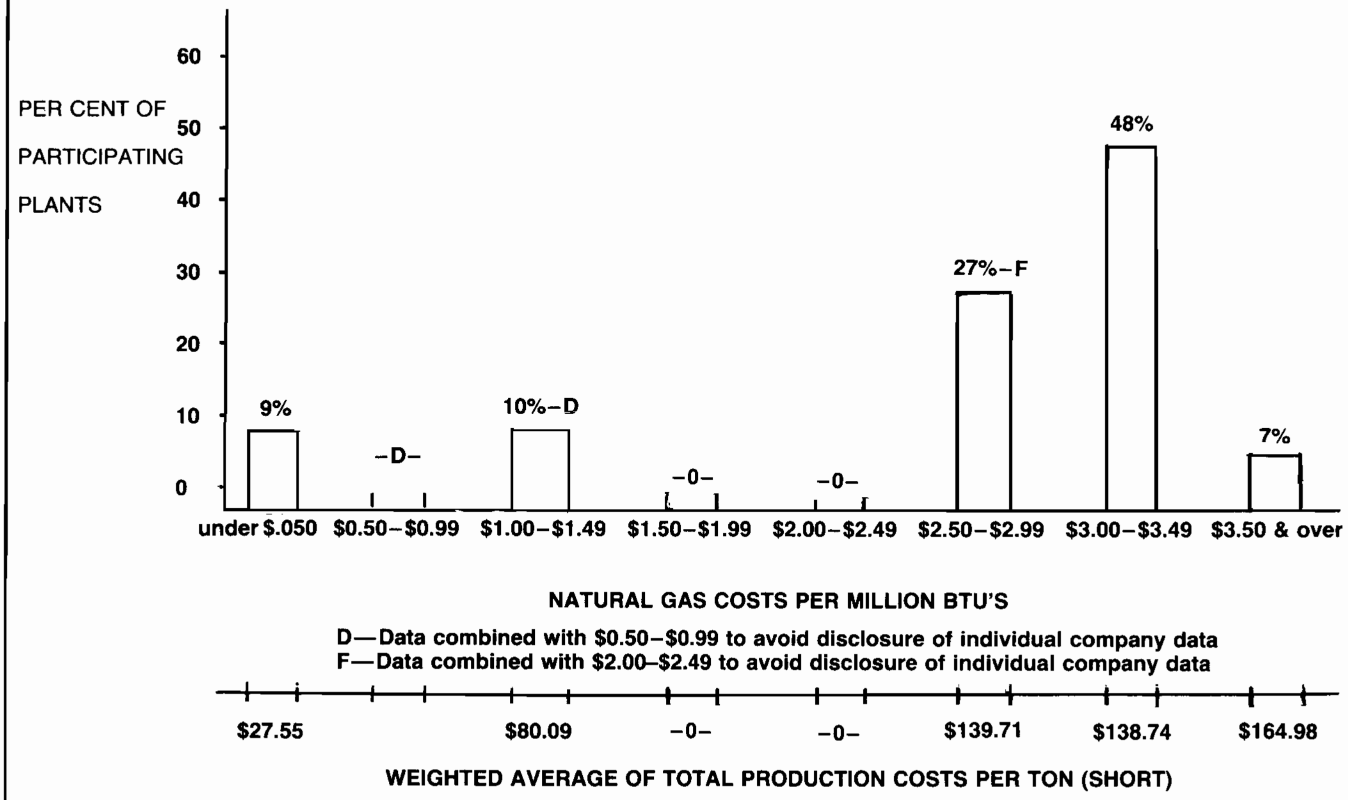
	Exports	Imports
1974	645	438
1975	361	598
1976	326	767
1977	546	960
1978	480	1,054
1979	554	1,735
1980	776	2,219
1981	816	2,161
1982	760	2,244
1983	428	2,144
1984	389	3,258
1985	1,068	2,956
1986	759	2,805

U.S. IMPORTS OF ANHYDROUS AMMONIA BY COUNTRY JULY TO JUNE 1985 vs 1986 (Thousands of Short Tons)

	1985	1986
Canada	998.5	1,208.4
Mexico	186.6	130.3
Trinadad Tobago	701.3	470.4
Soviet Union	934.9	803.1
Others	135.1	192.9
Total	2,956.4	2,805.1

Source: U.S.D.C.

U.S. ANHYDROUS AMMONIA GAS COST SURVEY
CALENDAR YEAR 1985



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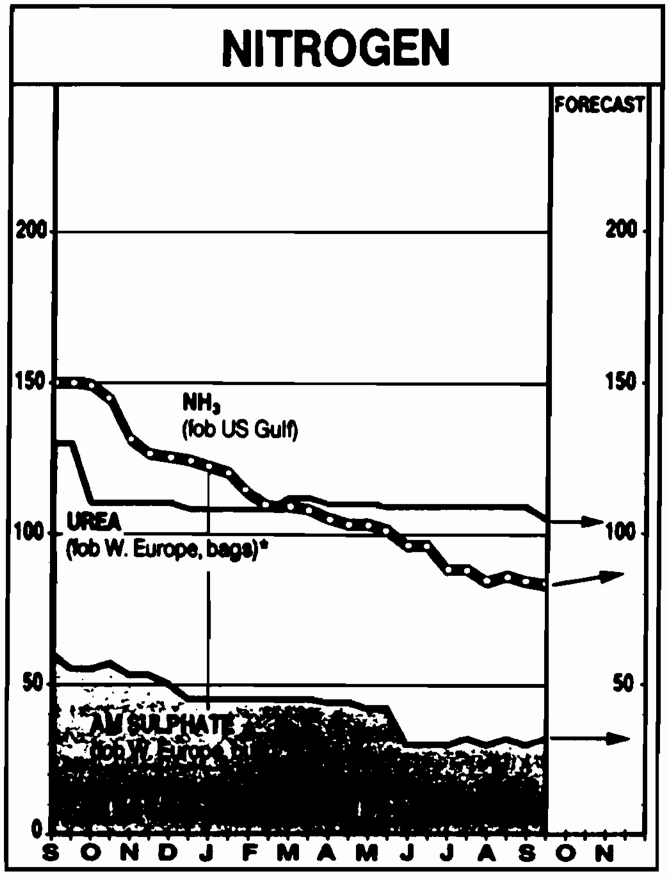

U.S. UREA EXPORTS & IMPORTS DURING FERTILIZER YEARS 1975-1986
(Thousands of Short Tons)

	Imports	Exports
1975	812	450
1976	528	581
1977	1,466	368
1978	1,430	917
1979	1,090	1,550
1980	1,136	1,467
1981	931	2,003
1982	952	1,753
1983	1,636	1,317
1984	2,083	1,033
1985	1,990	1,388
1986	3,104	718

Source: U.S.D.C.

Phosphate Outlook—Near Term and Through 2005

James M. Williams
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INTRODUCTION

Forecasting demands for phosphate is a risky undertaking. In October 1982, I presented the Roundtable Phosphate Outlook. Reviewing those predictions is very sobering in view of the real events of the last four years.

The prediction of the '83 demand slump was about correct and the portion concerning demand by '84 and '85 was also not too far off. The critical shortcomings of that projection concerned:

- the decapacitating plunge of product prices,
- continued weakness in fertilizer demand driven by world and U.S. economic difficulties, overproduction in the agricultural sector, and the tenacity of governments in continuing to subsidize agricultural overproduction,
- world P_2O_5 demand growth at an average of 2.7% per year was too high a rate for the next two decades,
- the impact of these problems on the industry.

These shortcomings were difficult to foresee. I assure you, however, that this matter is of grave concern to us, as it is to you, and we have wrestled diligently with the issues. The future today is even more complex and difficult to predict, so the forecasts have been kept simple.

We will briefly address the following issues in order to assist in justifying the predictions:

- Economic factors.
- Agricultural factors.
- Costs, Prices and Margins
- Demand Basis
- Supply Basis

Predictions addressed in an overview manner will consist of:

- Short and long term P_2O_5 demand.
- The U.S. rock supply outlook.
- Recovery and the future U.S. rock industry configuration.

ECONOMIC CONSIDERATIONS

I have relied on the work of Management Technologies Inc.[1] to provide some insights into the effects of certain economic factors on the agricultural/fertilizer industry. The following factors were identified as important to our predictions:

- Disinflation—Long-term interest rates are predicted to move steadily and slowly downward. Disinflation will continue for some time. Thus, the continuation of adjustments in costs, prices and margins may continue and those inflated dollar investments of the late '70's and early '80's will continue to be a problem for business, including many farmers. This disinflation also affects our trading partners.
- Value of the dollar—The lower interest rates are a source of downward pressure on the dollar, thus the continued decline in the dollar is also expected. The dollar is forecast to remain at relatively low levels for the remainder of the decade.
- Foreign trade—MTI predicts that the lower dollar will eventually reduce the trade deficit, but it may take until 1989 to reduce it by half its present unprecedented high level. The recent lower dollar values have not brought relief to our industry trade problems. Evidently, it may take a lot longer than many expected. MTI makes the following assessment: "Several major points arise from our work. First, despite major indices demonstrating a substantial devaluation of the U.S. dollar during the past 18 months, there is solid evidence that the value of the dollar has changed little over that period when viewed on a broad basis of changing trade weights and currency prices. Second, import prices are on the average moving lower. Third, the major factor in the current trade deficit is anemic export growth caused by weak international demand. And, fourth, an improvement in the trade deficit, however long delayed, is essential for healthy U.S. economic growth for the next few years."[2]
- Reduced world economic growth—Increased external debt costs have hurt major purchasers of U.S. agricultural products. Imports have been cut while exports have been subsidized. Subsidized products have displaced the U.S. in other markets.

AGRICULTURE

The economic factors outlined have direct impacts on U.S. farmers, but none more direct than reduction of grain exports and weak prices. "One-third of U.S. grain production is exported; exports account for over one-fifth of total farm cash receipts. Although the U.S. had a favorable trade balance in 1985 of $11.4 billion, this was down nearly $16 billion from the figure in 1981."[3]

U.S. AGRICULTURAL PRODUCTS[3]

	1984	1985	Change
U.S. Exports	$38.0 Billion	$31.2 Billion	−18%
U.S. Imports	$18.9 Billion	$19.8 Billion	+5%
Balance	$19.1 Billion	$11.4 Billion	−40%

In 1985, 38 countries are shown with significant decline in U.S. agricultural imports from the U.S., while 17 countries show increased agricultural exports to the U.S. ". . . debtor nations continue the push to increase exports and new agricultural projects in developing countries continue to come on line, . . ."[3]

Meanwhile, back on the farm in the U.S., production in 1986 (with 5% less acreage) will be near the record of 1985.[4] Although world consumption of grain is estimated to have increased in 1986, it is still estimated to be less than production.

Acreage reductions and subsidies for next year will probably be forced to even higher levels as record grain inventories continue to grow to unprecedented levels.

Further to the problem, MTI points out, "More than 45% of the second quarter 1986 gains in personal income come in the form of proprietor's income. 30% of total income gains can be found in farm income growth. Given the depressed state of most of the nation's farm regions and falling farm produce prices, this may seem hard to believe. The answer, however, lies in farm subsidy payments which increased approximately $15.5 billion during the second quarter to a level of $19 billion. This represents 94% of the increase in farm income."

COSTS, PRICES, AND MARGINS FOR ROCK PRODUCERS

The really bad news is that costs are evidently at rock bottom, with prices still under great downward pressure. Margins are mostly a figment of the imagination. This puts the remaining highest cost producers in an even greater pinch and will likely lead to more shutdowns of production. Thus, those that remain should not expect any price relief.

DEMAND BASIS

Demand for P_2O_5 is basically driven by crop production/consumption. Historical crop production and corresponding P_2O_5 are shown in Figure 1, with world population footnoted.

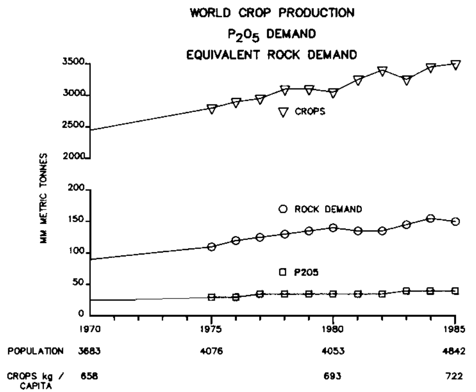

Figure 1

FIGURE 1
Data Sheet
WORLD CROP PRODUCTION
World P_2O_5 Total Demand
Equivalent Rock Demand
(MM Metric Tonnes)

	Year											
	1970	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Major Crops	2425.5	2826.2	2928.2	2950.6	3114.8	3122.8	3081.0	3255.6	3370.4	3254.2	3448.9	3497.3
P_2O_5 Demand, 000 Convert to Millions	24.1	29.4	31.6	33.0	34.7	36.0	36.7	35.6	35.6	38.3	41.2	39.9
Equivalent Rock Demand	90.9	110.9	120.0	125.4	131.9	136.8	141.9	135.3	135.3	145.5	156.6	150.0
Population, Millions	3,683	4,076	—	—	—	—	4,453	—	—	—	—	4,842
Crop Production/Capita Kg/Capita	658	—	—	—	—	—	693	—	—	—	—	722

During the period 1970–1980, and 1980–1985, the following compounded average annual world growth rates occurred:

HISTORICAL WORLD GROWTH

Item/Period	70–75	75–80	80–85	Overall 70–85
Major Crop Production	3.2%/yr	1.7%/yr	2.6%/yr	2.5%/yr
P_2O_5 Crop Demand	4.1%/yr	4/6%/yr	1.6%/yr	3.4%/yr
Population	2.0%/yr	1.8%/yr	1.7%/yr	1.85%/yr
P_2O_5 Total Demand	4.0%/yr	4.6%/yr	1.65%/yr	3.4%/yr

Our studies[5], of world crop and P_2O_5 demand over the 20 year period of 1985–2005, resulted in the forecast shown in Figure 2. The period of 1985–1990 will be discussed in more detail in the section on short range forecast. These estimates were derived from complex studies of crop production, and numerous other factors on a regional basis. In general, these long range forecasts rely on knowledge of historical crop mixes, acreages, cultivation methods, rainfall/irrigation, population growth[6], and fertilizer practices. In addition, the advancement of the agricultural art and some allowance for technological improvements were estimated to provide estimates of P_2O_5 demands for world agriculture. These forecasts show the following compounded average annual growth rates:

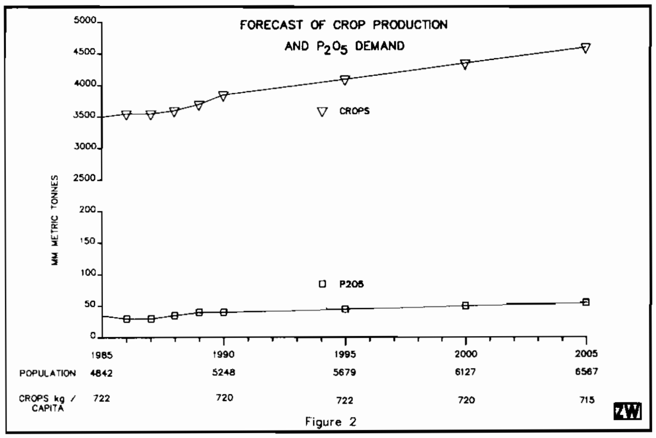

Figure 2

These forecasts show moderation in the growth rate of crop production and also indicate an assumption of minor improvement and future stabilization in the crop production per capita on a world basis. This entails assumptions on improved agricultural recovery and food processing efficiency, but also indicates consideration of economic limitations. These predictions could be conservative, but are considered as the probable case.

Estimates of feed and industrial phosphates were added to the agricultural demand. The total P_2O_5 demand and equivalent rock demand are presented in Figure 3.

The future total demands for P_2O_5 forecasted by major region are shown at five year points on the following table:

FORECASTED WORLD GROWTH

Item/Period	85–90	90–95	95–2000	2000–05	Overall 85–05
Crop Production	1.6%/yr	1.6%/yr	1.5%/yr	1.3%/yr	1.5%/yr
P_2O_5 Agricultural Demand	2.1%/yr(a)	2.1%/yr	1.8%/yr	1.3%/yr	2.0%/yr
Population	1.6%/yr	1.6%/yr	1.5%/yr	1.4%/yr	1.55%/yr

(a) 1984–1990

FIGURE 2
Data Sheet
FORECAST OF CROP PRODUCTION
P_2O_5 Agricultural Demand

	Year								
	1985	1986	1987	1988	1989	1990	1995	2000	2005
Major Crop Production	3497.3	3553.0	3540.0	3638.0	3728.0	3779.3	4097.8	4414.4	4698.3
World P_2O_5 Agric. Demand	35.2	33.0	31.5	33.8	38.8	41.8	46.4	50.5	53.7
Population, Millions	4,842	—	—	—	—	5,248	5,679	6,127	6,567
Crop/Capita Kg/Capita	722	—	—	—	—	720	722	720	715

FORECASTED TOTAL P_2O_5 CONSUMPTION BY MAJOR WORLD REGION

Region	1980	1985	1990	1995	2000	2005	%/yr 80–2000
	Million Tonnes P_2O_5						
North America	6.87	6.12	6.42	6.91	7.22	7.53	0.4%
Central America	0.58	0.69	0.78	0.87	0.94	0.98	2.1%
Africa	1.22	1.62	1.84	2.15	2.45	2.66	3.1%
West Asia	0.47	0.76	0.98	1.10	1.23	1.36	4.2%
South Central Asia	1.55	2.34	2.96	3.48	3.80	4.13	4.0%
East Asia	5.68	6.10	9.20	10.51	11.72	12.42	3.1%
Oceania	1.23	1.12	1.22	1.32	1.32	1.32	0.3%
South America	2.47	2.07	2.41	2.65	3.09	3.32	1.3%
West Europe, Turkey Cyprus	7.09	7.42	7.44	7.85	8.26	8.76	1.0%
East Europe, USSR	9.55	11.63	13.65	15.07	16.29	17.40	2.0%
TOTALS	36.71	39.87	46.90	51.91	56.32	59.88	2.0%
Equivalent Rock Demand, MM Tonnes	142	150	179	205	222	232	

This table shows the maturity of the North American and West European markets. Since the U.S. presently provides about 19% of the world grain production, it is expected to continue as a major supplier as the present market situation and overstocking is brought into balance.

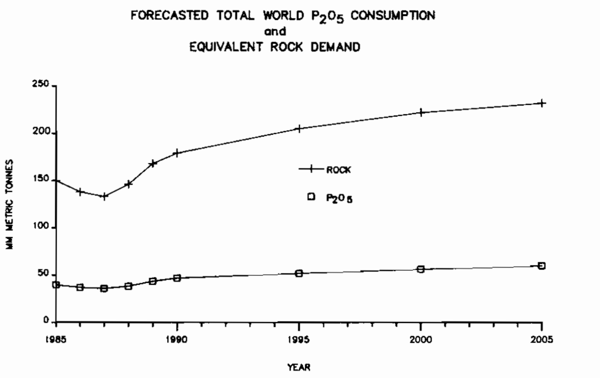

Figure 3

SUPPLY BASIS

World phosphate rock supply, like agricultural production capacity, surged to a capability which greatly exceeded demand in the early 80's. Some new capacity continued to come out of the system, even as demand in the U.S. crashed in the PIK year of 1983. Fortunately, several mines were shelved in the U.S., but some world plans continued to roll on to completion. Several mining projects around the world are still alive, but most are for long range goals.

The present world rock production capability is estimated at 176 million tonnes. This is about 17% over the 1985 demand of 150 million tonnes and 29% over the estimated demand of 137 million for 1986. These capacity estimates do not allow for any final closing of existing mines. To date, no mines of significant tonnage capacity have been disassembled and abandoned.

As has always been the case in modern times, phosphate rock supply capability exceeds demand. The ability to respond to any minor supply deficit is swift and traditionally deficits result in oversupply.

From a short range perspective, the oversupply is devastating; therefore, it is incumbent on forecasters to estimate when the present oversupply will reach equilibrium with demand.

On a world basis, the next nine years of rock consumption and existing supply capability were

FIGURE 3
Data Sheet
FORECASTED TOTAL WORLD P_2O_5 CONSUMPTION AND EQUIVALENT ROCK DEMAND

	Year								
	1985	1986	1987	1988	1989	1990	1995	2000	2005
Total World P_2O_5 Consumption	39.9	37.2	36.0	38.3	43.6	46.9	51.9	56.3	59.9
Equivalent Rock Demand	150	138	133	146	168	179	205	222	232

predicted as shown in Figure 4. Adjustments were made to the near-term demand to account for the reduction of the existing grain surplus which must logically be brought down to manageable levels and to account for some depression of the economy. This is a complex assessment, but one deemed prudent. Supply capability was also adjusted to reflect delays in mine out of existing capacity and certain other considerations such as excess present stock of rock and chemicals.

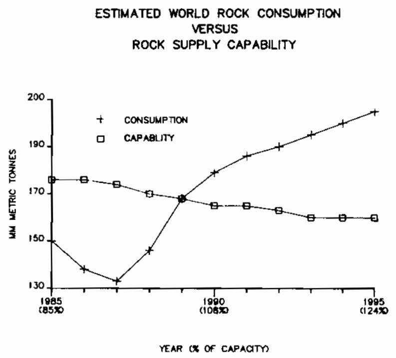

Figure 4

The adjustments are by necessity a matter of judgment, but the impact of these adjustments can shift the demand-supply equilibrium year forward by as much as two years. Thus, the period indicated for equilibrium in the world market is 1990–1991. It is important to note that new supply capability can respond rapidly to minor deficits of supply in the early 1990's. This could possibly lead to an over-reaction with capacity overbuild. This is not expected as extreme caution will be exercised by all following the market and price-margin problems experienced until equilibrium is achieved.

This world overview does not accurately reflect the U.S. situation. The U.S. has 36% of the world rock supply capability, has large rock and chemicals inventories, and holds 60% of the world grain surplus. Our latest estimates of U.S. rock internal consumption plus exports versus supply capability without new mines or expansions are shown in Figure 5. Thus, the recovery for the U.S. balance is estimated as 1992–1993.

ROCK PRODUCTION SCENARIO—RECOVERY PERIOD

World The world demand (consumption) estimates up to the demand-supply balance point in 1990 reflect estimated corrections for oversupply in the agricultural market. On the rock supply side, the adjustments are more severe, especially in view of the long period of depression already suffered. It is assumed that the world rock production will essentially follow the consumption curve shown in Figure 6, with corrections for overstocking. Since markets and prices are depressed and are likley to remain so

FIGURE 4
Data Sheet
ESTIMATED WORLD ROCK CONSUMPTION VERSUS ROCK SUPPLY CAPABILITY
1985–1995
(Million Tonnes of Rock)

	Year										
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Consumption	150	138	133	146	168	179	186	190	195	200	205
Supply Capability	176	176	174	170	168	165	165	163	160	160	160
% of Capacity	85%					108%					124%

FIGURE 5
Data Sheet
ESTIMATED U.S. ROCK CONSUMPTION PLUS EXPORTS COMPARED TO EXISTING U.S. SUPPLY CAPABILITY
1985–2005
(Million Tonnes of Rock)

	Year												
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2005
Consumption and Export	42.1	37.3	36.2	39.7	42.0	46.0	48.0	53.0	53.0	55.0	55.0	50.0	46.0
Supply Capability	62.0	62.0	61.0	60.0	58.0	55.0	55.0	53.0	50.0	48.0	46.0	32.0	22.0
% of Capacity	68%	60%	60%	66%	72%	84%	87%	100%	106%	115%	120%	156%	209%

until not more than one year prior to demand-supply equilibrium, it is not likely that overproduction of rock will occur.

United States The U.S. situation is of most interest. The adjusted U.S. consumption curve shown in Figure 5 reflects total rock needs, but the required production must be corrected for excess stock of rock and chemicals. The rationalized production rates would equal the U.S. consumption plus exports, less some correction for excess stocks up to 1992 where capacity would be fully utilized. Thus, use of U.S. rock supply capability will be limited to the 60–80% range through 1990 and not reach full utilization of existing capacity before 1992.

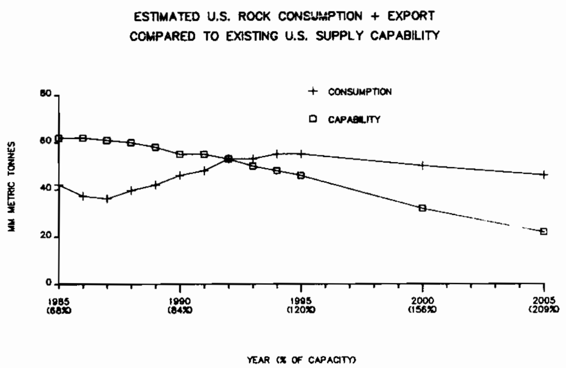

Figure 5

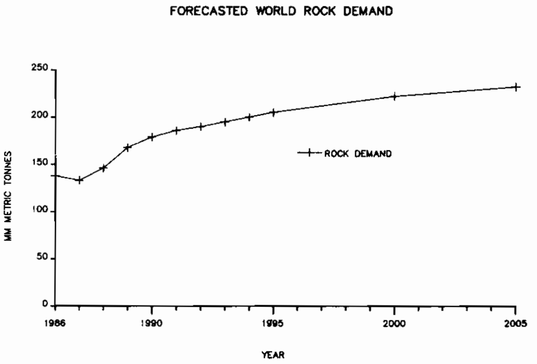

Figure 6

ROCK SUPPLY BEYOND THE RECOVERY PERIOD

All major world rock supply sources are forecast to remain in their supply roles through the turn-of-the-century. The market shares, however, are estimated to change substantially, with Morocco gaining a dominant role in world supply. The major suppliers with estimated contributions to future world demand are shown in the table below:

FORECASTED ROCK PRODUCTION BY MAJOR WORLD SUPPLIERS

	Million Tonnes of Rock				
	1985[1]	1990	1995	2000	2005
United States	48	46	55	50	46
Morocco	21	31	36	48	57
Jordan	5	6	10	12	13
Tunisia	5	7	10	11	13
USSR, East Europe	31	35	39	43	45
China	7	18	21	24	25
Remainder	26	36	34	34	33
Total Demand	143	179	205	222	232

[1] Production was 81% of capacity

Morocco, Jordan, and Tunisia are expected to more than double present capacity. China also has plans to double capacity, while the USSR is expected to grow by 50%. The remainder of the world will hold its own at about present capacity.

In the U.S., some replacement of depleted production capability would probably be supplied as follows:

U.S. ROCK PRODUCTION ESTIMATE
Millions of Tonnes

	1990	1995	2000	2005
Existing Capacity	55	46	32	22
New Capacity, Florida	0	3	11	15
New Capacity, N. Carolina	0	6	6	8
New Capacity, West	0	0	1	1
Total Demand	46	55	50	46

The need for replacement capacity in the U.S. is predicated on the assumptions that world markets will require this supply, and prices will justify the new capital required. This 24 million tonnes of new

FIGURE 6
Data Sheet
FORECASTED WORLD ROCK DEMAND
(Million Tonnes of Rock)

	Year											
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2005
Equivalent Rock Demand	138	133	146	168	179	186	190	195	200	205	222	232

capacity will most likely be furnished by expansions and extensions of existing mines in Florida. It is still probable that some new mining capacity could be built in central Florida between 1995 and 2005. We realize that this is not a very popular opinion today; however, it is less realistic to estimate that Morocco can achieve 75 million tonnes of capacity by 2005. No other large supply sources are evident.

As predicted in late 1982, the U.S. industry configuration has changed significantly and additional changes are probable. Most internal changes have occurred as a result of management imposed austerity programs to counter the disappearance of profit margins and business arrangements to reduce investment bases.

In central Florida higher cost operations are being "moth-balled" and producing mines are using reduced schedules. The forecasted long period of continued low demand will probably result in permanent loss of some capacity, but this is expected to be relatively minor. Two major problems for inactive mines will be holding cost and startup costs.

Those mines continuing to produce will, by necessity, "high-grade" their remaining reserves. The total impact of these considerations has not been completely analyzed, but looms as a large problem in competitive costs for the export market by 1995 and thereafter.

There has not been a movement within the industry to attack the problems of competetive position by improved technology, use of existing facilities and use of infrastructure resources for the future, and use of other inherent capabilities. Response to the future competitive cost problems is essential.

SUMMARY

- The major concern is the export market. The value of the dollar, the excessive trade deficit, and reduced world growth will have a negative impact on our industry for the next 2–3 years.
- Farm overproduction, surplus, and export problems will continue to have a negative effect on fertilizer demand and prices.
- World demand growth for phosphates may be decreasing from the traditional 3–3.5% per year rate to around 2% per year. This requires longer to balance demand against the present oversupply.
- World demand-supply balance will probably return by 1990–1991.
- U.S. demand-supply balance will lag behind world balance, returning by 1992–1993.
- In the U.S., the recovery period will be very difficult, continuing to force basic changes and restructuring in the industry.
- In spite of the interim difficulties, additional new supply from the U.S. will probably be needed to meet world demands after 1995. In our opinion, it is unrealistic to assume that all the new production requirements can be met by Morocco and other world producers.

ACKNOWLEDGMENTS

The work and background information developed in "The Phosphate 1985/1986" study by Zellars-Williams Company, Blue, Johnson and Associates, and FERTECON, were used extensively. This work was the result of many contributors within these companies and their help is greatly appreciated. Mr. A. J. Roth directly assisted in collection and updating of many of the statistics, which is gratefully acknowledged.

The assistance of the Jacobs Engineering/Zellars-Williams staff is also appreciated, as always.

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[1] A division of the Pace Consultants Inc., which is a Jacobs Engineering Group company.

[2] Feedback, Page 28, Fall 1986, Management Technologies, Inc.

[3] "U.S. Agriculture Trade—A Bleak Outlook," Page 10, by Ellen Welsh, Countertrade and Barter Quarterly, summer 1986.

[4] U.S.D.A.

[5] Phosphate 1985/1986, ZWC, Blue, Johnson & Assoc., FERTECON, June 1986, Multiclient Study.

[6] United Nations Population Studies, No. 86, data of 1982–1983, printed February, 1985.

Outlook for Potash

Rolf H. Holzkaemper
President
PCS Sales

OUTLOOK FOR POTASH

There is an old saying that forecasting is difficult, particularly when it concerns the future. Those of us who produce or consume potash forecasts have learned at least one lesson. Forecasts do not always lead to the decisions necessary to turn those forecasts into reality. For example, forecasts of increasing demand for potash in the early 1980s led to decisions to increase productive capacity; they did not lead to increased potash consumption. Figure 1 shows various potash demand forecasts made between 1968 and 1986. The more recent forecasts reflect slower growth in demand, but clearly those forecasts made a few years ago were all looking at demand which did not materialize.

**FORECAST VS ACTUAL
POTASH CONSUMPTION 1968 - 1990**

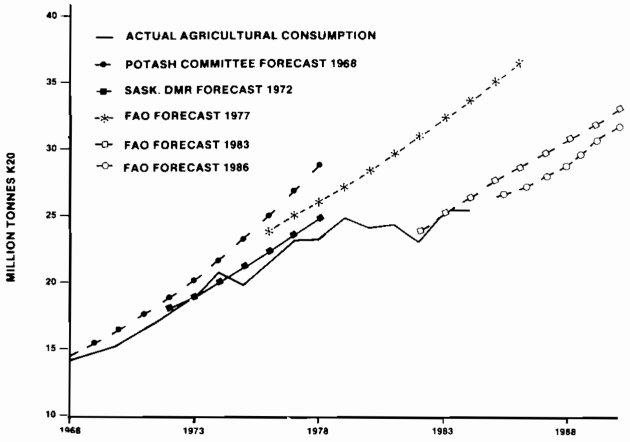

Fig. 1

Why do we continue to forecast, in spite of the fact that forecasts are frequently wrong? The reason is that in the process of looking ahead, we can build on our strengths, correct our weaknesses and identify major challenges and problems. The graph confirms how easy it is to be overly optimistic in one's outlook.

The outlook I will present today takes into account the overall supply and demand situation, as well as some economic factors facing our industry. I will discuss the world supply/demand situation and the major factors which will affect it to the mid-1990s. Then, from the perspective of a North American producer, I will present an outlook for the North American potash market and for the offshore market it serves and the factors which will determine the state of those markets over the next decade.

WORLD POTASH SUPPLY AND DEMAND

In order to set the scene for the discussion of world supply and demand, it is useful to identify the major players. World potash capacity is centered in four geographic areas: the Comecon bloc with the USSR being the world's largest producer; North America where Saskatchewan dominates; western Europe and the Dead Sea. The shares of world potash production (Figure 2) show the dominance of eastern Europe and North America. Figure 3 shows the distribution of potash sales. Developed market economies and centrally planned economies account for 81% of potash sales.

On a worldwide basis, excess productive capacity is expected to be a fact of life until the mid-1990s. PCS corporate forecasts, taking into account the most recent FAO/UNIDO/World Bank Working Group forecast, show that available potash supply will outpace anticipated growth in consumption with surpluses ranging from 4.6 million tonnes K_2O in 1986 to 4.1 million tonnes in 1990 and 2.2 million tonnes in 1995. (Figure 4)

**WORLD POTASH PRODUCTION
1985**

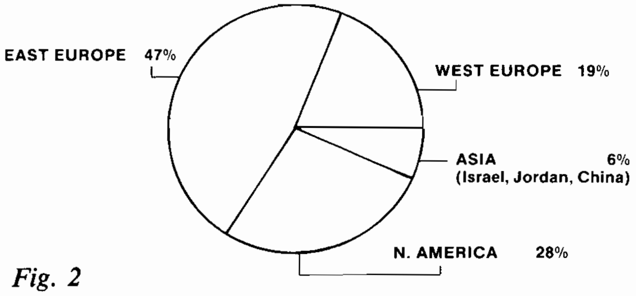

Fig. 2

WORLD POTASH SALES

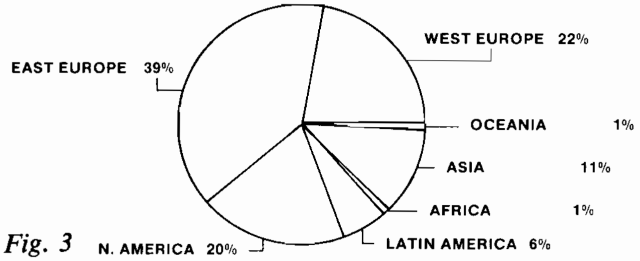

Fig. 3

**WORLD SUPPLY AND DEMAND
1970 — 1996**

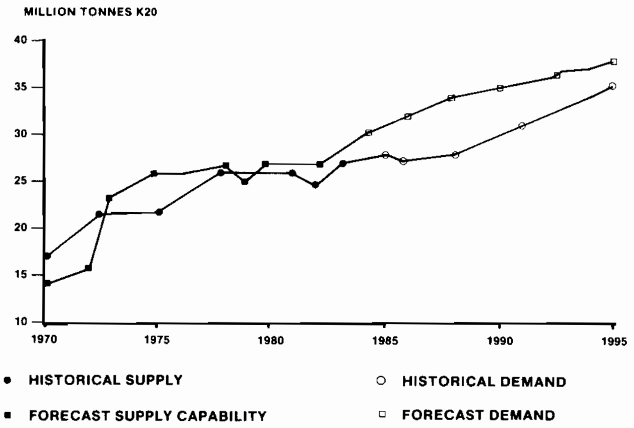

Fig. 4

An important caveat in interpreting the meaning of the forecast surpluses is that excess productive capacity does not automatically mean global oversupply. Some producers have historically reduced production in response to reduced demand. As an example, capacity utilization in the Saskatchewan potash industry will likely not exceed 65% in 1986.

Our latest forecast shows potash demand rising from 27.3 million tonnes K_2O in 1986 to 35.6 million tonnes in 1995. Production capability is expected to rise from 31.9 million tonnes to 37.5 million tonnes over the same period.

These forecasts suggest an average annual growth in world demand of 3% to 1995. Most of the growth will originate in Developing Market Economies (4.9%) and Centrally Planned Economies (3.6%) while Developed Market Economies (primarily North America and Western Europe) will show little growth—1.3%.

On the supply side, new facilities have come on stream in the past two years or so in Atlantic Canada (New Brunswick), Jordan and Brazil. Additional production is contemplated in thirteen countries including Canada, specifically in Manitoba and New Brunswick, and of course Michigan.

These new projects are being considered in the light of today's potash prices—prices which are less than 70% of the level at which a new mine in Saskatchewan could provide a 10% return on investment. The high ore grade and established supportive infrastructure in Saskatchewan rank among the world's lowest in capital and operating costs. It would therefore appear that a new potash mine cannot be justified in the next decade on economic grounds alone. Which projects will go ahead remains uncertain.

From the perspective of a North American consumer or producer. we can and should discount the large productive capacity that exists in the USSR and East Germany. About 80% of that capacity is tied to potash consumption in the Comecon countries. Both the USSR and East Germany are exporting potash to countries outside the Comecon trading bloc; however, these sales have been fairly stagnant over the past 10–15 years and the majority of these sales are tied to bilateral trade agreements. In total, about 2.5 million tonnes annually are sold outside the Comecon bloc. Figure 5 shows world potash demand and capacity excluding Comecon countries. Clearly, the surplus is smaller and disappears faster than the world total, but do bear in mind the product exported from the U.S.S.R. and G.D.R.

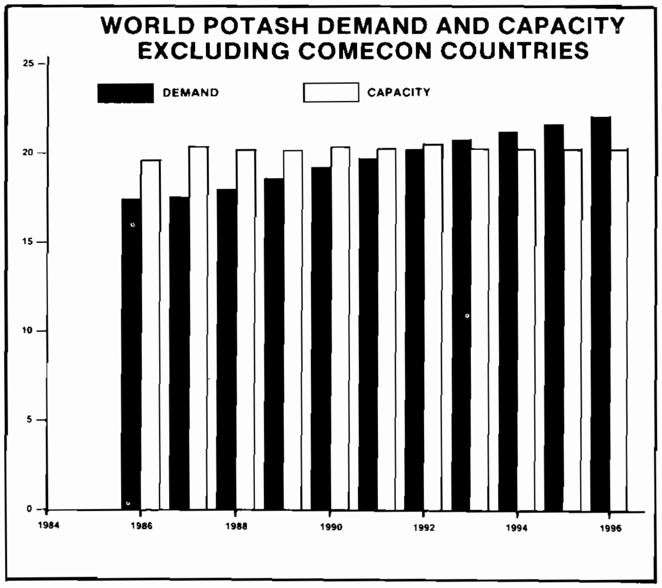

Fig. 5

Western Europe has a well-established potash industry which markets both indigenously and worldwide. However, France has become a net importer of potash; the U.K. sells most of its potash domestically; Spain markets primarily within Western Europe and sells only small volumes overseas. Thus, the Federal Republic of Germany (West Germany) is the major producer and exporter in and from Western Europe.

From the perspective of a North American potash producer, the markets which offer the most potential are those offshore markets where demand is not satisfied by trading bloc arrangements or by producers with logistical advantages.

NORTH AMERICAN POTASH MARKET

The North American potash market is one of the most open and volatile in the world. The volatility of North American potash demand since 1979 is shown in Figure 6. The open nature of U.S. demand, the predominant market in North America, is shown in Figure 7. Imports in general, primarily those from Canada, figure prominently in meeting U.S. demand.

In North America, large volumes of product are sold in defineable market areas. Indigenous production in the U.S. and Canada is joined by product from Europe and Israel. The dynamism of the market has been reflected in the dramatic swings both in volume and price over the past decade.

Since 1980/81, annual agricultural potash demand in North America has declined 18%. Total North American demand for calendar year 1986 will probably be 28% lower than the peak level reached in 1979. This decline is due to the deterioration in the North American agriculture sector. A major factor which continues to dampen the prospects of the U.S. farmer is reduced exports of U.S. grain.

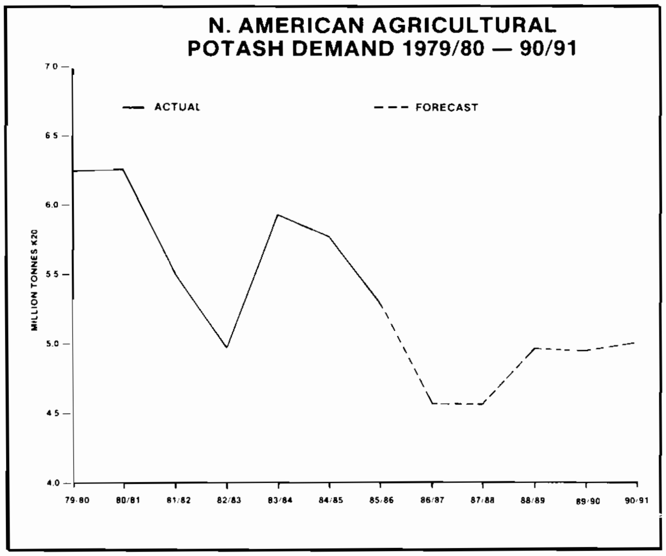

Fig. 6

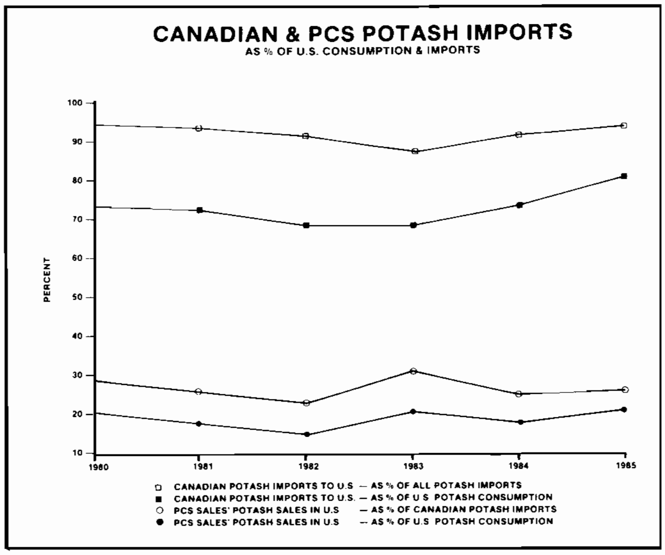

Fig. 7

The health of the corn producer is the main factor which drives or impedes potash sales. We have not seen record potash sales since 1979/80 and 1980/81 when U.S. corn exports were 2.4 billion bushels. Estimates of U.S. corn exports for 1986/87 are 1.2 billion bushels.

As shown in Figure 8, over the past five years, the U.S. share of export trade in coarse grains fell from 64% to 43%. In the same period, the Common Market's share rose by 64% to 9.2%; Australia's share tripled to 6.2%; Canada and Australia registered slight increases; and other countries' shares rose from 10% to 22%, including China, India and Thailand.

The U.S. response to the world grain trading situation, and particularly European participation, has been a series of farm programs which have had the effect of lowering world grain prices, setting aside planted acreage, and supporting farm income. While these short term goals have been achieved, the longer term goals of reducing production of U.S. grain and increasing the U.S. share of exports have not been achieved.

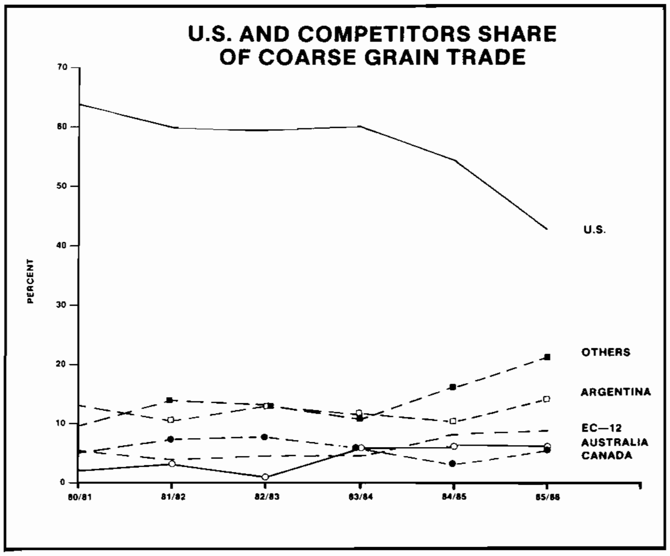

Fig. 8

The U.S. farm policy debate is increasingly being focused on two major alternatives. On the one hand, it is argued that mandatory production controls are necessary to balance the worldwide supply of and demand for agricultural products. Under this scenario, production would be held down and farm incomes supported at total annual costs of US $35–45 billion. On the other hand, it is argued that supply control programs will not work since farmers will be producing for demand set by fiat rather than by the market. Instead export loan programs are advocated which would allow U.S. producers to meet demand worldwide. The ultimate goal of the export subsidy program would be to regain the U.S. share of world agriculture trade.

Observers outside the agriculture sector are increasingly skeptical of both approaches. Concerns about the cost of farm programs emanating from the 1985 Farm Bill and the universality of such programs have been questioned. It is also pointed out that the cost of farm programs over the past four years has been US $64 billion; it can be argued that if this money had been used to reduce the estimated $US 75 billion in farm debt, the farm financial crisis would be virtually over.

For 1987, it appears that U.S. farmers will plant about 65 million acres of corn and that potash sales will fall. The forecast drop in sales varies from 2% to 10% depending on the acreage levels and application rates one assumes. It is certain that Congress will turn its attention to Farm Policy in 1987. What is not certain is the outlook for potash demand. It is the view of PCS Sales that calendar 1986 shipments in North America may be down nearly 10% from 1985; the same applies for the 1986/87 fertilizer year. 1987 will see a further drop of 5–6%; 1988/89 will be about the same as 1987 and we expect a modest recovery beginning in 1989/90.

OFFSHORE MARKET

From the perspective of a North American producer, the offshore market comprises those countries which are accessible, logistically and politically, from North America. Excluded in this are all of the Comecon trading bloc and western Europe. Western Europe is excluded on the assumption that a Saskatchewan producer, for example, has to overcome major logistical barriers to compete effectively in a market where five major producing countries are strategically placed with tremendous shorthaul transportation and distribution advantages.

Saskatchewan producers are well-positioned to supply the Pacific Rim and Latin American markets. Producer investment in port facilities in Vancouver provides reliability and stable costs based on unit train shipments. The Saskatchewan industry, through Canpotex, offers offshore buyers the advantage of multiple production facilities and in addition to the Vancouver terminals deep water access through the Great Lakes and Montreal as well as the New Orleans gateway.

As shown in Figure 9, four countries dominate offshore potash demand. Japan, India, China, and Brazil accounted for almost 60% of offshore potash sales in 1985. These markets differ substantially in their level of agricultural development and in their purchasing priorities.

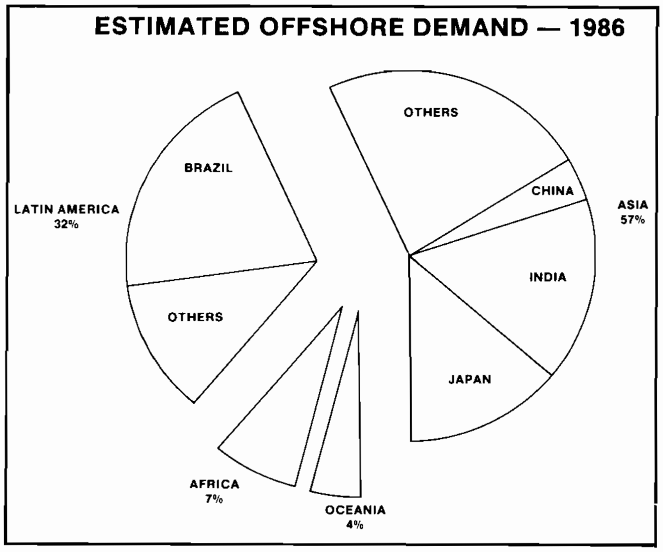

Fig. 9

Japan has a long history of fertilizer use. It is a stable market and no increase in potash demand is expected. Japanese purchasers' priorities are high quality product and reliable supply.

Potash demand in India has grown steadily. All potash purchases are handled by the state-owned Minerals and Metals Trading Corporation (MMTC). Fertilizer production and purchasing policies reflect government concerns. The Indian government has made countertrade provisions in foreign trade a priority. It is expected that countertrade will become a dominant issue for potash suppliers in years to come. A portion of Canpotex sales to India was made under countertrade provisions this year. This trend is expected to continue and expand.

Considerable potential exists for increased potash sales to China. Large areas in China have soils which are deficient in potassium. Potash consumption has not kept pace with consumption of nitrogen and phosphates. Currently China consumes over 15 million tonnes of nitrogen and 3–3.5 million tonnes of P_2O_5. Potash imports in 1986 are around 400,000 tonnes K_2O. This level reflects what I term the lag effect in transfer of technology. The need exists and may well be recognized. Educating farmers and overcoming import and distribution bottlenecks or economic restrains cause K and P demand to be delayed between five and ten years. As shown in Figure 10, potash imports have varied from year to year in part tied to shortages in foreign exchange. As well, internal transportation problems have constrained potash imports. Domestic production of potash currently takes place on a small scale at Chaerhan Lake in Qinghai province. Capacity at this location is to be expanded to one million product tonnes per year in the early 1990s.

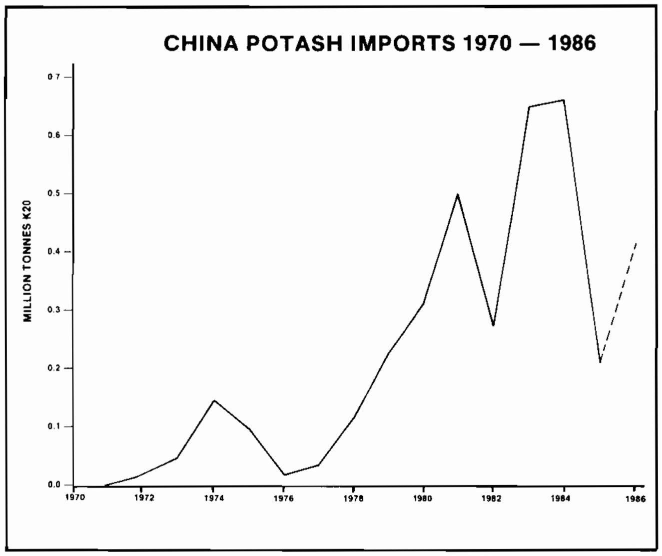

Fig. 10

Agronomic education is a key requirement in boosting potash demand in China. In addition to the regular programs by the Potash & Phosphate Institute, Canpotex is funding a substantial market development program, using radio plays, newspaper and television ads, and demonstration plots to educate Chinese farmers in the benefits of potash use.

In Brazil potash imports have recovered from the slump induced by that country's debt crisis. Government subsidies led to rapid growth in potash consumption through the 1970s but annual imports from 1981 to 1983 fell to less than 70% of the peak level reached in 1980. Potash use is again well established and recognition of its importance to the country's agricultural industry should ensure substantial consumption in the future. A new potash mine at Sergipe commenced production in 1986. The availability of domestically produced potash may further boost demand.

Even under current difficult conditions, there is a great potential for increased potash consumption in Asia and Latin America. Many countries' imports of potash have been limited by shortages of foreign currency. Some of these, such as Indonesia, Sri Lanka, and Bangladesh have been able to purchase potash from Canada using funds from the Canadian International Development Agency (CIDA).

PCS Sales believes that Canadian offshore sales will grow from 4 million tonnes KCl in 1986 to 4.5 million in 1987, 4.7 in 1988 and 5 million in 1989. This trend could be accelerated dramatically by a dedicated support of agricultural production in China.

INDUSTRY OUTLOOK

Based on a review of the world and North American markets, it is clear that the potash industry faces:

—excess productive capacity;

—reduced demand in mature markets; and

—delayed demand in developing markets.

These facts of life will continue to face the industry over the next decade.

For North American producers, growth in demand will be in offshore markets. This growth is coming, albeit at a slower rate than expected. Expansions in Canadian productive capacity have all been primarily targetted towards the offshore growth. Economic conditions generally and lag effect in transferring agronomic technology to the farm level in markets such as China, have strung out that growth. However, it will come.

Potash markets have been increasingly competitive. That in turn has led to a great deal of innovation as producers strive to maintain and expand markets. The deregulation of transportation in the U.S. and to a lesser extent in Canada has proved to be fertile ground for improvements in distribution facilities and service to meet customer needs. Canpotex, which markets Saskatchewan potash outside North America, has also developed new southern and eastern gateways—via New Orleans to Central and South America and via Thunder Bay to Europe.

The future of U.S. potash producers is uncertain. A U.S. Bureau of Mines report stated that "American producers suffer from a competitive disadvantage in respect to its competitors." The report cited higher production costs, lower ore grade and higher-cost processing as the major causes of that disadvantage. Likely it will be the mines engaged in producing higher value specialty products that will best withstand the current cycle of oversupply. In the long term a yet higher percentage of U.S. potash demand will be met by imports.

The Saskatchewan potash industry has built its reputation as a reliable supplier of quality product. In recent years, operations have become leaner and marketing techniques increasingly tailored to fluctuating levels of demand. It can be expected to remain as a reliable and efficient supplier to U.S. customers in the future.

It is evident that this situation suggests some major structural changes. What follows are some thoughts on where those changes may be leading us.

The present overcapacity situation has not had an equal impact on all producers. The USSR and East Germany operate in centrally-planned economies where they are sheltered from the impacts of the interaction between supply and demand as we know it in North America. Western European markets have been the near exclusive domain of indigenous producers and established importers. The "battleground" for customers and market share has been in North America and in what I view as logistically and economically accessible overseas markets.

As noted earlier, overcapacity has not led to an equal oversupply in each geographic market. Statistics indicate that production in Saskatchewan has ultimately been matched to demand. When inventories became excessive, producers shut down plants, as shown in Figure 11. Unfortunately these measures have led to higher costs.

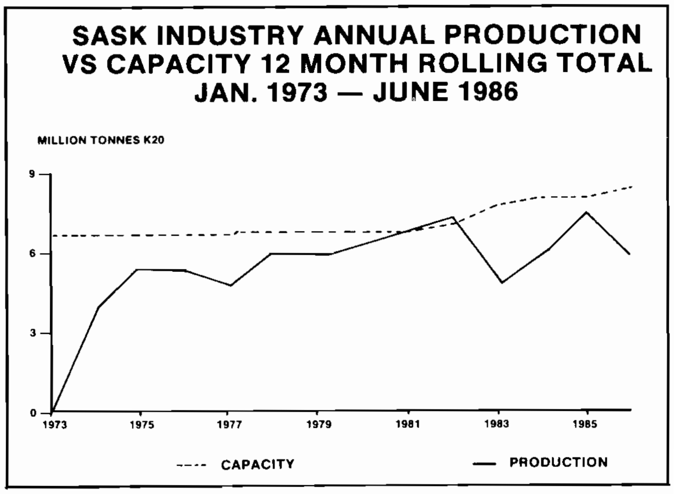
SASK INDUSTRY ANNUAL PRODUCTION VS CAPACITY 12 MONTH ROLLING TOTAL JAN. 1973 — JUNE 1986

Fig. 11

In the face of prevailing geological conditions and the need to manage corrosion in the surface operations, a long term shutdown of a potash mine in Saskatchewan translates into an annual cost of C $5–7 million per mine, unless one walked away from the property altogether.

Additional initial shutdown costs could amount to C $10–12 million. These cost levels justify a shutdown only if the property is to remain closed for at least 4 or 5 years. The revenue levels experienced in 1986 may cause some or all operators to closely review their options.

A factor which should not be lost sight of is the always present danger of mine flooding. In early 1986, the 2 million tonne per year Berezniki III plant in the USSR was flooded. It is widely considered that this mine is not likely to be rehabilitated for a long time, if ever.

A similar danger was narrowly averted in the spring of 1985 at PCS Mining Rocanville Division. IMC's K2 mine at Esterhazy, Saskatchewan has been experiencing water inflow since December 1985; likewise PCA in Saskatchewan has been encountering increasing water levels for some time.

We should not assume that water inflows will eventually lead to mine closures; however, we must bear in mind the large costs associated with management and stoppage of water.

Another factor affecting cost management is the proliferation in North America of secondary storage. More than half of producer-held inventory is now located downstream. The market area served by each local warehouse is quite small; the producer is required to carry a relatively larger inventory to service a smaller market.

In spite of the needed increase in producer-held inventory, statistics compiled by the Potash & Phosphate Institute show that inventory levels have been gradually but steadily falling. Present inventory in the hands of producers is approximately 3 million tonnes KC1. It should be noted that some 50–55% of the total is spread over several hundred storage locations.

The fertilizer industry is undergoing change. Financial and economic circumstances are changing the ways in which producers, dealers and farmers organize themselves to do business and to survive.

Potash producers must analyze, each one for itself, the outlook for demand in North America and offshore and its anticipated role in each market. Decisions will vary from multi-product producers to multi-mine and single-mine operators.

There will not be a rapid turnaround in our industry within the next four years. Growth in demand will be slow and primarily come in offshore markets. Once crop production returns to higher levels, farm input costs will be slow to follow. Given the economic circumstances of the basic fertilizer producers, I am inclined to believe that prices may have bottomed as we witness a stiffening attitude in response to price concessions demanded by dealers.

I do not exclude some long term or permanent mine shutdowns. Surviving potash producers can be expected to operate leaner than ever before; producer held inventories will come down further to preserve cash flow and service levels at the expense of the producer will be trimmed.

Quite clearly there is no need for a new potash mine in the next 10 years. It is difficult to be optimistic. We must stimulate and create new demand through agronomic market development programs. I am convinced, however, that our industry will see better times, hopefully sooner than later.

At the conclusion of Monday morning's session, Mr. John L. Medbery, Chairman, together with Mr. Charles Davis, TVA and Mr. James Schultz, IFDC presented Mr. Travis P. Hignett with an award. The citation read as follows:

"The Fertilizer Industry Round Table Outstanding Service Award"

awarded this seventeenth day of November 1986 by The Fertilizer Industry Round Table to

TRAVIS P. HIGNETT

In recognition of a lifetime of outstanding service and technical contributions to the fertilizer industry, farmers and people of the World."

Monday, November 17, 1986

Afternoon Session
Moderator:

Mabry M. Handley

The Stamicarbon Strip Venturi Scrubber A New Concept of Dust and Fume Extraction

J.P. Nommensen
Stamicarbon B.V.—The Netherlands

Presented by Marcel A. Tanke
Stamicarbon B.V.—The Netherlands

SUMMARY

A new scrubber design has been developed by Stamicarbon for the dedusting of large-scale particulate emissions such as from fertilizer prilling towers and rotary dryers. This paper discusses the operating principle and a number of improvements such as the use of two interactive auxiliary media and of strip venturis, which make for high flexibility with respect to capacity, pressure drop and collection efficiency. Re-entrainment of the concentrated wash liquor is negligible thanks to a specially designed demister.

The upscaling factor is unity, which means that commercial units are essentially identical to the pilot unit. Consequently, the pilot unit can be used for the purpose of determining the maximum energy economy at the desired collection efficiency for any service. Higher capacities can be attained through paralleled operation. A number of experimental results are discussed.

INTRODUCTION

Environmental legislation that has been introduced in recent years has had a profound impact on the fertilizer industry in that particulate emissions need to be dedusted more thoroughly than ever.

This has prompted Stamicarbon, the licensing subsidiary of DSM, to develop a new scrubbing system for its fertilizer processes such as urea and high-density ammonium nitrate. First, an inventory was made of emissions in these processes and their particle size distributions. Evaluation of proven dust control technologies soon showed that there was no commercial design that completely filled the bill, particularly in respect of physical weight and operating cost for proper collection of submicron particles.

PRELIMINARY INVESTIGATION

In the past few years Stamicarbon has tested many small-scale dust collectors in a number of urea plants. The performance figures so collected were brought under the following common denominators in order to allow meaningful comparison of the running cost per 1000 m3/h air stream versus collection efficiency.

—Air flow	100,000 m3/h
—Airstream inlet temperature	70°C
—Relative humidity of airstream	5%
—Dust concentration	150 mg/m3
—Dust granulometry, see Fig. 1	70% wt < 1 micron

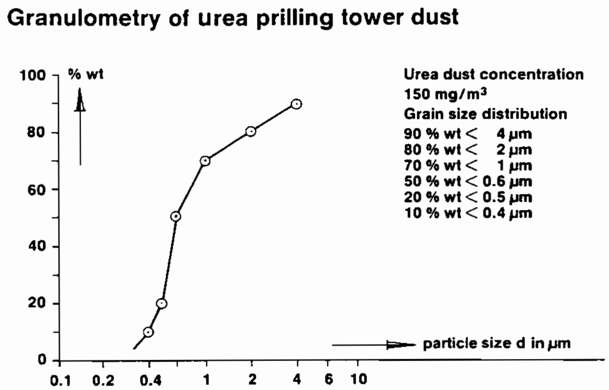
Granulometry of urea prilling tower dust

Fig. 1

Also calculated were:

—The energy required per 1000 m3 of airstream.

—The cost of cleaning 1000 m3 of airstream in terms of depreciation and energy.

The installed cost of the equipment has been assumed to be twice the F.O.B. cost, including for fan, pumps and motors. Depreciation is over 10 years, so 80,000 hours, and the cost of 1 kWh is 15 Dutch cents, which equals 6 dollar cents.

The relation between cost and dust collection efficiency is shown in Fig. 2.

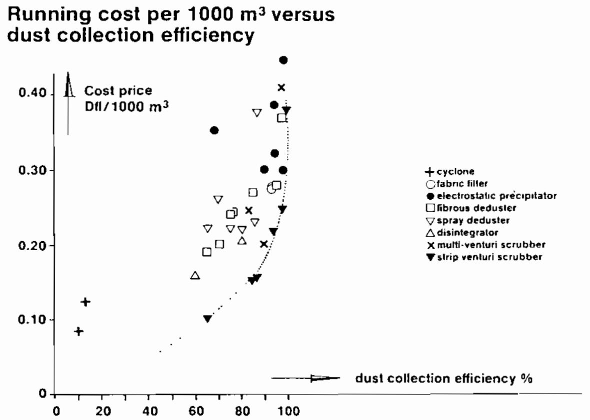

Fig. 2

All in all, the preliminary investigation indicated that fundamental conceptual improvements were needed if compliance with the environmental regulations was not to be too heavy a financial burden.

The new design had to be light-weight so that it could be placed atop existing prilling towers, so obviating the need for piping to return the off-gases to ground level. Also, it had to offer wide flexibility with respect to capacity and collection efficiency but yet low energy consumption. These requirements and considerations have resulted in the development of the Stamicarbon Strip Venturi Scrubber.

OPERATING PRINCIPLE

The design of the pilot unit is shown in Figure 3.

The scrubber consists essentially of a spray zone where the dry air stream is humidified by means of the recirculating spray liquor, being the first auxiliary medium. In this way, the bulk of particulates is scrubbed out. The wash liquor is largely separated from the air stream and a second auxiliary medium is injected in zone II. This interacts with the remaining fine droplets of the first auxiliary medium entrained in the air stream. Interaction between the two auxiliary media is an essential feature of the design. One auxiliary medium may already be present in the feed stream whilst low-pressure steam is often used as the other. As water vapour condenses on the fine droplets of the first auxiliary medium (the recirculating wash liquor) the fine dust particles in the air stream are driven to the cold liquor droplets by thermoforetic and diffusioforetic forces. This is why the collection efficiency is higher than it would be without the interaction.

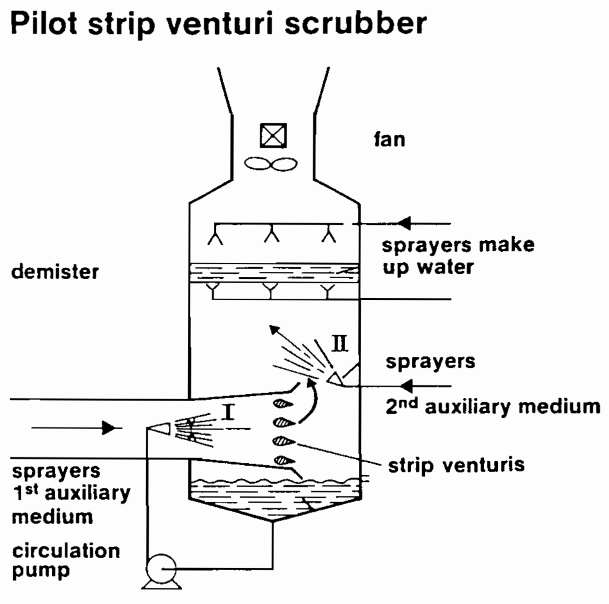

Fig. 3

The second auxiliary medium may also be a gas, for instance ammonia, that reacts with the acidified first auxiliary medium to produce a similar interaction. The higher collection efficiency so achieved is apparent from the results of Tests 2, 6 and 7.

Finally, the fine liquid droplets are removed in a multi-layered demister package, the smallest submicron particles being caught in an intermediate agglomeration package and separated in a subsequent demister package. Evaporated water is replenished by condensate being sprayed intermittently onto the demisters.

The geometry and overall design of the venturi strips is the same for the pilot unit and the commercial unit except that the numbers of sprayers and venturi strips should be related to the capacity ratio.

The residence time and gas and liquid velocities are the same for both units.

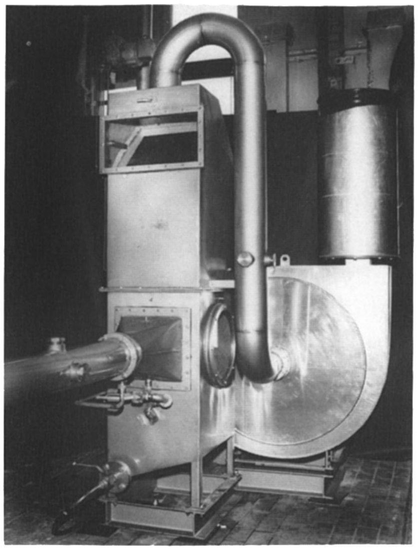

Fig. 4

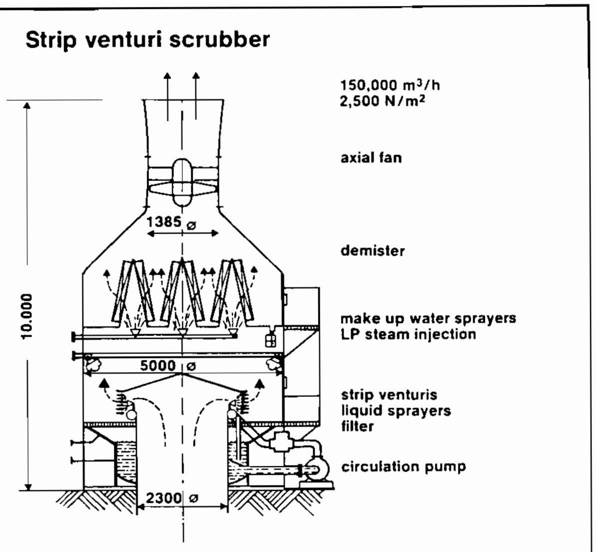
Strip venturi scrubber

Fig. 5

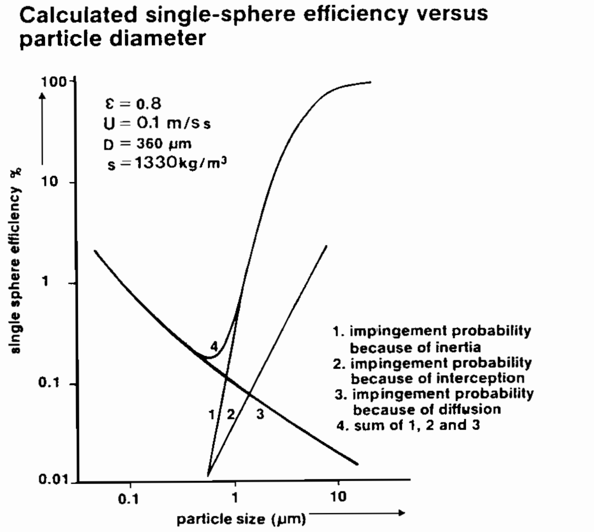
Calculated single-sphere efficiency versus particle diameter

Fig. 6

DUST COLLECTION PERFORMANCE AND EFFICIENCY, THEORETICAL ASPECTS

The dust collecting effect of the Strip Venturi Scrubber is based on a combination of the following principles:

—Saturation of the airstream with water vapour and wetting of the dust particles for better adhesion to the liquid surface. The droplets will evaporate in a dry gas atmosphere so that the chances of the dust particles impacting will be significantly smaller than in a humidified gas stream.

—Impaction of dust particles on droplets as a result of inertia, interception and diffusion, stimulated by the interaction of the auxiliary media. The collection efficiency is the sum total of the individual impactions and can be predicted fairly accurately as discussed in literature.

Figure 6 shows the single-sphere efficiency, which is the calculated impaction probability of a particle against a sphere of 360 microns in diameter, as well as the improvement in collection efficiency to be expected from utilizing the diffusion effects.

The dimensional analysis indicates that collection performance through inertia and interception depends mainly on five parameters.

$$\eta \text{ scrubber } f(K, R_e, W, Fr, N)$$

where

$$K = \frac{sd^2U}{18v\ D} \qquad Fr = \frac{U^2}{gD}$$

$$R_e = \frac{SUD}{v} \qquad W = \frac{s}{S} \qquad N = \frac{Qq}{fvd^2\ DU}$$

An approximate equation has been developed for the collection efficiency where R_e lies between 0.50 and 50, while ignoring electrostatic influences and diffusion.

$$\eta_1 \left([1 + (1.53 - 0.23 \ln R_e + 0.0167 \ln^2 R_e) (2.K)^{-1}]^{-2} + \sqrt{\frac{2}{R^eW}} \right) \left(1 + 3 \frac{2K}{R_eW} \right)$$

The electrostatic effects are significant mainly where $K < 1$ and $R_e < 10$.

The contribution of Coulomb forces to the collection efficiency is approximately as follows:

$$\eta_2 \left[1.22(2 - \ln R_e)N \right] \left[\left(\frac{K}{2\sqrt{R_e}} \right)^{1.5} + 1 \right]^{-1}$$

The diffusion effect is important for particles smaller than 0.5 microns; its contribution to the collection efficiency is approximately:

$$\eta_3 = \frac{2.9}{Ko^{1/3}Pe^{2/3}} + \frac{0.624}{Pe}$$

where

$$Ko = -1/2 \ln (1 - \varepsilon) - 0.5$$

The diffusion coefficient Dc is inversely proportionate to the particle diameter d; hence

$$\eta_3 : : (UDd)^{-2/3}$$

In other words, the collection efficiency through diffusion decreases with increasing velocity U and/or particle size D and d.

The overall collection efficiency then is

$$\eta \text{ total} = \eta_1 + \eta_2 + \eta_3$$

While not all effects can be fully explained yet, current theoretical and practical research has yielded valuable information on the correlation and influence of the variables mentioned above. By keeping the shape factors constant, the pilot scrubber makes it possible to measure the collection efficiency and power consumption for a given airstream. Furthermore, the performance of the pilot unit can be optimized selectively by means of the equation last mentioned. Consequently, the fractional collection curve for a given airstream and the energy requirement per 1000 m^3 for a given overall collection efficiency and equal particle size distribution can be applied to a commercial design without any adjustment.

TEST RESULTS OF PILOT UNIT

Tables 1 and 2 show the averaged results of a large number of tests with and without two interacting auxiliary media. For convenience, the fractional collection figures are compared for the whole submicron area.

Table 1 first shows the process variables relating to Tests 1 through 4.

The collection efficiency is calculated on the basis of the particle concentration measured at the scrubber outlet. The spray nozzles used for the auxiliary medium in zone I were commercially available full-cone nozzles, producing droplets in the range of 100–500 microns. The spray nozzles used for introduction of the second auxiliary medium in zone II in Tests 1 and 2 were of the "Laval" nozzle type, those in Test 3 of the full-cone nozzle type referred to above.

As can be seen, the collection efficiency in Test No. 1, with interaction of steam, is 5% better than in Test No. 3 under otherwise equal test conditions. In Test No. 3 the second auxiliary medium was not steam but the first medium was re-used.

No second auxiliary medium was used in Test No. 4.

In Test No. 2 the second auxiliary medium was gaseous ammonia and the first was acidified with sulphuric acid. Here, the fractional collection efficiency in the submicron range is 10% higher than in Tests 3 and 4.

Table 2 shows process variables relating to Tests 5, 6 and 7.

For these tests, ammonia vapour was introduced in zone II and an acid liquor in zone I. The size distribution of the particles to be removed from the gaseous medium and of the removed particles are given in the graph of Fig. 7.

In Fig. 7 the curves A and B represent the particle-size distribution of the feed material in Tests 5 and 6 and in Test 7, respectively. Curve C represents the particle size distribution at the scrubber outlet.

TABLE 1

Volume flow	: 1000 m3/h
Pressure	: atmospheric
Temperature	: approx. 40°C
Relative humidity	: approx. 70%
Particles	: urea dust
Particle concentration	: 250 mg/m3
Particle size distribution	: 100% wt < 100 micron
	: 90% wt < 10 micron
	: 75% wt < 5 micron
	: 50% wt < 1 micron
	: 5% wt < 0.5 micron
Airstream velocity	: 10 m/s
Air velocity at Venturistrips	: 50 m/s
Air velocity before demister	: 2 m/s
Total pressure drop across	: approx. 1500 N/m2
Energy consumption	: approx. 0.4 kWh/1000 m3

	Test 1	Test 2	Test 3	Test 4
Aux. medium I	20% wt urea solution	20% wt urea solution + 1% H_2SO_4	20% wt urea solution	20% wt urea solution
—amount	1 m3/h	1 m3/h	1 m3/h	1 m3/h
—temperature	20–40°C	20–40°C	20–40°C	20–40°C
Aux. medium II	steam	NH3 (vapour)	20% (m/m) urea sol.	—
—amount	1 kg/h	0.2 kg/h	1 m3/h	—
—pressure	2 bar	12 bar	—	—
—temperature	120°C	5°C	40–60°C	—
—collection efficiency submicron particulate	55%	60%	50%	50%

TABLE 2

Volume flow : 1000 m3/h
Pressure : atmospheric
Temperature : approx. 30°C
Relative humidity : 40%
Particles : urea dust
Particle concentration : 250 mg/m3
Particle size distribution : see Fig. 7
Energy consumption : 0.2 kWh/1000 m3

	Test 5	**Test 6**	**Test 7**
Aux. medium II	Ammonia	Ammonia	Ammonia
amount fed	250 ppm	250 ppm	250 ppm
Aux. medium I	20% wt urea solution	20% wt urea solution + 0.7% wt H2SO4	20% wt urea solution + 1.0% wt H2SO4
amount fed	1 m3/h	1 m3/h	1 m3/h
collection efficiency sub-micron particles	50%	52%	55%

In Test No. 5, the second auxiliary medium was ammonia but the first was not acidified. As a result, the level of interaction was significantly lower, which explains why the collection efficiency is 10% lower than in Test No. 2.

In Test No. 6, the first auxiliary medium was acidified only lightly, corresponding with a 2% improvement of the collection efficiency in the submicron range.

Also in Test 7, the recirculating wash liquor was made more acid, resulting in a greater improvement of the submicron collection efficiency.

CONCLUSIONS

Injection of a second auxiliary medium after the strip venturis improves the collection efficiency for sub-micron particles by about 10%. A similar improvement without the interactive effects of a second auxiliary medium would call for a significantly higher pressure drop. Consequently, the running cost per 1000 m3 is lower than for other dedusting systems, assuming equal service conditions. The Strip Venturi Scrubber is particularly suitable for airstreams whose submicron fractions need to be reduced.

Particle size distributions

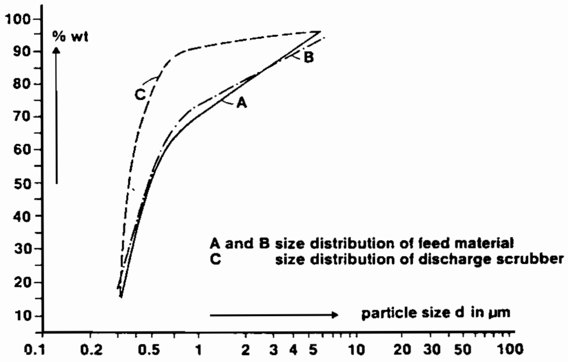

Fig. 7

NOMENCLATURE

D = drop diameter m
Dc = diffusion coefficient m2/s
U = relative velocity m/s
Re = Reynolds number $\frac{SUD}{v}$ —
W = specific mass rate —
s = specific mass of the particles kg/m3
S = specific mass of the gas kg/m3
Fr = froude number —
g = acceleration due to gravity m/s2
K = inertia parameter —
v = viscosity of the gas medium N sec/m2
N = parameter for electrostatic forces —

$$N = \frac{\text{elecst. force}}{\text{inertial force}}$$

$$N = \frac{Q.q}{fvd2\ DU}$$

Q = electrostatic charge of droplet per unit area C
q = electrostatic charge of dust particle C
f = constant —
porosity —

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Dual Pipe Reactor Process for DAP, NP and NPK Production

P. Chinal, C. DeBayeux and J.F. Priat
CdF Chimie AZF, France
Presented by
C. DeBayeux

1. *FOREWORD*

When reviewing how most of the granulated fertilisers containing ammonium phosphate are now produced in the world, it becomes obvious that

- —the production are generally very classical
- —few (and minor) improvements have been achieved during the last decades

Most of these processes include a reactor vessel of high capacity (neutralizer) where ammonia (often gas) reacts with phosphoric acid up a molar ratio N/P of 1.35 to 1.5 when DAP is to be produced. The phosphoric acid, prior to its introduction in the neutralizer, generally goes through a washing section designed to recover the ammoniac losses from the neutralizer and the granulator. If needed for the production of fertilisers some sulphuric acid may also be added in the neutraliser.

The neutraliser may or may not be stirred; most of the time it is operated at atmospheric pressure or under a slight pressure.

The ammonium phosphate slurry flowing from the neutraliser must be fluid enough to flow by gravity, or to be pumped, into the granulator where more ammoniation takes place. A minimum water content is thus needed, between 12% and 25% according to the design. As a consequence a high recycle ratio (often higher than 5) and a high drying fuel consumption are unavoidable.

A typical flow-sheet for these processes is given in Fig. 1.

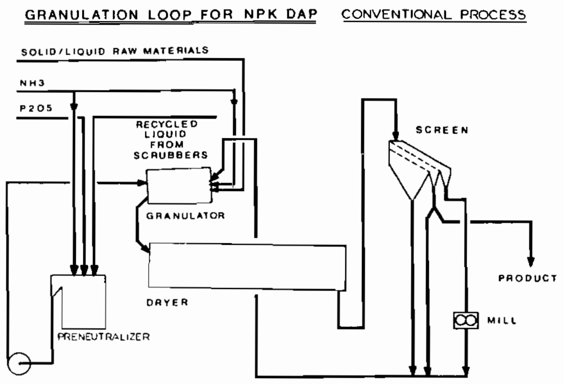


Fig. 1

It is somewhat surprising to ascertain that the powerful USA fertilisers industry still works along these lines for DAP production and that relatively recent investments have been made using this process.

It is all the more surprising that the first industrial uses of a pipe reactor, a possible substitute for the neutralizer, took place in the USA. It is in the USA too, that much information on the pipe reactor has been made available through TVA publications and demonstrations as well as papers given in various conventions (IFA, Round Table, AICHE, etc.).

An interesting historical point on pipe reactors, including a significant bibliography, is included in a paper given in 1982 at the IFA meeting in Kalithea (Greece) by MM. Ph. Moraillon and Y. Cotonea (Saving on Energy in Granulation of Fertilisers by a new method of using pipe reactors).

A table, extracted from this paper, is given in Fig. 2.

How could the lack of success of this new technology be explained?

It is probably related to the operating problems the first pipe reactors were faced with (scaling in the pipe, plugging inside the granulator) and the disappointment of producers considering the few improvements of granulation brought in by the use of a pipe reactor.

Use of the Pipe Reactor	Company	1st Date
Direct feeding of granulator-ammoniator mixing drum	Swift	25.01.50
	Continental Oil	3.02.65
Feeding of a granulator-ammoniator drum via a cyclone separator	Swift	3.11.52
	Consolidated Mining	30.12.60
	Dorr-Oliver	30.10.62
Direct production of solid ammonium salt, in particular MAP powder, by prilling	Kerley	27.01.55
	Swift	1.04.65
	Sonic Eng.	17.08.65
Liquid fertiliser based on ammonium orthophosphate	Barnard	28.11.56
	Monsanto	21.01.63
	Barnard	30.08.60
	Sonic Eng.	17.08.65
Ammonium polyphosphate solid or in solution (liquid fertilizer 10.34.0 or 11.33.0), from orthophosphoric or superphosphoric acid	Collier Carbon	22.08.60
	Dorr-Oliver	18.03.64
	W.R. Grace	30.03.64
	Swift	18.08.65
	W.R. Grace	30.08.65
Manufacture of ammonium nitrate (Stengel packed pipe reactor)	Commercial Solvents	3.05.47

Figure 2: Pipe Reactors - Patents applied for between 1947 and 1965

The timorous use of promising, but still imperfect, new technologies without the will to promote them may well jeopardize their future for a long time. In the same field the risky choice of a brand new process, without any industrial background, could if it fails, induce a move back to a technology proven in the past.

Maybe it happened in India when the failure of a new fluidised bed granulation process appears to have been the main reason for the choice of a traditional process for new units.

Nevertheless conclusive improvements have been made in the production of granulated fertilisers based on ammonium phosphates when using a pipe reactor process and specially the AZF Dual Pipe Reactor system. This process has now been widely proven as 50 pipe reactors are now operating in 12 different countries and represent together more than 12 million tons of fertiliser per year.

2. *THE DUAL PIPE REACTOR PROCESS*

2.1. *Origin of AZF Pipe*

Although the first patent covering the dual pipe reactor process is only dated 1981, it has always been the will of our production people to eliminate the troublesome neutralisers.

Indeed this vessel was an actual bottleneck, hindering most of the improvements in granulation we were looking for:

—decrease of the recycle ratio

—increase of production capacity

—decrease of energy consumption (power, steam, oil)

—decrease of pollution

—increase of flexibility

—adaptability to a wide range of formulations.

Detailed reports on the problems inherent in the neutraliser operations are presented in papers given by P. Chinal, Y. Cotonea and C. Debayeux during the AICHE meeting in Clearwater - May, 1984 (3) and the United Nations Conference in Istanbul - May 1985 (4) as well as in a communication made in New Delhi, India - December, 1985 by Mr. Sundaravadivelu (5) to the India Association of Fertiliser Producers (FAI).

At the beginning, early in the 60's AZF had been testing two different ways, first in pilot plant, then industrially, of reacting ammonia with sulphuric and/or phosphoric acids in various pipe reactors and in a "free-air" reactor (patented 1967).(6)

Having mastered the concept and the running conditions of the pipe reactors (scaling, corrosion, spraying of the slurry) AZF was in a position in 1976 to build two new plants without neutraliser, the granulator being fed by a sulpho-phosphoric slurry delivered by a pipe reactor.

In both these new plants, as well as in old plants where the neutralisers were progressively removed, the pipe reactors gave complete satisfaction.

On the other hand the decrease of the recycle ratio and the increase of capacity were somewhat disappointing when producing high grade fertilisers (17.17.17–18.22.12–23.23.0 with ammonium nitrate) and DAP (18.46.0).

As a matter of fact, the large amount of steam and heat entering the granulator was inducing over-granulations of these products.

Other fertiliser producers working with a pipe in the granulator have had the same problem and recommend the use of cold recycle to control granulation (e.g., UKF).(7)

If AZF chose any other solution when looking elsewhere in the granulation loop, it could be possible to use the extra heat and liquid phase.

2.2. *The Second Pipe*

It is clear enough that the right place to crystallise salts fast and to eliminate steam, could be the drier. Thus a second pipe was fitted at the drier inlet, allowing the best possible use of the reaction and crystallisation heats; a nuisance in the granulator turned out to be a help in the drier. This pipe, the salient point of the AZF process, produces a powder of monammonium phosphate which crystallises in the gas of the drier. Part of the powder (about 30%) is carried away into the cyclones of the dedusting loop, the remaining part (about 70%) crystallises on the fines of DAP and is recovered after screening. The granulometry of the MAP powder (80% bigger than 50u) is such that the efficiency of cyclones is nearly 100%. This fine and warm powder, slightly wet and plastic, is highly reactive and very easy to ammoniate and granulate along with the recycle product and the slurry entering the granulator.

A simplified flow-sheet of the dual pipe process is given in Fig. 3.

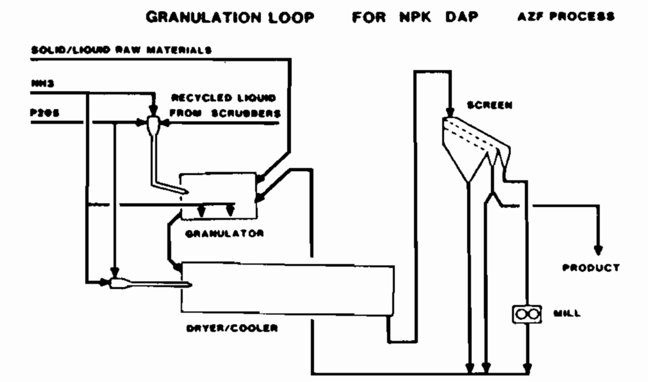


Fig. 3

2.3. *The "Third Reactor" of AZF Process*

While improving the design and the operating conditions of the 2 pipes in the granulation loop, we soon realised that it was necessary to control the unescapable "third reactor" existing in a plant working on diammonium phosphate.

This "third reactor" is the gas washing section which must recover the ammonia escaping from the granulator and the dryer. For economical reasons, as well as because of pollution rules, an efficiency of 99% at least is needed for the washing section (no liquid effluents, very low fluorine emission). The third reactor must be specifically adapted for the fertiliser industry. AZF has developed its own gas washing system generally including 2 venturi and a cyclonic scrubber.

Using the dual pipe system, washing the effluent gas is much easier than using any other process. The ammonia losses from the granulator (ammoniation spargers + pipe reactor) are much lower than the losses from granulator + neutraliser in a conventional process.

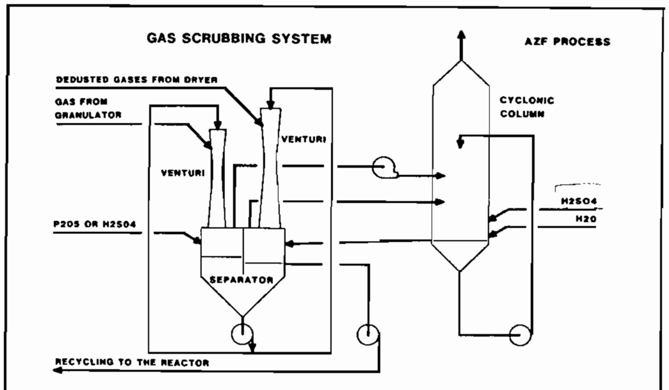


Fig. 4

3. DESCRIPTION OF A TYPICAL DUAL PIPE PLANT

3.1. *Granulation Loop*

The process works with a classical granulation loop, phosphoric acid and/or sulphuric acid are neutralised in two pipe reactors one fitted in the granulator, the other in the drier.

The pipe reactor in the drier is fed with 50–54% phosphoric acid and gaseous or liquid ammonia. The phosphoric acid may or may not be subject to some preliminary decantation. According to the original rock, the operating conditions may vary. AZF has experimented in this pipe reactor acids produced from Togo, Morocco, Tunisia, Florida, Taiba and Jordan rocks. Gaseous ammonia may be used when it is necessary to condition the air of the cooler.

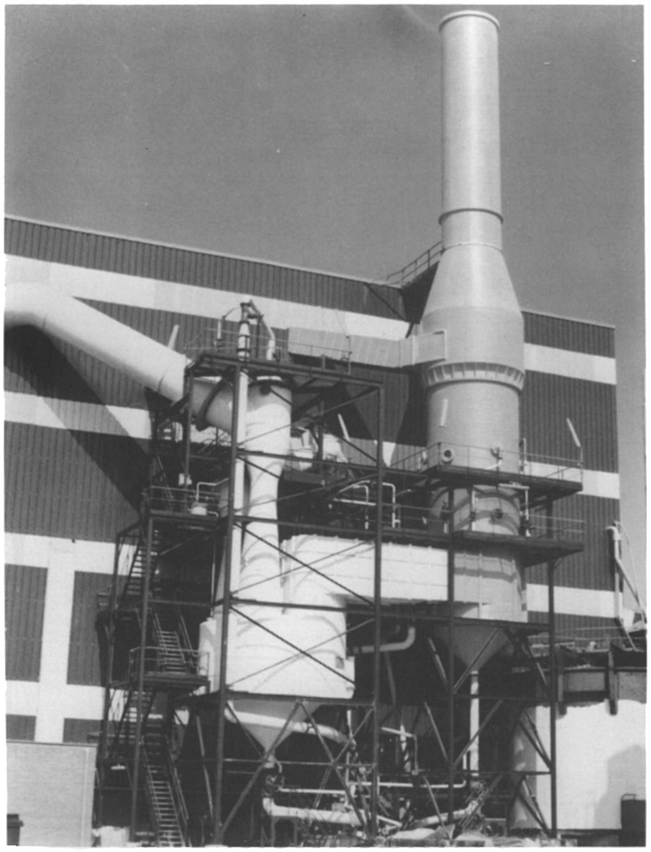


Fig. 4a bis — **AZF Scrubbing system.**

Normally the pipe works with an N/P molar ratio of 1.05, the ammonia efficiency thus being higher than 98%. Both flows of acid and ammonia are automatically controlled and adjusted.

At present, the biggest AZF pipe reactor in the drier is able to be fed with 2,5 t/h ammonia; for new projects we consider 5 t/h if possible.

The pipe reactor in the granulator is designed to get rid of all the other fluids needed for a given formulation.

- Liquid or gaseous ammonia (depending on need for cooling)
- unclarified phosphoric acid at various concentrations
- Sulphuric acid (70% to 98%)
- Liquid effluents from the gas washing section
- Should be case arise, ammonium nitrate or urea solution (if needed these solutions can be sprayed directly onto the bed). The ammoniation ratio N/P could vary between 0.6–1.8 depending on the formulation. The ammonia efficiency depends on the N/P ratio and is generally located between 90% and 99%.

At present the biggest AZF pipe reactor in the granulator is fed wwith 14 t/h ammonia.

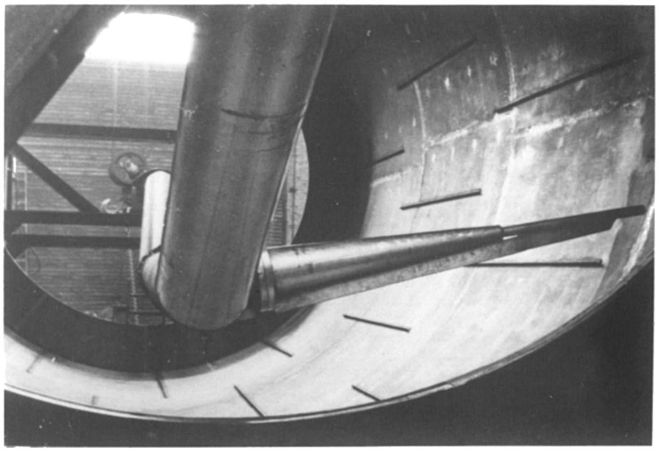


Fig. 5 — **Ammonia sparger.**

3.2. *Special AZF Device*

The result of a close collaboration between production and development people was the elaboration of special equipment aimed at resolving some specific problems.

- A brace-shaped ammonia sparger, electrically driven, leaves free the whole inside of the granulator. It is thus possible to spray the slurry onto the bed without any plugging inside the granulator (see Fig. 5).
- The chute between granulator and drier, which is normally a troublesome place (scaling – plugging) is fitted in AZF plants with an automatic cleaning system thus avoid any manual cleaning (Fig. 6).
- AZF has designed a new hammering system on the drier, efficient and not too noisy, needing little maintenance (Fig. 7).
- Granulator and drier outlets include rotating grids allowing the breakage of possible big blocks of fertilizers (Fig. 8).
- The fluidised bed cooler is designed by AZF so as to ensure an even cooling of the fertilisers, an easy circulation of the product in order to avoid as much as possible maintenance and cleaning (Fig. 9).
- The recycle ratio in the granulation loop is kept constant by means of an automatically controlled splitter on the merchant grade; the control is made by a weighing belt include in the recycle belt.

3.3. *Gas Washing*

It is generally designed in accordance with Fig. 4. The first stage receives wet and dusty gas from the granulator plus dry and dedusted gas from the drier. The gas/liquid contact is good in low pressure drop venturi scrubbers flooded by sulphate, phosphate, or suphophosphate solution at a pH of 4 to 5 allowing a good fluorine absorption. The gas then flows through a cyclonic washing tower and sprayed with a weak acid solution (pH 2 to 3) before going to the exhaust chimney. Liquid effluents from the second stage overflows to the first stage. The drain from the first stage is pumped to the pipe reactor of the granulator. The concentration of the recirculated washing solution is controlled by a flow of make-up water.

4. *DAP PRODUCTION*

At first we wondered whether it would be possible to manufacture diammonium phosphate by this process. Would not the injection of mono-ammonium phosphate into the drier reduce the N/P ratio in the final product?

A simple calculation shows that with a recycle rate equal to 3 times the production rate, and a molecular ratio of 1.97 in the product leaving the granulator, by introducing half of the phosphoric acid into the pipe reactor of the drier (at a mol ratio of 1.1), the mean mol ratio in the whole of the product leaving the drier, is equal to 1.86, which remains satisfactory.

The experimental results are far more favourable.

Most of the Map produced in the drier is recovered as

—dust in the cyclones

—fines after screening

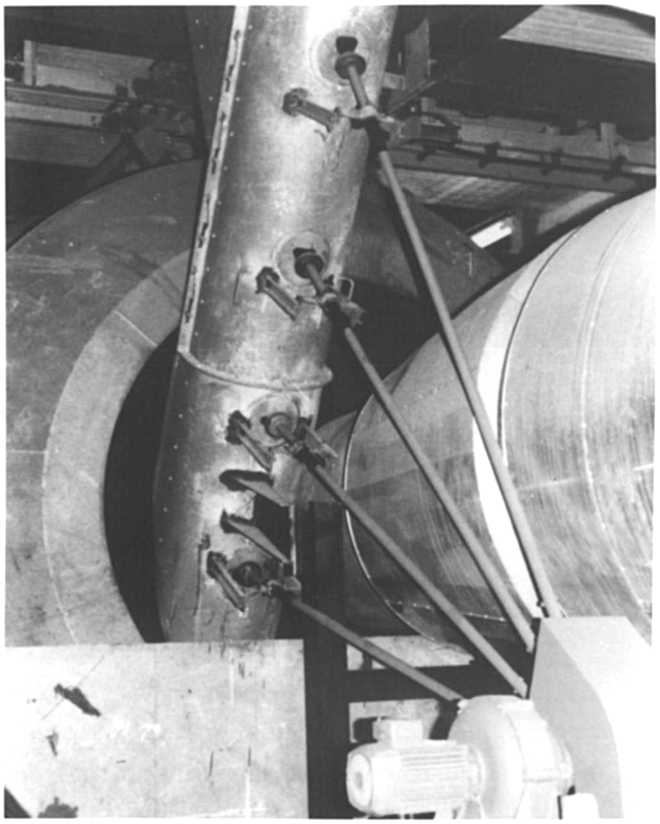


***Fig. 6* — Chute between granulator and drier.**

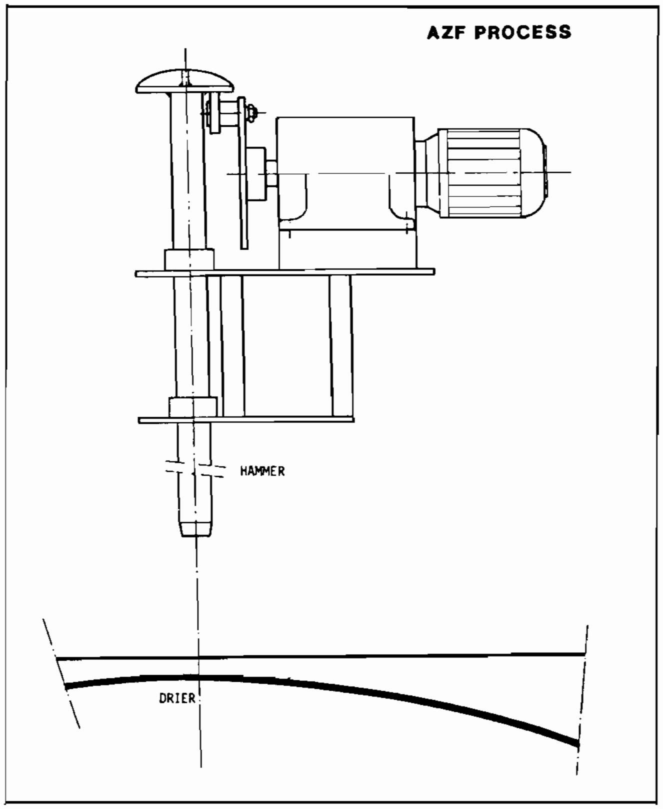


***Fig. 7* — Hammering System.**

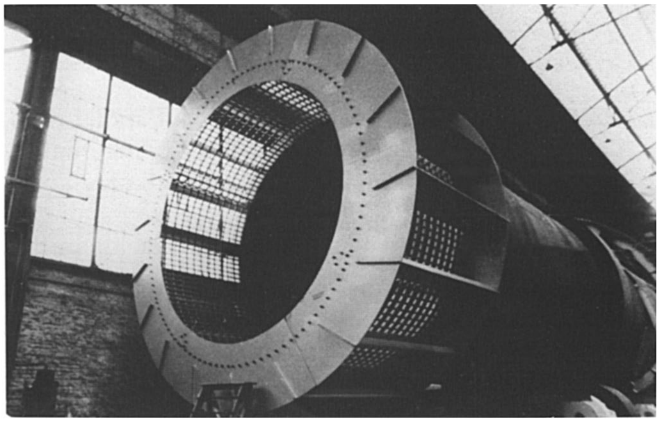


***Fig. 8* — Drier grid.**

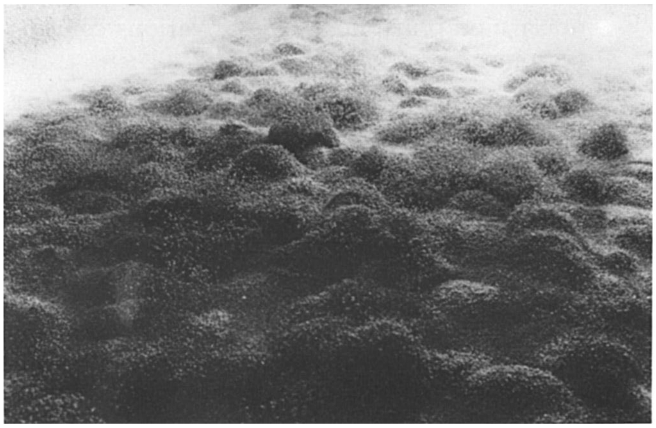


***Fig. 9* — Fluidised bed cooler.**

The following mol ratios have been measured at different points of the granulation loop:

	Outlet granula-tor	Final Product 2–4 mm	Fines after screen-ing	Dust particles from the cyclones
Mole ratio N/P	1.90	1.87	1.60	1.30

Figure 10

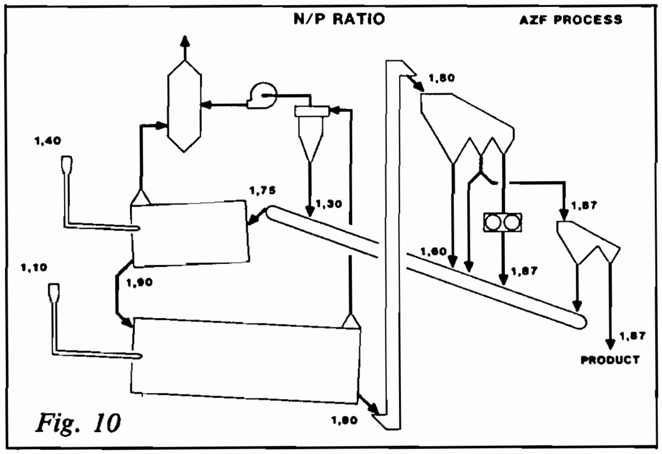


Fig. 10

In other words, a large part of the fine droplets of molten mono-ammonium phosphate crystallises in flakes in the drier or is fixed preferentially to the fine particles, which are separated by screening and return to the granulator with the dust particles. Their divided state is eminently suitable for the complementary absorption of ammonia in this apparatus, up to the ratio 1.9–1.95. Everything works as if this mono-ammonium phosphate had been introduced into the granulator in a hot powdery solid state and then ammoniated into the granulator up to the diammonium N/P ratio.

Apart from the reduction in recycling ratio, another advantage of the process is that the heats of reaction and crystallisation are fully utilised for the drying of the product. The super-heated steam which leaves the pipe reactor of the drier at about 140 C is evacuated from the latter apparatus at about 100 C, mixed with air. It therefore contributes by its sensible heat to the heating of the air and the drying of the product.

In addition, the amount of water which has to be introduced into the gas scrubbing system, in the form of acid containing 28–30% P2O5, is less than in the traditional process, as the ammonia losses at the outlet of the two pipe reactors are far smaller than those of a neutralisation tank; about 10% for the reactor of the granulator functioning with the mol ratio 1.4 and less than 2% for the reactor of the drier with the ratio 1.0–1.1.

There is, therefore, both less water to be evaporated than in the traditional process and more heat available. As a result, the process can become autothermal. By limiting to the value absolutely necessary the air flow through the drier, heating of this air becomes superfluous if the average concentration of the phosphoric acid is about 46%.

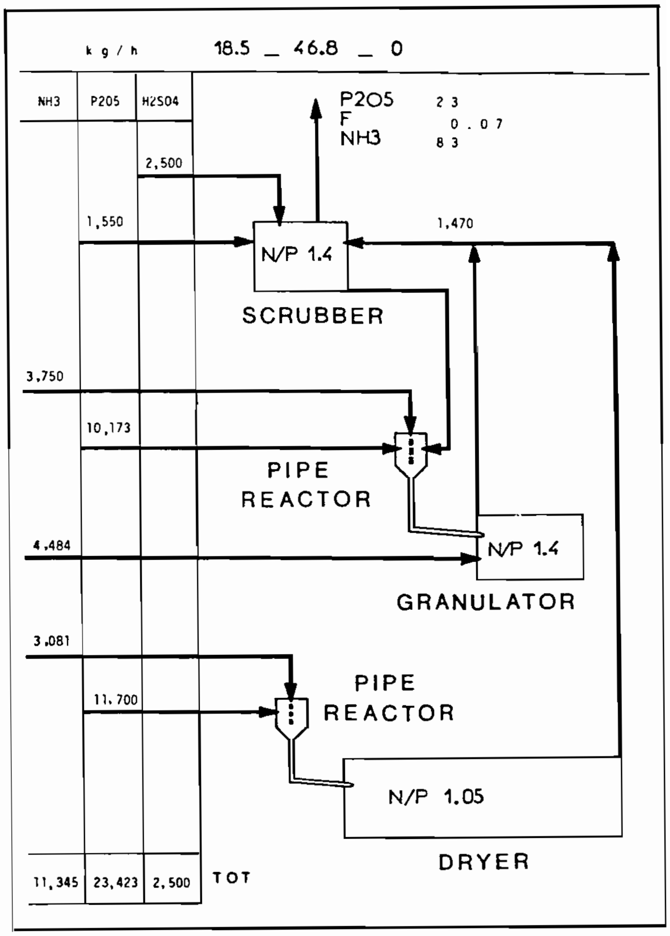


Fig. 11

Operating conditions

Fig. 11 gives the operating conditions for an international demonstration of DAP production (at full Industrial Scale) with a dual pipe process in our plant in Avignon (France) in May, 1984. This demonstration was made in front of 60 fertiliser experts coming from 15 different countries.

The distribution of the phosphoric acid and the ammonia between reactors, granulator and scrubber was as follows:

	Pipe Reactor Drier	Pipe Reactor Granulator	Granulator Sparger	Scrubber
Phosphoric acid	50%	43,4%		6,6%
Ammonia	27%	33%	40%	(13,5%)*

*accurate controls have established that 13% only of the ammoinia entering the granulator (pipe + sparger) was to be found later in the gas washing section.

5. *COMPUTER MODEL*

At the very beginning the most important thing was to design and to realise a reliable process and materials of construction, easy to operate and with a good efficiency. This was done with the help of a close collaboration between process and plant people.

AZF processes are designed by fertiliser producers.

Later on after reaching a satisfactory level of production (capacity and efficiency) it became apparent that in order to optimise the design some deeper understanding of the overall process was needed.

This was a big job as it required an amount of theoretical data that is scarcely available in the literature as well as exhaustive information coming from the actual plants. Adding to this a lot of iterative calculation, it became soon clear that a computer model was needed.

A tentative model, developed by hand calculations, has been developed over the years; this model was greatly improved and adapted to computer calculations.

Figs. 12 and 13 give examples of computer calculations for the process.

6 *MAIN ADVANTAGES OF THE DUAL PIPE PROCESS*

6.1. *Ease of Operations—Flexibility*

They are probably the main advantages as they directly concern production people.

The starting up of the plant is easy and fast. Shutting down is immediate and requires no special precaution.

It is possible, in the same plant, to produce easily a number of products as differents as DAP (18.46.0), 17.17.17 (with ammonium nitrate), 30.10.0 (containing about 80% ammonium nitrate), 6.15.30 (ammonium sulphophosphate) or 20.10.0 (50% of H2SO4).

With two pipe reactors, ammonia and phosphoric acid are easily split between the drier (giving powdered MAP) and the granulator (giving a slurry well adapted for granulation).

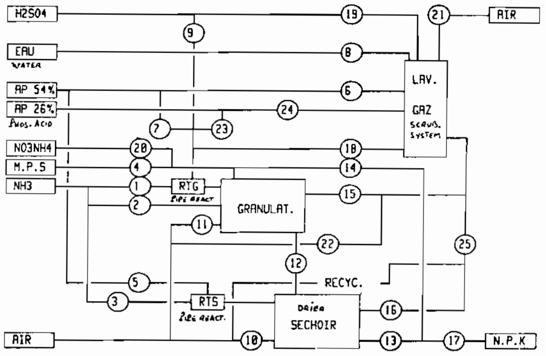
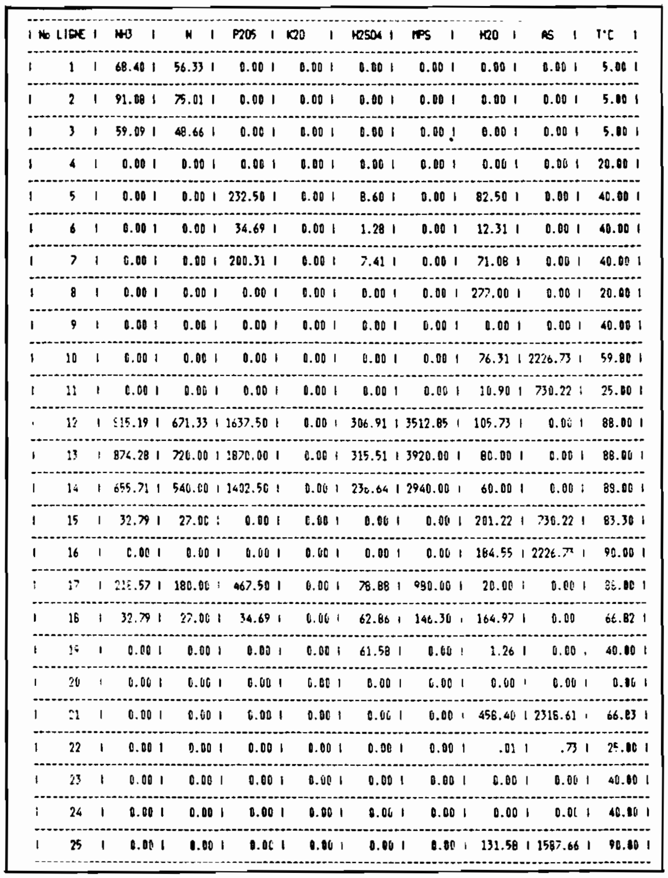


Fig. 12 — **Computer Flow Diagram.**



No LIGNE	NH3	N	P205	K20	H2S04	MPS	H20	AS	T°C
1	68.40	56.33	0.00	0.00	0.00	0.00	0.00	0.00	5.00
2	91.08	75.01	0.00	0.00	0.00	0.00	0.00	0.00	5.00
3	59.09	48.66	0.00	0.00	0.00	0.00	0.00	0.00	5.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00
5	0.00	0.00	232.50	0.00	8.60	0.00	82.50	0.00	40.00
6	0.00	0.00	34.69	0.00	1.28	0.00	12.31	0.00	40.00
7	0.00	0.00	200.31	0.00	7.41	0.00	71.08	0.00	40.00
8	0.00	0.00	0.00	0.00	0.00	0.00	277.00	0.00	20.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.00
10	0.00	0.00	0.00	0.00	0.00	0.00	76.31	2226.73	59.80
11	0.00	0.00	0.00	0.00	0.00	0.00	10.90	730.22	25.00
12	815.19	671.33	1637.50	0.00	306.91	3512.85	105.73	0.00	88.00
13	874.28	720.00	1870.00	0.00	315.51	3920.00	80.00	0.00	88.00
14	655.71	540.00	1402.50	0.00	236.64	2940.00	60.00	0.00	89.00
15	32.79	27.00	0.00	0.00	0.00	0.00	201.22	730.22	83.30
16	0.00	0.00	0.00	0.00	0.00	0.00	184.55	2226.73	90.00
17	218.57	180.00	467.50	0.00	78.88	980.00	20.00	0.00	86.00
18	32.79	27.00	34.69	0.00	62.86	146.30	164.97	0.00	66.82
19	0.00	0.00	0.00	0.00	61.58	0.00	1.26	0.00	40.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	456.40	2316.61	66.83
22	0.00	0.00	0.00	0.00	0.00	0.00	.01	.73	25.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.00
25	0.00	0.00	0.00	0.00	0.00	0.00	131.58	1587.66	90.00

Fig. 13 — **Computer material balance.**

When producing a formula with an ammonium nitrate solution at a low concentration, it is better to work with the pipe in drier only.

On the other hand, when using a high amount of potassium chloride, making difficult the granulation of the product, the pipe in granulator is much more suitable as giving a warm slurry sprayed on the bed.

6.2. *Investments for a New Plant*

For a new plant the low recycle ratio, the elimination of the neutraliser and the design of the gas washing section allows significant reduction of the investment.

A proprietary report (unpublished) shows, for practical cases, a decrease of investments of some 20% when compared with conventional plants. Above this decrease in investments some specific advantages must be outlined: low energy and fuel consumptions, high efficiency on raw materials (99% for ammoniac—99.5% for P2O5).

Plants and Grades		Before	After	Profit	Profit %	Remarks
AZF ROUEN FRANCE 17.17.17	Production t/h	65	110	45	70	DUAL PIPE REACTOR PROCESS
	Power kwh/t	40	25	15	37	
	Fuel oil kg/t	8	1	7	87	
ZUID CHEMIE SAS VAN GENT HOLLAND 23.23.0	Production t/h	35	60	25	71	DUAL PIPE REACTOR PROCESS
	Power kwh/t	48	30	18	37	
	Gas Nm3/t	6	3	3	50	
SAEPA GABES TUNISIA DAP 18.46.0	Production t/h	50	70.8	20.8	42	ONE AZF PIPE REACTOR IN THE DRIER
	Power kwh/t	-	-	-	-	
	Gas Nm3/t	6	3.12	2.88	48	
SICNG THESSALONIKI GRECE 16.20.0	Production t/h	65	100	35	54	ONE AZF PIPE REACTOR IN GRANULATOR
	Power kwh/t	33	21	12	36	
	Fuel oil kg/t	23	4	19	83	

Fig. 14 — **Performances of converted plants with AZF Pipe Reactor Process.**

6.3. *Revamping of Existing Plants (Fig. 14)*

Experience gained in retrofitting our own plants as well as clients' plants allows us to offer 3 possible revamping solutions to:

—increase the production capacity (often more than 40%)

—decrease energy consumption (often more than 50%)

—improve the on-stream time

—decrease the losses

—suppress pollution

—improve the working conditions in the plant.

a) Setting-up of two pipe reactors

One in the granulator, one in the drier. This solution allows every improvement listed here above. It is necessary to modify the equipment inside the granulator and generally to modify or replace most of the gas washing section.

This is the solution recommended for a DAP plant when the target is to increase the capacity, the efficiency and to produce granulated MAP; and for a TSP plant when the target is to modify it for MAP/DAP production.

b) Setting-up of one pipe reactor in the drier

While keeping a neutraliser in operation. This is the cheapest solution possible when the only goals are an increase of production and a decrease of fuel consumption. The modification can often be made practically without shutting down the plant.

c) Setting of one pipe reactor in the granulator

Keeping or not a neutraliser in operation. It may be interesting when the formulas produced give problems due to excessive water content in the slurry, when there are pollution problems due to the neutraliser, or when the granulation is difficult. This may happen with formulas with a high content of sulphuric acid, e.g. 16.20.0 or 20.10.0. An interesting example of an outstanding improvement has been given in a paper at "Fertiliser 1983," British Sulphur (8).

6.4. *AZF PIPE Reactor Design*

Fifty pipe reactors are now working or under construction. Good working results are achieved thanks to a simple design, including specific geometrical ratio, and well defined operating conditions (it is often easier to design a complicated device than a simple one).

The scaling and plugging problems often mentioned by pipe reactor users around the year 1965 have been totally eliminated.

When the formula composition makes it necessary to add an important amount of sulphuric acid in the pipe, AZF designs a special reactor able to resist the severe corrosion conditions.

6.5. *High Capacity Plants*

Designing and setting up of very high capacity plants are possible with dual pipe reactor (130–150 t/h DAP or 150–180 t/h 17.17.17) (9).

7. *REVAMPING EXAMPLE—THE DAP PLANT OF SAEPA-GABES—TUNISIA*

This is a very interesting example of the possibilities of the AZF process with a pipe in the drier. Originally the design capacity was 1,000 t/d DAP produced in a conventional plant.

After some years of production, with the help of the experience gained and of some improvements, the Saepa people had progressively increased the capacity up to 1,200 t/d which was a rather unexpected achievement.

Trying to increase again the capacity by some 500 t/d more was a real challenge in itself as the problem was to improve the situation of a plant which was then supposed to be working at its utmost level.

Furthermore, some details of the granulation loop were unfavourable, especially the internal design of the drier (large flights leaving little free area for spraying the slurry). Finally a solution was reached and a successful test-run achieved in 1983. During the 3 days of the test the results were as follow:

7.1. *Capacity*

date	operating hours	production t/d in 24 h	average increase of capacity
04.23.83	24	1 637	492
04.24.83	22	1 640	492
04.25.83	24	1 680	492
		4 957	1476 +43%

In April 1983, the production reached a peak at +576 t/d DAP, an increase of 48%.

7.2. *Gas Consumption*

During the 3 days test the gas consumption has been 3.12 Nm3/tDAP. Before the fitting of the pipe it was 6.00 Nm3. The improvement is 48%. Later on operating conditions have been adjusted to work without any gas consumption.

7.3. *Ammonia Efficiency*

Some problems with the main ammonia flowmeter made impossible a direct calculation of ammonia consumption and of losses. It was agreed that the efficiency was the same. But an indirect calculation based on the flow of phosphoric acid entering the gas washing section and on the N/P mol ratio of the washing solutions shows that the ammonia efficiency was probably increased by 2.7 points.

Since that time the design of the flights in the drier has been modified to avoid any sticking of MAP and the hammering system has been improved.

In 1985, a contract was concluded between Saepa and AZF to making complete the revamping of the plant by adding a pipe reactor in the granulator and by replacing the gas washing system.

8. *ECONOMICAL INTEREST OF A REVAMPING WITH A DUAL PIPE REACTOR*

The benefits coming from a better ammonia efficiency, a reduction of the energy consumption, an increase of the on-time factor and the production capacity are important enough to pay the investment in one year or less.

The actual benefits depend on every individual situation.

As an example, for a DAP unit, it is often possible to achieve

—a better ammonia efficiency, about 5 kg/t

—a reduction of the fuel consumption, about 4 kg/t

For a 1,000 t/d DAP plant (330,000 t/a), with an ammonia price between $140 and $210/t and a fuel oil price of $160/t the yearly saving will be between $430,000 and $530,000.

Apart from that, considering only a 40% increase capacity (by fitting-up a pipe reactor in the drier) the possible saving is very important.

Let R.M.: Annual Raw Materials Costs
F.C.: Annual Fixed Costs
S.: Total Income

The annual Cash-Flow is $N1 = S - RM - FC$

Adding a pipe in the drier increases the production by 40% with the same fixed costs:

$$N2 = 1.4\,S - 1.4\,RM - FC$$

The benefit $N2 - N1 = 0.4\,(S\text{-}RM)$

Based on average prices in 1984 (for Rock, ammonia, DAP selling price)

$$S = 195\ \$/t$$
$$RM = 170\ \$/t$$

and for 330,000 t/a DAP Net Cash $= 0.4 \times 330{,}000 \times 15 = \$2$ millions.

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The Horizontal Belt Vacuum Filter—Its Value to Texasgulf Chemicals Company

E. Barrie Winn
Texasgulf Chemicals Company

INTRODUCTION

Texasgulf Chemicals Company operates a phosphate mine and chemical plant at Lee Creek in Beaufort County, North Carolina. Phosphoric acid production capacity is based on four Mark II Prayon reaction/crystallization systems. The original capacity with four Prayon systems and four 30-C Bird-Prayon tilting pan filters was 680,000 ST P_2O_5/year. This capacity has been increased to 1,270,000 ST P_2O_5/year by debottlenecking the Prayon systems and by adding four Enviro-Clear ECF 2425 L425 horizontal belt filters, two in 1980/81 and two in 1985/86. Experience gained with the first two belt filters was used to improve the design of the next two filters.

This paper explains why horizontal belt filters were selected in the plant expansions and compares their performance with the Bird-Prayon tilting pan filters.

THE SELECTION OF HORIZONTAL BELT FILTERS

The decision to install belt filters rather than additional tilting pan or table filters in 1980/81 was based on capital cost considerations. A detailed study carried out in 1978 prior to the expansion concluded that two belt filters could be installed for significantly less capital than a tilting pan or table filter of similar capacity. A study published by Edwards and Salter of Badger in May, 1979, reached the same conclusion for capacities of up to 1000 tons P_2O_5/day. For greater capacities, belt filters were more expensive.

The decision to install two more belt filters during a plant expansion in 1985/86 was based on a combination of factors, mainly cost and plant downtime considerations (Table 1). In addition to these factors, the belt filters offer some operating cost advantages. This is described in detail later.

BELT FILTER OPERATING PRINCIPLES

The principles of belt filter design are shown in Figures 1 and 2. The heart of the filter is an air-supported transport belt which supports a filter cloth. Product acid is removed via a vacuum box centered beneath the transport belt. Texasgulf's filters consist of natural rubber transport belts and polyester filter cloths. A major benefit of a belt filter over a tilting pan or table filter is that the cloth is washed on both sides after each cycle, rather than just one side. This greatly prolongs the useful life of a cloth.

Early designs of belt filter could not operate under a high vacuum because of the friction between the transport belt and vacuum box. To reduce this friction, a special wear belt was developed to travel between the vacuum box and transport belt. This belt has a plastic fabric surface on one side which rubs against high density polyethylene wear strips on the top of the vacuum box. The wear strips are lubricated with water. There is a rubber surface on the other side of the wear belt which adheres to the bottom of the transport belt. The wear belt has a life to 4 to 6 months. Wear strip life is often dictated by product dilution considerations. This is discussed later.

Texasgulf has worked with Enviro-Clear to improve the design of the belt filters purchased in 1980/81. Some important improvements in the filters recently purchased are summarized in Table 2. Many of the improvements have been retrofitted on the older filters.

In addition to basic filter changes, the newer filters were installed without seal tanks. The absence of full barometric legs permits low-level filter installation, but there is no difference in elevation compared with our older belt filters since their seal tanks are underground. However, there are other advantages, such as the replacement of vertical filtrate pumps with cheaper horizontal pumps.

PRODUCTION CAPACITY

The belt filters have higher production rates per unit area than the Bird filters thanks to lower cycle times (Table 3). However, a strict comparison of production capacity must also include a discussion of washing efficiency and product dilution.

WASHING EFFICIENCY

Washing efficiency is best judged by the water soluble P_2O_5 losses in the discharged phosphogypsum. As a rule, the water soluble losses on our belt filters are higher than on our Bird filters. However, one reason for this is the addition of clarifier sludge to the belt filters. A test comparison of a Bird and a belt filter processing the same slurry, without the addition of sludge, showed a 21% higher average water soluble loss on the belt filter (Table 4). However, because of the spread in the data, as measured by the standard deviation of the losses, it is not possible to state with more than about 85% confidence that losses on the belt are higher. A 95% confidence limit is usually desirable in statistical analysis. Two other qualifications should be added to the results.

1. The belt filter ran above its design rate during the test period.
2. Cake samples from a Bird filter tend to underreport water soluble losses since it is difficult to obtain a complete cross section of the cake. On the other hand, samples of belt filter cake include the bottom of the cake where the water soluble P_2O_5 losses are usually higher.

Another recovery consideration is that spillage losses from the feed box on a Bird filter can remain undetected since the box is enclosed within the fume hood. Severe spillage losses will report straight to the gypsum tank. Spillage losses on the belt filter feed box will be detected immediately.

PRODUCT DILUTION

The dilutions on our Bird filters tend to be fairly stable, usually around 1 percent drop in P_2O_5 concentration. These dilutions can be controlled in a number of ways (e.g. by optimizing filter settings and maintaining cloudy ports) but, in general, they do not vary much. On the other hand, belt filter dilutions can become excessive unless great attention is paid to wear strip lubrication water flow and the condition of the wear strips. As the strips deteriorate, the amount of water entering the vacuum box increases. Texasgulf's experience with a recent 9 month wear strip cycle is documented in Table 5. This shows that after 7 months of operation the wear strips began to deteriorate to the extent that serious dilution occurred.

The cloudy port concept was found to reduce belt filter dilutions considerably by diverting filter cloth wash water soaked into the cloth to the No. 2 filtrate section. An experimental cloth dewatering fan has also been tested, but with inconclusive results.

OPERATING COSTS

Labor costs, filter cloth usage, power consumption and maintenance supplies are described in turn below.

(1) *Labor Costs*

There is no difference in operating labor between the two filters—in fact one operator is responsible for a Bird and a belt filter. Equally, one mechanic is responsible for preventive maintenance on two filters. However, labor required for cloth maintenance is higher on the Bird filters. Typically, 24 man-hours per week are spent changing or repairing cloths on each Bird filter, for an annual total of approximately 1,200 man-hours. On the other hand it takes five men about 2½ hours to change a belt filter cloth. For a typical cloth life of 2 months, 75 man-hours per year are spent on each belt filter.

Annual turnaround labor is considerably higher on the Bird filters, but because of differences in filter age (12-20 years for the Bird filters as compared with 1 to 6 years for the belts) direct comparison may not be valid.

(2) *Filter Cloth Usage*

Filter cloth costs on the belt filters are more than on the Bird filters. The 600 ft^2 filters at Texasgulf require 228′10″ long, 8′5″ wide polyester cloths which cost approximately $7,000 each. A tear caused for example by a broken roller can result in the complete loss of a cloth. Texasgulf has salvaged old cloths to minimize costs, but in general once a cloth fails it must be replaced. Cloths have been in service for as long as four months, but a typical cloth life is one to three months. An average two month life will result in an annual cost of around $40,000, as compared with the annual cost of $10,000–$20,000 for the polypropylene cloths on a Bird filter.

There are a number of belt filter cloths on the market and new cloths are constantly being tested in an effort to reduce cloth costs.

(3) *Electric Power*

The installed horsepower on a belt filter is 57% of that on a Bird filter (Table 6). Since the production capacity is 62%, there is a power savings on a belt filter amounting to about $20,000 per year per belt filter.

(4) *Maintenance Supplies*

The routine maintenance supplies costs for the two oldest belt filters averaged 64% of that on the four Bird filters in 1985. This proportion is close to the relative production capacity so for all practical purposes these costs can be taken as the same per ton of P2O5.

Annual turnaround maintenance supplies are currently more on the Bird filters but a direct comparison is difficult because of age differences. Nevertheless, it can be stated that our experience has been that the Bird filter car frames last about ten years while the belt filter transport belts last about five years. The cost of one car frame replacement is more than the cost of two transport belt replacements.

AVAILABILITY

Our experience in 1985 (Table 7) shows that, although the non-scheduled mechanical downtime on the two belt filters was greater than on the Bird filters, the overall "internal" downtime was slightly less. A major reason for this is the more extensive annual turnarounds conducted on the Bird filters. Also, the wash time required on the Bird filters is ten hours per week compared with six hours on the belt filters. The reason for the lower wash time on the belt filters is the better cloth washing possible on a belt filter.

OPERABILITY

Ease of operation, although important in equipment selection, is difficult to quantify. In our experience the belt filters pose more operational problems. For example, the belts are more sensitive to deterioration in slurry filterability than the Bird filters. A related problem is that of maintaining a good vacuum seal at the feed end of the belt. The slurry feed must run up to the feed dam roller to ensure a good seal. However, the degree of sealing will vary as filterability varies and it is difficult to make compensations for this. This problem could be overcome by making the feed box position more easily adjustable.

CONCLUSION

Belt filters have strong and weak points when compared with tilting pan filters. These factors must be weighed against one another when attempting to compare the two designs for a particular application. In fairness to both designs, filter performance is as much a function of operating and maintenance attention as it is of design. In our experience, examples of extremely good and extremely poor performance of our Bird and Enviro-Clear filters can be found in our records. It is necessary to have an ongoing program of process improvements to demonstrate top performance on all our filters.

ACKNOWLEDGMENT

The assistance of Steven M. Weiss, Vice President of Sales for the Enviro-Clear Company, in preparing this paper is gratefully acknowledged.

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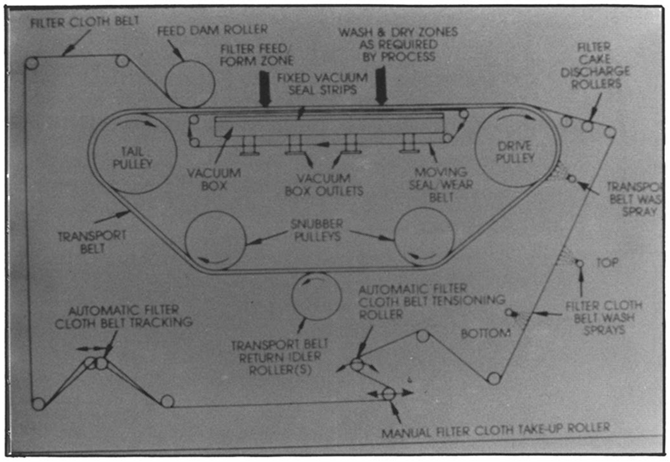

Figure 1. Horizontal Belt Vacuum Filter

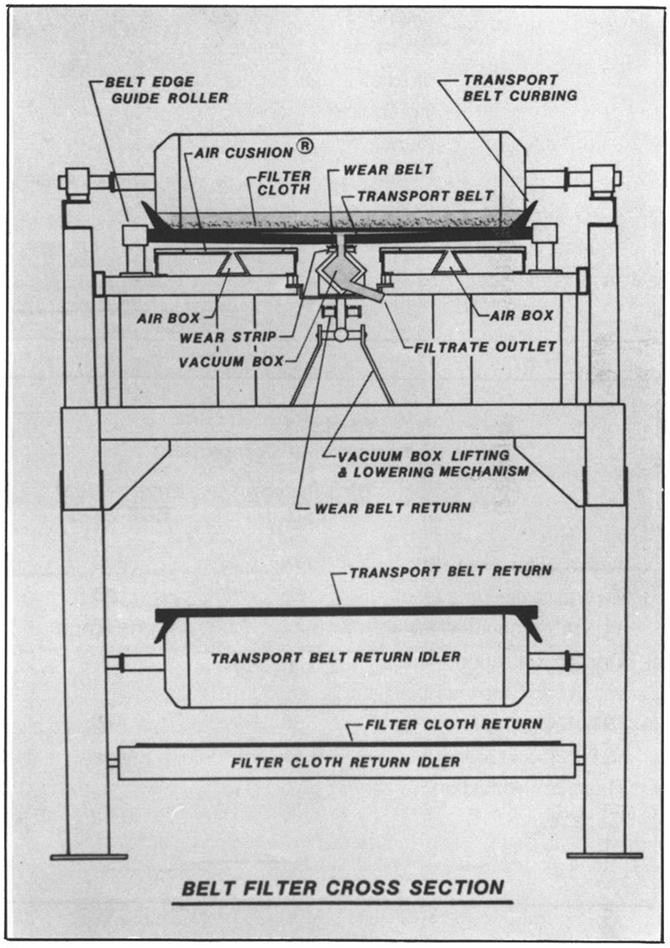

Figure 2. Belt Filter Cross Section

TABLE 1
Choice of Filters for 1985/86 Expansion

Option	Replacing two existing tilting pan filters with larger table filters	Install one additional table filter	Install two additional belt filters
Advantages	Use existing real estate	No downtime on existing equipment	1) No downtime on existing equipment 2) Use existing real estate*
Disadvantages	1) Requires extended downtime of existing equipment 2) Higher cost	1) Requires new real estate 2) Higher cost	

*Space was left in the belt filter buildings in 1980/81 for two additional belt filters.

TABLE 3
Filter Operating Data Comparison

	Bird-Prayon 30-C	Enviro-Clear ECF 2425
Active Filter Area (Ft2)	1445	600
Typical Cycle Time (sec)	180	40
Typical Vacuum (″Hg)	18-22	14-18
Design Filtration Rate with North Carolina Rock		
(ST P2O5/Day)	650	400
(ST P2O5/Ft2/Day)	0.45	0.67
Relative Production Capacity	1	0.62

TABLE 2
Significant Improvements in Belt Filter Design

	1979/80	1985/86
Vacuum Box		
Box Thickness	0.109″ 317L	0.125″ 317L
Raising Mechanism	Manual	Powered
Transport Belt Curbing	Trapezoid	"Fold-Down" (more flexible)
Air Support System		
Design	Air Box	Air Cushion
Air Fans	2 × 15 HP fans	1 × 25 HP fan
Cloth Tracking Mechanism	Pinch rollers	Moveable roller (Sandy-Hill-Thune)
Dilution Control Features	None	Cloudy port; dewatering fan
Roller Design		
Head and Tail Drums	Rubber coated mild steel; shaft welded to end plates	Rubber coated mild steel; through shaft attached with Bikon couplings
Belt Support Rollers	Rubber coated; $1\frac{5}{8}''$ shaft	Stainless; $2\frac{3}{16}''$ shaft
Cloth Rollers	Rubber coated; $1\frac{7}{16}''$ shaft	Stainless; $1\frac{11}{16}''$
Filtrate Header Design	317L	High density polyethylene ("Drisco")

TABLE 4
Comparison of Bird 30-C Filter and Enviro-Clear 2425 Filter on The Same Slurry Feed (No. 2 Train, 10.1.86–10.26.86)

Filter	Bird-Prayon 30-C	Enviro-Clear 2425
Number of Washes	2	2
Water Soluble P2O5 Loss (a)		
Mean %	1.47	1.78
Standard Deviation %	0.62	0.85
Average Instantaneous Filter Production Rate (b) (ST P2O5/Day)	651	425

(a) After pond water correction

(b) Split between filters calculated from filter feed flow

TABLE 5
No. 1 Belt Filter Wear Strip Cycle (04/10/85–02/11/86)

Date	Average Dilution
May 1985	1.10
June 1985	0.95
July 1985	0.65
August 1985	0.88
September 1985	1.07
October 1985	1.22
November 1985	1.14
December 1985	1.62
January 1986	1.46
AVERAGE	1.12

TABLE 6
Installed Filter Horsepower

	Bird-Prayon 30-C	Enviro-Clear ECF 2425
Primary Vacuum Pump	300	200
Secondary Vacuum Pump	200	–
Filter Feed Pump	125	50
No. 1 Filtrate Pump	30	30
No. 2 Filtrate Pump	75	30
No. 3 Filtrate Pump	30	20
No. 4 Filtrate Pump	30 (a)	–
Filter Wash Pump	150	100
High Pressure Spray Pump	50	40
Gypsum Pump	400	250
Filter Drive	25	60
Air Support Fans	–	30
Cake Discharge Blower	7½	–
No. 1 Seal Tank Agitator	7½	3
No. 2 Seal Tank Agitator	7½	3
No. 3 Seal Tank Agitator	7½	3
No. 4 Seal Tank Agitator	7½	3
TOTAL	1,452 ½	822

(a) Not always needed in two-wash operation.

TABLE 7
Filter Downtime Analysis—1985 (% of Year)

Filters	Bird-Prayon 30-C (Average of 4)	Enviro-Clear 2425 (Average of 2)
Non-Scheduled Mechanical	1.93	4.05
Total Internal (Including Turnarounds)	14.20	14.05

TVA's Versatile Pipe-Cross Reactor

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Presented by:
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TVA's first work with pipe reactors was in the early 1970s when pipe reactors with a pipe "tee" for a reactor section were used to produce ammonium polyphosphate solutions (10-34-0 and 11-37-0 grades). TVA was allowed a U.S. patent for this work in 1973 (1). Figure 1 shows a sketch of this tee reactor. These reactors are made from a common stainless steel pipe tee and straight pipe. More than a hundred of these reactors in the United States are producing an estimated 1.5 million tons of ammonium polyphosphate solution each year.

Pipe-Cross Reactor (PCR) for Granular Fertilizers

Later the tee reactor was altered to use a pipe-cross instead of a pipe tee so that other acids, such as sulfuric, and fluids could be added. Therefore, the reactor used to produce granular fertilizers is usually designated as a pipe-cross reactor (PCR) (2). During the mid-1970s the PCR was first used in commercial plants to produce granular, homogeneous NPK mixtures.

A typical PCR for producing granular, homogeneous mixtures is shown in Figure 2. About twenty of these reactors in the United States are being used to produce these high-quality granular, homogeneous NPK products. These products are gaining popularity for use in minimum tillage programs and as solid starter fertilizers. More recently, we have shown that this same reactor can be used to produce ammonium polyphosphate sulfate fluids (3). In producing a granular product, the phosphoric and sulfuric acids are reacted in the PCR to produce mostly an anhydrous melt of monoammonium phosphate (MAP) and ammonium sulfate. This melt is sprayed onto a bed of recycle and solid raw material in a standard TVA-type rotary ammoniator-granulator. Some plant operators have shown they can operate with superior results with no ammonia sparger in the granulator. In these operations all of the ammonia is added to the PCR. Usually the ammonia addition is enough to convert the sulfuric acid to ammonium sulfate and the degree of ammoniation of the phosphoric acid is such that the N:P mole ratio is kept between 0.8 and 1.2.

Typical operating data for producing a 15-15-15-8S grade are shown in Table 1. The PCR for this type of operation is usually operated at low pressure (0-15 psig). These data show that the maximum average temperature is usually kept below 300°F and at this temperature and the pressures and degree of ammoniation mentioned above, ammonia loss is usually quite low (<2%). The off-gas from the granulator is usually scrubbed in a wet scrubber. The scrubbing medium is primarily water with a small quantity of sulfuric acid added to keep the scrubber liquor pH in the range of 4 to 5. This scrubber liquor is returned to the reactor and is used to control the temperature within the reactor or it can be sprayed above the bed of material in the granulator. Most of these plants report that with the PCR substantially less fuel is required to dry the product. Several have reported no fuel is required. The plant operators report the following advantages for the PCR:

1. Larger quantities of sulfuric and phosphoric acid can be used.
2. No fuel is required to dry the product.
3. The product has a superior spherical shape. It generally is hard and resists degradation.
4. There is less dustload in the plant.

High-Pressure PCR for Diammonium Phosphate (DAP)

This is a different type of reactor because it is operated at higher pressures. Generally, it is operated between 25 and 100 psig. TVA has been allowed a U.S. patent for the use of this high pressure reactor to produce DAP (4). This is a larger reactor than those used to produce granular NPK mixtures. Its ammoniation volume (cubic inches per pound of ammonia per hour) is about twice that of the low-pressure PCR.

One commercial firm, the Royster Company of Mulberry, Florida, has installed a reactor of this type. Figure 3 is a sketch of this reactor. This project was a cooperative venture between TVA and Royster personnel. Design criteria developed at TVA's National Fertilizer Development Center were used. About a hundred pilot-plant tests were made with a similar reactor to produce DAP. The design criteria were established in these tests. Royster's reactor is made of 10-inch standard stainless steel pipe (type 316L). It has an overall length of about 47 ft. The reactor has a sloping section (10° slope). The reaction is completed in this section. The distribution section is positioned to discharge melt from the reactor onto a rolling bed of material in the granulator. It is equipped with a flanged section. Plates with different sized slots are attached to this flange. The operating pressure of the reactor is controlled by the size of the slot in this plate and production rate.

Pilot-plant tests for producing of DAP have shown that only single-stage scrubbing of the exhaust gases from the granulator is required. Commercial-plant-scale tests show there are advantages in using two-stage (dual N:P mole ratio) scrubbing. Figure 4 shows a sketch of the Royster plant that has two-stage scrubbing and a high-pressure PCR. This plant has operated successfully for several months at a production rate of 60 tons per hour. It has been reported that the PCR has been used to produce over 100,000 tons of DAP (18-46-0 grade).

Table 2 shows some of the operating data collected when the plant was operated at 55 tons per hour. During this operation, about 35 percent of the total P_2O_5 was added as weak acid (30% P_2O_5) in the second-stage scrubber and the remainder was added as concentrated acid in the PCR and a small amount as pond water to the scrubbers. These and other data show that by using the two-stage scrubbing, larger quantities of concentrated acid can be used in the PCR. The equivalent concentration of all phosphoric acid added to the process is about 40 percent P_2O_5. This higher strength acid and high pressures in the PCR result in higher slurry temperatures and slurry concentrations in the PCR. The slurry temperature and moisture when the preneutralizer is used are usually 245°F and 15 to 20 percent respectively. Results in Table 2 show when the high-pressure PCR is used, the average temperature of the slurry in the PCR is 283°F and moisture of the slurry discharge from the reactor is 5-11 percent H_2O. Because of its higher temperature, the slurry from the PCR contains more energy than the slurry from the preneutralizer. Therefore, at the higher temperature the slurry will release its moisture more readily into the exit gas of the granulator. This results in a lower moisture content in the product from the granulator. With the lower moisture content, no fuel is required to dry the product. This lower moisture content is also favorable to lower recycle rates and higher production rates. If the dryer is used as a cooler, no ammonia loss should be expected during cooling. In new plants that use TVA's high-pressure PCR, probably the troublesome wet-scrubbing systems used for dryers will be replaced with bag filters. This should further improve the water balance of the process which in turn should decrease the recycle rate with a corresponding increase in production rate. The total capital investment in a new plant should be substantially less because no dryer is required, no dryer scrubbing is required, and smaller equipment can be used because of the lower recycle rate.

There was some indication of lower nitrogen loss in commercial plant operations with the PCR than is received with a preneutralizer operated at comparable slurry temperatures. These results were confirmed by pilot-plant tests. Probably, one of the reasons for the lower nitrogen loss was that the PCR is operated at elevated pressures. TVA tests have shown that the high-pressure PCR can be operated quite well at N:P mole ratios of 1.65 if the temperature of the slurry is kept >280°F. With these conditions and high pressure, the slurry is fluid enough to be sprayed onto the bed of material in the granulator as very small particles of spray. By shifting more of the reaction into the PCR (operating at a higher N:P mole ratio), the granulator can be operated with a lower discharge temperature. One of the most common causes for nitrogen deficiency in DAP (18-46-0) is that the operators are operating the granulators with granulator bed temperatures that are too high. TVA's pilot-plant tests during the past 25 years have shown that the optimum granulator discharge temperature for good granulation efficiency and low ammonia loss is 180°F. Operators of the conventional plants (with preneutralizer) report that when this is done, larger quantities of fuel are required to dry the product and the production rate is decreased.

Tests have shown that because the slurry from the high-pressure PCR has a low moisture content, less drying is required. Therefore; perhaps the granulator discharge can be lowered without adversely affecting the plant operation. At these lower temperatures there should be less problem with nitrogen deficiencies in the product.

Plant operators report there is definitely less dust in the plant and warehouses when the PCR is used instead of the preneutralizer. By using a high-pressure slurry spray of small particles from the PCR, a more uniform coverage of the recycle may be received. This results in well-shaped, hard granules that resist degradation.

Here is a summary of the advantages in using the PCR as compared to the preneutralizer:

1. Low nitrogen loss and less problem with nitrogen deficiency in the product.
2. Less dust during handling and in production.
3. No drying required.
4. Probably less recycle per ton of product is required.
5. Quality of product is improved.

PCR for MAP and Ammonium Polyphosphate (APP)

The high-pressure PCR has been used effectively to produce both MAP and APP.

In changing from the production of DAP to MAP, the recycle load is lowered and the N:P mole ratio in the PCR is lowered to the range of 0.6 to 1.0. This can be accomplished in minutes instead of the hours it takes to adjust the N:P mole ratio of the slurry in a tank preneutralizer (from N:P mole ratio of 1.45 to 0.6). Those of you who have attempted to change the slurry in a preneutralizer from an N:P mole ratio of 1.45 to 0.6 know how difficult this is to accomplish. The solubility curves of figure 5 explain one of the reasons for this problem. To decrease the N:P mole ratio to 0.6, the operator must pass from a solubility of about 400 lbs of salt per 100 lbs of water at an N:P mole ratio of 1.45 and a temperature of about 250°F, to about 200 lbs of salt per 100 lbs of water at this same temperature and an N:P mole ratio of 1.0. Therefore, the slurry becomes viscous and sometimes solidifies, since only acid is added during this adjustment. To avoid this problem, the operator usually adds water to the preneutralizer which in turn causes problems with the water balance in the plant. This is not a problem with the PCR because there is very little hold up of material in it and the change can be made rapidly. Therefore, changing from the production of DAP to MAP with the PCR process is a rather simple procedure. Royster has produced a significant amount of MAP in their DAP plant that has been converted to the PCR process. However, the mole ratio of the recirculating solid load must be changed. We recommend the following procedure:

1. Lower or empty the DAP recycle load from the plant.
2. Recharge the recycle system with granular MAP.
3. Restart the plant with MAP recycle and slurry.

Only single-stage scrubbing is required for producing MAP. Pond water is used as a scrubbing medium. Ammonia losses from the PCR and granulator are so low that at times some fluorine has been lost from the scrubber. This problem probably can be eliminated by adding a small amount of ammonia to the scrubber liquor to keep its pH near neutral. No fuel is required to dry the product if the phosphoric acid concentration is as high as 46 percent P_2O_5 and vaporized ammonia is used.

Production of granular APP is quite similar to that of MAP except all of the phosphoric acid is added as merchant-grade (0-54-0 grade). This acid is preheated by steam to 250°F before it is pumped to the PCR. The maximum temperature of the melt in the reactor is between 450° and 480°F. At this temperature the melt is anhydrous and contains some pyrophosphate (polyphosphate). The product contains from 8 to 15 percent polyphosphate and has very good storage characteristics and quality. Grades that have been produced are 12-52-0 and 11-56-0. The product has worked well for producing both fluid and dry blends of fertilizers. Its cost of production is about the same as MAP if there's no charge for steam; however, it has a wider market potential since it can be used to produce suspensions or dry mixed fertilizers. High-quality acid is necessary to make 11-56-0 and sludge acid must be used to produce other products. This may cause the cost of production of the 11-56-0 grade of APP to be higher than the other ammonium phosphates.

Summary

The new pressure-type PCR has shown it is certainly versatile for producing several types of granular ammonium phosphate products. Perhaps the companies that use the PCR may discover that it can be used to produce several granular phosphate products. This may be a marketing advantage. Probably the emerging phosphate companies may find it advantageous to offer more than only one commodity-type product such as DAP. TVA's high-pressure PCR process appears to provide the phosphate producer a way to easily produce several ammonium phosphate products with only one reactor in the plant. TVA is prepared to assist all engineering and producing companies to design and operate plants that can use this new process.

TABLE 1
Plant Test 15-15-15-8S grade TVA Pipe-Cross Reactor 6″ Diameter, 4″ S.S. Sleeve Granulation Plant, Ohio

Test No.	**TVA-PC-9**
Production rate, tons/hour	25
Formulation, lbs/ton product	
Raw Materials	
Pipe-Cross Reactor (PCR)	
Ammonia (82% N)	92
Phosphoric acid (54% P_2O_5)	502
Sulfuric acid (66° Be)	75
Water	70
Ammoniator-Granulator	
Ammonium nitrate (prilled, 34% N)	–
Granular urea (46% N)	147
Ammonium sulfate (21% N)	704
DAP, 18-46-0	75
Potassium chloride (60% K_2O)	492
Operating Conditions	
Temperature, °F	
Product from granulator	203
Product from dryer	192
Product from cooler	148
Melt from pipe-cross reactor	271-297
pH of product from granulator	5.3
Heat flux (PCR sleeve 4″ diam.) Btu/hr/in^2	470,200
Total heat, Btu/ton	236,300
Recycle rate, lbs recycle/lb product	1.7
Chemical Analysis, % of Total	
N	14.5
P_2O_5	14.9
K_2O	15.6
% H_2O	0.5

TABLE 2
Production of DAP (18-46-0) with TVA's High Pressure Pipe-Cross Reactor

Production rate—ton/hr	55
Operating time—hours	23
Feed Rates, lbs/ton	
Weak acid to 2nd stage scrubber (32% P_2O_5)	1034
Pond water to 2nd stage scrubber (0.5% P_2O_5)	318
Strong acid to pipe-cross reactor (54% P_2O_5)	1116
Anhydrous ammonia	442
Operating Data	
Second stage scrubber	
% total P_2O_5 to this scrubber	36
pH	2.0
Gal/min to first stage	115
Specific gravity	1.34
First stage scrubber	
pH	6.3
Temperature, °F	199
N:P mole ratio	1.5
Specific gravity	1.4
Gal/min to pipe-cross reactor	102
Pipe reactor	
% of total P_2O_5 fed to pipe-cross reactor	64
Specific gravity melt	1.56
Maximum melt temperature, °F	283
Minimum melt temperature, °F	270
Pressure, in pipe	
Ammonia, entry line	55
Phosphoric acid, entry line	30
pH	6.0
Granulator	
Temperature product, °F	223
N:P mole ratio	1.9
Recycle temperature	190
Dryer	
Exit gas temperature, °F	170
Product temperature, °F	190
Chemical Analysis, %	
Total N	17.8
Total P_2O_5	47.5
C.I. P_2O_5	<0.1
Moisture	0.8
Screen Analysis, %	
+6	1.5
+14	93.0
−14	5.5

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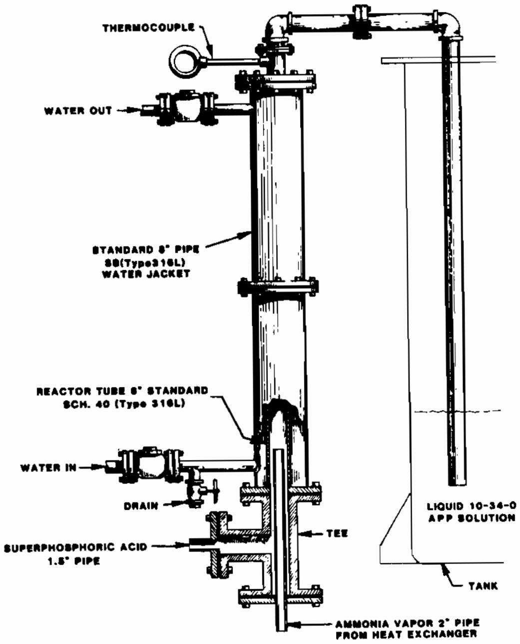
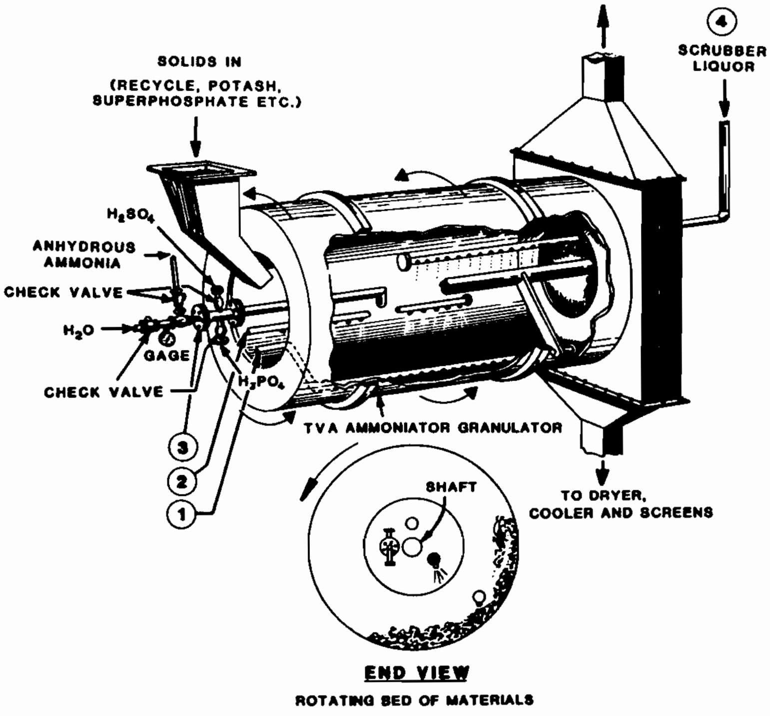


Figure 1
PIPE TEE REACTOR



① AMMONIA SPARGER - LOCATED AT THE 4 O-CLOCK POSITION 4½" FROM GRANULATION SHELL WITH HOLES FACING THE ROTATING STREAM OF MATERIALS. OVERALL LENGTH -12 FEET. ONE HUNDRED AND FORTY TWO ⅛" HOLES ON ONE INCH CENTERS WITH SMALL QUANTITY OF WATER ADDED TO PREVENT CAKE AROUND SPARGER.

② PHOSPHORIC ACID SPARGER — LOCATED TO DISCHARGE PHOSPHORIC ACID ONTO THE TOP AND NEAR THE CENTER OF THE ROTATING BED OF MATERIALS. OVERALL LENGTH - 8.9 FEET. SIXTEEN 3/16 INCH HOLES ON THREE INCH CENTERS.

③ PIPE-CROSS REACTOR — LOCATED AT LEAST TWO FEET ABOVE AND NEAR CENTER OF BED IN GRANULATOR.

④ SCRUBBER LIQUOR - LOCATED ABOVE THE BED IN GRANULATOR TO DRIBBLE SCRUBBER LIQUOR ONTO BED.

Figure 2
LOCATION OF TVA'S PIPE-CROSS REACTOR AND SPARGERS IN TVA AMMONIATOR-GRANULATOR

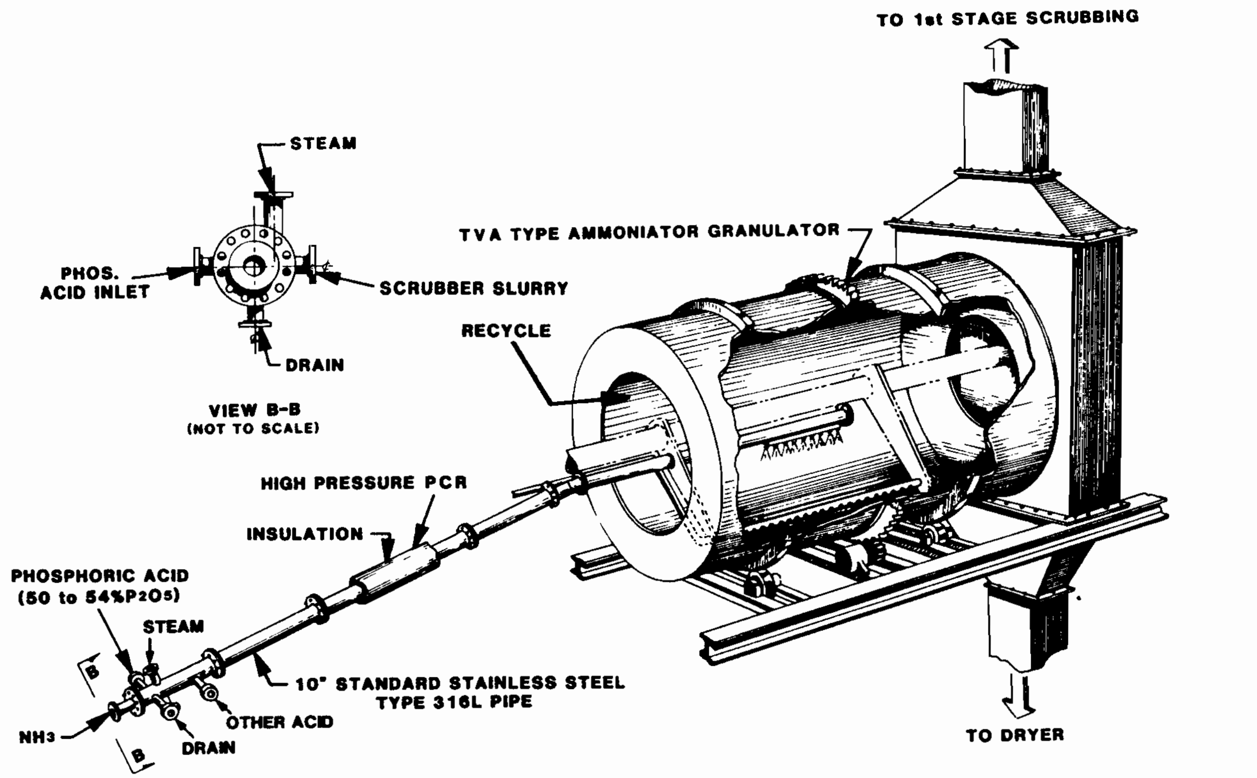


Figure 3
TVA HIGH-PRESSURE PIPE-CROSS REACTOR FOR GRANULATOR OF MAP-DAP COMMERCIAL PLANT

TVA-OACD-DWS

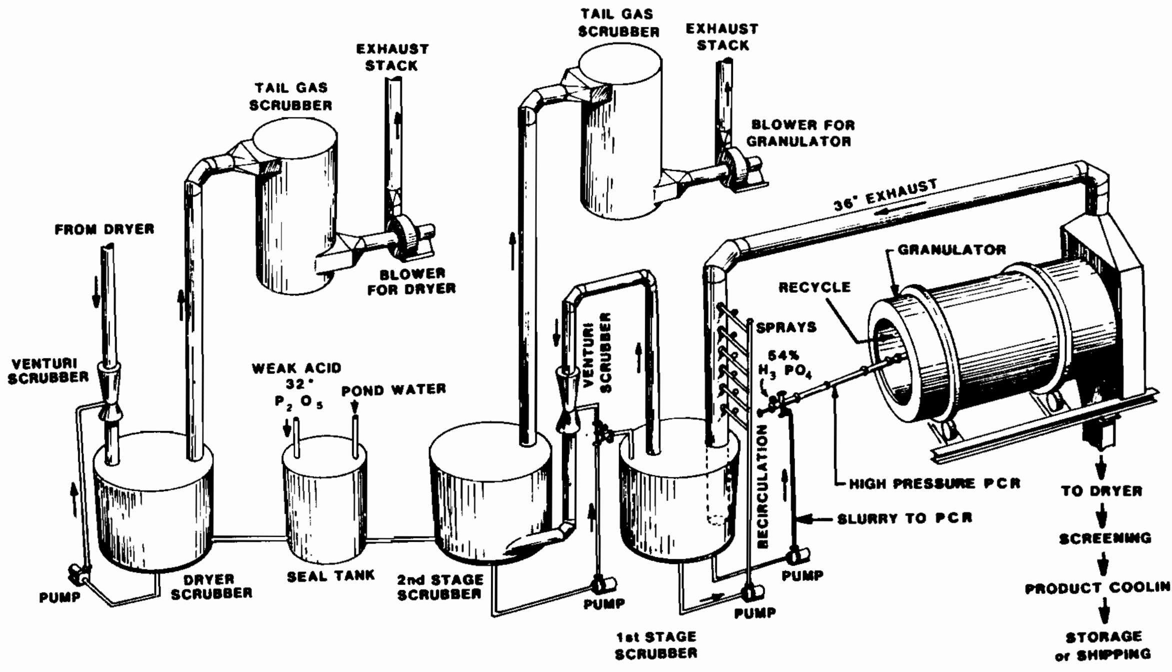


Figure 4

HIGH PRESSURE PIPE-CROSS REACTOR FOR MANUFACTURE OF DAP

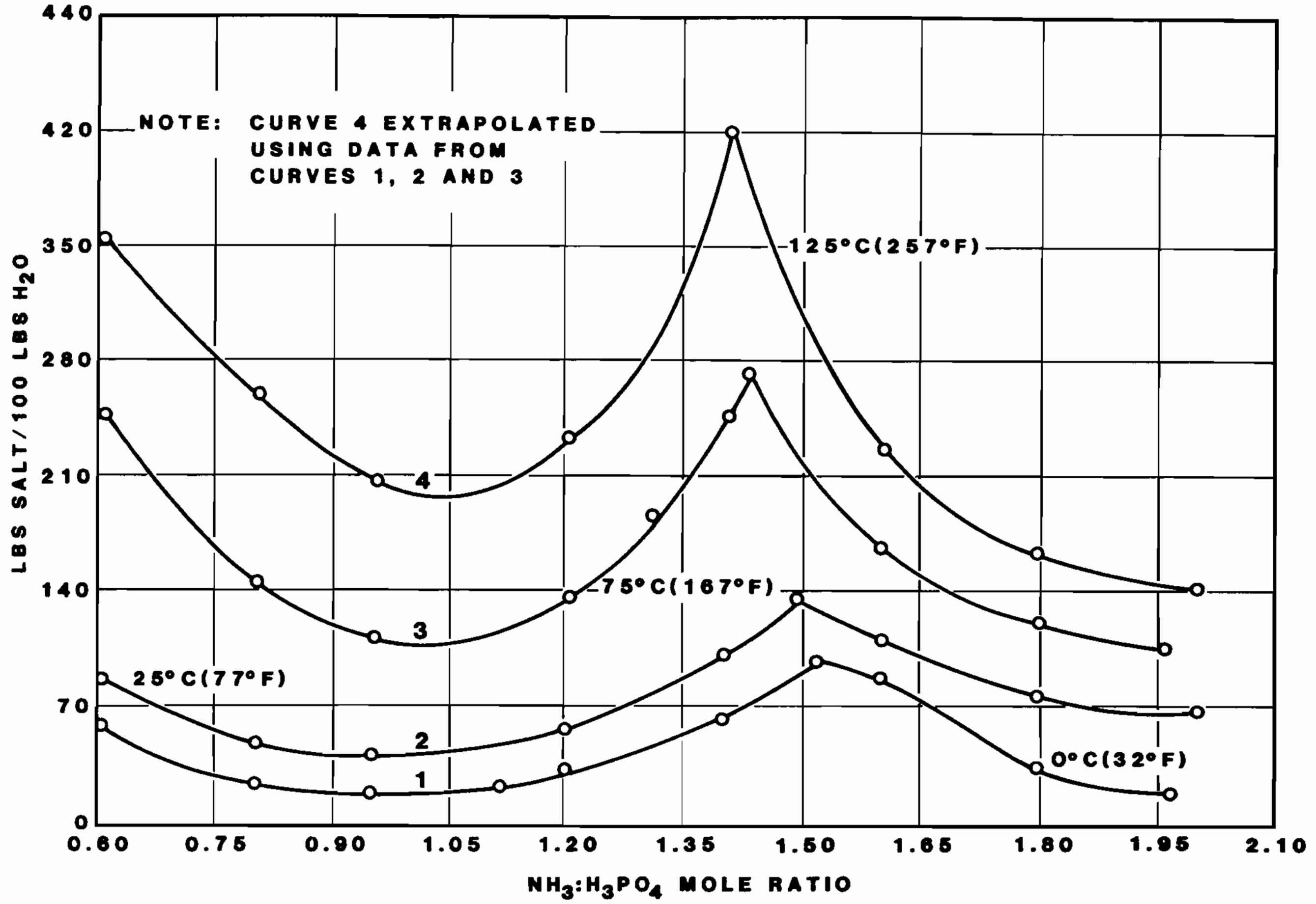


FIGURE 5

SOLUBILITY SYSTEM NH_3-H_3PO_4-H_2O (PURE SYSTEM)

Disposal of Phosphogypsum

Phosphogypsum—An Exciting New Raw Material

G. Michael Lloyd, Jr.

Florida Institute of Phosphate Research

The Florida Institute of Phosphate Research's program for phosphogypsum utilization has evolved into a three-pronged approach to the opportunity presented by the almost 400 million tons of phosphogypsum stockpiled in our state. The primary goals of this program have been to develop applications for phosphogypsum as:

1. A Chemical Raw Material for
   a. SO_2 production
   b. Sulfur production
2. A Construction Material for
   a. Road building
   b. Building products
3. Agricultural Products

In addition to technical feasibility, the basic criteria for selecting phosphogypsum research proposals includes the following requirements:

Research should have the potential to develop:

1. A high-profit use, and/or
2. A high-volume use.

While we would prefer that every project develop a high-volume, high-profit use, our primary purpose is to eliminate the existing 400 million ton stockpiles and we, therefore, have equally great interest in any high-volume, low-profit uses that can be developed.

Since this group is probably more interested in the chemical processing of phosphogypsum to recover sulfur values, I will briefly describe our efforts to develop construction and agricultural uses and devote most of the time to reviewing our experiences with the various thermal processing schemes that have been proposed to recover the sulfur values in phosphogypsum.

Florida phosphogypsum is slightly radioactive, containing low levels of radium. We do not believe that this low-level radioactivity presents any problem when phosphogypsum is used for either construction or agriculture, but the very fact that there have been concerns expressed has influenced our research programs.

In the construction area we have demonstrated that it is possible to produce phosphogypsum-cement-aggregate structural forms that are equal, or superior, to those now is use. Our present emphasis is on producing items, roofing tiles, highway dividers, acid-proof bricks, etc. that would not be used in home construction in such a way as to generate concerns over health problems. We will continue working to develop products for home building, but they will require extensive testing before we would be in a position to promote their use. The construction area where the most progress has been made is road building. Phosphogypsum has been used for both the subbase and the base courses for two county roads built in Florida.

The Columbia County road utilizes phosphogypsum from Occidental's hemi-hydrate phosphoric acid operation. The hemi-hydrate phosphogypsum road base has excellent strength characteristics and is virtually impervious to water, retaining its strength characteristics even when submerged in water. The properties of both the road bases and other construction materials made from hemi-hydrate phosphogypsum are unique. These products are so impressive that the advantages of using hemi-hydrate phosphogypsum in building materials, combined with the other reported advantages of producing phosphoric acid by this process, could justify the conversion of phosphoric acid plants to the hemi-hydrate mode of operation.

As a direct result of the construction of these secondary roads, Polk County is actively promoting this phosphogypsum construction technique for county maintained roads and has even proposed construction of a section of a major highway to better demonstrate road performance under heavy traffic conditions.

In the agricultural area we have funded phosphogypsum programs to investigate:

1. The amelioration of sub-soil acidity.
2. Improvement of the physical properties of southeastern soils.
3. Phosphogypsum as a carrier of micronutrients and a source of Ca and S.
4. Phosphogypsum as a means to increase yields and quality of forage.
5. Phosphogypsum to provide Ca and S for citrus without changing the soil pH.

For many of these programs we have also required that the fate of the radionuclides in the phosphogypsum be determined. Research to date indicates no problems with radionuclides, but our program will develop sufficient data to define the problem—if there is a problem.

Both the agricultural and present construction uses for phosphogypsum can be classified as high-volume, low-profit uses. However, we believe development of such uses is essential if we are to ever reduce the 400 million ton stockpile. Our concept is that the recycling of phosphogypsum to sulfuric acid will stop the growth of the phosphogypsum inventory, and construction and agricultural uses are the most probable ways to eliminate the existing stockpiles.

As you would expect, we have made a major effort to investigate existing processes to recover the sulfur values in phosphogypsum and have funded a number of research projects in this area. Historically, thermal processing of phosphogypsum (gypsum) has been accomplished by utilizing one of two fundamental processing schemes as shown in the following equations:

SO_2 Production:

$$2\ CaSO_4 + C \longrightarrow 2\ CaO + CO + 2SO_2 \quad (1)$$

Sulfur Production:

$$CaSO_4 + 2C \longrightarrow CaS + 2CO_2 \quad (2)$$

$$CaS + H_2O + CO_2 \longrightarrow CaCO_3 + H_2S \quad (3)$$

H_2S from the second reaction step is processed to recover sulfur, with the Claus process being the most commonly used recovery method.

Most of our research effort has been directed toward the SO_2 production process, with the first study carried out by Zellars-Williams to investigate Dr. Wheelock's ISU Fluid Bed Process. The somewhat complicated process included the following steps:

1. Phosphogypsum washing and cleanup
2. Preparation of sized phosphogypsum granules
3. Granule drying
4. Fluid bed thermal decomposition of granules
5. Washing and cleaning the SO_2 gas stream
6. Production of sulfuric acid
7. Recovery of solids (lime) from the reactor

This study confirmed and better defined the primary problem areas that have long been recognized as being common to, and largely responsible for, the lack of acceptance of phosphogypsum thermal conversion systems as a sulfuric acid production method.

1. High capital cost/unit production
2. By-product value
3. Fuel (energy and chemical reductant) cost

The Zellars-Williams' study was a vital step in the development of the Institute's programs since it provided a case study that could be used to demonstrate that the economics of thermal processing are basically dependent upon:

1. *Capital cost.* This is perhaps the only contributor to the product cost that could be changed enough to have a major effect on the economics. It was obvious

that a higher production rate must be achieved with the same or lesser capital investment if the fluid bed process is to be economically viable. Analysis of fluid bed operating characteristics reveals that system capacity is largely a function of particle size of the solid processed, operating temperature, and particle residence time. When structural limitations are imposed upon the operating conditions the only solution to increased capacity is multiple units. The conclusion reached was that a different type of thermal processing unit was required in order to achieve a lower capital cost per unit of production.

2. *By-product value*. Sale of the lime by-product could make this process economically viable. The lime product, containing all the radium from the phosphogypsum, has a higher level of radionuclides than the phosphogypsum and this could be a cause for concern. While the lime by-product is not truly dead-burned, it is less reactive than commercially available limes. Covered storage would be required for any inventory. It is highly probable that this material could find use in stabilizing phosphatic clays or perhaps power plant stack gas scrubbing, but these uses might not consume everything that would be produced. A single 1000 tons per day P_2O_5 complex operating with a fluid bed phosphogypsum-processing system would generate 1600 tons per day of CaO product.

3. *Fuel cost*. The fuel used provides energy and also acts as a reductant in the reaction. The type of fuel used is not overly critical and any of the conventional fuels can be used as well as hydrogen, sulfur, pyrites, etc. Fuel consumption for all of the proposed phosphogypsum thermal processing schemes is high and while greater fuel efficiency would make a process more attractive, it would be highly unlikely that fuel efficiency would significantly improve the process economics. Significant fuel cost reductions would be possible only by the use of a lower cost fuel.

With the background information developed by investigating the ISU Fluid Bed Process, the proposal by Davy McKee to utilize the circular grate technology for thermal processing was received with interest. The circular grate appeared to offer two primary advantages:

1. High capacity that could equal to lower capital cost/ton product
2. Excellent fuel efficiencies

The initial series of tests were run to produce lime and SO (Figure 1). While results were encouraging, they did not represent a major breakthrough. The SO_2 content of the gas stream was lower than desired. With SO_2 levels in the order of 8% (with adequate oxygen for sulfuric acid production) it would be extremely difficult to retrofit an existing sulfuric acid plant without incurring a significant reduction in plant capacity. However, when the circular grate and a new metallurgical type sulfuric acid plant were constructed as a unit, the cost of producing sulfuric acid was just slightly more than the cost of sulfuric acid produced by burning sulfur.

The first phase test results were sufficiently encouraging to justify a second test series. This second test series demonstrated that circular grate capacities much higher than those achieved in the first test series were possible. By the end of this test series, the production rate had been increased to 380% of the rates achieved in the first test program. This second test series was also designed to produce a silica-based aggregate material as the solid product (Figure 2). The decision to produce an aggregate was reached after studying the aggregate situation in Florida and reviewing the Bureau of Mine's forecast that Florida was short of suitable aggregate materials and would be importing all the state's aggregate needs by the year 2000 at the latest. The aggregate material produced was not the best quality, but it was felt that it could find application in the Florida market. With no aggregate credit, the sulfuric acid cost was reduced to the point of being competitive with sulfur-derived acid. The results were sufficiently encouraging to justify the preparation of detailed engineering and operating cost estimates.

Not being satisfied with the properties of silica-based aggregate, we reviewed our options for aggregate production and concluded that a mixture of phosphogypsum and pyrites should produce a superior aggregate material. This research option had been rejected previously on the basis that pyrites were not available in large enough quantities at an attractive price. A more in-depth study was initiated and several possible sources of pyrites were developed:

1. Natural pyrites mined for this purpose (Georgia, Canada, Spain).
2. By-product pyrites from other mining operations (Canada).
3. High sulfur coal now being mined (Canada).
4. High sulfur coal that could be mined (USA).
5. Coal wastes.

Sufficient pyrites were obtained and a new test series begun (Figure 3). The results were strongly positive. The aggregate material was very hard and the SO_2 content of the gas stream was increased (9% SO_2, 9% O_2). The aggregate material was tested and, within the limits of the test, was found to be highly satisfactory for road building purposes. The only real way to adequately test an aggregate product is to build a road after completing all laboratory tests, but we could not produce the quantity of aggregate needed for such a test road in the pilot plant.

Up to this point in our research program, the basic concept had been to produce sulfuric acid at a reduced cost and accept the fact that it would not be possible to generate adequate steam and/or power from a sulfuric acid plant utilizing the circular grate technology. Recognizing that the energy value assigned to sulfur burning is not calculated in the same manner at all companies, no attempt was made to assign an energy debit to the cost of the sulfuric acid produced by the process; companies were supplied with details of operating and capital cost in order that they could determine their economics in accordance with their own accounting procedures. Based on capital repayment and no return on investment, the cost to produce sulfuric acid had now been reduced to $37/ton when zero value was assigned to the aggregate product.

The continued effort to develop a phosphogypsum thermal processing scheme that would be able to generate as much energy as a sulfur burning sulfuric acid plant finally paid off. A process utilizing either high sulfur coal or coal wastes was developed (Figure 4). Perhaps one of the most unique features of this process is the ability to consume coal wastes without having to be concerned about either the sulfur or ash content. Most of the organic sulfur would be recovered as a dirty elemental sulfur that would be combined with the phosphogypsum, pyrite and carbon to make the pellets fed to the grate. The char from the coal containing the pyrites would also be used as a raw material and would supply the carbon and at least a part of the pyrites required. In this system, the coal ash would end up as a part of the aggregate and would have little affect on the overall operation.

Using this processing scheme, the capital and operating costs to retrofit an existing gulf coast phosphate complex have been estimated. The basis for the estimates are shown in Table 1. At break even cost with no return on investment (depreciation provided for) and taking no credit for the aggregate, sulfuric acid cost is $27.24 per ton, a reduction of more than $25 per ton when compared to sulfuric acid from burning sulfur. Operating in this mode, the Davy/FIPR circular grate will generate as much energy (steam and/or power) as a sulfur-burning sulfuric acid plant. Therefore, no allowance needs to be made for energy. The circular grate is quite flexible and by changing the amount of coal fed to the system, it would be possible to produce much more power than could ever be generated in the most efficient sulfur burning sulfuric acid plant.

The Institute has also funded work to develop a small-particle phosphogypsum reactor. This reactor would process off the pile phosphogypsum. The phosphogypsum feed would require no pretreatment and retention time in the reactor would be quite short. Bench scale work to prove this technique has been successful and a larger scale pilot plant is planned. Processing steps for the ISU Fluid Bed Process and the SAIC Small Particle Reactor Process are compared in the following table:

Comparison of ISU Fluid Bed Process and SAIC Small Particle Reactor Process

ISU Fluid Bed Process	Processing Steps	SAIC Small Particle Reactor
x	Phosphogypsum Cleanup	–
x	Granule Preparation	–
x	Granule Drying	–
x	Thermal Decomposition	x
x	SO_2 Gas Cleanup	x
x	H_2SO_4 Production	x
x	Solid Product Recovery	x

During the past two years the Institute has collaborated with the Bureau of Mines in the development of a process to produce sulfur from phosphogypsum. This process takes a somewhat different approach to the problem, employing as a first step the thermal conversion of $CaSO_4$ to CaS.

$$CaSO_4 + 2C \longrightarrow CaS + 2CO_2 \qquad (2)$$

And a second step to produce ammonium bisulfide,

$$CaS + NH_3 + CO_2 + H_20 \longrightarrow NH_4SH + CaCO_3 \qquad (4)$$

The second and third reactions are solution reactions. The third reaction occurs when the concentrated NH_4SH solution is passed over a catalyst where sulfur is recovered and the ammonia solution recycled.

$$2NH_4SH + 0_2 \longrightarrow 2NH_3 + 2\,H_20 + 2\,S \qquad (5)$$

To date, bench scale work has proven the reaction conditions, but there are still problems with yields. The Bureau is confident that these problems can be overcome and is actively pursuing this investigation.

One other area that has received limited research attention is the microbiological conversion of phosphogypsum to sulfur. The traditional route to accomplish this employs the bacterial production of H_2S and the Claus processing of the H_2S to obtain sulfur. Both of the processes investigated with funding from our organization have employed this first step. The first process studied would have converted the H_2S to sulfur and hydrogen by photochemical or other means. The second process was all biological with the H_2S produced by one type bacteria used as a feed material for the second type bacteria that would convert the H_2S to sulfur.

It may appear that we are devoting an overly large percentage of our overall efforts toward the recovery of sulfur values in phosphogypsum. While one of our basic goals is to eliminate the phosphogypsum stockpiles in Florida, the economic incentive can hardly be presented more effectively than it is in this illustration from a paper presented at the April

IMIC meeting by Tas Kouloheris of Zellers-Williams (Figure 5). With sulfur costs accounting for almost 50% of the Florida P_2O_5 manufacturing cost, any cost saving in this area will measurably impact the profitability of our industry.

The research programs I have described here today have not been addressed in great detail due to the time restraints of our program. If anyone would like more detailed information concerning the work of the Florida Institute of Phosphate Research, please feel free to contact us at any time.

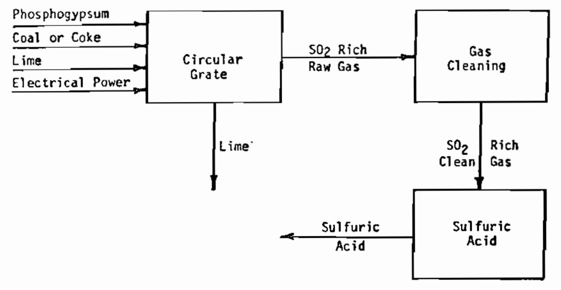


Figure 1. DM/FIPR Phosphogypsum Process-Operating Mode: Lime

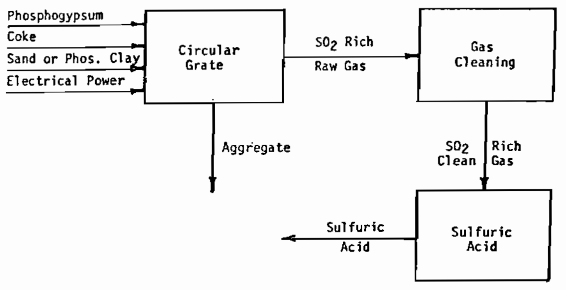


Figure 2. DM/FIPR Phosphogypsum Process-Operating Mode: Aggregate (Silica Base)

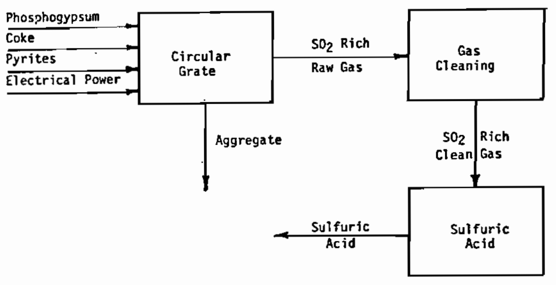


Figure 3. DM/FIPR Phosphogypsum Process-Operating Mode: Aggregate

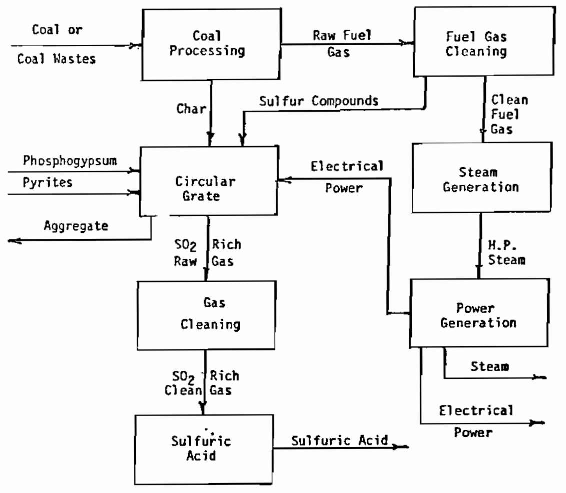


Figure 4. DM/FIPR Phosphogypsum Process-Operating Mode: Cogeneration

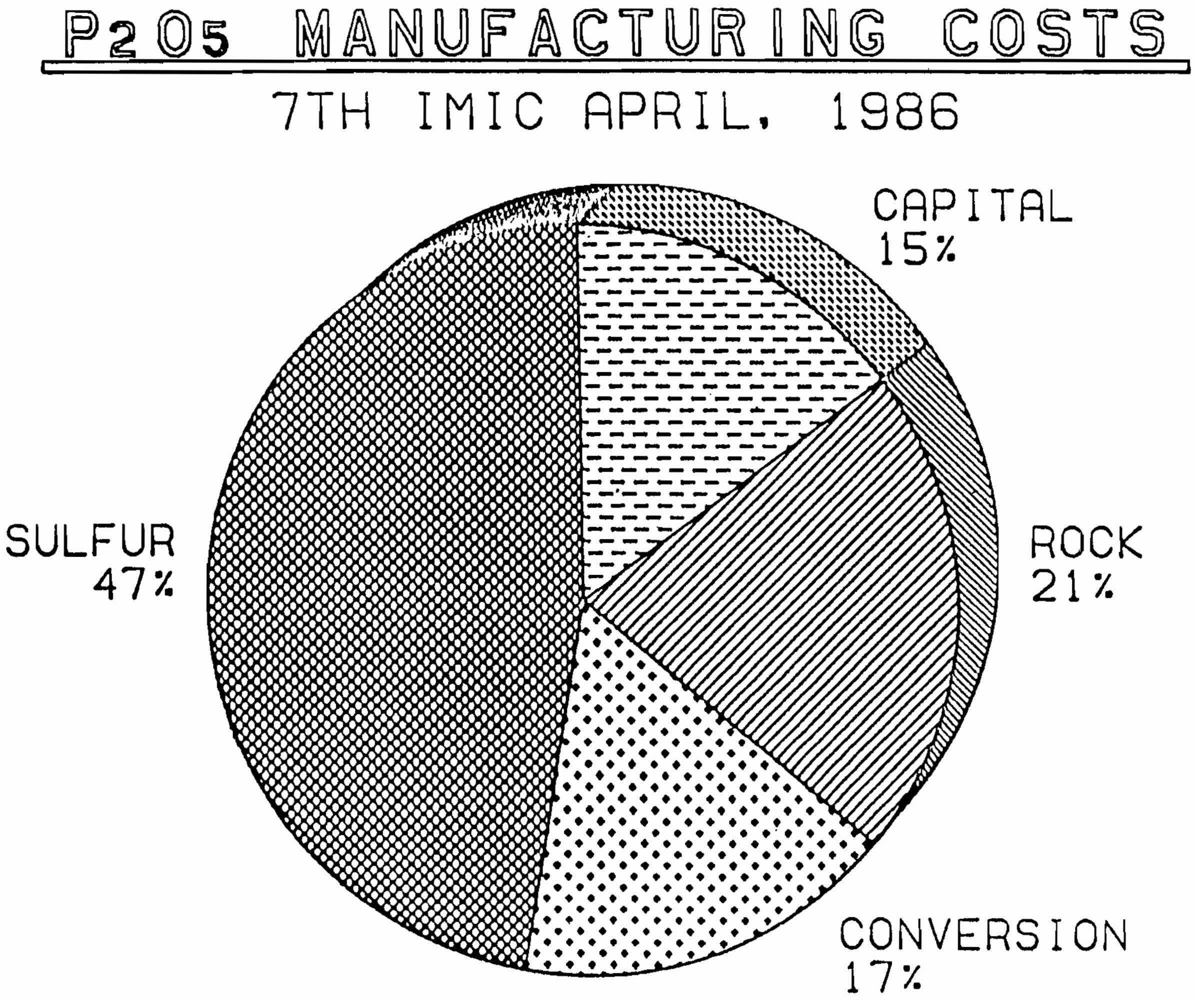

P_2O_5 MANUFACTURING COSTS
7TH IMIC APRIL, 1986
CAPITAL 15%
ROCK 21%
CONVERSION 17%
SULFUR 47%

Figure 5

TABLE 1
Davy McKee/FIPR Process

Plant Location: Adjacent to an existing phosphoric acid complex with a cogeneration facility, Gulf Coast, U.S.

Total Installed Cost, MM$ (1st Quarter 1986)		75
Investment Equity, %		100
Construction Period, years		2
Investment Tax Credit, %		10
Tax Depreciation Life (ACR), years		5
Plant Life, years		15
Production, days/year		330
Plant Capacity, short tons per year		
	Sulfuric Acid	924,000
	Aggregate	830,000

● Raw Materials	Unit Price ($/Short ton)	Usage/Year (millions short tons)
Phosphogypsum	.50	1.13
Pyrites	32.00	.28
Clay	4.00	.03
Coal	28.00	.26

● Utilities	Unit Price $	Usage/HR
Water	.2/1000 gal	10,000 Gallons

● Materials	
Operating	$700,000/YR
Maintenance	$2,250,000/YR

● Personnel	
Operators	44
Supervision/Administration	7
Maintenance/Supervision	22

	BASE*	BREAKEVEN*
Sulfuric Acid Selling Price, $/s.ton	50	21
Aggregate Selling Price, $/s.ton	7	7
Discounted Cash Flow, After Tax Rate of Return %	26	–

*No Credit for Exported Steam or Exported Electric Power

Tuesday, November 18, 1986

Morning Session
Moderator:

Ted Schulte

Application of Fertilizer—No-Till and Minimum-Till Agriculture[1]

B. R. Bock
Research Soil Chemist
NFDC
Tennessee Valley Authority

INTRODUCTION

This paper discusses some of the implications of changing tillage practices for fertilizer application. For consistency, the following tillage definitions from *No-till Farmer* magazine will be used:

No tillage—soil is undisturbed prior to seeding and planting is completed in a narrow seedbed, usually 1–3 inches wide.

Minimum tillage—any tillage and planting system other than no-tillage that retains at least 30% residue cover on the soil surface after planting.

Conventional tillage—topsoil is mixed or inverted by plowing, power tiller, multiple diskings, or other means leaving less than 30% residue cover on the soil surface after planting.

The broad term, reduced tillage, will be used to include both no tillage and minimum tillage.

The 1985–86 *No-till Farmer* magazine survey indicates that the no-tillage acreage in the United States has increased every year since the first survey in 1972 and now accounts for about 6 percent of the field crop acreage. Minimum-tillage acreage has increased each year except 1985 and accounted for about 28 percent of the field crop acreage in the 1985–86 survey. A recent survey of farmers, extension agents, and fertilizer dealers in the Corn Belt indicated that further adoption of reduced tillage can be expected, Fletcher (1984). This trend is expected to continue in other areas. Also, changes in tillage practices are having considerable impact on both agricultural research, agribusiness, and the fertilizer component of the agricultural community.

The primary goal of fertilizer application is to maximize farm income. Mostly, this involves using least-cost inputs to assure adequate plant nutrients. Although the same goal could be stated for any tillage system, *assuring adequate plant nutrients is more challenging with reduced tillage than with conventional tillage.* With reduced tillage, maximizing return from fertilizer use also involves optimizing some systems considerations in addition to assuring adequate plant nutrients. These systems considerations concern mainly N placement.

A secondary but very important goal is minimizing adverse environmental impacts of fertilizer use. Public concerns and perceptions about environmental effects of fertilizer use suggest that this goal will receive increasing attention. There is greater potential for nitrate leaching from the root zone with reduced tillage than with conventional tillage. Some of the nitrate that is lost can contaminate ground or surface waters and more emphasis on efficient N application will likely be required with reduced tillage to prevent nitrate contamination. Loss of P with runoff into surface waters also poses environmental problems, particularly with surface-applied P that remains on the soil surface with reduced tillage.

The primary objective of this paper is to overview some implications of reducing tillage for optimizing N rate, placement, and timing. This information is based mainly on cooperative research involving the National Fertilizer Development Center (NFDC) and land-grant universities. Also included are some general comments about P and K application for reduced tillage.

NITROGEN RATE

Shifting from conventional tillage to reduced tillage can affect the three major factors that determine the optimum N rate:

- amount of N supplied from the soil
- efficiency of N recovery by the crop
- yield potential (i.e., yield with nonlimiting N rate)

Thus, type of tillage system should be considered in making N rate recommendations.

Figure 1 shows the typical "cross-over" effect of tillage system on corn response to N. On the lower portion of the response curves, higher N rates were required to achieve a given yield with no tillage than with conventional tillage. The higher portion of the response curves shows that no tillage resulted in a higher yield potential, and thus, more N was required to maximize yield with no tillage than with conventional tillage. Similar results have been reported from Kentucky, Thomas and Frye (1984).

With efficient N timing and placement, N recovery efficiency is similar across tillage systems. This leaves yield potential as the primary tillage-related consideration in making N rate recommendations. For example, Figure 1 shows that no tillage gave a yield potential of 165 bu/A and conventional tillage gave a yield potential of 155 bu/A. Nitrogen rates required to achieve these yield potentials were 205 and 175 lb/A, respectively. When choice of tillage system affects yield potential, the N rate needs to be adjusted proportionally with yield potential.

Tailoring N rate recommendations according to tillage system becomes more complex when relatively inefficient N timing or N placement is used. In these cases, the type of tillage system often affects N recovery efficiency by the crop as well as yield potential, and both factors must be considered in making N rate recommendations. With inefficient N timing and placement, N recovery efficiency tends to differ by tillage system because there is generally greater potential for both N loss and N "tie up" in soil organic matter with reduced tillage than with conventional tillage.

Broadcasting and injecting urea are examples of inefficient and efficient N placement. As shown in Figure 2 for no-tillage corn, a higher N rate is often required to achieve a given yield with surface than with injected placement of urea. Placement effects on N rate requirement generally are more important with reduced tillage than with conventional tillage. Similarly, in more humid areas higher N rates often are required for early N applications than with applications at planting time or later. A higher N rate is required to compensate for less efficient N recovery by the crop with early application. As with N placement, N timing effects on N rate requirements often are more pronounced with reduced tillage than with conventional tillage.

NITROGEN PLACEMENT

Shifting from conventional to reduced tillage probably has more implications for N placement than any other aspect of N application. Most importantly, N placement often affects efficiency of N recovery by the crop. As shown in Table 1, placing N below the soil surface becomes more important as the level of tillage decreases. In this example, injecting N gave no yield advantage over broadcasting N with a plow system, but increased yield by 9 bu/A in the chisel-plow system and by 16 bu/A in the no-tillage system. The yield increases likely were mainly due to improved N recovery efficiency by the crop.

Placing N below the soil surface is particularly important with reduced tillage for three reasons. First, subsurface placement reduces N "tie up" in the decomposing crop residues that occur near the soil surface. Second, subsurface placement reduces and usually eliminates ammonia volatilization that can occur from surface application of urea-containing fertilizers. Ammonia volatilization from surface-applied urea and urea ammonium nitrate solution (UAN) is usually greater with reduced tillage than with conventional tillage. Finally, subsurface placement reduces gaseous losses of N by denitrification, a type of N loss that occurs mainly in soils with excess moisture. The potential for denitrification is greater with N placed in the zone of decomposing crop residues than with N placed below the residues. Thus, subsurface N placement can increase N recovery efficiency by reduced-tillage crops by reducing the extent of one or more of the following: N tie up in crop residues, ammonia volatilization, and denitrification.

Nitrogen placement can have important effects on other systems considerations in addition to efficiency of N recovery by the crop. In some reduced-tillage systems, the soil and residue disturbance associated with subsurface fertilizer placement detracts from efforts to do one or more of the following: control weeds, conserve soil moisture, clear residues during a subsequent planting operation, and minimize equipment and labor inputs, Bock and Wilson (1985). Thus, efficient N use by the crop usually is favored by subsurface N placement methods which involve significant soil and residue disturbance, but the other systems considerations listed above usually are favored by minimum disturbance of soil and residue. To optimize all the systems considerations related to N placement, subsurface placement methods are needed which give efficient N use by the crop while minimizing disturbance of soil and residue.

Effects of N placement differ by N source. Of course, anhydrous ammonia (AA) must be applied well below the soil surface because of its extreme volatility. Proper AA application results in efficient N placement relative to N use by the crop but usually also involves significant disturbance of soil and residue. Ammonium nitrate (AN) is often more effective than urea and UAN for surface application; an example of this is shown in Table 3 for AN vs. UAN. One reason is that, when applied on the soil surface, urea and UAN are more susceptible than AN to ammonia volatilization. Another possible reason is that, when applied in contact with decomposing crop residues, urea and UAN appear to be more susceptible than

AN to tie up by the residues. Thus, subsurface placement is more important for urea and UAN than for AN.

Although AN is often agronomically superior to urea and UAN for surface application, urea and UAN use is increasing at the expense of AN because of fertilizer production, transportation, and marketing factors. Already, combined use of urea and UAN is comparable to that of AA, and AN accounts for only 6% of the N applied in the United States (Table 2). Urea and UAN also account for a significant portion of the N used in mixtures. For these reasons, options are needed for using urea and UAN efficiently in reduced-tillage systems.

The NFDC has been involved in evaluating several N placement options for reduced tillage. This work has emphasized placement options that result in minimum disturbance of soil and residue. Dribbling or surface banding (applying narrow bands of fertilizer on the soil surface) is one option that has received considerable attention. Table 4 shows comparisons of broadcasting, dribbling, and knifing UAN at four locations using N rates that were optimum for no-tillage corn provided that N was used efficiently. At all four locations dribbling was superior to broadcasting, but dribbling was comparable with knifing at only two of the locations. These data represent some of the more favorable results that have been obtained with dribbling of UAN. In other cases, dribbling UAN has given little improvement over broadcasting as illustrated in Figure 3. Dribbling UAN is usually as good as or better than broadcasting but is not so consistent as knifing in terms of N use efficiency by the crop. Similar comparisons between broadcasting, surface banding, and knifing have been obtained for urea.

There are two special cases where dribbling UAN appears to be particularly effective in achieving efficient N use by the crop. One case is ridge tillage where stalks have been chopped and most of the crop residue moves off the ridges into the furrows. In this case, surface banding on the ridges avoids fertilizer contact with most of the crop residue, and thus holds promise for achieving efficient N use by the crop. The second case is reduced-tillage small grains seeded with deep-furrow openers. The deep-furrow openers move some soil and residue to the side of the seed rows and relatively residue-free soil is packed over the seed rows. As shown in Table 5, dribbling UAN on soil packed over seed rows gave yields comparable to those from injecting UAN 1/2 inch below seed rows. Dribbling on ridges and dribbling behind deep-furrow openers both result in the UAN being placed in relatively residue-free zones. These practices hold promise for achieving efficient N recovery by the crop even though crop residues remain on significant portions of the soil surface. Similar results would be expected with urea surface banded on residue-free portions of the soil surface.

Shallow injection rather than surface application of N sources can give significant improvements in N use efficiency with reduced tillage. Figure 3 shows how yield of no-tillage corn is affected by injecting UAN 2 inches below the soil surface. With injection 2 inches below the soil surface, yield was maximized with 200 lb N/A, whereas surface application would have required significantly more N to maximize yield. Injecting UAN 2 inches below the soil surface also gave results similar to those with AA injected 4 inches below the soil surface (data not presented). Thus, shallow injection appears to be adequate for achieving efficient use of N by reduced-tillage crops. If narrow knives and coulters are used, shallow injection often can be achieved with relatively little disturbance of soil and residue. Double-disk openers also achieve shallow injection with minimum disturbance of soil and residue. These types of shallow injection may optimize placement-related systems considerations discussed earlier.

Other emerging technologies also hold promise for achieving subsurface placement with minimum disturbance of soil and residue. One is use of coulters with low-pressure fertilizer streams directed into slots opened by the coulters. This is referred to as coulter-stream. Table 3 shows results with the coulter-stream relative to several other placement options for no-tillage corn. Coulter-stream placement was superior to dribbling on the soil surface and was comparable to knifing. In subsequent studies, the coulter-stream was somewhat inferior to knifing. In the same study (Table 3), high-pressure streams applied directly on the soil surface (Nutri-blast®) did not perform as well as the coulter-stream (low pressure). The effectiveness of high-pressure streams used with coulters has not been determined but should be evaluated as a possible placement option. The point injector is a minimum disturbance subsurface placement option involving spoke wheels with the spokes extending beyond the rim. Fertilizer is dispensed at the moment each spoke enters the soil. This placement technique, in early stages of development at Iowa State University and at the University of Minnesota, shows promise for reduced-tillage systems. The point injector may be particularly applicable for injecting N sources into ridges in ridge-tillage systems without significantly disturbing the ridges. This type of placement shows promise for providing excellent N availability while minimizing disturbance of soil and residues.

Applying most or all of the N requirement for small grains during the seeding operation (the one-pass concept) has significant advantages with reduced tillage. This practice enables precise placement relative to seed rows, a factor which can be used to achieve efficient N recovery by the crop while minimizing soil and residue disturbance associated with

N placement. Placing N below seed rows gives little more soil and residue disturbance than seeding alone. Studies in Washington, Oregon, and Idaho have shown that the total N requirement for small grains can be applied below seed rows without causing seedling and germination damage when the N is placed 2 inches or more below the seed rows. A 1/2-inch vertical separation between small grain seeds and the N source will prevent seedling and germination damage in some cases involving low-to-medium N rates; an example is the study involving medium-textured soils (Table 5). When done in a way to avoid germination and seedling damage, N placement below seed rows gives efficient recovery of N in reduced-tillage systems. As indicated earlier, dribbling N in residue-free areas over seed rows is a promising practice for achieving efficient N use by small grains. These placement options involving the one-pass concept are also promising relative to effects on weed control, soil moisture conservation, residue clearance, and overall labor and equipment requirements, Bock and Wilson (1985).

By definition, some tillage is performed in minimum-tillage systems. In many minimum-tillage systems, subsurface placement of N during a tillage operation is an excellent way to optimize systems considerations related to N placement. This has been a common practice for some time in the Great Plains and often is applicable when AA as well as other N sources are used, Murphy (1982). Cultivation is required in ridge-tillage systems to build ridges for the subsequent year. This provides an opportunity to subsurface apply N with no further disturbance of soil and residue due to N placement. Application of UAN with cultivators is an effective subsurface placement technique; AA can sometimes be applied with cultivators, but the depth of cultivation may need to be increased to prevent volatilization.

NITROGEN TIMING

Timing of N application is an important management tool for achieving efficient use of N by crops, particularly in the more humid regions of the United States. This is true regardless of tillage system. However, N timing is even more important with reduced tillage than with conventional tillage, because of greater potential for N loss with reduced tillage and the ability to minimize these N losses by using efficient N timing. The general concept is to apply N as close to the time of plant need as is practical. This approach minimizes the time that applied N is exposed to N loss pathways and N tie up in the soil before the crop takes up the N.

Timing of N application mainly affects losses of nitrate, although losses of other N forms may be affected. The nitrate form is very important because the major N sources either are applied in or readily converted to the nitrate form in warm, moist, productive soils. The potential for loss of nitrate is greater with reduced tillage than with conventional tillage for two main reasons. First, nitrate moves with soil water, and generally, there is more downward movement of water with reduced tillage than with conventional tillage. The greater downward movement occurs because reduced-tillage systems conserve more soil moisture and develop more large soil pores which result in relatively rapid downward movement of water. Both factors result in greater potential for leaching of nitrate to below the root zone. Second, nitrate is susceptible to denitrification losses. There is greater potential for these losses with reduced tillage than with conventional tillage, particularly when nitrate is near the soil surface where crop residues are decomposing, as mentioned earlier.

Table 6 shows an example of the importance of N timing with no-tillage corn. Sidedressing UAN gave higher yields than the planting-time application, probably because nitrate losses were lower with sidedressing. Also, the advantage for sidedressing UAN was greater with broadcasting than with injection. This may have been because, with broadcasting, delayed N application was more important in reducing both N tie up in surface residues and denitrification losses associated with surface residues.

As shown in Table 7, Corn Belt farmers generally apply more of the N for corn after planting and less of the N in the fall and spring with both no-tillage and till-plant systems than with either plow or chisel/disk systems. One interpretation of these data is that farmers recognize the greater potential for N loss with no-tillage and till-plant systems and are delaying part of the N application in these systems to achieve efficient recovery of N by the crop. Part of the reason 49 percent of the N was applied after planting in the till-plant systems may be the efficiencies associated with applying N during cultivation. Whatever the reasons, data in Table 7 suggest that N application time for corn may shift from primarily preplant to primarily planting time and postplant as farmers shift from conventional to reduced tillage.

PHOSPHORUS AND POTASSIUM: GENERAL COMMENTS

Generally, shifting from conventional to reduced tillage increases the probability of yield response to starter P and K. With reduced tillage, yield responses to starter P and K are more frequent, even on soils testing medium to high. The main reasons for greater probability of response are that reduced-tillage systems are often associated with one or more of the following conditions: wetter, cooler, and compacted topsoils. These conditions can result in reduced movement of P and K to roots and reduced ability of roots to proliferate into significant volumes of soil and to recover the P and K that moves to roots. One of the reasons for using reduced tillage is to enable earlier planting, which, combined with various properties of reduced-tillage systems such as surface residues, gives extraordinarily cool, wet soils during early growth. These factors result in increased probability of response to starter P and K.

The benefits of placing nonstarter P and K below the soil surface in reduced-tillage systems differ somewhat in drier and more humid areas of the United States. The key point to remember is that P and K are much less mobile than N in soil. With reduced tillage, surface-applied P and K remain near the soil surface because they are not mechanically mixed with significant amounts of topsoil. In drier regions, P and K applied on the soil surface are often unavailable to crops because the surface soil containing the P and K is too dry to support root activity. For that reason, P and K should be injected below the soil surface in drier regions.

In more humid regions, the need for applying nonstarter P and K below the soil surface is less clear. Surface-applied P and K also remain near the soil surface with reduced tillage in the more humid regions. However, there is usually more root growth near the soil surface in more humid regions than in drier regions. In fact, more of the roots are near the soil surface with reduced tillage than with conventional tillage. The heavier concentration of roots near the soil surface often results in efficient recovery of surface-applied P and K unless the surface soil dries out. The surface soil is less likely to dry out with reduced tillage because of the surface residues. Thus, placing P and K on the soil surface is often effective with reduced tillage in the more humid regions but may not be as consistently effective as subsurface placement. Building up P and K levels before shifting to reduced tillage should be the safest approach.

SUMMARY AND CONCLUSIONS

Nitrogen rate recommendations should be adjusted according to effects of tillage system on yield potential and, in some cases, for effects of tillage system on N recovery efficiency by the crop. With efficient N timing and placement, yield potential is the main tillage-related consideration in making N rate recommendations; in these cases N rates need to be adjusted proportionally with changes in yield potential. With inefficient N placement and timing, tillage-system effects on N recovery efficiency as well as yield potential need to be considered in making N rate recommendations; in these cases the N rate requirement for a given yield potential will tend to be higher with reduced tillage than with conventional tillage. The higher N rates are required to compensate for less efficient N recovery by reduced-tillage crops.

With reduced tillage, N sources generally need to be placed either below decomposing residues or, at least, in residue-free zones on the soil surface to consistently achieve efficient N recovery by the crop. This type of precision placement is less important with AN than with urea or UAN as N sources. In some tillage systems, soil and residue disturbance associated with traditional injection techniques detracts from efforts to do one or more of the following: control weeds, conserve soil moisture, clear residues during a subsequent seeding operation, and minimize equipment and labor inputs. In these tillage systems, precision N placement can be achieved with minimum disturbance of soil and residues using one of the following options:

- surface banding, especially on residue-free areas, such as on ridges or behind deep-furrow openers on small-grain drills.
- shallow injection, using either narrow knives with coulters or double-disk openers.
- coulter-stream injection.
- point injection (not yet commercially available).
- one-pass seeding and fertilizing for small grains.
- in minimum-tillage systems, injecting fertilizer during a tillage operation.

Timing of N application is even more important for achieving efficient N recovery by crops with reduced tillage than with conventional tillage. The general concept is to apply N as close to the time of plant need as is practical. Farmers are apparently recognizing the importance of N timing for reduced tillage, because a Corn Belt survey suggests that N application time for corn may shift from primarily preplant to primarily planting time and postplant as farmers shift from conventional tillage to reduced tillage.

Shifting to reduced tillage generally increases the probability of yield response to starter P and K. In drier regions, nonstarter P and K should be injected below the soil surface in reduced-tillage systems to assure ample root activity in the fertilized zone. In more humid regions, surface-applied P and K are often effective with reduced tillage but may not be as consistently effective as subsurface placement. Building up P and K levels before shifting to reduced tillage should be the safest approach.

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TABLE 1.
Effects of N Placement on Corn Yield With Differing Tillage Systems, Piney Purdue Agricultural Center, 1971–73.

N Placement	Plow	Chisel	No-Till
	corn yield, bu/Ac		
Broadcast	136	131	121
Injected	136	140	137

Mengel, 1985

TABLE 2.
Relative Use of N Sources in the United States—1986.

Mixtures	Direct Application			
	AA	N soln's.	Urea	AN
	% of total N used			
21	36	19	15	6
		34		

Hargett and Berry, 1986.

TABLE 3.
Effects of N Placement and Source on No-Tillage Corn Yield Averaged Over 5 Locations in Maryland—1984.

	Corn yield, bu/Ac
No N	87
120 lb N/Ac:	
AN broadcast	167
UAN broadcast	153
UAN dribbled	154
UAN Nutri-blast®	157
UAN coulter-stream	164
UAN knifed	168
$LSD_{0.05}$	9

Bandel, unpublished data.

TABLE 5.
Effects of N Placement on No-Tillage Wheat Yield Averaged for 3 Locations and 2 P Rates in Colorado—1985.

N rate (UAN)	Broadcast	Dribbled over seed rows	Banded below (1/2″) seed rows
	wheat yield, bu/Ac		
0	52		
30	53	60	58
60	59	59	60

Westfall and Ward, 1986.

TABLE 6.
Effects of N Application Time and Placement on No-Tillage Corn Yield Averaged Over 3 Locations and 6 Years in Maryland—1980–85.

N placement	N application time	
	Planting	Sidedress
	corn yield, bu/Ac	
Broadcast	136	146
Injected	150	155
	$LSD_{0.05} = 4.5$	
Mean	143	151

Bandel, unpublished data.

TABLE 4.
Effects of N Placement on No-Tillage Corn Yield in Maryland.

	Location 1 120 lb N/Ac	Location 2 120 lb N/Ac	Location 3 120 lb N/Ac	Location 4 160 lb N/Ac
	corn yield, bu/Ac			
UAN broadcast	99	120	136	159
UAN dribbled	120	157	149	176
UAN injected	124	167	150	178

Bandel, unpublished data.

TABLE 7.
Timing of N Application in Major Tillage Systems as Indicated by a Survey of Corn Belt Farmers—1983.

Tillage system	Fall	Spring	Planting	Postplant
	% of applied N			
Moldboard plow	7	58	8	27
Chisel/disk	10	65	6	18
Till-plant	21	21	9	49
No-till	7	33	24	37

Fletcher, 1984.

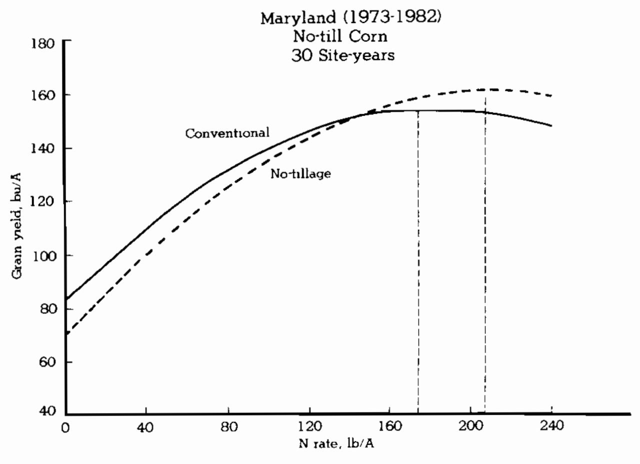
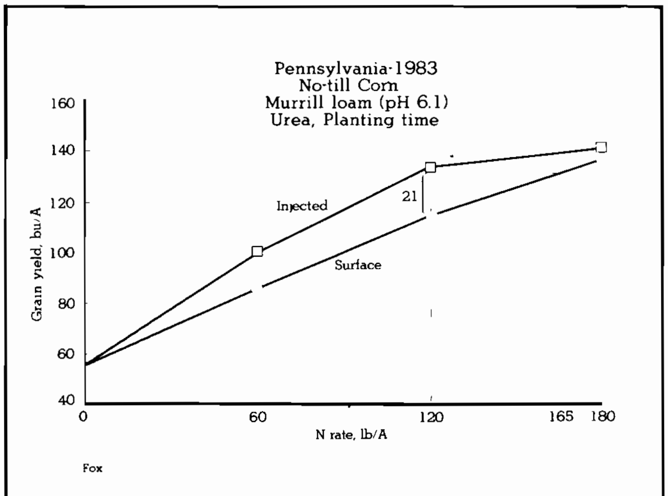
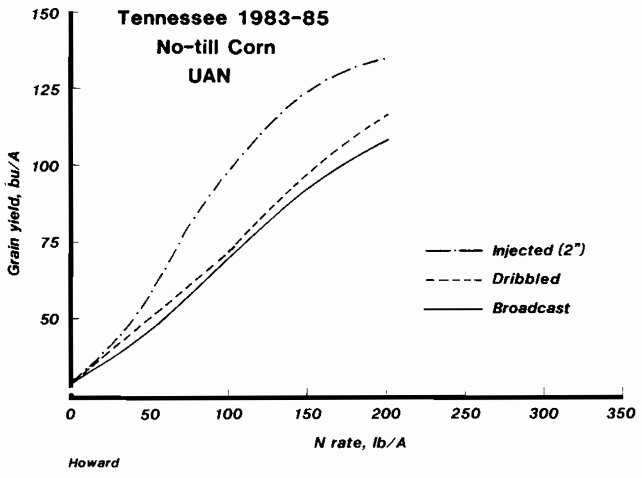


Figure 1 Typical "cross-over" effect of tillage system on corn response to N



Fox

Figure 2 Example of effect of urea placement on N rate requirement for no-tillage corn



Howard

Figure 3. Effects of UAN placement on response of no-tillage corn.

Latest Developments in Fluid Fertilizers with Emphasis on Liquid Conversion of Prilled Urea

Bill Armfield, President
Kansas Crop Service, Inc.

For some reason over the past year or so, I have evolved as the authoritative proponent of the "Let's Melt Urea World." I have been on several programs and answered dozens of phone calls on this subject. So, regardless of my feelings and the feelings and thoughts of others, the subject of liquefying urea has been very much on the minds of fertilizer dealers around the country for the past several months. I only propose to address this topic as a retailer of liquid fertilizer who was faced with a price situation between the product we normally marketed and cheap low cost import urea. During the course of my research on this subject, I found out that liquefying solid urea wasn't anything new. Some dealers have been doing just this for many years, not necessarily for the economics of it but for the finished product, which worked better for them than did urea solution. So . . .

During the course of one's life we are taught that there are plenty of opportunities that will present themselves to us. We are also taught that unless we are able to recognize these opportunities, they will slip by and nothing will be gained. One of these opportunities has presented itself to our industry this past season, and that was cheap, low-cost urea. In the fertilizer business, there is one word I absolutely don't like to hear and that word is "cheap." I always try to replace the word cheap with the phrase—low cost, but in the case of most of the imported urea I saw last winter and spring it was "cheap"—I mean substandard and low quality which makes it easy to use the word "cheap." Remember though, in our plan, this is what we wanted—cheap, substandard, low cost product.

I will tell you a little story about my first experience with urea. It was about 20 years ago and at that time I was with Smith-Douglass which later became Borden. I got the word from higher up to start ordering and promoting urea. It seems as though Borden came into the picture and had a large plant at Geismar, Louisiana which was producing more urea than they were able to sell to the Lumber industry. Urea was promoted from that time on. We had many Coops in the area who were still with the ammonium nitrate program who jumped on us and our customers by telling them of the great amount of loss they would have when urea was put on top of the ground. A few years later Farmland Industries built a large NH3 plant at Enid, Oklahoma and they started producing urea. The same word came down to the local Coops that I had earlier received—start promoting and selling urea right away. Everything was OK about urea. We thought we recognized an opportunity when last fall we started hearing about some of those cheap urea prices. When we started figuring the cost of N it was very apparent that urea was to be reckoned with. Being in the fluid business and remembering that we who are in the fluid business are supposed to be the innovators of our industry we started thinking and figuring just how we could best utilize the cheaper cost of the N from urea. We are located in an area where dry blenders are many and we knew we didn't want to compete with them by selling and applying dry urea because in most cases the cheap urea was of very poor quality. I mean small, not uniform prills with a lot of fines and dust in the product. You guys that spread dry urea this past season know what I mean, don't you!

We contacted Allied sales people for help. Allied was contacted because we have been buying ammonium sulphate from them from which we make our sulfur products. It didn't take long to decide that it would serve our own purpose best by selling a product containing sulfur, because our company has been very active the last three or four years promoting sulfur. We also concluded that maybe everyone of our customers would not want sulfur even if they needed it. So, we decided we would have two grades which we would promote for wheat top dressing and early feeding of brome pastures. The grades were 20-0-0 and 21-0-0-(3s).

We have a Bard & Bard mixer and we knew we would have no problem making these grades if the formula were correct. The first problem we encountered was the lack of *hot water*. We couldn't completely dissolve the urea prills in our well water which produces 55 degrees water. You also lose about one degree of temperature with each 100 pounds of urea that goes into the mix. Our finished product was ending up at below 32 F, degree temperature. We never really encountered any problem with this other than the prill would not dissolve. Resulting from this, we had urea crystals settle out in our storage tank and unless brought back into our mixer and dissolved after the solution warmed up, we had tip plugging problem in the field during application. So this resulted in double handling of the product and thus increased our production cost. After fighting these problems we decided we would add some ammonia (NH_3). This would replace some of the urea needed, but best of all we increased the temperature of our water to 70 F degrees and this would allow us to completely dissolve all of the prills and we would go to storage at about 38 F degrees temperature, or just above freezing. We have since negotiated with a steam electrical generator plant (KG & E) near us to get 90 F degrees warm water. This will help us make the grades we have been making plus we will be able to make others. Our capacity with our 10 ton Bard is about 3 batches an hour or 25/30 tons of finished product.

If you think I am up here to tell you that the only way to go is to get into melting urea, you are wrong. There are lots of problems in adjusting to this operation. First of all, you have to have a good high volume mixer or your capacity is too small. Next, if you have any sales volume at all, you will have to have a lot of dry storage space to get the urea to your location. You will also need more liquid storage because of the lower N content of the finished product. Another big problem is traffic in you mix plant, especially if you are top dressing wheat at the same time you are needing your plant for making alfalfa or corn fertilizer. So keep this in mind when thinking of getting into the urea melting business. As agronomics go, we see no real problem. We are concerned with the free ammonia in the product. However, in our case, we do our wheat top dressing in February–March. We still have very cold temperature during this period so I doubt the loss is very significant during this operation. As we get into our warmer season when we are getting our ground ready for milo, we recommend working the ground immediately after application in order to cover the urea solution. This is rather easy in Central Kansas as we still do a lot of weed and feed which requires incorporating. When this is not the case, most of the N is knifed in either pre-plant or side-dress with a knife applicator, which by the way, this practice is still growing for us. We have always recommended that urea be incorporated or covered after we get into the warmer part of our season. However, the amount of loss when left on top of the ground is still something to argue about.

I have not, from a layman's view, seen any visible losses from the use of urea. No matter if it was broadcast on top of the ground or worked in on wheat, urea has always performed equal with any other source of N. So I paid special attention to our customers this year. In areas where the wheat was good, we had some of the best wheat. In areas where the wheat was bad we were well within the average. So again, I can say of the 17,000 or so acres we topdressed we saw no difference where our urea solution was used versus NH3 fall applied or dry urea spread or even where 28% solution was used.

Now in closing, I once again want to point out that melting or liquifying urea is not for everybody, but if this program can work for you, maybe you too can capitalize on this opportunity and maybe you can increase your Nitrogen profits. If you think melting urea might work for you, my advice is to look long and hard before making many changes in your operation. A mistake here might be very costly for you.

Preserving Quality in Opposition to Cost Trends

Lewis Coalter
Arcadian Corporation

Bill Armfield has done an excellent job of reviewing opportunities for converting prilled urea into liquid fertilizers, and he also has pointed out some pitfalls. My assignment this morning is to approach the subject from a different angle . . . to analyze and report on the issue of preserving quality in the liquid fertilizer industry . . . in opposition to current cost trends. Today, manufacturers and dealers are fighting a battle for survival in the fertilizer business. Is quality worth preserving in the liquid industry? If it is, can it be maintained in the process of fluidizing urea, and then applying it as a substitute for UAN solutions?

To answer these questions . . . or to at least help give you a clear perspective so that you can come up with your own answers . . . let us first examine the aspects of quality that make liquids special . . . and that have spurred the growth of the fluid fertilizer industry. Then we'll relate quality to the matter of cost. What are the risks—both obvious and hidden—of lowering quality . . . and what impact may they have on your bottom line?

To those of us who fought the battle to gain market share for fluid fertilizers against dry materials and anhydrous ammonia . . . and it certainly was an uphill battle . . . quality is not a subject to be taken lightly. Liquids have been growing their market share faster than any other segment of the fertilizer industry. The last numbers available . . . 1985 statistics for the '84-'85 fertilizer year . . . revealed that UAN solutions, for example, comprised 21% of the total nitrogen market, including dry nitrogen materials and anhydrous ammonia. In recent years, that figure has been growing at the rate of 4% per year, on the average. Even in those years when total N use declined, nitrogen solutions market share continued to grow at about 4% annually.

In itself . . . that says something for the built-in quality of UAN solutions, and it makes old timers like me want to look pretty carefully at the process of melting dry urea to make either reduced nitrate UAN solutions or urea solutions.

It has taken a lot of hard work . . . a lot of dollars invested in research . . . and an army of expert sales representatives across the country to gain the market share that liquids . . . and particularly UAN . . . now enjoy. Even in these tough times, UAN still is the backbone of our industry and the foundation upon which many dealerships are built.

In assessing the issue of quality, however, let's take an even broader look than just a head-to-head face-off between UAN and fluidized urea. I think we can agree that quality in any product must be gauged by performance . . . especially performance that is obviously better than competitive products. Liquid fertilizers are often measured as being more available to crops than other forms of fertilizer. In other words, their efficiency can be measured . . . proved . . . and commercially recognized. Precision application, positive placement and spoon feeding of nutrients to crops can be achieved more easily and accurately with liquids than with either dry products or ammonia. The ability of liquids to serve as a carrier for secondary elements, micronutrients, and pesticides in combination applications . . . such as feed and weed . . . to cut down on costly trips across the field has been recognized in terms of contributing to the efficiency of modern agriculture. We also must remember that improved storage, handling and ease of application are characteristics of liquids enjoyed by both the dealer and grower. All of these handling, application and performance benefits add up to a deserved reputation for liquids for highest quality, when compared with competitive forms of fertilizer. And all this has been reflected in the rapidly-rising position of liquids in the marketplace.

Now if there is a star performer on the liquid fertilizer team, UAN would have to be recognized as the leading candidate, as I have already indicated. If these were normal times, the old adage: "If it ain't broke don't fix it," would apply in the case of UAN versus fluidized urea. But in times like these, you can understand how we all are tempted to lower our costs. We want to survive! As we watch profits go down and then disappear, we look for ways to bring them back. If we can't sell more product at a better price, maybe we can make the product cheaper and then squeeze out a little profit.

Of course, it won't really be the same product, but in the case of fluidized urea, if it looks like a nitrogen solution . . . smells like a nitrogen solution . . . and applies like a nitrogen solution . . . hell, maybe it is a nitrogen solution!

If we are leaning in this direction, perhaps now is the time to ask ourselves the question: "What about the agronomics of quality?" If our new liquid fertilizer made from melted urea does not feed the crop as efficiently as UAN solution, that fact will soon be known . . . or at least strongly suspected. The quickest way to increase farmer costs is to lower his yields.

Now we enter an area where making an absolute judgment . . . and knowing you're right . . . becomes difficult. I don't think we really know the answer to exactly how urea nitrogen solution compares with a standard UAN non-pressure nitrogen solution. The reason we don't have a strictly scientific answer to this comparison is because most of our research data and field experience are based on comparisons of UAN and solid urea. The typical UAN solution contains a combination of urea and ammonium nitrate with about 50% of the total nitrogen coming from urea.

The uphill battle to establish liquids . . . and especially UAN solutions . . . was due in large part to strong resistance by university extension agronomists. What did they object to? Mainly it was the fact that nitrogen solutions contained urea. The only university agronomists who ever expressed concern about ammonium nitrate in UAN have been those who work with rice, a crop that favors nitrogen in the ammonium form. So, aside from rice, it was urea that was . . . and still is . . . the target of many agronomists. You can get a headache reading all the research papers that point out the potential for volatilized loss from the urea in UAN. What do you think these university scientists are going to write when they discover any kind of trend toward nitrogen solutions with increased urea nitrogen or 100% urea nitrogen?

As we see it, for applications that are injected below the soil surface . . . or incorporated soon after they are placed on the soil surface, the urea content will not be a major factor in agronomic performance. For applications that are subject to volatilization loss of nitrogen, the amount of urea in the solution will determine the extent of the loss and be a factor in performance . . . and a factor that will show up clearly in research and field trials.

We can ask ourselves . . . if urea is the only ingredient that keeps UAN non-pressure nitrogen solution from being a perfect source of fertilizer nitrogen in the minds of agronomists . . . for crops other than rice . . . then why would we want to increase the urea content of the nitrogen solutions that we make and sell? You could stand up and yell that cost is the reason, and we have an opportunity to take advantage of cheap, low-cost dry urea. After all, we are not personally responsible for this depressed economic situation in the fertilizer industry . . . and in agriculture. The explanation of the need to lower manufacturing costs usually is followed by rationalization that most of the urea solution is being immediately incorporated or injected into the soil, anyway. But what's the real situation? I would guess that much more that half of all the non-pressure nitrogen solution applied during the spring of '86 was left on the soil surface for at least 48 hours or longer. If that is not a recommended practice for conventional UAN solution because it contains some urea, what do you think the recommendation would be for a solution that contains much more urea? If I were doing it I would pray for rain!

And what do you think the chance for good results would be for urea solutions applications on minimum-till cornfields with heavy residues of stalks on the surface? One thing that agronomists do know for sure is that rapid hydrolysis can cause a serious loss of N by volatilization from urea placed on the soil surface and not incorporated by tillage or about one-half inch of water from rain or irrigation within a few hours after application. The risk of loss is increased when the soil surface is covered with plant residue. In extreme cases, the loss from *solid* urea placed on a bare soil has exceeded 30% of the total applied N rate, and in the same study, loss climbed above 80% when plant residues covered the soil surface.

We have been successful in showing, through research, that the typical UAN solution has less risk for loss than solid urea under the same conditions. If we alter the solution by increasing the urea content, the current data we are using will not be applicable.

To answer the question of how serious is the loss potential from fluid urea, let's take a look at a recent field trial by Purdue University. There is no data available showing fluidized urea vs. UAN solution, but in this Purdue study, solid urea, solid ammonium nitrate and 28% UAN solution were applied on the surface of a Lyles sandy loam soil at a no-till corn site near Vincennes, Indiana. The nitrogen application rate was 150 pounds per acre, and it was applied during May.

Notice that the greatest loss of volatilized N came from solid urea. In fact, it is quite spectacular. This loss began a few hours after application and peaked on the second day after application when a daytime loss rate was measured at 2.6 pounds of N per acre per hour. On the third day, one inch of rain stopped volatilization loss. During the 55 hour period from application to rain, about 30% of the total nitrogen applied in the form of urea was lost through volatilization.

Note that loss from the 28% UAN solution peaked at .33 pounds of N per acre per hour and ended with a loss of about 4% of the total N application, It was 8.1 times less subject to losses via volatilization than urea. Since the UAN solution contained approximately 50% of its N content in the form of urea, it is apparent that the urea solution was less subject to volatilization loss than that in the solid urea.

This information does not answer the question about loss from fluid urea, but it does indicate that it may be somewhat less than solid urea. How much loss might have occurred from a non-typical UAN solution that contained less ammonium nitrate and more urea? Most agronomists feel that the loss will increase as urea content is increased.

Many other studies could be cited, but none has been conducted that will give us answers on direct agronomic comparisons between UAN solutions and fluid urea solutions. Various studies show that N loss can be much more severe than the Purdue data indicate.

In North Carolina, a topdress N source study on winter wheat supports the Purdue data by indicating that the urea in UAN solution may be less subject to volatilization than that contained in solid urea. It also challenges those who say that volatilization loss is not a factor for wheat topdress because temperatures in late winter and early spring are too low to trigger rapid hydrolysis.

Here's another very important thing to keep in mind. Data and field experience with UAN solutions used in feed and weed programs may not apply to fluidized urea solutions. A recent laboratory test by ARCADIAN® chemists measured the pH of a urea solution made from dissolved solid urea at 9.0. The pH of ARCADIAN® URAN® ranges from 6.8 to 7.2. This difference is great enough to raise some serious questions about possible performance differences between the two materials when used as carriers for pesticides. Most pesticides labeled for application with nitrogen solution were tested with URAN® or a product of similar composition.

If you are considering manufacturing urea solutions . . . and expect them to be used in combination applications with pesticides . . . you must take into account the free (uncombined) ammonia that may be produced during the manufacturing process. At the temperatures required to dissolve urea, small amounts of biuret and ammonia are likely to be formed. As small an amount of free ammonia as 0.5% by weight can change a 50% urea solution from pH 8.8 to a pH exceeding 10.8. Many pesticides are not compatible with high pH solutions either physically, chemically or both. For example, carbamates, organophosphates and systemics rapidly lose their effectiveness in an alkaline medium. With a high pH solution, pesticide degradation time may be as short as one hour for a half-life of the solution. Many of the pesticides which carry labels indicating suitability for use with nitrogen solutions assume that the solution pH will fall within a narrow range of 6.8 to 7.2. Fluidized urea solutions are well out of this pH range unless buffers have been used to adjust the pH down. Difference in pH of the unbuffered material is great enough to cause serious performance problems, and in some cases, physical compatibility problems with these pesticide products.

But to sum up the agronomical side of fluidizing urea . . . we believe that agricultural university agronomists have one main theme in mind. While they would be pleased to see the cost of nitrogen solutions reduced, not one of them will be willing to stand for increasing urea content to reduce that cost. If melting urea takes over in the trade, we'll see university agronomists shifting to stronger recommendations for anhydrous ammonia.

And, in many cases, they might be right . . . because they serve agriculture, and if nitrogen that we sell does not get into the crops and provide a financial return to the farmer through higher yields of quality commodities, that nitrogen has no value, regardless of how much we lowered our manufacturing costs . . . or what price the farmer paid for his fertilizer.

But can we really lower our costs by fluidizing urea, and if so . . . by how much? How about the quality of the product as it relates to solubility, storage and handling?

At first glance, it appears that costs can be lowered dramatically by melting cheap, dry urea. Next, however, you must add up all the extra costs required to do the job, and subtract that from that initial "good-news" of the low-cost dry product. Then, after you have considered the agronomic performance consequences that we have just reviewed . . . and perhaps put a figure to that . . . add it all up, and break it down on a per ton basis. Then compare it to your regular per-ton figure for manufacturing and handling UAN solutions. How you settle on figures for the good quality performance of UAN, versus the somewhat uncertain performance of fluidized urea solutions . . . well, I'll leave that up to you. If we polled the audience, we would get figures that vary all over the place, but I think most of us would agree that there should be some bottom-line comparisons between the two solutions products on projected performance . . . that is, if you are planning to stay in business for a few more years.

How do we get some real manufacturing cost figures for melting the dry urea? As Bill Armfield said earlier, it is not as simple as it looks. It involves more than just pouring urea into water, stirring the mixture and waiting for the urea to disperse.

To begin with, most urea is manufactured as a prilled or granular material to keep the product as free-flowing as possible. These large particles are harder, and much more dense than crystalline urea, and consequently dissolve slowly, even with vigorous agitation. Also, the liquefaction of urea in water produces an endothermic reaction characterized by absorption of heat. The heat of solution for urea . . . 46% N . . . is a negative 108.2 British thermal units . . . Btu's . . . per pound of urea dissolved, or 108,200

Btu's per ton of product for a 50% urea solution. To raise the temperature of ambient water above the saturation point for the resulting product, and to insure complete dissolution of the urea, an initial water temperature of at least 160 degrees Fahrenheit is required. Obviously, the higher the water temperature, the quicker the urea will disperse; however, with the cost of most energy sources, it stands to reason that extra mixing time may be less expensive than the fuel cost. Other manufacturing costs to be considered besides fuel are electricity, labor, shrinkage and water (extensive quantities). These costs vary considerably from one manufacturing locale to another, but can easily exceed $10 per ton of finished product. Making some assumptions for a typical situation, here is a break-down of average costs for manufacturing a ton of fluidized urea.

Let's review how we arrived at the numbers on this slide. They are not exact for any given location, but they are typical numbers that would be developed for many locations.

Once again . . . we know that the heat of solution for urea is a negative 108.2 Btu's per pound of urea dissolved, or 108,200 Btu's per ton of product for a 50% urea solution. I won't go through the rest of the calculations, except to say that they are based on a water temperature increase of 125 degrees F. Figuring gas at $4.00 per 1000 cubic feet, we wind up with $1.00 per ton required for the heat necessary to manufacture one ton of 50% urea solution.

In arriving at the per-ton manufacturing costs for electricity, labor, shrinkage and the large quantities of water required, we have based our arithmetic on average industry costs for these inputs. We urge you to go through the same exercise for both urea and UAN solutions. Develop your own to sets of figures for comparison, and you will determine that the manufacturing costs for fluidizing urea are considerably more than those of UAN solutions.

But now that we have manufactured the product, what about storage, handling and application? We are going to have to add some more costs onto the urea solutions side of the ledger. Transportation costs for extra tons of the fluidized urea product that will be necessary to apply the same amount of N . . . compared to applying it through a UAN solution . . . would run about $1.50 per ton. Storage costs for those extra tons could be figured at about 30 cents per ton. Urea solutions, due to solubility limitations, require the handling of substantial volumes of product in comparison with UAN solutions.

For example, a 28% nitrogen (by weight) UAN solution can be readily stored and field-applied at temperatures well below freezing . . . while a 28% N urea solution would require temperatures in the range of 95 degrees Fahrenheit, to make a fair but somewhat ridiculous comparison. A 50% urea-water (23% N) is difficult to handle and apply at temperatures below 60 degrees Fahrenheit. At temperatures below freezing, the solubility limitation drops the nitrogen content of urea solutions to less than 19%, and increases the tons of product to be handled by 35% versus a 28% UAN solution. The relationships of urea solubility and salting-out temperatures are shown in the following slides.

It is generally not recommended to store urea solutions for prolonged periods in areas where temperatures regularly drop below freezing for more than a few hours at a time. Urea salt crystals which precipitate from such solutions in cold weather have a tendency to form a solidified compact mass which is extremely difficult to redissolve. These limiting solubility factors make it advisable to produce urea solutions as close to the use period as possible.

Another factor to be considered—and I'm sure you noticed this on the slide—is the amount of free (uncombined) ammonia that may be produced during the manufacturing process. At the temperatures required to dissolve urea, small amounts of biuret and ammonia are likely to be formed . . . as I pointed out earlier when discussing feed and weed problems. This skyrockets the pH up beyond 10, causing incompatibilities with many major pesticides. How do you put a dollar figure on that? Even if you can't figure how much that would cost your business in terms of poor performance and reduced orders, you certainly know it's a problem you don't want!

In summary, I've tried to present an overview of the issue of preserving quality in opposition to cost trends—particularly in relation to the production and marketing of UAN solutions vs. urea solutions. To fluidize or not to fluidize, that is the question, and I hope I've given you some new perspectives to help you make up your own mind, based on your own operation. Keep in mind that an apparent low-cost source of nitrogen, such as urea, may not be suitable for marketing in a fluid form once all the critical factors affecting manufacturing and use are taken into consideration. While cost will always be one factor in selecting plant food sources, marketers must remember the relationship between chemical, physical and agronomic properties of these fertilizer materials, and make choices based on a balancing of all the factors involved. For my own part, I believe we, as an industry, certainly will lower the quality of our nitrogen solutions if we make a significant switch to fluidized urea . . . from UAN solutions. The lower quality product will be recognized, and we'll have to pay for that. But then, that's kind of like what the man says on TV . . . "You can pay me now, or you can pay me a whole lot more later." We're still going to have to pay more than we realize now to fluidize urea, and we may have to pay a whole lot more later to make up for the consequences.

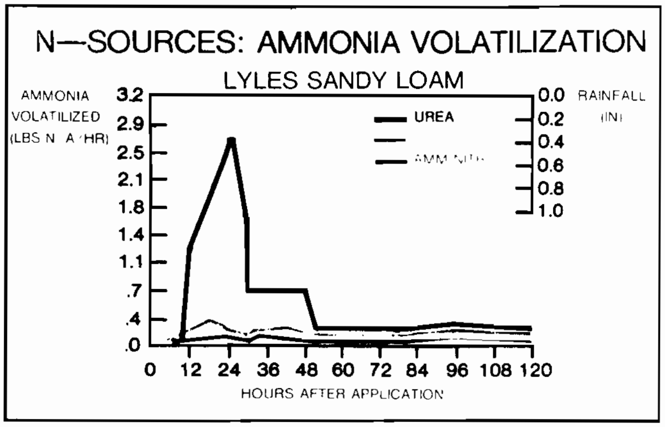


Exhibit 1

LIQUEFACTION OF UREA

Manufacturing Costs Per Ton Of 50% Urea Solution

Heat	**$ 1.00**
Electricity	**3.00**
Labor	**5.00**
Shrink	**0.90**
Water	**0.60**
	$10.50

Exhibit 2

SOLUBILITY OF UREA IN WATER

Temperature °C	°F	Percent Urea By Weight	Percent Nitrogen * By Weight
-11	+11	32.5	15
0	32	40.0	19
10	50	46.0	21
17	63	50.0	23
20	68	52.0	24
25	77	54.8	26
30	86	57.5	27
35	95	60.0	28
40	104	62.5	29
50	122	67.0	31

*Rounded to nearest whole number

Exhibit 3

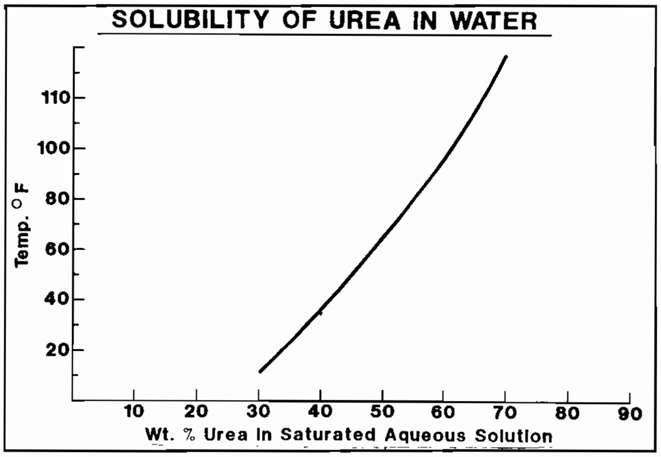


Exhibit 4

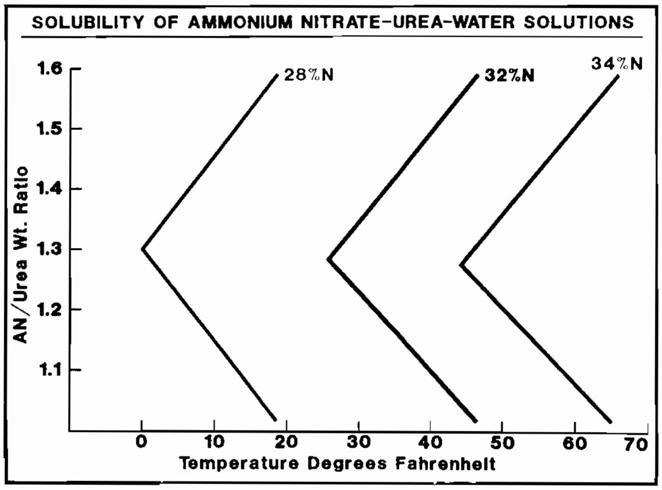


Exhibit 5

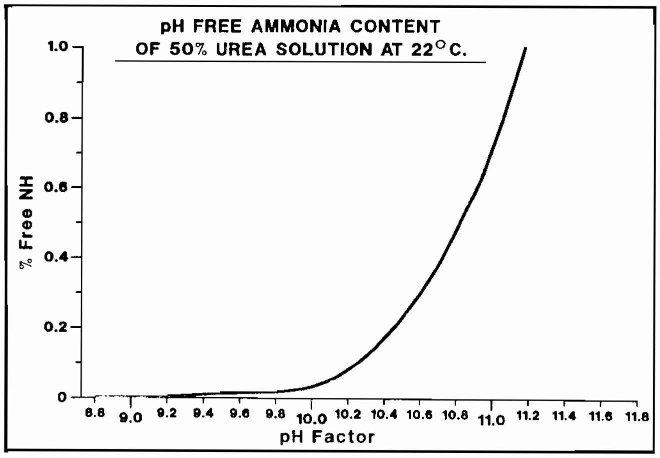


Exhibit 6

Dealer Risk Management . . . In a Crisis Environment

Jay J. Vroom, Executive Vice President/CEO
National Fertilizer Solutions Association

Fertilizer & ag chem dealers across North America are screaming about the high cost and limited availability of all lines of insurance. NFSA has been directly impacted by the insurance crisis . . . our group product liability insurance package, which had more than 200 of our dealer members covered, was cancelled effective December 1, 1984—just ahead of the Union Carbide disaster at Bophal, India. It's been mostly downhill ever since!

This crisis is *more* than a simple insurance problem—that's why we're terming it a *Dealer Risk Management Crisis* . . . which is recognition that there are two distinct elements:

1. Insurance crisis; and
2. Liability crisis.

The insurance market *itself*, across-the-board, became very "tight" in 1984 as insurance industry profits shrank due to poor management of their basic business. Most insurance firms had been engaged in "bidding wars" aimed at snaring insurance premium cash flow—almost at any price—so as to provide cash investment fuel for their T-Bill and CD investment portfolios. Then interest rates fell, exposing the fact that the insurance industry's underlying business was fairly sick—especially given the increasing incidence of "bleeding heart jury awards" for liability suits involving "pain and suffering" compensation to victims.

The evolution of this second part of the crisis—generally termed liability or "tort" reform is also very significant. Legislation that would have turned part of the "tort" problem around just failed passage in the recently adjourned 99th Congress . . . but tort reform, I believe, will come.

So with higher premiums and more select business the insurance industry now is being accused of windfall profits . . . and competition for the "better" low-risk insurance business is generally softening rates. And tort reform will help the general crisis environment. Problem is . . . we're unique and both of these *general* improvements will still leave the fertilizer/ag chem dealer somewhat out in the cold . . . we're victims of CHEMICAL PHOBIA which means insurance will be a tough buy for as far into the future as I can see.

To get a specific handle on the magnitude of the problem . . . NFSA conducted a survey of dealer members. We were overwhelmed by the response—slightly more than 500 fertilizer/agricultural chemical dealers responded to the March 1986 National Fertilizer Solutions Association survey seeking information on the current liability insurance crunch. Taking time out during the "busy season" to create a 55 percent return rate for the survey indicates the concern dealers have about their liability premiums and coverage. The survey generated responses from companies doing business in 47 states.

Two-thirds of those completing the survey indicated renewal difficulties in the areas of vehicle, product, environmental and general liability. Premium increases of 50 to 300 percent were common among those reporting sharply higher insurance bills. Thirty-eight percent of the dealers polled indicated that one or more companies had refused to renew their property/casualty insurance coverage. Nearly 14 percent of those returning the survey were unable to obtain, or decided to go without selected liability coverage.

Several questions were asked to better understand the "liability history" of NFSA dealer members. The message this survey provides is that past performance has little to do with the current sky-rocketing premiums. Slightly less than one-third of the dealers surveyed reported liability damages awarded against their companies during the past five years.

The median award for claims paid on behalf of these dealers was $10,147 (this award averaged over a five-year period would only amount to a pay out by insurance companies of $2,029.40 per dealership.) The median premium increase experienced by all members answering the survey fell right at 100 percent. The range of premium increases were from 3 to 1200 percent. Many dealers are paying well over $2,000 each month for liability coverages.

Comments received on the survey forms find dealers pointing their collective finger at the insurance industry for its lack of understanding of the fertilizer business and its risks. Dealers see an overreaction on the part of insurance companies as a major contributing factor to increased premiums. The survey comments indicate that maintaining required coverage for anhydrous ammonia has reached a critical stage. Survey comments show that dealers seek relief from the current crisis through intervention by the U.S. Congress and state legislators to correct a court system that is "far too liberal."

Dealers also reported that many lenders require a certificate of insurance in order to keep their operating and long term lines of credit open. *Some sample survey comments from dealers—*

- "State and Federal Governments are not facing up to the fact that there are serious problems in obtaining and the cost of liability."
- "Cannot get it on herbicides. Took tests to be certified applicator but will not certify without liability coverage."
- "We are plagued with small farmer dealers and agri chemical 'dealers.' These people break what-

ever price structure we have and are not regulated by minimum insurance requirements nor are they inspected by D.O.T. or EPA.

- "EPA & DER requirements for accidental contamination clean-up are prohibitive. No longer sell restricted pesticides and herbicides."
- "I am concerned about environmental liability."
- "Expect limitations on product liability & pollution exclusion upon renewal (6/1/86). Have encountered problems placing D & O coverage."
- "Court system not prorating damages to those actually responsible. Awards four times greater than any actual damages."
- "Right now workers compensation insurance is the most difficult to obtain."
- "In our state one cannot get a license to sell or apply chemicals or fertilizer without at least $500,000 liability not to mention the various bonds one must have for diesel and gas tax, etc."
- "Umbrella insurance is not available."
- "Liability insurance, pollution insurance, storage and transportation of NH_3 is becoming a big concern."
- "We cannot continue to have the 300 percent increases and operate a profitable or even break-even business. We have not had a single dollar paid out in claims."
- "Can't provide even $5,000 public liability/financial responsibility coverage to get renewal of commercial pesticide applicators license."
- "I am afraid to turn in a claim because of a possibility of cancellation."
- "I feel that in many cases the insurance companies do not understand the fertilizer business operations. The courts are far too liberal. I believe that there should be a limit as to how much a suit can be."
- "We are going to be insured out of business."
- "We think that the insurance industry has overreacted. There should be a limit on liability claims."
- "The entire insurance scenario beginning with one's local agent, the company, the company's representative, courts, jury awards and politicians is disgusting."
- "It sounds like the poor management and greed in the insurance industry is getting the best of us."
- "You are the only organization that is on top of the problem—liability and lending."
- "The demon whom we work for is going to have to be partly responsible for liability and environment damages. Insurance is too costly and we can't pass on the cost to the farmers and bankers."
- "I see insurance companies continuing to increase insurance premiums and I also see them start reducing coverage. We are discontinuing the handling of ammonia this spring because of insurance premium increases and liability exposure."
- "Your questionnaire is what has become our largest problem. U.S. Congress will have to make some changes or only large businesses with a law firm will be able to be in business."
- "Insurance companies pay off too soon by settling out of court even if the person suing does not have a good case. Some cases need to set a point just to slow things down."
- "Our company has an excellent track record as far as claims to insurance companies. We have been in business since 1937 and have had $55,000 worth of claims in all those years. But what we are really concerned about are some of the outrageous environmental claims for enormous amounts of money with no time limit on the claim. These things are making liability insurance unavailable."
- "Even though our business has had two profitable years (in spite of the ag economy) the direction of our bank is to dump all ag accounts. Consequently, even with a good P & L we're considered a risk."

In the same Spring '86 Survey NFSA asked several questions about financial lending support . . . both for the dealer's business and his farm customer. We were pleased to learn that our member dealers *did not* perceive a major, substantial deterioration of their image as a worthy credit risk by their traditional source of credit (although no improvement is felt, either!). And, we also found that dealers see their farmers' credit crunch worsening . . . and that farmers are looking increasingly to fertilizer dealers for financing.

We also heard from dealer survey respondents that about 1/4 find supplier companies willing to share part of their product liability risk and only 13 percent of our dealers are currently using *written* disclaimers with farmers.

Here are some of our suggestions to dealers in coping with their respective risk management crisis situations:

1. *Shop* your insurance needs . . . early and often . . . most carriers now require applications for new business 90 or more days ahead of your renewal target date . . . and application forms are long (some over 100 pages) and complex.
2. Get your plant housekeeping in order.
3. Elevate employee safety.
4. Comply with Hazard Communication Act (MSDS).
5. Enhance applicator driver training.
6. Use written disclaimers.
7. Focus on new hi-efficiency product technology & use.
8. Keep better records.
9. Tell employees and farmer customers about the liability threat to your dealership.
10. Participate in community emergency response programs.
11. Watch change of insurance forms (claims made vs. occurrence).
12. Use financially strong carriers.
13. Put a value on carrier continuity.
14. Increase your deductibles.
15. Rethink your insurance broker-brother-in-law's "horse power."
16. Look at batching your deductibles.
17. Know state insurance commission.
18. Explore group plans/captives.
19. Invest in loss prevention equipment.

As always, good sound business management practices are the first step to solving this crisis. The MO-AG Industries Council—dealer group in Missouri—has an exciting new development just approved by their Board a week ago. It's a group plan to pool dealer's risk on spill clean-up—an environmental impairment policy of sorts. NFSA will be working to extend this program into other states!

Efforts like the MO-AG program are the next important step—toward the industry finding solutions to the risk management crisis. All of us have a role—and a responsibility—in pursuing these solutions. We need YOUR HELP!

The Outlook for Sulphur

Michael Kitto
Head of the Sulphur Group
The British Sulphur Corporation Ltd

Mr. Chairman, delegates, it is a great honour to be invited to speak to you here today, and a particular privilege to share this platform with such eminent speakers as those whom we have heard this morning. As forecasters, ours is a very perilous occupation, and I am especially aware of that fact in view of what has happened to sulphur over the last eighteen months or so. I must begin by admitting that, about two years ago, all of us, and I include British Sulphur, got it wrong. It may be as well to start by looking at the assumptions that were made at that time, and the conclusions that were drawn from them.

Let's take a look at a major forecast report which was prepared in late 1984/early 1985. In this report, the overwhelming conclusion drawn from the trends that were then apparent was that "the world sulphur industry faces a supply crisis which is unparalleled in the past 35 years." It was felt that in the period up to the early 1990s, combined Western World brimstone production and imports from the Centrally Planned Economies would be insufficient to meet rising demand, and that substantial withdrawals would therefore have to be made from vatted stocks, particularly those in Western Canada, with the result that these stocks would become exhausted by the end of the 1980s. Very little in the way of major new brimstone supply sources was foreseen, though it was stated that the start-up of at least three major recovered sulphur projects in the USSR from 1986/1987 onwards would eventually produce an export surplus which would help meet Western World demand. Involuntary production from sour natural gas and at oil refineries was felt to have only limited growth prospects. It was therefore concluded that "in the present perception of world brimstone supply and demand there is no inhibiting element that could preclude the continued escalation of prices. In the short term, only a substantial recession of brimstone demand could exert any downward pressure on prices as no new major additions to competitive supplies are in sight."

I must confess, first, that the report from which I've been quoting was produced by British Sulphur and, second, that it no longer represents our view of the future. In defence of our company, I must say that the study contained much that is still very valuable and valid, and in combined modesty and self-defence I should perhaps add that I was not personally involved in its preparation. I should also say that many analysts are still producing studies which arrive at broadly similar conclusions. That they do so I find very surprising. They are either extremely slow to react to radically altered circumstances or so reluctant to admit to error that they refuse to change their tune. As far as we at British Sulphur are concerned, the supply crisis and impending exhaustion of producers' stocks previously forecast are no longer indicated. Let's now look at the changes that have occurred over the past eighteen months, and the effect they have had on our perception of the future.

In very broad and general terms, the three key issues which have obliged us to revise our forecasts are as follows:

> First, a very significant reduction in the rate of sulphur demand growth from the P_2O_5 fertilizer industry;
>
> Secondly, larger than expected export surpluses developing in the USSR; and
>
> Thirdly, the slump in the price of crude oil which occurred early in 1986, and its effect on brimstone supply and demand.

I would like to examine each of these factors in turn.

It has been clear for a number of years that the US phosphate fertilizer industry has needed to undergo a degree of rationalization, but it was not until late 1985 that the true magnitude of the industry's difficulties became fully apparent. Then, this year, the failure of the US spring phosphate fertilizer season and the dramatic downturn in P_2O_5 exports reinforced the message that the changes that were occurring were not ephemeral but structural. It's easy to have 20:20 hindsight, but we should all have been more confident and vociferous in stating our belief that some sort of crisis was inevitable. If we stand back from the situation and try to get things in perspective, we see agricultural systems in North America and Western Europe which have become so sophisticated that their only major problem is persistent over-production. I say the only problem, but it is a massive one. It leads to an erosion of prices for agricultural outputs and consequently to a devaluation of agricultural land. It forces farmers to borrow but reduces the value of their collateral. It alienates public sympathy for the farming community, since the average taxpayer resents subsidizing production for which there is no apparent market. And it causes governments to seek means of reducing the excesses.

I have already used the word sophisticated to describe the agricultural systems of the developed western world, and that implies a considerable degree of scientific knowledge on the part of farmers. The majority of them know full well that, if they need to cut back on agricultural inputs, phosphate fertilizers are a prime target for economies. Farmers have been applying these economies since the end of 1985, but this summer's harvest, both in North America and in Western Europe, seems to have been a bumper one. What's more, the Soviets also appear to have done well, reducing the prospects for US grain exports, and the key buyers of P_2O_5 in export markets have built up buffer stocks of fertilizers to a level where they can afford to absent themselves from the market for some considerable time.

The main growth region in phosphate fertilizer consumption has been and continues to be Asia, but the Indians and the Chinese have not been active purchasers recently, and two trends are working against North American suppliers as far as these markets are concerned. The first is that both countries are working to develop indigenous resources. In the case of India, the potential for development is limited, but as far as China is concerned, a considerable amount of their domestic P_2O_5 requirement can and will be met from their own reserves of phosphate rock and sulphur, whether as pyrites or as native refined sulphur. In both instances, the move towards greater self-reliance will undoubtedly slow down the rate of growth of imports, and the example can be expected to be followed elsewhere.

The second trend which is having an adverse effect on North American export sales is the rapid emergence of the North African and Middle Eastern vertically integrated phosphate industries as a major force in world trade. The Moroccans, Tunisians and Jordanians are all aggressively seeking increased market share, particularly in the Asian region, and whilst none of these countries possesses its own sulphur resources, all are more conveniently supplied by Middle Eastern producers than they are by those in North America. Of course, this trend does not affect overall sulphur demand, but it does bring about a shift in the balance of power, to the detriment of Canada and the USA. To get back to demand, although the Asian region displays the greatest growth in P_2O_5 consumption in percentage terms, the consumption increments are insufficient, in tonnage terms, to fill the gap formed by stagnant or even declining demand in North American and Western Europe. No significant increase in sulphur usage can be expected in the more developed Western countries from the non-fertilizer sector either, the trend in the industrially advanced economies being to move away from sulphur-consuming technologies. All-in-all, then, the outlook for sulphur demand in the key consuming regions of the world for the next four or five years is decidedly flat.

Let's now look at the supply side of the equation. Both involuntary and voluntary supply of sulphur are very intimately connected with the energy market. The dramatic fall in the price of crude oil at the beginning of this year has had a number of effects on the sulphur supply situation. Firstly, it gave the Saudi Arabian oil exporters an ideal opportunity to recapture lost market share, whilst at the same time handing out a salutary lesson to those OPEC and non-OPEC producers who had in the past failed to exercise restraint in production. Offering netback pricing deals to refiners, and so giving them a guaranteed margin, the Gulf Arabs unloaded cheap oil on the world at a very rapid rate. Stocks of refined products were at a very low level, and refinery throughputs rose enormously, with a consequent increase in the recovery of sulphur—up 26% in the United States in the first half-year as compared to the same period of 1985. This rate of growth cannot be maintained. The oil industry, like the P_2O_5 industry, is grossly oversupplied at both upstream and downstream ends, but it does seem likely that the Saudis will regain a strong hold on the market, particularly as so much exploration and development work has now been indefinitely deferred, and that will mean more sour crude runs. The steady rise in refinery recovered sulphur production that has been seen over the last ten years has been attained despite falling refinery throughputs. We are not predicing a price-led demand surge for refined products, but we do believe that refinery recovered sulphur will make a greater impact on the overall supply situation than had previously seemed likely.

At the same time, the low price of crude, and consequently of fuel oil, has put downward pressure on gas prices, and this in turn has led producers wherever possible to exploit the sweeter gas fields so as to minimize treatment costs. Nevertheless, looking at the United States, we find that declining natural gas sulphur production is more than offset by increased supply of oil refinery sulphur, with the result that the country's overall level of recovered sulphur output continues to rise.

The low energy prices have been of little help to US Frasch sulphur producers, however. At a time when their production costs are at very low levels, the abundance of refinery recovered material, coupled with the weak demand from the P_2O_5 industry, has forced them to reduce production, which seems unlikely to reach 4.5 million tonnes in the full year. The same phenomenon of low energy prices also has its effect on the use of brimstone as a raw material for sulphuric acid manufacture. The value of the energy credit in a brimstone-based acid plant is not an absolute or unchanging figure. It has to be linked to the cost of raising an equivalent amount of steam by other means, and in Europe we are already seeing that those manufacturers who used brimstone just for the steam are beginning to rethink their policies, with the result that smelter acid and pyrites acid are beginning to displace a certain amount of elemental sulphur consumption.

Low energy prices in the West have little or no effect on the development of oil and gas reserves in the Centrally Planned Economies. It is our certain knowledge that the exploitation of the massive gas condensate fields of Astrakhan on the shores of the Caspian Sea is being progressed with all possible speed, in parallel with and in addition to the sweet gas fields of Western Siberia. If the various phases of the Astrakhan project, and of other projects at Karazheganak and Tengiz, come on stream as scheduled, they will more than quadruple Russian sulphur recovery capacity by 1992. It is likely that there will be delays, particularly because of the drilling difficulties which are known to have been encountered already, and it is unlikely that full capacity utilization will be achieved, but a conservative production estimate shows incremental output of well over five million tonnes per annum by 1991, and still rising rapidly. Anyone who doubts the Soviets' desire for foreign currency, or their ability to arrange the logistics of large-scale export sales when they wish to do so, should take a look at what has happened in nitrogen fertilizer markets recently.

Where does all this place us with regard to the brimstone balance over the next four or five years? The balance, as everyone knows, is the comparatively small difference between two very big numbers. Relatively small changes in either the supply or the demand side can therefore have a proportionately very large effect on the balance. The depression of the P_2O_5 market is the major change that has occurred since we produced the report that I referred to at the beginning of this talk. Apart from uprating the growth of refinery recovered sulphur, the only really major change that we have made in our analysis of the supply side results from the intelligence that we have obtained from Russia regarding Astrakhan and other sour gas projects. Nevertheless, the effect of these changes on the Western World brimstone balance is very substantial. Taking what I can only describe as a mitigated case between an optimistic and a pessimistic demand forecast, we now see minor deficits arising only for the next couple of years, and a surplus developing thereafter. Even if an optimistic demand forecast for phosphate fertilizer production is assumed, apparent net deficits of no more than 1 million tonnes per annum are encountered only in the short term, with the balance still moving into surplus before the end of the decade. Whatever scenario is assumed, none produces a deficit which cannot comfortably be met from producers' stocks. Even more significant is the fact that none of the demand scenarios which lies within the bounds of what may reasonably be expected leads to the exhaustion of Western Canadian stocks by 1990, and in the following year it is expected that Eastern Bloc exports to the West will be beginning to make a major impact.

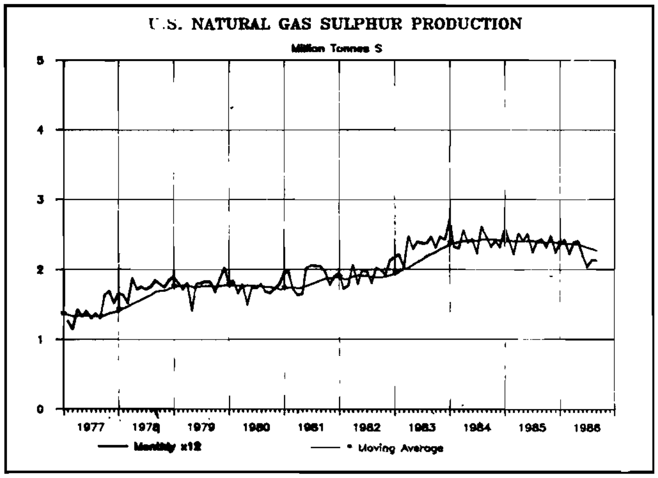
I began this short talk by quoting from a comparatively recent British Sulphur report, and by pleading for some degree of sympathy for the lot of the forecaster. Perhaps I can draw towards a close by quoting from a very different source—a letter written by the English parliamentarian Oliver Cromwell to the General Assembly of the Church of Scotland more than 300 years ago. In that letter, he included a sentence which might serve as a good motto for all of us who produce forecasts. "I beseech you, in the bowels of Christ," he wrote, "think it possible you may be mistaken." In conducting our latest analysis of the outlook for sulphur, we have tried throughout to "think it possible we may be mistaken." As in any forecast, there is an element of conjecture, and in this case, the factors which are the subject of the greatest uncertainty are threefold. First, there is the rate of implementation of sour natural gas projects in the USSR. I have already indicated that our assessment is based on first-hand information and on very conservative estimates both of timing and of capacity utilization. The second major uncertainty concerns the domestic supply/demand balance of the USSR and the People's Republic of China, but we have tried to allow for rapidly increasing levels of phosphate fertilizer production, whilst also assuming that not all of this will be phosphoric-acid based. The final and perhaps the greatest uncertainty concerns the level of Western World demand for phosphate fertilizers. The scenarios which we have examined lie, as I have said, within the bounds of what we consider to be reasonable probability. Despite the fact that we believe that there will be increasing use of partially- and non-water soluble phosphate fertilizers, especially in many of the Less Developed Countries of the Western World, and that nitro-phosphates will become more significant in Western Europe, these beliefs have not formed a part of our assumptions in all scenarios, and we have been far from bullish in respect of supply. Even so, we fail to see a supply shortage developing in the short, medium or longer term. I have tried to describe the fundamental changes which have occurred in the sulphur market in the past eighteen months, and to outline the alterations that we have consequently made in our forecast of sulphur supply and demand. You may, and I am sure some of you will, choose to differ with our view, but I can only end by repeating that the overriding conclusion of our latest analysis of the outlook for sulphur is that the continued tight market situation and the threatened supply crisis resulting from the impending exhaustion of Canadian stocks are no longer indicated.

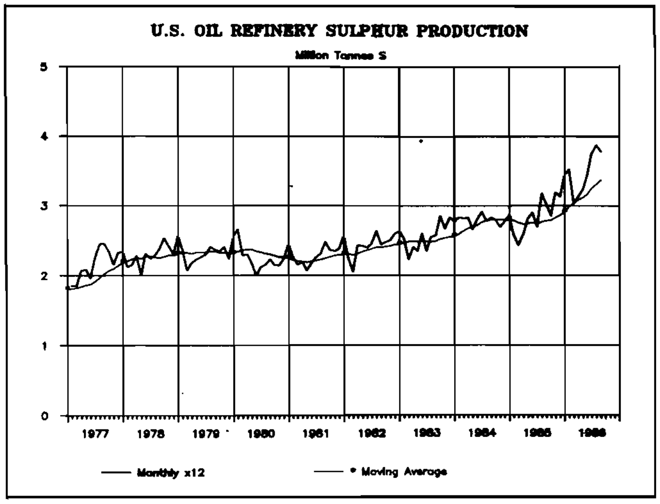
KEY ISSUES IN 1986

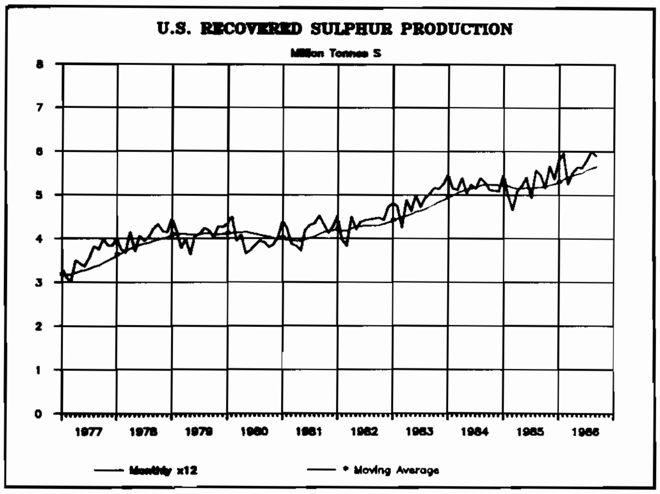
- REDUCED RATE OF SULPHUR DEMAND GROWTH FOR P_2O_5 MANUFACTURE
- LARGE USSR EXPORT SURPLUSES POST 1990
- DEPRESSED ENERGY PRICES

THE 1984 OUTLOOK

- IMPENDING SUPPLY CRISIS
- NET W.WORLD SUPPLY INADEQUATE TO MEET DEMAND
- STOCKS EXHAUSTED BY 1990
- FEW MAJOR NEW SUPPLY SOURCES
- LIMITED GROWTH PROSPECTS FOR RECOVERED SULPHUR
- CONTINUED PRICE ESCALATION UNLESS BRIMSTONE DEMAND RECEDES


U.S. NATURAL GAS SULPHUR PRODUCTION


U.S. OIL REFINERY SULPHUR PRODUCTION


U.S. RECOVERED SULPHUR PRODUCTION
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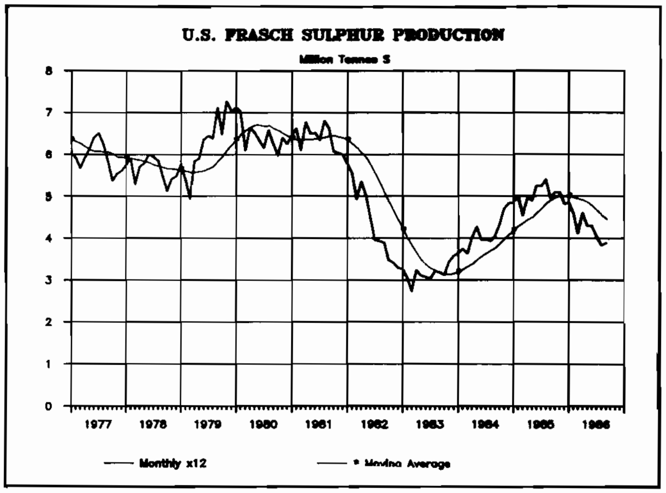
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* Moving Average

Tuesday, November 18, 1986

Afternoon Session—TFI SEGMENT

Moderator:
Karl T. Johnson

Chemical Emergency Preparedness Program

Elaine Davies
EPA

PAPER UNAVAILABLE AT TIME OF PUBLICATION

EPA's Ground-Water Protection Program

Donna Fletcher, Senior Analyst
U.S. EPA Office of Ground-Water Protection

During the past two years, EPA has greatly broadened its role in protecting ground water by establishing a leadership role, assisting state ground-water protection activities, dealing with major sources of contamination, and creating a framework for decision making. In addition, with the passage in June of the Safe Drinking Water Act Amendments of 1986. EPA will be implementing the first federal statutory program for the protection of the ground-water resource.

EPA's Ground-Water Protection Strategy

Although the States have the primary responsibility for managing ground water, EPA has a broad array of federal statutory authorities to control certain contaminants, such as toxic wastes and pesticides, which greatly affect ground-water quality. The Resource Conservation and Recovery Act; the Superfund; the Federal Insecticide, Fungicide, and Rodenticide Act and the Toxic Substances Control Act are some of the laws which contain such authorities.

In August, 1984, EPA issued its Ground-Water Protection Strategy. The strategy was designed to enhance protection of ground-water quality through improved use of existing federal statutes EPA has for protecting ground water. Thus, it focused on achieving four broad objectives:

- to enhance state programs;
- to deal more effectively with ground-water problems of national concern;
- to create a policy framework for guiding EPA programs and;
- to strengthen EPA's internal ground-water organization.

Since 1984 EPA has successfully moved forward on implementing the strategy's goals. Ground Water Offices are in place in EPA headquarters and the Regional offices for policy development and coordination. In fiscal years 1985 and 1986, $14 million in grants specifically for ground-water protection, was provided to 49 states under section 106 of the Clean Water Act. EPA also has provided seminars, publications, and other technical information on managing ground water, for state and local officials. Some of EPA's other activities include the development of a major regulatory program dealing with leaking underground storage tanks; development of a strategy to address agricultural chemicals in ground water and the development of a classification system to help define management strategies that reflect the use, and vulnerability of the resource.

Safe Drinking Water Act Amendments of 1986

On June 6, 1986, the President signed the SDWAA of 1986. The ground-water provisions of this law establish two, new, technically complex programs that will require innovative approaches to resource assessment and protection. The Wellhead Protection Program and the Sole Source Aquifer Demonstration Program for the first time, provide a clear, Federal statutory role in establishing a national framework for the protection of ground water.

The Wellhead Protection Program is designed to protect wells that supply public water systems. It is a State developed and administered program, however, EPA is required to issue technical guidance and assist in funding State efforts. The purpose of the Sole Source Aquifer Demonstration Program is to promote the adoption of special protective measures for critical aquifer protection areas within a designated sole source aquifer, and to identify and evaluate exemplary programs and techniques for controlling ground-water contamination.

Both of these programs are designed to protect ground water while allowing States the flexibility to tailor these programs to specific conditions and geologic settings. At the same time, EPA will make every effort to assure that these programs will be implemented within the overall context of Federal and State ground-water protection strategies.

EPA's Agricultural Chemicals in Ground-Water Strategy

In EPA's Ground-Water Protection Strategy, issued in 1984, the use of pesticides and fertilizers was recognized as a potentially significant source of ground-water contamination that needed additional national attention. Shortly after the Strategy was released, the Office of Ground-Water Protection (OGWP) began collaborating with EPA's Office of Pesticides and Toxic Substances (OPTS) to see how the Agency's authorities and existing activities under the Federal Insecticide, Fungicide and Rodenticide Act and Toxic Substances Control Act could be better used to address the problems of agricultural chemicals in ground water.

As a result of these initial efforts, the issues and potential solutions as well as the variety of statutory authorities that could be used became better understood. Last fall, the Agency selected the problem of agricultural chemicals in ground water for a major strategy development initiative. Led by OPTS, the effort includes all EPA offices and has top management support and involvement.

The strategy will address:

- Sources of contamination and the statutory and program authorities available to prevent and respond to contamination incidents
- Environmental fate and health effects assessment tools
- Policy regarding registration and re-registration of pesticides found to have leaching potential
- Roles of EPA, States, and other Federal agencies in addressing various aspects of the problem
- Research needs in environmental fate assessment and cleanup technologies.

In June, the OPTS held a workshop in Coolfront, West Virginia, with key representatives of Federal and State agencies, environmental organizations, and the agricultural chemical industry to obtain their views and insights on the development of EPA's Agricultural Chemicals in Ground-Water Strategy. The Agency is now in the process of evaluating the ideas and suggestions which emerged at the conference, and is refining options for addressing the problem with regulatory and non-regulatory actions. These options will be presented to the Administrator soon and a draft strategy will be widely circulated for public review by this winter.

While the strategy is still under development, several pieces are already in place. Of particular interest is EPA's planned National Survey of Pesticides in Drinking Water Wells. The survey is statistically designed to assess the severity of pesticide contamination, estimate the potential population at risk, and understand the relationship between pesticide use and hydrogeology. Drawing samples from both public and private wells, EPA will analyze for approximately 60 pesticides. Samples will also be tested for the presence of nitrates to help estimate the extent of nitrate problems nationwide.

Hazardous Waste Management

Jeffery D. Denit
EPA

PAPER UNAVAILABLE AT TIME OF PUBLICATION

Water Quality: A National Priority

Al Giese, VP
Land O'Lakes
Presented by
Everett Leach
Land O'Lakes

You've seen the headlines . . . You've heard the reports . . . "Nitrate contamination growing at alarming rate" . . . "Lakes, rivers being polluted by farm runoff" . . . "Groundwater purity is new rural issue" . . . "Fear emerges about 'blue baby' syndrome."

Without question, agriculture is in the spotlight. Among the many questions being raised regarding water quality is the increased presence of two nutrients: phosphorus and nitrogen.

Although many efforts are focusing on pesticide infiltration and other *chemical* hazards, a number of state, county and municipal lawmakers are proposing restrictions on commercial *fertilizers* as well. Despite its role as an essential plant food, commercial fertilizer is viewed as a controllable culprit—particularly in areas where nutrient levels are above the norm.

The water quality issue is highly complex and becoming increasingly emotional. Unfortunately, in all the complexity and emotion, the facts have sometimes been brushed aside. So, let's review what we know.

First, we know that nature is not leak-proof. Despite the tremendous strides made for improved crop production efficiency, we still depend upon the limited root systems of plants to capture and utilize available nutrients.

And—what do we know about those available nutrients? In the case of nitrogen, we know that only about 39 percent of the 28 million tons available for food production comes from commercial fertilizers. Obviously, nature plays a large role in contributing the other 61 percent of available nitrogen.

It surprises many to learn, for example, that an alfalfa crop can add to the soil 100 to 150 pounds of nitrogen per acre per year—having drawn that nutrient from the air we breathe. And, soybeans, likewise, can add 60 to 100 pounds of nitrogen per acre. Average commercial application of nitrogen to a major nitrogen consumer—corn—stands at about 130 pounds per acre. Average applications to all crops, by comparison, is around 75 pounds per acre.

The obvious question raised by these facts is: If there's so much nitrogen contributed by nature, why do we add commercial fertilizer?

To answer that legitimate question, we must first look at our daily nutritional needs. For example, each of us needs to consume about 12 grams of nitrogen in our daily diets. Over a year's time, this nitrogen intake through the food chain in the United States represents 1.1 million tons. This figure, compared to the 28 million tons of total nitrogen available for crop production, reveals a ratio of only 1 pound of nitrogen consumed for each 25 pounds available.

Again, this illustrates the inefficiencies of a system dependent upon plant uptake. So, as long as farmers must economically produce foods, there will continue to be large requirements of nitrogen to produce these crops. And, regrettably, there will continue to be losses to the environment—until a geneticist or molecular biologist develops plants that do a better job of nutrient recovery.

American agriculture absolutely depends upon the use of fertilizers for maintaining soil productivity. In many instances, per-acre yields of key grain crops would be half of what they are today without fertilizers. Such a loss would be an economic catastrophe to farmers who rely on fertilizers to reduce their per-unit cost of production. A farmer can achieve his yield goals only if nutrients are sufficiently available in the soil—whether they come from commercial fertilizers, the soil itself, or other sources such as manures.

Again, it's worth re-emphasizing: There is no complete recovery of nitrogen by crops. Major grain crops typically recover 50 to 70 percent of applied nitrogen. For those who want spinach and lettuce in their salads, and for those who want strawberries in their ice cream, there is the bad news that such plants seldom recover much more than about 25 percent of applied nitrogen. But, without adequate nutrients available, we could not enjoy these foodstuffs at such affordable prices.

We also know that the fertilizer industry—while it would like to sell every ton of product it can—has long been a promoter of precise applications. Soil and tissue tasting—at company, university and private laboratories—has been the mainstay of the industry's agronomic education program. It's an image which flies in the face of those who think we just "dump it on."

The industry has a strong record of promoting the full range of Best Management Practices on the land—encouraging better cropping practices, endorsing conservation tillage methods and urging proper timing and placement of applied fertilizer. Coordinating and unifying these industry leadership efforts has been a major undertaking of the industry's national association, The Fertilizer Institute.

In 1983, the Institute's board of directors formally urged judicious application of nutrients on the land—and called for special emphasis on the use of soil tests and careful consideration of soil type and crop conditions.

In issues of the bimonthly magazine *Fertilizer PROGRESS*, The Fertilizer Institute has published—since 1983—an unbroken series of regular articles on Best Management Practices for crop production. The magazine is read by nearly 28,000 in industry—most of whom are retailers who provide management advice and product service to the nation's farmers.

The magazine also published a major cover story on nutrient runoff in 1983. The article was reprinted, and more than 20,000 additional copies have been distributed.

In 1984, the Institute produced a special publication on Clean Water. The brochure identifies some of the sources of nutrient losses to the environment, but also suggests actions by farmers which can improve fertilizer use efficiency and reduce nutrient loss. Again, more than 20,000 copies of this publication have been freely distributed.

In 1985, the Institute sponsored a comprehensive symposium on "Plant Nutrient Use and the Environment." The event brought together some of the best scientific, environmental and agronomic minds in the nation—drawn from universities, research institutions, and government. It produced a 370-page proceedings with the most authoritative assessment available today on the use of plant nutrients in agriculture, and the role of these nutrients in the environment. A 10-page executive summary of these proceedings is available from The Fertilizer Institute.

The Fertilizer Institute sponsored four regional meetings during the summer of 1986 on "Toxic Substances in Agricultural Water Supply and Drainage. In addition the Fertilizer Institute provides on-going assistance to State Fertilizer and Chemical Associations to monitor and influence state of local community legislative and regulatory activities on behalf of the industry, the farmer, and the consumer.

The Institute's efforts on behalf of protecting water supplies—efforts which continue today—actually pale in comparison to the hundreds of local and regional programs developed by individual companies. Test plots, computer-assisted agronomic advice and technical support, research projects, analysis of fertilizer placement, tillage interaction and crop varieties, and a host of other programs designed to abate nutrient losses are the rule rather than the exception in the fertilizer industry.

Two programs in the Agronomy Division of my own company further illustrate industry efforts to ensure judicious and responsible use of fertilizer by our customers.

First, the Land O'Lakes Croplan Agronomist Program provides guidance to our member dealers on optimum nutrient application rates through consultation with professional agronomists on our staff. Our agronomists rely on the latest scientific information, along with computerized data systems, to develop recommendations on fertilizer use.

Second, Land O'Lakes conducts extensive research at our "Answer Farm" facility in North Central Iowa. Here, we conduct both short-term and long-term research on improving nitrogen utilization by plants. For example, our researchers are investigating the effects of tillage practices on nitrogen uptake, as well as evaluating the nitrogen uptake efficiency of different corn varieties.

Overall, the Land O'Lakes system employs nearly 300 professionally trained agronomists in the seven Upper Midwestern states in which we market fertilizer and pesticides.

These efforts were not mandated by any state or federal regulation. They have long been an integral part of the way the fertilizer industry does business. It's of little benefit to the fertilizer industry to promote unnecessary application of its product. To do so would do economic harm to the farmer and, ultimately, to the company which serves him.

In all the debate and concern over water quality, it's well to take a lesson from the story about the city boy—who couldn't see why we needed farmers, when we can get all the food we need from grocery stores. The point is, there's more here than meets the eye—the issue is too complex, too all-inclusive to single out some villain or scapegoat. If we follow that path, we can all start finger-pointing:

- we can blame trees for contributing too many nitrate-laden dead leaves
- we can protest the growing of soybeans and alfalfa
- we can accuse animal wastes from livestock and feedlot operations of heightening the problem
- we can point to urban and rural residential and recreational contributors
- we can even point to Mother Nature, and the role of soil, natural plant decay and bacteria, as well as wind and rain
- we can blame 'most anything, because 'most anything could be—and probably is—adding to the problem of elevated nutrients in the environment.

But, the most appropriate course of action is to take a cue from the fertilizer industry: work together to find ways to minimize nutrient losses to the environment. In the case of the fertilizer industry, it is the informed management decisions of individual farmers—taking into account their local climatic, cropping and soil conditions—which will be the best means of achieving that goal.

For those who would seek state or federal laws to strengthen water quality protection, our industry supports any approach which is practical, based on facts, and seeks an attainable goal. But we simply see no way any single piece of legislation could address the nearly infinite number of combinations of conditions to best manage nutrients in the environment.

Even in a single state, there are extremely wide ranges of conditions—not only precipitation but geological and soil characteristics—that affect not only the quantities of elements entering groundwater but also the rate at which they may be transported within the soil.

All of us in this room share in our national goal of preserving and protecting America's natural resources—one of the most precious of those being our water supplies. Our industry and the farmers we serve are all people, too. We have children and grandchildren and future generations for which we seek the same goals of natural resource preservation.

As we seek such ideals, we need to focus on a rational formula which achieves our ends—not one which renders judgments that have yet to be verified, and could actually reduce the national heritage we seek to preserve.

Farmers have an economic imperative of producing at peak efficiency. Consumers expect abundant food supplies at low costs. Both groups share concerns about the environment. Commercially applied nutrients satisfy the first two needs of productivity and efficiency. And, the industry which provides that product is working to exceed public expectations related to environmental protection.

Rinsate and Stormwater Management at Retail Fertilizer Facilities

Sheila Blower Lang
Terra International, Inc.

INTRODUCTION

Stormwater runoff from retail fertilizer facilities has become an issue of increasing concern. Barren ditches and sterile patches of ground adjacent to retail fertilizer facilities have prompted complaints and lawsuits by neighboring land owners, violation notices from state and federal agencies, and increased insurance rates for the entire industry. In addition there is the less visual but more costly concern of potential contamination of surface and groundwaters which can result if rinsates and stormwaters are not managed properly. If this is not enough, by June 30, 1989, retail fertilizer facilities will enter a new level of state and federal regulation as each facility will be required to obtain a stormwater discharge permit. These permits will at minimum require compliance with Best Management Practices and regular sampling and reporting of stormwater quantity and quality.

Daily spills associated with receiving, loading, and mixing operations have often been considered insignificant. It was commonly thought that these small spills would be assimulated by the soil. Sampling has shown this not to be entirely true. Although the migration of spilled materials may be limited by soil in the instances of fertilizers and pesticides, the soil is often left incapable of supporting vegetation for many years and unacceptable levels of nutrients and pesticides have been found in nearby surface waters as a result of contaminated stormwater.

The potential for contaminated stormwater is not the only reason of responsible management of rinsates, heels, and spillage. Proper management can be justified from a strictly economic view point. Once a product has been spilled to the ground, very little if any economic value can be recovered. Instead of selling the products the facility will "pay" for their disposal. Payment will be made by either the cost of environmental clean up or by severely damaged community relations and sometimes both. Spills, careless product transfers, inadequate storage practices and other operations which may result in contaminated stormwater mean retail shrink and reduced profits.

Terra's retail fertilizer facilities are located in 27 states. Methods that are effective in some areas are not always acceptable in others. The potential for severe environmental contamination, cropping practices, soil type, climate, and volume dictate the degree of control required. In order to be cost effective with control efforts, it is not possible or reasonable to protect against every conceivable scenario for environmental contamination which can occur. In the following pages I will discuss the various control measures Terra has undertaken to address the most probable sources of contaminated stormwater from it's retail facilities.

LIQUID FERTILIZER STORAGE

Spillage which results in contaminated stormwater originates from three major sources at liquid fertilizer storage areas: receiving operations, loading operations, and tank failure. Each source in and of itself may or may not pose a problem depending upon volume but combined these incidental spillages have a synergistic effect on the environment. Spillage, occuring when a transport (supply) truck disconnects it's hose from a storage system can be significant over a season. An uncontrolled facility with an annual volume of 1500 tons of liquid fertilizer can lose approximately three tons annually through this source alone (~0.2%). This loss shows up as bookkeeping "shrink", and environmentally as soil typically void of vegetation due to excessive fertilization. Loss of vegetation promotes erosion of soil, clogging of catch basins, tiles, and ditches which in turn can promote contamination of ground water supplies by increasing potential land area for recharge to occur over.

In some areas the truckers have solved the loading hose problem by equipping their trucks with compressed air to "blow out" the hoses into the storage vessels prior to disconnection. However since most trucks are not equipped this way, a simple and economical alternative is to provide the permanently connected hoses with end valves and adapters for the truckers to attach to their trucks.

Spillage from loading operations is also reduced by the same concept. Permanently connected pipe or hose, with valves placed at the exit points can reduce spillage significantly by not permitting the material in the pipe to drain out. Valves strategically placed within the manifold system will permit the use of one pump for several different fertilizer blends without disconnecting the pump. If the valves are properly placed, there will not be any significant mixing of the various blends (see Figure 1).

A liquid fertilizer storage tank failure can have a devastating impact on nearby stormwater receiving streams. There are several methods which can be used to protect against such an event such as using only stainless steel plugs and valves, limiting the number of openings in a tank, keeping all valves locked when not in use, providing security measures to protect against vandalism, and regularly scheduled thorough tank inspections. However, the only method to be reasonably sure fertilizers will not enter nearby streams as a result of a tank failure is to dike the tanks.

The cost of this project is not immediately justifiable because tank failures are not common if the tanks are well maintained and replaced as necessary. The cost of diking becomes reasonable when the costs of clean up, determination of environmental impact, resolution of potential fines, and cost of lost product are considered. One good spill or circumstantial allegation and defense costs can convince you.

Many state environmental agencies have "requested" retail fertilizer dealers to install dikes, usually after spill incidents. A few states have actually passed legislation requiring them. Seldom do these agencies give the dealer any assistance in how to construct an effective dike. Historically, ground water protection has deferred to surface water protection in priority. The results are dikes that "don't hold water" because only berms were installed, not a whole secure diking system with an integral impervious base. When a dike truly has an impervious base, provisions must be made for stormwater removal and management.

At Terra facilities we have opted to use compacted clay for liquid fertilizer dikes whenever possible. Compacted clay provides adequate containment for fertilizers at a reasonable cost as compared to concrete. Clay dikes can also be constructed on rented properties as they are not considered permanent structures. The advantages of concrete dikes include they can be constructed in a smaller space than clay dikes because the berms do not have to be as wide, and can be constructed in areas where clay is not economically available. Concrete's space advantage however may be offset by the need to consider the probable "leak trajectories" over closely built walls.

Terra's clay dikes are constructed with a one percent base slope to a sump pit. The difference in base grade is made up with a washed gravel pad, which also provides tank support and base protection. The berms of Terra's clay dikes are covered with two inches of washed gravel to help maintain their moisture content, preventing them from cracking during dry weather. A sump pit has been used at the Terra facilities with success but, we do not install a permanently connected automatic sump pump, as this "system" cannot distinguish between uncontaminated stormwater and liquid fertilizer. Management of the "sump pump" must be a conscious decision based on any contaminants found or expected. We prefer to use a small gasoline pump to discharge stormwater in order to eliminate any safety concerns with electricity.

To provide the most overall protection for the least cost, an evaluation must be made as to where you would be most likely to sustain a spill and at what point would it have the greatest effect on the environment. The dike plan area must be large enough to prevent spilled material from simply "squirting" over the dike berm. From a financial and available space point of view, protecting against this phenomena entirely is not possible. An attempt must be made to protect against the most likely occurences. In Figure 2 I have indicated the approximate trajectory of liquid fertilizer "squirting" with varying tank levels and head pressures. The maximum distance case is a full tank with a sidewall hole half way up. For Terra dikes, we have used varying distances between the tanks and inside shoulder of the berm of 10–12 feet depending on available space and tank height. The trajectory is a function of gravity and available head pressure at the point of any leak.

BULK LIQUID PESTICIDES

Most Terra retail fertilizer facilities sell and custom apply pesticides as well as fertilizer. Both materials are similarly controlled but have different means of containment required due to their chemical properties and how the products are handled. Their storage can pose a much greater threat to the environment than liquid fertilizer if spillage occurs and it is not contained. Continual spillage from loading, mixing, and receiving operations can result in extensive damage to area vegetation and water resources.

Unlike fertilizer, pesticide in concentration of parts per billion can be acutely toxic if ingested by fish, wildlife, and humans. Pesticides do not degrade as rapidly or as completely as fertilizers, and therefore they can pose a chronic threat to the environment, affecting greater numbers of life forms. Given this, spill prevention is the best-control option.

Spill containment for bulk pesticide drips and drains and more catastrophic events is essential to prevent contamination of the environment. At Terra facilities we have preferred to use individual containment devices constructed of mild steel or crosslinked polyethylene rather than clay. Individual containment devices prevent the possibility of two pesticides being mixed, creating an unsaleable product which would be difficult and costly to dispose of. The pump, hoses and valves are all stored within the containment device when not in use. The dispensing nozzles consist of normally closed valves similar to those used at self-serve gas stations to reduce the possibility of over filling. Drip pans can also be used to further reduce the risk of spills from disconnecting hoses.

A few states have advocated the use of concrete containment for pesticides. Concrete does have an advantage of a larger storage capacity in a smaller space but, it generally increases the risk of contamination of collected stormwaters with incompatible materials because individual containment is uneconomical with this building material.

Another area of concern with the use of concrete dikes in the northern states is that adverse weather conditions (quick freeze/thaw cycles and ground heaving) will usually crack even the most well constructed dikes in time. Although sealing of dike cracks and seams can be attempted, a very real potential exists for contaminated stormwaters or pesticide spills to seep through the cracks into the soil beneath and eventually to the ground water. (It is also noted that there is no source of ultra-violet light to help break them down in such a scenario). If this occurs, a remedial action may be to remove the concrete in order to properly manage contaminated soil.

Concrete loadout pads carry similar problems, with additional concern over "drag-out" and mixed bag stormwaters. They have been proposed by various states and may become a necessary evil for high volume dealers. We believe this type of "after the fact" control is inferior to source control.

PRE-PACKAGED PESTICIDES

Pesticides in small containers are not without problems either. After installing bulk pesticide control systems which had minimal spillage associated with them, the spillage from the pre-packaged pesticides became more evident.

Several Terra managers requested a method of inducting pre-packaged pesticides that would reduce spills. Our homegrown and recommended solution is found in Figure 5, i.e., an induction system that will reduce spills associated with loading, improve triple rinsing, and reduce loading time.

PESTICIDE SPRAYER FLUSH SYSTEMS

Pesticide sprayer flush systems have been developed to contain sprayer heels and rinsates. In the past, heels were indiscriminately sprayed on fence rows, field drives, along railroad right-of-ways, at the plants, etc. Although this practice is not necessarily illegal, the potential does exist for application rates to be exceeded. Often after a sprayer has been "emptied," it is necessary to flush or clean out the sprayer prior to using a new product. An example, some corn and bean herbicides are not label compatible. This situation has been handled in several ways, one of which is to redilute and spray the diluted pesticide rinsate over acres just covered however, in some instances the material was merely dumped in an inconspicuous portion of the field.

Terra uses 1000 gallon nurse tanks to hold heels and sprayer rinsates (flush water) temporarily until it can be beneficially reused. Fifty gallons of this diluted material can be used as dilution water for a 1000 gallon sprayer without effecting application rates significantly. The number of tanks required per location depends upon the number of products sprayed that are not label compatible. To allow for more complete washing of both the booms and the inside of the sprayer we developed what we refer to as the "octopus" (see Figure 6). The octopus is made from mostly scrap parts and permits sprayer washing in about 5 minutes. A significant advantage of this system over concrete wash pads is that the spray material is never contaminated with dirt which could later clog nozzles on your sprayer and affect spray pattern. Maintenance related spills/drainings therefore do not happen or create compatibility and solids problems.

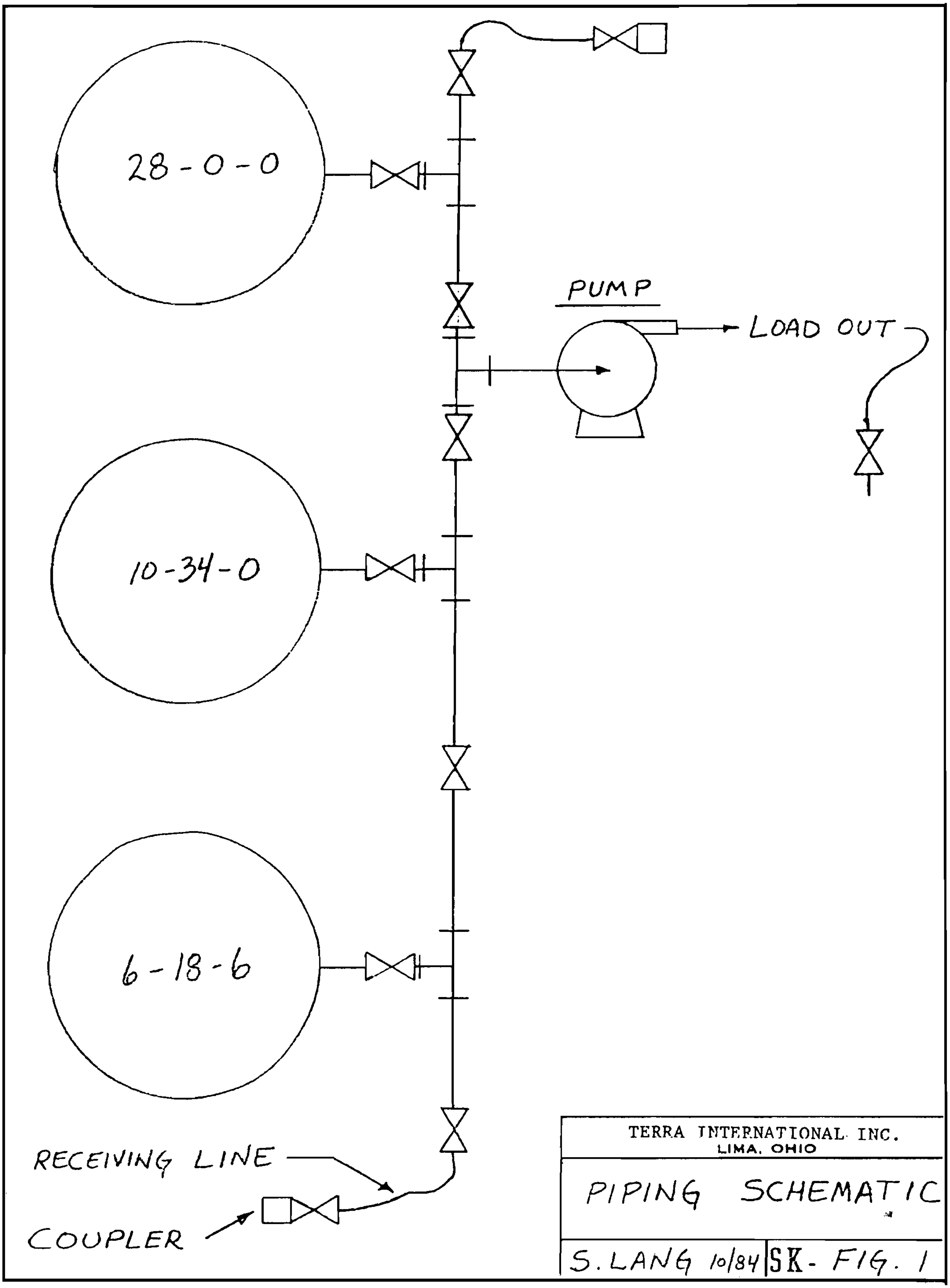
DRY FERTILIZERS

Dry fertilizer spill "source control" is straightforward and the incident spills are easier to clean up completely than liquid fertilizer spills. Additionally the potential for creating contaminated stormwater runoff through storage and handling practices is much less with dry fertilizers unless the dry fertilizer has been impregnated with pesticides.

One area where dry fertilizer handling has posed a problem is with dust control from load out chutes. Mechanically operated extendable shrouds have worked well for large manufacturing facilities but, initial cost and maintenance expense make them impractical for the average retail dealer. At a few Terra locations where fugitive dust has been a concern, we have installed a manually operated extendable shroud. The concept is simple, a weighted canvas tube is attached around the load out chute by two nylon cords. The cords are held to the chute with eye hooks. At optimum height the cords are joined at a small ring. The ring is attached to a crank which is used to manually raise and lower the shroud. By keeping the shroud as close as possible to the hopper, the quantity of dust is reduced (see Figure 4).

CONCLUSION

The above methods of preventing spillage thereby eliminating contaminated stormwater are by no means all encompassing. Each site must be reviewed for it's own special circumstances and the most efficient and cost effective method or methods should be implemented in each product area as soon as possible. Protection of surface and ground waters is in everyones best interest, both environmentally and economically. Terra believes it has met this challenge and profitted from it.



TERRA INTERNATIONAL INC.
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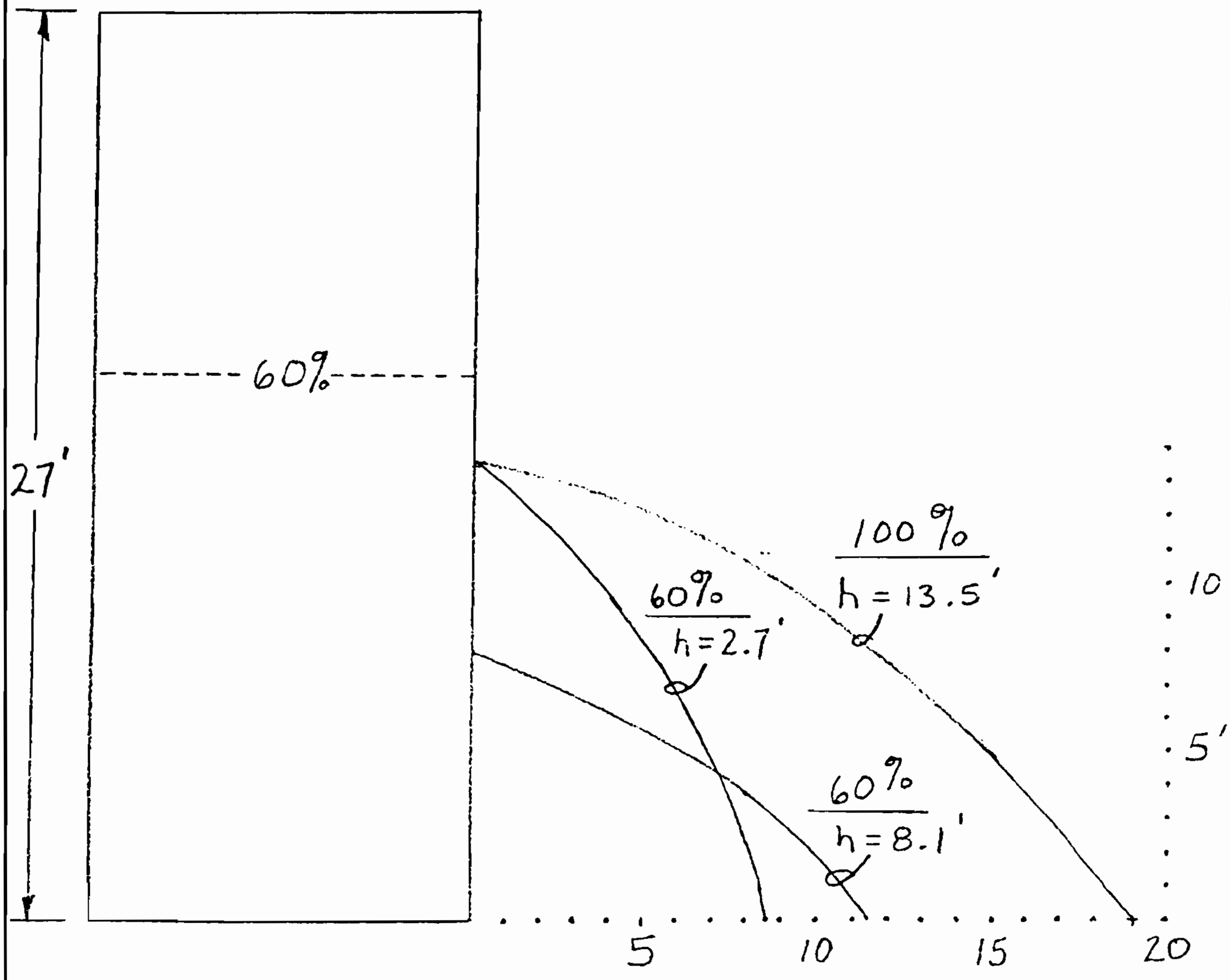
PIPING SCHEMATIC

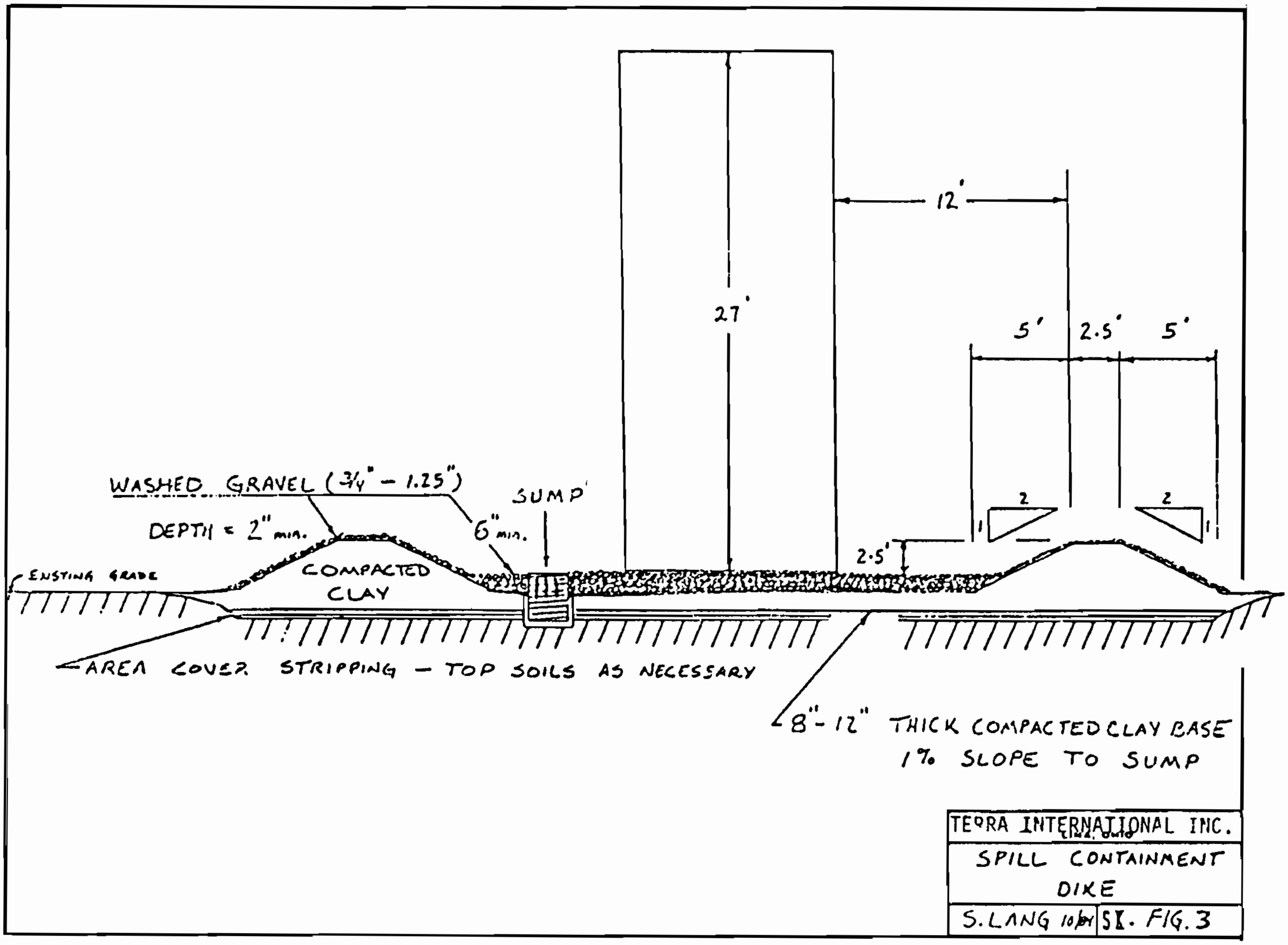
S. LANG 10/84 | SK- FIG. 1

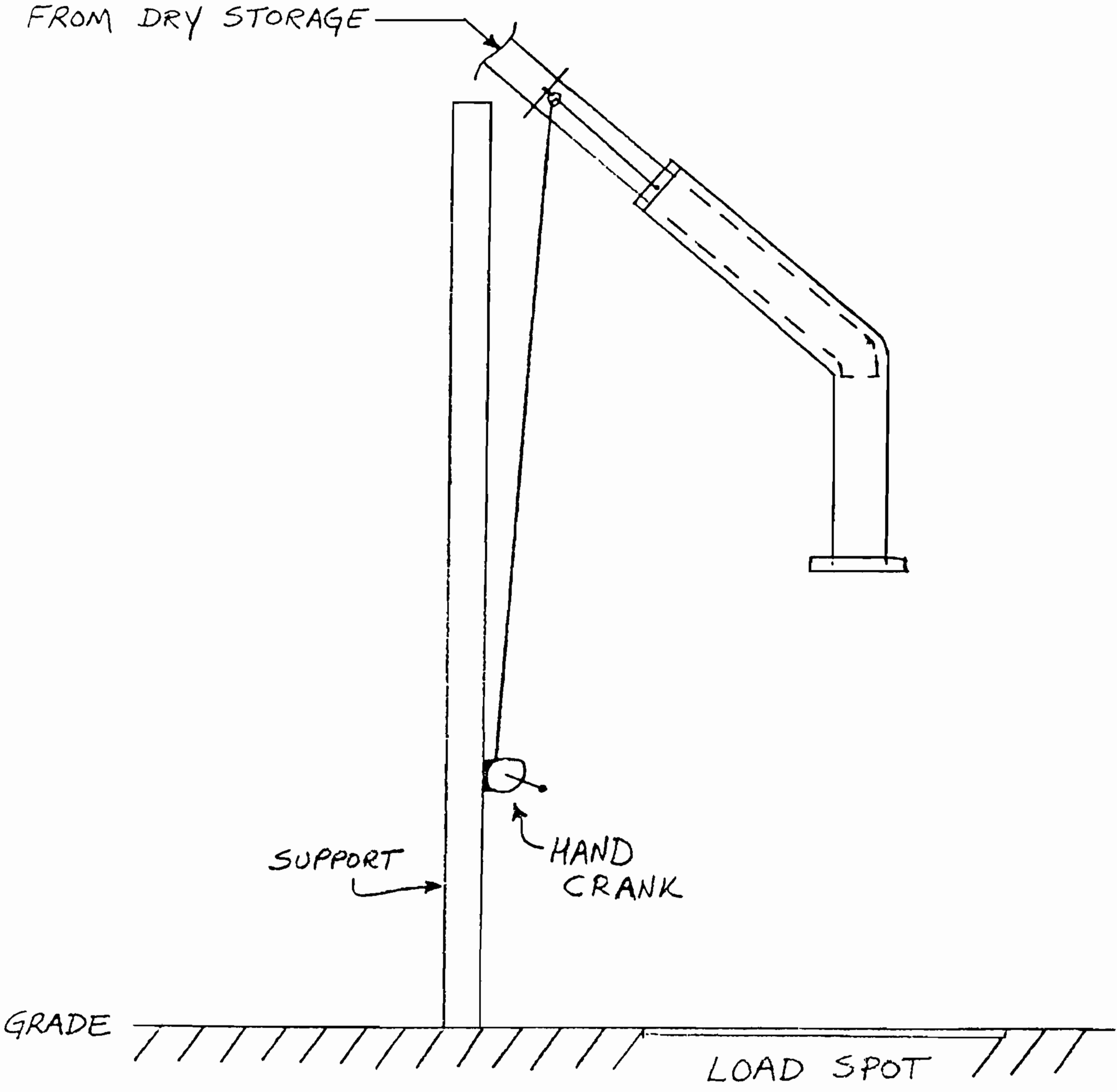


TERRA INTERNATIONAL INC.
LIMA, OHIO

"SQUIRT" TRAJECTORY

S. LANG 10/94 | SK- FIG. 2


WASHED GRAVEL (3/4" – 1.25")
DEPTH = 2" min.
SUMP
6" min.
EXISTING GRADE
COMPACTED CLAY
27'
12'
5'
2.5'
5'
2
1
2
1
2.5'
AREA COVER STRIPPING – TOP SOILS AS NECESSARY
8"-12" THICK COMPACTED CLAY BASE
1% SLOPE TO SUMP
TERRA INTERNATIONAL INC.
CINTI, OHIO
SPILL CONTAINMENT DIKE
S.LANG 10/81
SI. FIG. 3

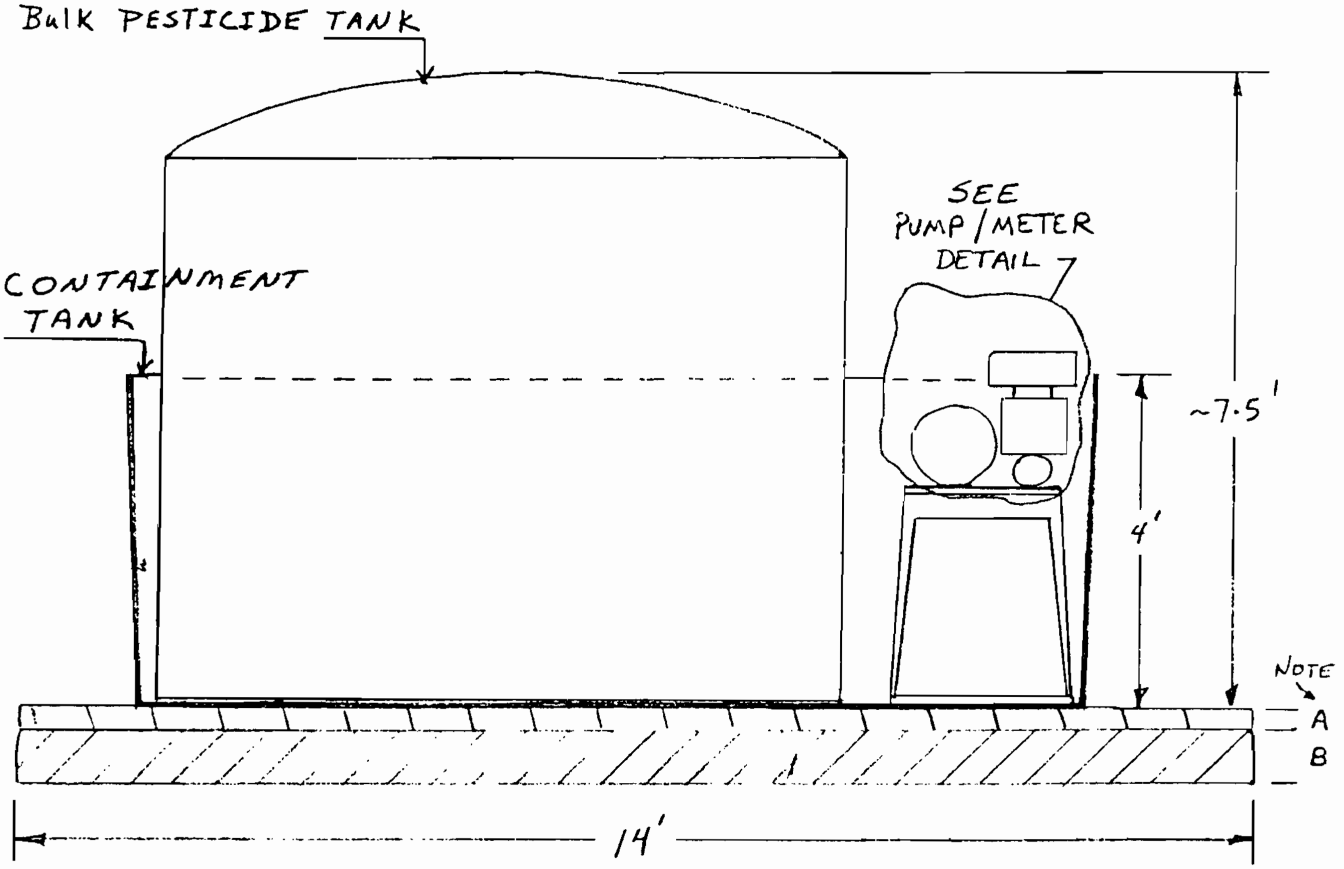


TERRA INTERNATIONAL INC.
LIMA, OHIO

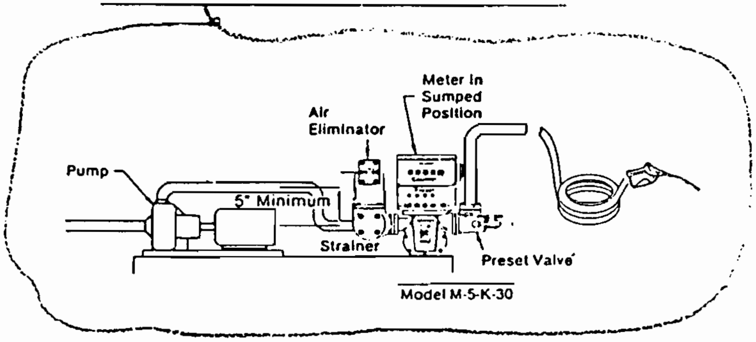
EXTENDABLE SHROUD

S. LANG 10/84 | SK- FIG. 4

TYPICAL CROSS-SECTIONAL VIEW



PUMP / METER DETAIL



NOTE

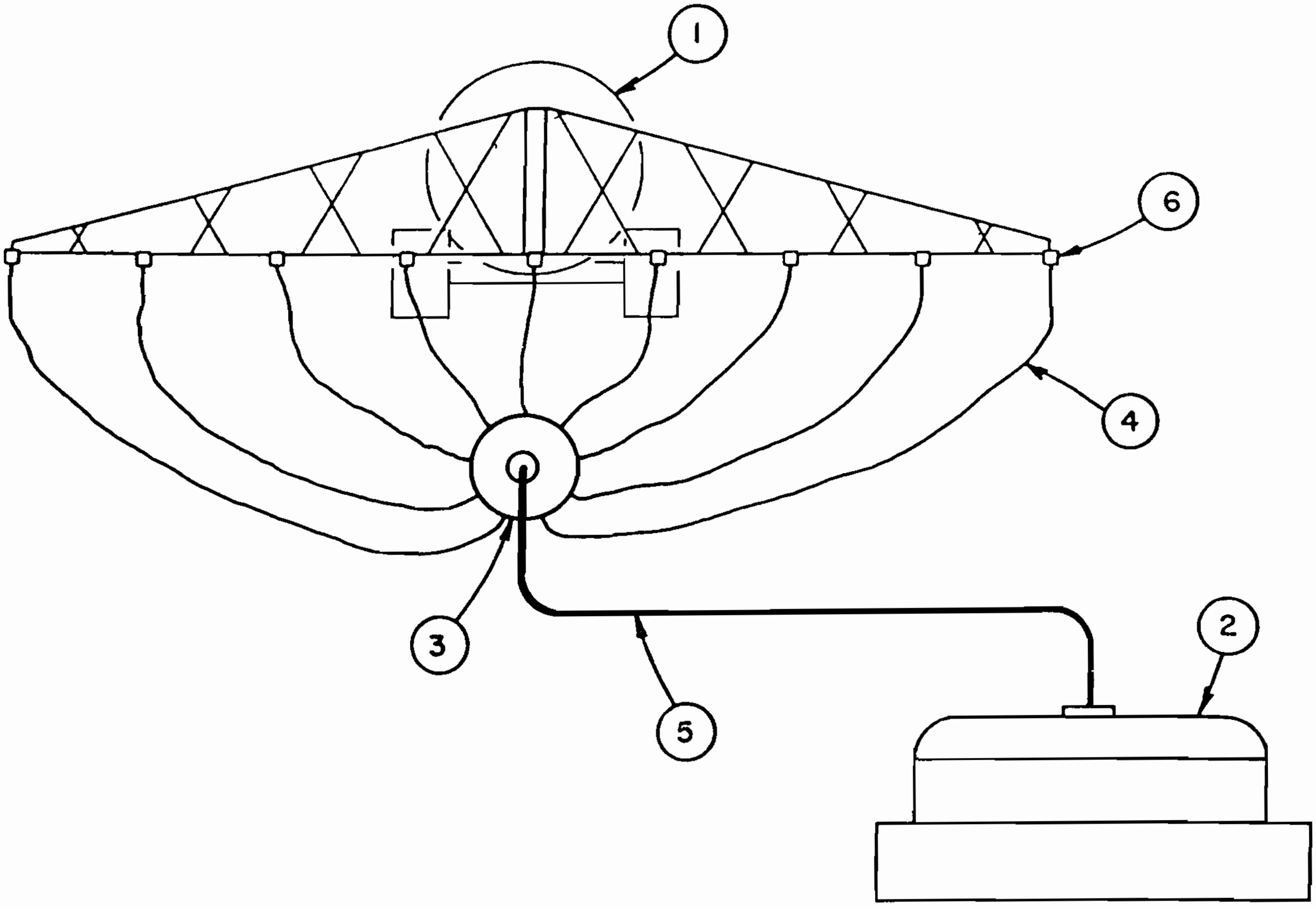
A 3" MINIMUM SAND BASE

B 8" COMPACTED GRAVEL

TERRA INTERNATIONAL INC.
LIMA, OHIO

BULK PESTICIDE STORAGE SYSTEM

S. LANG 11/84 SK-



1. Application Equipment

2. Flush Tank

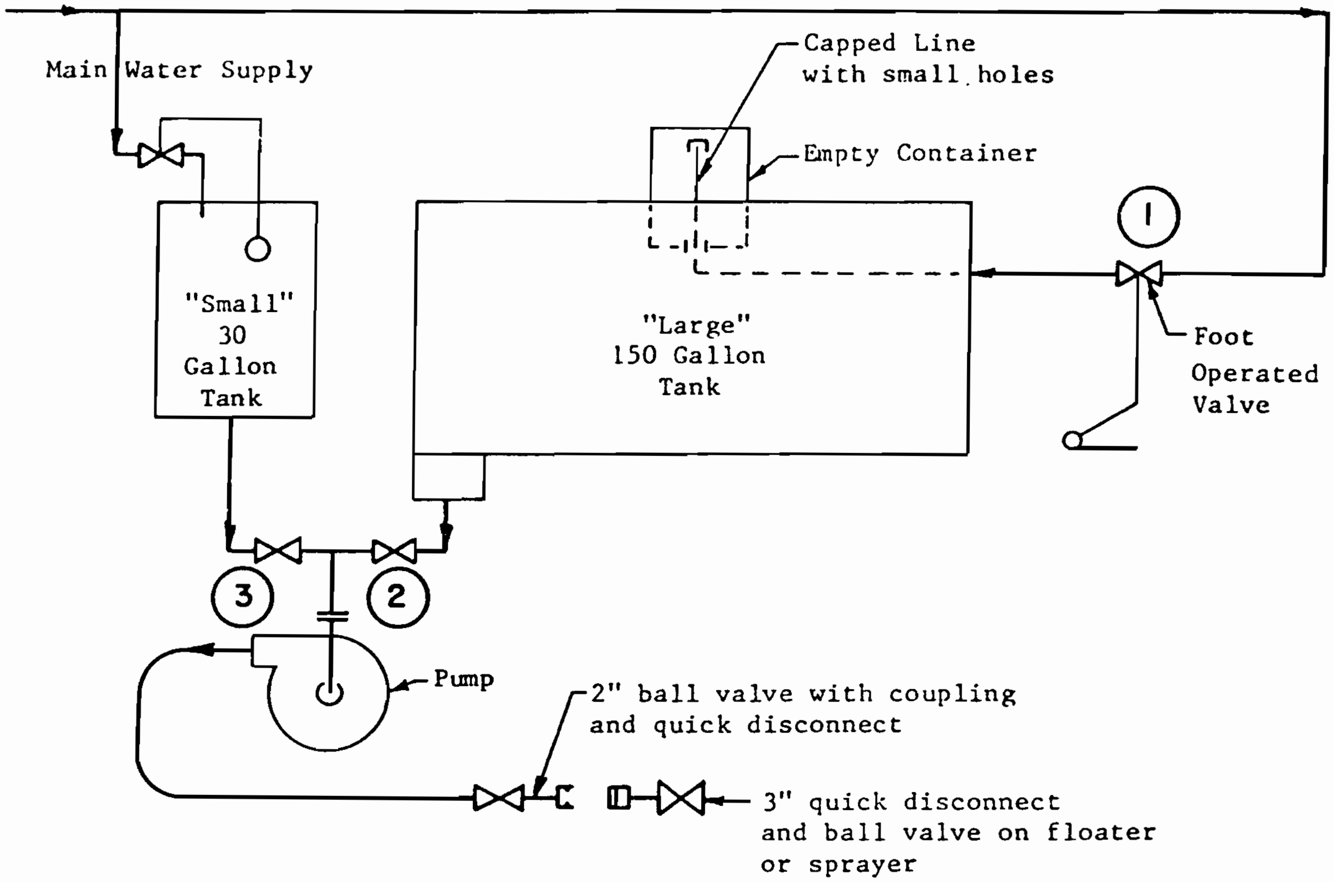
3. Used S.S. NH_3 Application Manifold

4. Used 3/8" Anhydrous Ammonia Hose

5. 1¼" Hose

6. Spray Nozzle - Connections vary with equipment

TERRA CHEMICALS INTERNATIONAL INC SIOUX CITY, IOWA					OCTOPUS	
Drawn	Checked	Approved	Scale	Date	Job No. (AFE)	Drawing No. Figure 6



OPERATION PROCEDURE

1. Dump chemical and put jug on capped line.
2. Push foot pedal #1.
3. Start engine on pump and open lines on truck.
4. Open drain valve #2.
5. When big tank is empty close valve #2.
6. Open valve #3.
7. Empty small tank ½ way.
8. Close valve #3.
9. Turn off pump.
10. Disconnect pump from truck.

The fill and triple rinse should take 5 minutes.

TERRA CHEMICALS
INTERNATIONAL INC
SIOUX CITY, IOWA

OPERATION PROCEDURE FOR
PESTICIDE INDUCTOR

Checked	Approved	Scale	Date	Job No. (AFE)	Drawing No.

Wednesday, November 19, 1986

Final Session
Moderator:

William E. Byrd

Elements of a Safety Program

F. C. McNeil
Corporate Safety Manager
International Minerals & Chemical Corporation

The elements of a safety program is a very broad and in-depth topic—but because of time we are only going to be able to barely scratch the surface. Today I would like to talk about the elements as they apply to the management side of safety.

Through the years the fertilizer industry has gone through many changes—from pick and shovel to draglines. Safety has also experienced many changes from basically nothing to an array of personal protective equipment. A safety program no longer consists of 8 or 10 vague and general rules written on a piece of paper and tacked on a bulletin board. The more that is learned about hazard and loss control, the more evident it has become that the job is too great for any individual or small group to handle by itself. The foundation for maintaining a safe and healthful work environment requires a team effort by everyone in the organization—management *and* hourly employees.

It has been clearly shown that the more intensive and complex industrial operations become, the more critical it is for the control of occupational injuries and illnesses.

But before we continue on this topic; one important fact must be recognized and that is:

SAFETY IS A MANAGEMENT FUNCTION

And since management is responsible for safety then management is held accountable for the success or failure of the safety program.

The more initiative and decisive approach that management takes in establishing safety and health functions as an integral part of management mission, the more safety and health programs can be geared to the prevention of injuries, illnesses, and property damage which in turn will have a positive effect on the achievement of the organizations overall goals.

To achieve its safety objectives, management must develop a comprehensive and active safety program which contains the following elements:

I. *LEADERSHIP*

The first is leadership:

A. (Support)—for a safety program to be effective, it must be fully supported by all levels of management—beginning with the chief executive officer.

B. Management must visually demonstrate this support by:
   1. Including safety as a part of management and staff meetings.
   2. Taking part in plant safety inspections and accident investigations.
   3. Attend safety meetings or even better, occasionally taking an active part.
   4. Include safety as an individual item in the operational budget.
   5. Properly review all safety aspects of new installations and processes, and
   6. Take the lead in establishing safety goals and the development of programs to achieve them.

C. Management should develop a safety policy that:
   1. Allows managers to delegate safety and health activities.
   2. Supports the need for safety and health throughout the operation, and does not confine safety/health matters just to the safety man or small group.
   3. It should also promote unified thinking among managers so that they may view safety problems in the context of the total group. It should make managers members of a team—and not isolate individuals when they have problems.
   4. A policy will take pressure off operating managers since it represents a total viewpoint of all management.
   5. It will also allow improved decision-making by crossing functional lines and provides a common base for solving

problems—since all are equally affected by the policy and equally responsible for following it.

To be effective and establish stability, a policy must be committed to writing. Verbal policies quickly become vague, distorted and may even create disagreement. A written policy can be readily referred to for clarification.

To assure a greater degree of consistency and application, copies of the written policy should be distributed to every level of management within the operation and also be part of the management guide.

II. *ASSIGNMENT OF AUTHORITY RESPONSIBILITIES*

The next element is the "Assignment of Authority/Responsibilities."

A statement of policy is of no value unless the policy's objectives are related to practical, and achievable results. Actual achievement is directly related to clearly defining the responsibilities of every person involved in the safety program. A clear assignment of responsibilities will assure that:

A. The policy objectives are integrated into the overall organizational functions and.

B. That the purpose and requirements for the programs are clearly defined and someone is given the responsibility to carry them out. Some examples of assignment responsibilities are:

—*Operating Officials/Management* will exert policy direction, review control information, delegate safety/health responsibility and authority, and make budgetary allocations. In addition to support, management will also provide training.

—*The Safety Department or Personnel*—will be charged with the responsibility to keep abreast of current safety/health legislation and information—arrange for pre-employment medical examinations—establish new employee indoctrination and other safety/health training programs—conduct training—maintains medical and other safety records—inform management of safety/health problems—advise the purchasing department of new safety standards—perform safety inspections.

—*Supervisory*—would be delegated the responsibility to conduct or oversee on the job training—supervise workers to insure correct working procedures—insures use of protective equipment and safe working practices—oversees proper housekeeping procedures—insures compliance with safety/health regulations—effectively communicates hazards to workers.

—*Employees* will be responsible for conducting their work activities in compliance with established rules/procedures—report unsafe conditions to supervisor—report any injury or accidents to supervisor.

III. *THE NEXT ELEMENT IS THE "MAINTENANCE OF SAFE WORKING CONDITIONS" AND IS AFFECTED BY SUCH THINGS AS:*

A. *Purchasing*—The safety man or department will provide safety guidelines to assist in the purchase of equipment to assure it complies with appropriate standards and codes. Where standards do not exist or are inadequate, guidelines may have to be developed for purchasing by engineering and safety.

B. (*Building New Facilities*)—During the construction of new facilities, installation of new equipment or processes, safety personnel and management should work jointly in reviewing all safety aspects of the project prior to start up. During construction or installation—establish an inspection program to assure that all safety requirements are carried out.

C. *Compliance with Codes and Standards*—Safety will assure that all building, equipment, and procedures are in compliance with local, state and federal codes/standards.

D. (*Inspections*)—An on going inspection schedule should be established which contain a method of follow up. This inspection schedule would require that:

Safety personnel/department perform scheduled plant inspections.

Supervisors accompanied by one or two of their workers will conduct periodic safety inspections of their assigned work area. Supervisors should also be encouraged to be continuously on the lookout for unsafe acts/conditions since they are in the best position to observe them when they occur. Of course when they are identified appropriate steps should be taken to correct them.

Periodic inspections should also be made by middle and upper management.

Copies of all written inspection reports should be routed to the appropriate managers for review and discussion at staff meetings.

Correcting Hazardous Conditions—As mentioned earlier it is most important that a system be developed and established to provide a method for correcting any unsafe condition in an expeditious manner after it has been identified. This procedure should contain a method for follow-up to assure the unsafe condition has been corrected.

This system should make available the support and assistance of management, engineering, and safety.

IV. *TRAINING*

In today's era of rapid change, safety and health activities must be periodically reviewed to assure that they adequately address the location's needs, because safety and health must keep up with new equipment, processes, changing economic and environmental constraints, emerging social and governmental pressures, and higher worker expectations. There is a need for every individual in the organization to have some degree of safety and health training in order to respond intelligently to these changes.

In many cases management has no choice as to whether or not to provide safety and health training—it may be mandated or strongly suggested by a governmental agency. Before any training is started, adequate time should be taken to develop training programs using the following basic steps:

—Identify training needs

—Formulate training objectives.

—Gather materials and develop course outline.

—Select training method and techniques.

—Conduct the training program—and

—Assure that a method has been established to evaluate the training effectiveness.

A. (*Department Heads*)—Training for department heads could address such topics as:
   —Accepting responsibility for safety and health.
   —Delegating safety and health responsibilities in an effective manner.
   —Allocating resources to effectively achieve objectives.

Often it is found that training directed at this level of management may be more effective if conducted by an outside training or consulting firm.

B. (*Supervisors*)

Supervisor training should be directed at involving these people in the safety program and help them to understand and effectively carry out their safety responsibilities.

To achieve this objective, some of the suggested topics might include:

—Understanding the reasons for accident prevention and health measures.
—Developing safety awareness in workers.
—Supervising workers to assure use of safe working practices.
—How safety affects efficiency and
—Effectively enforcing safety rules and procedures

C. (*Employees*):

All new employees should receive indoctrination training prior to starting their job. This training would address such topics as:

1. Review of location's safety policy.
2. Plant safety rules/procedures including an explanation of their purpose.
3. A clear understanding that any unsafe conditions must be reported to their supervisor.
4. A review of the worker's safety responsibilities.
5. A complete review and understanding of the operations code of conduct.

Of course, employee training does not stop at indoctrination—any time a new piece of equipment or a new procedure is introduced to an organization, employees must be properly trained in its operation. One good method of conducting continuous employee training is through safety meetings.

V. *ACCIDENT RECORD SYSTEM*

Some managers might view an accident record system as time-consuming and costly task which apears to be unprofitable and offers little or no return for the amount of time and money invested. In the field of safety and health, requirements of government agencies are increasingly demanding, and management must be aware that simply meeting minimum recordkeeping requirements may not in fact be in his operation's best interest.

Costly as a thorough recordkeeping system may appear, it could in fact be far less than a single liability judgment, sizeable citation or fine—this fact was evident in recent events when two major corporations were cited over a million dollars each by OSHA for allegedly failing to maintain adequate records.

A. (*Reports*)

Federal agencies require employers to maintain certain reports and records such as:

1. MSHA's 7001 and 7002 reports or
2. OSHA's 200 log and 101 report just to mention a few.

In addition to the required records there are other that can pay dividends. They are:

—Injury investigations
—Near miss and property damage investigation
—First aid logs

—Monthly safety performance and
—Report of plant inspections

B. (Analysis):

One of the major sources for analyzing situations come from records. Without records we would not know how our business is doing—the same thing applies to safety and health records—without them, it would be difficult to determine just how effective or in what direction the safety program is going. Reports that measure results can be used as a tool or barometers to:

1. Identify hazardous areas and assist in determining methods of correction.
2. Effectiveness of safety program.
3. Cost analysis.
4. Assist management in allotment of money for the safety budget.

A thorough safety and health recordkeeping system should be designed with these objectives in mind:

—Meeting mandatory recordkeeping requirements.
—Providing data for management assessment of hazards and prevention programs.
—Enabling the company to trace all products and materials from purchase through manufacturing and final distribution.
—Furnishing backup material to defend the corporation against liability suits and
—Providing complete employee medical, health, and training records.

VI. *MEDICAL SYSTEM*

A. (*Medical Services*)—The scope of the medical system at any plant will be largely determined by its size, and needs—but regardless of size, there are certain functions every operation must consider basic to a viable medical program. These are:

—Medical examinations
—Diagnosis and treatment
—Health monitoring
—Special programs

Whether these functions are performed inhouse or are provided by community resources, management should see that the first three basic needs shown here are met.

1. The purpose for the medical examination is a must in assuring safety and health on the job—it is essential that applicants for employment be placed in a position compatible with their capacities and state of general health. Naturally, this will involve a medical assessment which is usually accomplished by a pre-employment physical. The scope of the examination will be determined by the type of operation, plant environment, government requirements, cost restraints, available medical facilities and personnel. The examination should assess total capabilities and limitations, as well as suitability for a specific job.

In addition, the pre-employment examination will provide data needed to establish baseline health parameters such as hearing, breathing capacity, blood chemistry, etc. that should be obtained prior to start of employment.

2. *Diagnosis and Treatment*—of work related injuries and illnesses is an essential element of the medical program. The company's responsibility to provide this treatment is dictated by law. The great majority of industrial injuries consists of first aid and can usually be treated inhouse. However, injuries that require treatment beyond first aid or its potential seriousness is in question, should be referred to a doctor. It is considered wise to refer any severe injury cases requiring extensive diagnostic studies, hospitalization, or major surgery to a specialist for the necessary care and treatment.

Employees claiming an occupational illness or disease should be referred to a doctor for a definitive diagnosis and possible treatment.

Because these cases may be classified and filed under what is known as "continuing trauma," which is instituted in a number of states. In these cases the statue of limitations does not apply until the affected employee becomes aware of the relationship between his/her illness and the work environment. Legal action may not be filed until long after the employee has been removed from contact with the offending condition or agent. In some cases, the problem may not surface until years after the employee has left your employment.

3. *Monitoring*—Safety has a key role in monitoring, particularly monitoring and controlling absenteeism due to illness. In a case where an employee frequently requests medical leave after reporting on the job, serious consideration might be given to having this worker examined by a physician.

Guidelines authorizing absences should be established and applied in a consistent manner.

Any employee returning to work after

being on leave because of a work-related or off-the-job injury/illness should have a doctor's release before starting. Consideration might be given to having the worker examined by the company physician before returning to the job. The importance of maintaining complete and legible medical records cannot be overemphasized. Not only is it required by law, but is also absolutely essential in defending claims.

4. *Special Program*—In today's industrial world there have been other problems that have had a significant impact on safety, efficiency, and profit. The problems of which I speak are emotional, and substance abuse.

   Coping with these problems will usually consist of a joint effort between the company and an outside agency which have resources in the form of counselors, doctors, and facilities to handle specific problems. Examples of some of the outside resources are the National Council on Alcoholism, Alcoholics Anonymous, Veterans Administration, Federal and Local Governmental Health Agencies, and several others. Usually these programs consist of four basic steps:

—The education of management/supervision to assist in early identification of possible problem

—Referral to counselor for evaluation and disposition.

—Treatment of the problem

—Follow-up interview and evaluation after the employee has undergone treatment and is back on the job.

Another program that can have a positive effect on employees is one that encourages the worker to maintain good health.

The public is beginning to place emphasis on preventive medicine and the medical profession is responding with efforts both toward preventing disease and keeping people healthy. Industry has much to gain by encouraging these efforts. The company is in an ideal position to assist since it actually has a captive audience.

Preventive medicine starts with health education, promoted through company publications, company sponsored displays, lectures, films, periodic examinations, and health counseling services.

Liberalization of some health insurance programs will pay reasonable cost for "well person examinations"—this is a great aid and should be promoted if available—many companies have found that the cost for funding these activities has been compensated by improvement of employees health and morale, both of which mean less absenteeism and higher production.

VII. *ACCEPTANCE OF PERSONAL ACCOUNTABILITY BY EMPLOYEES*

A. One of the major challenges we face in safety is maintaining interest in the program. Maintaining interest is synonymous with involvement.

Management formulates policy, the supervisor interprets it and makes it a reality to their employees.

Communication is probably the chief method of developing proper attitudes and interest in the worker. However, before we can convince the employee that safety must be an integral part of everything he/she does, all levels of management and supervision must first honestly establish and project this attitude.

There are many ways to stimulate employee interest. For example:

1. Enforcement of safety rules and procedures
2. Safety meetings
3. Training
4. Safety committees
5. Maintaining a line of communication that allows the worker the opportunity to provide input.
6. Award/incentive programs—just to mention a few.

B. *Off-the-job safety*—The principal aim of off-the-job safety is to encourage the employee to follow the same safety practices in their outside activities as they do on the job. Many employees may tend to leave their safety training at the workplace when they go home. Off-the-job safety should not be a separate program, but rather an extension of the operation's on the job safety program.

While industry has a legal responsibility to prevent injury on the job, it has a moral responsibility to attempt to prevent injuries away from the job. Another reason for off-the-job safety is cost. Operating costs and production schedules are affected as much when an employee is injured away from work as when they are injured on the job.

Even though an injury may occur off the job, you will find that the majority of the expense will still be borne by the employer.

Some of the same methods used to

encourage safety on the job will apply to off-the-job.

Safety. For example, meetings, the company paper, bulletin board notices, films, and posters.

It is not difficult to work off-the-job safety into the plant safety program. One method of doing this is to make reference at safety meetings to outside activities and how the topic presented applies to the employees in plant job functions as well as activities outside the workplace. For example, safe lifting practices can be used at home while moving furniture or performing spring housekeeping chores. No asset is more important to an organization than its employees. It is important that they be encouraged to be safe off the job as well as on.

There you have it:

—Leadership
—Assignment of authority
—Maintenance of safe working conditions
—Training
—Accident record system
—Medical system
—Acceptance of personal accountability by employees.

If these points are adequately addressed in your individual safety programs and carried out in a sincere manner in the workplace, I believe you will find that not only will it help to prevent injuries and illness but will have a positive impact on the other phases of your operation.

Today the fertilizer industry is experiencing some rather difficult times, but I am confident that it will rebound. This confidence is based on the all out efforts to take advantage of every means possible to produce a quality product with an acceptable margin of profit. Safety is one of these means that can contribute to the profit picture provided management take full advantage of its potential. The decision is yours—for as I said in the beginning—"Safety is a Management Function."

Material Selection for the Production of High Quality Blends

J.L. Cheval
United Co-operatives of Ontario

I appreciate the opportunity to speak on the subject of material selection for the production of high quality blends.

Bulk blending with granular materials has been around for more than thirty years. Meeting the guaranteed analysis requirements has often been a challenge. At first, it was assumed that the problem was caused mostly by variations in the chemical analysis of the materials themselves. George Hoffmeister and others at TVA eventually demonstrated that the most common cause of the problem was not a chemical but a physical one, namely particle size (Refs. 1, 2). If the materials being mixed do not have matching particle size distributions, handling will cause demixing, or segregation. Quality control samples reflect that de-mixing.

Six years ago, the Engineering and Technology Committee of the Canadian Fertilizer Institute decided to tackle the problem of providing blenders with the information required to select size-compatible materials. That effort received the endorsement of plant food officials in Canada (Ref. 3).

Since that time, a series of papers have been presented to this very forum, reporting on the progress of our efforts (Refs. 4, 5, 6). It is with considerable relief that we can, today, state that all this work has been worthwhile. In Canada, the quality control results show significant improvements and the "cost of quality" has been reduced at the same time.

To select size-compatible blending materials one must compare the particle size distribution curves of these materials. Our modest contribution has been to recognize that only two numbers, or measures, are required to adequately describe a distribution curve. You will find these two measures defined in "The CFI Guide of Material Selection For The Production of Quality Granular Blends." We have called them Size Guide Number, or SGN, and Uniformity Index, or UI.

The Size Guide Number is the technical name for what the layman would call "average particle size." SGN is that particle size which divides the mass of all particles in two equal halves, one having all the larger size particles and the other half having all smaller size particles. SGN is calculated by linear interpolation. We admit this method of determination does not yield an accurate value, but we also support the view that better accuracy is not warranted when one considers the quality of the data we deal with (two successive screen tests on the same sample will give different results, even in the absence of particle degradation).

SGN is calculated by linear interpolation using the screen test data. Let us assume that we have found 2% retained on 6 mesh Tyler Sieve, 35% on 8 mesh, 85% on 10 mesh and 98% on 14 mesh. Obviously the 50% point has a particle size smaller than 8 mesh (2.362 mm) and bigger than 10 mesh (1.651 mm).

Interpolating between 2.362 and 1.651 gives a value of 2.149 mm for the 50% point. This is the average particle size, or SGN 215. Determination of the size guide number by linear interpolation is described in Appendix B of the CFI Guide.

The Uniformity Index means what the name implies. It tells us how uniform the particles are. Technically it is the ratio of the size of "small" particles (retained at the 95% level) to the size of the "large" particles (retained at the 10% level). These values are also calculated by interpolation. Using the same example as before, one would know that "S", the size of small particles, is smaller than 10 mesh (1.651 mm) but bigger than 14 mesh (1.168 mm), since 95% is between 85 and 98%. Interpolating between 1.651 and 1.168 gives a value of 1.279 mm for the 95% point. And "S" = 127.9 with the method described in Appendix C of the CFI Guide. Similarly, the size of large particles would be found to be 3.093 mm for the 10% point and "L" = 309.3. The Uniformity Index would be obtained by dividing "S" by "L" and multiplying the result by 100. In this example, UI = 41.

A Uniformity Index of 100 would mean that the particles at the 95% level have the same size as the particles at the 10% level, and therefore the material could be considered perfectly uniform. Obviously a material with a UI 60 would be substantially more uniform than one with a UI 35.

But would you consider a material with SGN 260 and UI 60 better than one with SGN 225 and UI 45? Not necessarily so. It depends on the other materials going into the blend. What counts is that the SGN's of the materials mixed together, and their UI's, are all in as narrow a range as possible.

The CFI Guide proposes two possible application methods. We call the first one "The Empirical Approach". The ranges of "acceptable" values for SGN's and UI's are centered on the average of the materials considered. If all values fall within the ranges, then a given formulation overage is used. Otherwise, a higher overage is written in. At the same time, consideration may be given to substituting the material which falls outside of the ranges. For the example listed in the CFI Guide, the rule was set at "plus or minus ten per cent". There is nothing sacred about the choice of that number. In fact, the name of the method stems from the notion that trial and error will determine the extent of the ranges for a given plant.

The other method we offer in the CFI Guide is called "The Mixing Quality Index" method, or MQI. With this method the formulation overage, required for a given quality performance, can be made dependent on the SGN and UI values of the materials. The MQI is based on coefficient of variation calculations. My collaborators and I are convinced that we will, in time, determine a formal relationship between MQI and the required overage. We recognize, of course, that the required overage is also dependent on many other factors, such as plant equipment design and layout, procedures, etc. Whether a MQI of .83 means an overage of 4% as stated in the example of the Guide, or some other value, depends very much on the physical, and also the human factors within the plant.

For UCO's bagging plants, a partial implementation of the methods for the selection of materials has meant savings of about three per cent of the cost of goods.

In Canada, the quality control record has improved steadily during the last few years. The rate of deficiencies, which stood at 25.6% in 1982 and at 25.5% in 1983, dropped to 20.2% the next year and to 18.7% in 1985. The complete results are not in yet for 1986 but, with 10.9% in the next to last report, a new low record should be expected. There is little doubt that the spectacular improvement of the last three years has been brought about by the use of the size guide number in the selection of blending materials.

We expect further improvement in the quality control record of the Canadian blenders as the methods of the CFI Guide become understood, and followed. We know that "The CFI Guide of Material Selection for the Production of Quality Granular Blends" will help in the quest for better quality at a lower cost.

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SGN

The CFI Guide of Material Selection for the Production of Quality Granular Blends

The concepts outlined herein have been developed by the Canadian Fertilizer Institute. The use of these concepts is totally voluntary.

A necessary element of fertilizer quality is the ability to meet a specified guaranteed analysis. However, samples taken for quality control do not always reflect the true analysis of the fertilizer lot. It has now been recognized that segregation is the most frequent cause of such quality control problems. Segregation occurs when the materials used in blending are not particle size compatible. While procedures and equipment can be designed to minimize the problem to some extent, the most economical "remedy" to segregation is to select materials which are particle size compatible.

CFI has developed two measures to describe the average particle size and particle size distribution of blending materials. They are the size guide number (SGN) and the uniformity index (UI).

In the following pages we define these two measures, show how to calculate their values and offer two application methods. These methods have been found helpful in the selection of materials and the reduction of formulation overages. These two application methods are proposed as examples only. You may think of even better ways to improve quality performance by control of the particle size. It is the hope of the Canadian Fertilizer Institute that this information booklet will help you to improve the quality of the fertilizer blends produced for the Canadian farmer.

SGN—WHAT IS IT?

SGN stands for Size Guide Number. SGN is the calculated diameter of the "average particle", expressed in millimeters to the second decimal and then multiplied by 100. More precisely, SGN is that particle size which divides the mass of all particles in two equal halves, one having all the larger size particles and the other half having all smaller size particles. The methods of determination are described in appendix A (graph method) and appendix B (mathematical method). Blending materials in Canada have an average SGN of about 220, although some materials may be as low as SGN 160 or as high as SGN 280.

UI—WHAT IS IT?

UI stands for Uniformity Index. UI is the ratio of the sizes of "SMALL PARTICLES" to "LARGE PARTICLES" in the product, this ratio being expressed in percentage. More precisely, UI is the ratio, times 100, of the two extreme sizes in the range of particles retained at the 95% level and at the 10% level. UI is best determined by a mathematical method which is described in appendix C.

A uniformity index of 100 would mean that all the particles have the same size (perfectly uniform). Blend materials in Canada typically have a UI of about 50 (the small particles are half the size of the large particles in the sample), although some materials may be as low as UI 35 or as high as UI 60.

HOW TO USE SGN AND UI
THE MIXING QUALITY INDEX METHOD

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. In mathematical form:

$$\text{MQI} = 1.0 - \text{CV of SGN's} - \text{CV of UI's}$$

The closer this MQI is to 1.0, the better the 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 of the SGN's using the formula

$$\text{SD} = \frac{\sqrt{\Sigma x^2 - (\Sigma x)^2/N}}{N - 1},$$

where Σ means "sum of", x means, in this case, the values of SGN's and N = 4, since there are 4 materials and, therefore, 4 values of x. The calculations go like this:

N	X	X^2
1	230	52900
2	225	50625
3	215	46225
4	190	36100
	$\Sigma x = 860$	$\Sigma x^2 = 185850$

$$(\Sigma x)^2 = 860 \times 860 = 739600$$

$$SD = \frac{\sqrt{185850 - 739600/4}}{4 - 1} = 17.795$$

To obtain the coefficient of variation of SGN's, the standard deviation, 17.795, is divided by the average, 215.0, giving a CV of .08.

Now the operator will calculate the standard deviation of the UI's using the same formula as before,

$$SD = \frac{\sqrt{\Sigma x^2 - (\Sigma x)^2/N}}{N - 1},$$

where Σ means "sum of", x means, in this case, the values of UI's and N = 4, since there are 4 materials. The calculations go like this:

N	X	X^2
1	44	1936
2	44	1936
3	40	1600
4	36	1296
	$\Sigma x = 164$	$\Sigma x^2 = 6768$

$$(\Sigma x)^2 = 164 \times 164 = 26896$$

$$SD = \frac{\sqrt{6768 - 26896/4}}{4 - 1} = 3.830$$

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:

$$MQI = 1.0 - .08 - .09 = .83$$

With the best of equipment and operating staff, and this information, the blender operator may conclude for instance, that at least a 4% overage is required to keep the deficiency rate below 15% at the 95% confidence level when using these four materials together.

A higher MQI would either reduce the risk of deficiencies or allow lower overages. Conversely, a lower MQI would lead to more frequent deficiencies or would translate into larger (and costly) overages.

HOW TO USE SGN AND UI
THE EMPIRICAL APPROACH

The blender operator often develops a "rule of thumb" which works well in the particular plant, although not necessarily so elsewhere. After a certain amount of experimentation, it becomes fairly easy to set limits on the SGN's and UI's of materials mixed together. This empirical approach may take the form, for instance, of a rule "average plus or minus so much per cent". In this case, the blender operator calculates the average of the SGN's of the materials used together and establishes the "acceptable" range. A similar calculation is performed for the UI's of these same materials. If all materials used fall within the limits of the "acceptable" ranges, the formulation will be calculated with the standard overages. Otherwise, formulation overages will be raised to offset the risk of deficiency caused by increased segregation. Consider, for example, the case of the blender mixing together the following four materials. The averages have been calculated, as well as the "acceptable" ranges, with the rule set, in this case, at "average plus or minus 10%".

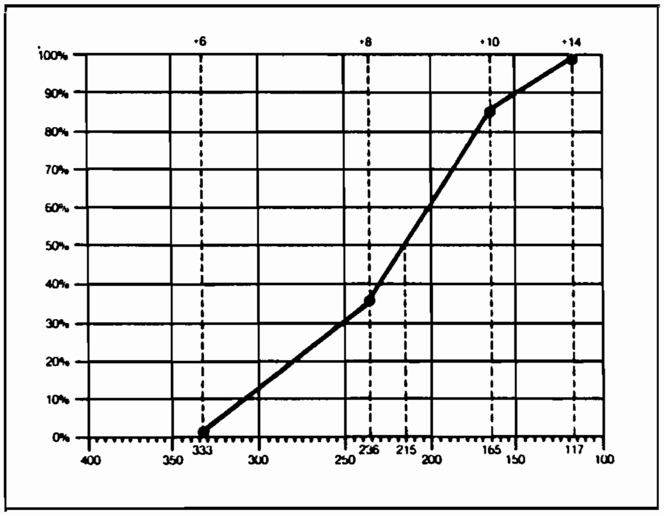
	Mat. 1	Mat. 2	Mat. 3	Mat. 4	Average	Accept. Range
SGN	230	225	215	190	215.0	193.5–236.5
UI	44	44	40	36	41.0	36.9– 45.1

In this example, material 4 falls out of both "acceptable" ranges. Therefore, higher overages will be required in formulation. (The proportion of material 4 in the formula may influence the amount of required overage.) Alternatively, the blender operator will seek another source of material 4 with SGN and UI values closer to the values of the other three materials.

APPENDIX A

DETERMINATION OF THE SIZE GUIDE NUMBER BY THE GRAPHICAL METHOD

The particle size distribution is plotted on graph paper per cent cumulative by mass versus particle size. The normally smooth distribution curve is approximated by drawing straight line segments



between adjacent data points. From the point where the data line crosses the 50% cumulative line, a vertical line is drawn down to the SGN scale for a direct reading of the SGN value. In the above example, the data points are: +6 = 2%, +8 = 35%, +10 = 85%, +14 = 98%. They have been plotted on vertical dotted lines which correspond to the scale values of the following table:

Tyler Mesh	4	6	8	10	14	20
Opening, Millimeters	4.699	3.327	2.362	1.651	1.168	.833
Increment to Next Mesh	1.372	.965	.711	.483	.335	
Scale Value	470	333	236	165	117	83

APPENDIX B

DETERMINATION OF THE SIZE GUIDE NUMBER BY THE MATHEMATICAL METHOD

1. Find the cumulative screen % closest to 50: the cumulative screen % below 50% and the cumulative screen % above 50%.
2. Use one of the following formulae, replacing the variable called "PLUSn" by the corrsponding cumulative % value for the screen "n".

If 50% is between +6 and +8

$$\text{SGN} = \frac{96.5\ (\text{Plus } 8 - 50)}{\text{Plus } 8 - \text{Plus } 6} + 236.2$$

If 50% is between +8 and +10

$$\text{SGN} = \frac{71.1\ (\text{Plus } 10 - 50)}{\text{Plus } 10 - \text{Plus } 8} + 165.1$$

If 50% is between +10 and +14

$$\text{SGN} = \frac{48.3\ (\text{Plus } 14 - 50)}{\text{Plus } 14 - \text{Plus } 10} + 116.8$$

Example:

+6 = 2%, +8 = 35%, +10 = 85%, +14 = 98%

50% is between +8 and +10
Use the second formula:

$$\text{SGN} = \frac{71.1\ (85 - 50)}{85 - 35} + 165.1 = 215$$

Note: These formulae are based on the mesh openings of the Tyler screen scale. See table of Appendix A.

APPENDIX C

DETERMINATION OF THE UNIFORMITY INDEX

1. Find the cumulative screen % closest to 95: the cumulative screen % below 95% and the cumulative screen % above 95%. Calculate the size of "SMALL PARTICLES", S, with one of the following formulae, replacing the variable called "PLUSn" by the corresponding cumulative % value for the screen "n".

If 95% is between +8 and +10

$$S = \frac{71.1\ (\text{Plus } 10 - 95)}{\text{Plus } 10 - \text{Plus } 8} + 165.1$$

If 95% is between +10 and +14

$$S = \frac{48.3\ (\text{Plus } 14 - 95)}{\text{Plus } 14 - \text{Plus } 10} + 116.8$$

If 95% is between +14 and +20

$$S = \frac{33.5\ (\text{Plus } 20 - 95)}{\text{Plus } 20 - \text{Plus } 14} + 83.3$$

2. Find the cumulative screen % closest to 10, the cumulative screen % below and the cumulative screen % above 10%. Calculate the size of "LARGE PARTICLES", L, with one of the following formulae, replacing the variable called "PLUSn" by the corresponding cumulative % value for the screen "n".

If 10% is between +4 and +6:

$$L = \frac{137.2\ (\text{Plus } 6 - 10)}{\text{Plus } 6 - \text{Plus } 4} + 332.7$$

If 10% is between +6 and +8:

$$L = \frac{96.5\ (\text{Plus } 8 - 10)}{\text{Plus } 8 - \text{Plus } 6} + 236.2$$

If 10% is between +8 and +10:

$$L = \frac{71.1\ (\text{Plus } 10 - 10)}{\text{Plus } 10 - \text{Plus } 8} + 165.1$$

3. To find the uniformity index, divide the value S by the value L and multiply by 100:

$$UI = \frac{S}{L} \times 100$$

Note: These formulae are based on the mesh openings of the Tyler screen scale. See table of Appendix A.

Impact of Gas and Oil Prices on Nitrogen Costs in the U.S.A.

Presented By Nelson E. Hay
American Gas Association

INTRODUCTION

In April 1985 A.G.A. published a study which concluded that the United States was becoming an attractive site to add reactivated and new ammonia capacity. For the prior decade, it had been the view of most analysts that ammonia produced from U.S. plants would be unable to compete in the future with ammonia imported from new plants abroad. The 1985 paper argued that recent events had called into question the underpinning assumptions of this conventional view.

The decontrol of new natural gas prices in the U.S. had been accomplished, and natural gas prices were declining, and the outlook for U.S. natural gas production had become far brighter than had been expected only a few years earlier. At the same time, the capital (construction) and other cost components of ammonia production had been inflating more rapidly than the feedstock components worldwide—particularly in developing nations. Since U.S. ammonia production already had a capital cost advantage (due to existing infrastructure, proximity to suppliers, etc.), the increasing relative importance of the capital component was working to the advantage of U.S. production.

The A.G.A. analysis found that, as a result of these developments, the economic attractiveness of the U.S. as a site for new ammonia capacity had increased markedly. The national average cost of ammonia produced from a new U.S. plant beginning construction in 1985 was estimated to be between 5 percent more to 63 percent less than the comparable cost of ammonia imported from newly constructed foreign plants. These estimates were based upon assumed natural gas prices to ammonia plants of $3/MMBtu in the U.S., $2 in Canada, and $1 elsewhere.

The purpose of this paper is to examine the developments in U.S. natural gas regulation, supply, and pricing which have occurred since our 1985 paper was published, and to ask whether these events strengthened or weakened our thesis.

RECENT DEVELOPMENTS

A great deal, indeed, has changed in the U.S. natural gas industry in the past two years. The natural gas distribution and transmission segments are experiencing a multi-faceted structural change while also coping with a precipitous drop in petroleum prices and a persistent surplus of gas deliverability. In two years' time, variable costs have been removed from minimum bills, pipelines and distributors have largely been opened to non-discriminatory transportation of gas for others, and old gas pricing has been effectively decontrolled.

What have been the results?

We already had intense gas-to-gas competition, increasingly, market-responsive contracts, and the development of substantial negotiated carriage. Yet, in the first six months of 1986, carriage volumes were up 45 percent compared to a year earlier. Roughly one-third of industrial gas is being purchased directly today. Forty to fifty percent of all gas purchases are being made by parties other than pipelines.

Gas prices are coming down, with all consuming sectors benefitting. Gas utility retail prices for August 1986 were down an average of 8 percent compared to a year ago—34 percent in the powerplant sector, 16 percent in the industrial sector, 9 percent in the commercial sector and 3 percent in the residential sector.

This has been the good news. On the negative side, these declines in gas utility prices, while impressive, have not been enough to maintain competitiveness vis-à-vis non-system gas or oil. We still have about 2 Tcf—over 10 percent of total system supply—under contracts which are not market-responsive. The average field price being paid by interstate pipelines today is roughly 85–90¢/MMBtu above the spot price. Note, however, that the spot gas price has maintained the roughly 50 percent of crude relationship, standing at approximately $1.25 today. The system price has not, and stands at about $2.13 today, based upon Purchased Gas Adjustment filing with the Federal Energy Regulatory Commission (F.E.R.C.). Both were $2.56 when the 1985 A.G.A. study was made. As a result of this divergence, gas utility sales for the first half of the year were down nearly 18 percent in the industrial sector and 33 percent in the powerplant sector.

The strong growth of carriage was not enough to offset these declines in utility sales. *Total volumes* moved through the system, including both utility sales and carriage, declined 6.5 percent in the first half of 1986 (again, compared to the same period last year). We're presently estimating that total gas sales for 1986 will be 16.8 Tcf—down 6 percent from 1985.

From next to nothing, take-or-pay liabilities rose to $6 billion at the end of 1985, and are expected to rise an additional $6 billion/year in 1986 and 1987. This is a real problem. Pipelines have lost some take-or-pay cases in the courts. If passed through fully to consumers we would be looking at a cost of $1/MMBtu by 1987. Even at settlements of 15¢ on the dollar we would not like the price pressure. And, the effect is circular. High take-or-pay liabilities are an impediment to gas purchasing and, ultimately, to gas drilling.

Finally, the decline in gas use this year has extended the life of the gas deliverability "bubble." In its seventh year, the surplus is now about 3 Tcf of domestic gas plus .6 Tcf of quickly available Canadian gas—over 20 percent of total consumption.

NATURAL GAS SUPPLY AND PRICE SITUATION

When I joined the gas industry in 1969 they told me that we had four years of gas left in the U.S. Gulf and eight years on shore. By contrast, I was told, we had a 200 year supply of coal. Today, we recognize that this comparison was completely wrong-headed. We were comparing the proved gas reserve to the whole coal resource thought to exist. Proved gas reserves, as you know, have been found, booked as corporate assets, and, for the most part, sold under long-term contract. On an apples-to-apples basis, the gas and coal resources are of the same order of magnitude, and I believe that gas may ultimately prove to be the greater.

My point is that today it is widely recognized that the natural gas resource base is not a constraint to natural gas supply. It is fair to say that we have a totally new perspective on gas supply and economics. Today, we all argue about deliverability, but no one doubts that the gas resource is there, abundant, and far cheaper to produce than we expected a decade ago. That is not to say that you don't hear a lot of noise to the contrary.

There are currently two basic problems facing the natural gas industry with respect to supply. The first is *current excess supply*. It is causing low spot prices, pressure for more carriage, an advantage for transportation gas over system supplies, and shut in gas which—with collapsing oil prices—is discouraging drilling activity. Also, these same low spot prices, along with pressure for transportation gas over system gas (for both pipelines and distributors) are adding to the huge take or pay problem—to the point that it is approaching a genuine crisis. Such a crisis is not just one for the pipelines directly involved, but for their LDC's and all consumers as well.

The second problem involves *concern with inadequate future supply*. This is an old problem. It is one which, even with the excess supplies of recent years, the industry has never been able to completely shed. The current lack of drilling has revitalized the fear of future gas shortages which is discouraging potential new gas users and depressing demand. While gas supply pessimism has been a chronic problem faced by gas marketers, the current low rig count is breathing new enthusiasm into negative supply assessments, and we now have clear indications that these arguments are not being lost on state regulators and potential customers.

No one can predict with exact certainty what the conventional supply situation will be in 5 years at current low levels of drilling activity. Our analyses indicate that there need not be any gas shortages—the remainder of this discussion will focus on why.

No one can say with absolute certainty what the level of gas prone exploration activity will be "beyond the bubble" when supply and demand is in balance—particularly now that field price controls are off for new exploration and drilling. A.G.A. has reason to believe that market forces will work, and drilling in gas prone areas will increase as demand increases relative to supply. This is especially true when most new market growth "beyond the bubble" is not expected to compete just with residual fuel oil, but with higher priced alternatives. Therefore, beyond the bubble, the huge natural gas resource base should be developed by more drilling that is increasingly gas prone. This is a likely future, although it can't be predicted with certainty.

What *is* certain is the industry's current problems: lack of demand, oversupply and growing take or pay liabilities. The current rash of negativism about supply works against their solution. With this as an introduction, the discussion will now focus on some revealing data.

Gas Supply Short-term

The Bubble. A.G.A.'s current estimate of excess production capability (the bubble) is about 3 Tcf/yr. See Figure 1. The Energy Information Administration (EIA) of the Department of Energy, estimates a 6-month bubble (for gas under contract only to interstate pipelines) at 2.3 Tcf for the period July 1 to December 31, 1986. This is up from 1.8 Tcf for the last six months of 1985. EIA's 6-month number includes some Canadian gas and may include some double counting, however, this EIA number is significant. It confirms the A.G.A. numbers and shows that in 1986, the bubble is not decreasing *and* that the bubble is moving almost exclusively to system gas.

> A.G.A. published its latest bubble analysis in early 1986. The purpose was to point out that: 1) at current levels of exploration and drilling activity, the bubble would indeed diminish by the winter of 1989/90 to the point of near non-existence; and, 2) that this was a clear signal that supply and demand would come into balance and that there should be steps taken toward regeneration of exploration and drilling activity.

Extended Bubble. In a recent analysis, ENRON Corporation evaluated the "extending bubble." Figure 2 presents the ENRON assessment of how the gas bubble could last until 1991 if gas demand remains at current, depressed levels. A combination of excess production capability from producing gas wells (currently 3 Tcf); plus additional production capability from nonproducing reserves (both committed and uncommitted), and new reserves added at basement level drilling (6 Tcf/yr. additions) should maintain domestic production capability at a minimum of 17 Tcf through 1991. Not even the most persistently gloomy forecasts predict less than 6 Tcf/yr. of new reserve additions over this period.

Beyond the Bubble. As the bubble contracts, several additional sources of gas will become available to ensure that no shortage occurs during the period it takes the exploration and production sector to turn around. Under a scenario with higher energy prices ($25/bbl crude oil) these incremental sources of gas could bring approximately 1.65 to 2.45 Tcf/yr. to the marketplace within 12 months, as needed. Under an extremely low priced scenario—that is, if present $15/bbl prices continue to 1990—gas that could be brought to market within 12 months from these sources could be as low as 1.15 Tcf/yr. This low price scenario is discussed at the end of this paper. Table 1 presents estimates of the incremental short-term gas supply potential under a high world oil price scenario ($25/bbl.)

Uncommitted, Nonproducing Gas Reserves

These were estimated by EIA to be 9.0 Tcf at year-end 1984. Production from these reserves when developed and hooked-up to the transmission network could supply betwen 0.5–1.0 Tcf annually. This gas is not part of the A.G.A. bubble estimate. The low level of production relative to the size of the reserves reflects a time lag in bringing all this gas to market.

Canadian Gas

U.S. companies currently have contracts with Canadian pipelines and producers to import up to 1.9 Tcf/yr. Considering seasonal and physical deliverability constraints, it is estimated that 1.5 Tcf/yr. of Canadian gas could be physically imported into the U.S. (with some minor additional pipeline construction). Given that current Canadian imports are about 700 Bcf/yr. (1986 estimate), 0.8 Tcf/yr. of additional gas could be made available to U.S. purchasers and up to an additional 1.3 Tcf/yr. with major new construction.

Accelerated Infill Drilling

It has been a point of some discussion as to how much infill drilling will increase reserves, but all will agree that infill drilling will increase production capability, and all will agree that when the bubble is gone there will be more infill drilling.

Furthermore, no doubt exists that several of the largest gas fields in the country remain amenable to infill drilling to increase production capability, and in some cases, proved reserves. Nationwide accelerated infill drilling could quickly increase production capability by 0.1–0.4 Tcf/yr.

Mexican Gas

The political uncertainty about Mexican imports is fully understood, but it is also known that Mexico has huge associated gas reserves. The potential *is* there, and the export of gas does *not* divert gas from Mexican industry. Large volumes of gas are being reinjected now and the gas to oil ratios are increasing. Before suspension of shipments due to pricing considerations, Mexican gas imports to the U.S. averaged 300 Mcf/day (100 Bcf/yr.) This amount could be doubled to 200 Bcf/yr. with existing pipeline capacity.

LNG

There are four LNG terminals which have been operational and one or more of them could become operational again. Collectively, these terminals could become operational again. Collectively, these terminals have the capacity to handle 770 to 900 Bcf per year. In the event that additional gas supplies were needed in the U.S., 50 Bcf could be anticipated from *LNG*

Natural Gas Resource Assessment

The conventional natural gas resource base is equivalent to about *50 years* of gas supply at the current production rate. (See Figure 3.) The resource base for near-term, currently producing *un*conventional sources (i.e., coal seam gas, Devonian shale gas, western tight sand gas and enhanced gas recovery from co-production of gas and brine in watered out gas fields, etc.) is two to three times the size of the conventional resource base. The pace at which these resources are developed (both conventional and unconventional) will depend on the economics of gas exploration and production, and the application of new technologies.

The long-term gas supply issue should therefore focus on the timing of resource development, not on the size of the resource base. This resource development issue is a matter of economics—are future gas prices, relative to the costs of production, sufficient to permit aggressive gas prone exploration and production programs.

> According to a new study by the Potential Gas Agency for GRI, at an average cost of $3 per Mcf (1984 $), recoverable potential lower-48 resources are 535 Tcf—about 83 percent of the total lower-48 potential. Adding the 535 Tcf potential to 160 Tcf of proved reserves (163 Tcf in 1984) equals 695 Tcf. If divided by 17 Tcf/yr. of production it results in *40 years* of supply at finding costs of $3/Mcf or less. In today's market, $3.00 per Mcf is about twice the current spot price *but* it is also just half of what was commonly projected as minimum field prices just a few years ago. The Potential Gas Agency's findings are in general agreement with the ENRON study that concludes that finding costs today have returned to the level that existed in 1974 (about $2/Mcf in 1985 $).
>
> National average finding costs appear closely related to the level of drilling occurring (see Figure 4). As more difficult (e.g., deeper water) areas are explored, the increased cost of exploration and development tends to be offset by improved technology. Further as the intensity of drilling increases, costs rise. As rigs become available during slack periods drilling costs fall. Thus supply and demand for attractive acreage, for rigs, and for other products and services, tends to be a critical influence on finding costs. When examining gas finding costs over extended periods, the upward pressure exerted by geology has been offset in part by improved technology; while the boom/bust cycles of the industry have had a pronounced impact on cost.

In the 1980–85 period, significant major new gas discoveries were made and/or developed in the lower-48 states. These indicate that at the levels of activity that existed through the 1980–85 period, adequate supplies can be made available.

While there is confidence that the drilling levels that existed in the 1980–85 period were sufficient, current prices and takes appear inadequate to sustain either proved reserves or the current production capability level. That's why the bubble will be dissipating. Gas well completions through May, 1986 were down 27 percent relative to 1985. It is impossible to determine how much of the downturn in drilling is related to low prices and how much to a lack of buyers for long-term supplies; but overall the level of drilling is too low.

Seasonal Gas Supplies

Part of the discussion on the possibility of shortages focuses on the adequacy of seasonal and peak day deliverability. This is a question of: (1) deliverability in the field; (2) pipeline capacity constraints; and (3) storage output capacity.

In 1970, the ratio of peak sales to minimum monthly sales was 1.9 to 1; in 1980 it was 2.1 to 1 and in 1984 it was 2.7 to 1. The seasonality of the load is increasing due in part to a lower percentage of industrial sales which contribute to summer sales and to a steadily increasing number of residential customers. The result is that while consumption has fallen from 20 Tcf in 1980 to 17 Tcf in 1986, peak day demand has remained stable.

The gas industry has responded to this situation by increasing storage. As contrasted with the mid-1970's when 40 percent of peak day consumption came from storage, 50 percent of peak day gas consumption today comes from storage. Working gas capacity is up nearly 50 percent from the early 1970's. With 50% of peak day supplies coming from storage, a ten percent decline in production capability in the field results in only a five percent decline in peak deliverability. As to pipeline capacity, it is known to be up since 1970, although for this paper there has not been an attempt to quantify how much.

Thus, of the three factors affecting winter peak deliverability, two are favorable. Storage is up, pipeline capacity is up, and one is projected to start down—field deliverability.

There is the exception that on an historically cold day, distribution systems with poor storage capacity and/or tight pipeline capacity could have deliverability problems. However, these exceptions are not indicative of overall gas supply availability.

Economics of Supply

Both short and long-term gas supplies will be impacted by the price of gas and the price of oil. Residual fuel oil prices are going to be a key influence on natural gas prices—and maybe in the short-term, a cap—but new gas markets will not compete with resid and will therefore diminish the importance of resid to gas pricing. However, a low oil price trajectory, at least in the short-term, implies a low natural gas price trajectory.

Low gas prices result in both less exploratory drilling as well as less gas from the transitional sources previously described. Certain transitional sources will not be materially affected by low gas prices (e.g., Canadian gas); while others will be severely impacted (e.g., LNG). Table 2 presents estimates of the volumes available from transitional sources under a low energy price scenario.

Low energy prices mean less long-term supplies (lower exploratory drilling) and, as indicated, smaller volumes from transitional supplies. Still, even under a low price scenario, between 1.15 Tcf to 1.7 Tcf/year of transitional supplies could be brought to market within 12 months when needed as the bubble dissipates.

CONCLUSION

The assumptions underlying the April 1985 A.G.A. ammonia analysis has proven to be quite robust. U.S. natural gas prices are lower today than we had anticipated, and prices are likely to remain lower (in real terms) for the foreseeable future. It is clear that the U.S. natural gas resource base is not an impediment to supply availability. In the post-NGPA world economics will determine supply, and those economics appear to be quite attractive.

TABLE 1
Possible Incremental Short Term Gas Supply Potential at High World Oil Prices (in Bcf)

	Within Twelve Months
Uncommitted Nonproducing Reserves	500–1,000
Canadian Gas[1]	800
Accelerated Infill Drilling	100–400
LNG[2]	50
Total Additional Supply Available	1,650–2,450

[1] Volume is in addition to the 700 Bcf anticipated to be imported in 1986. By 1990, a number of Canadian gas import projects currently pending regulatory approval should be concluded, increasing additional short-term potential from this source from 800 Bcf/yr. to 1,300 Bcf/yr.

[2] Volume is well below the physical limitations of the established terminals. This 50 Bcf could be doubled given adequate time to revitalize existing terminals.

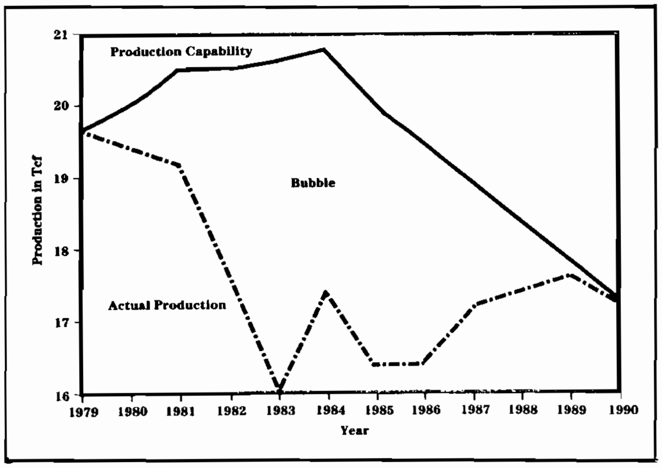


Figure 1 Production Capability versus Production 1979–1980

TABLE 2
Possible Incremental Short Term Gas Supply Potential at Low World Oil Prices (in Bcf)

	Within Twelve Months
Uncommitted Nonproducing Reserves	250–750
Canadian Gas[1]	300
Accelerated Infill Drilling	50–100[2]
Mexican Gas	—
LNG[3]	50
Total Additional Supply Available	1,150–1,700

[1] Volume is in addition to the 700 Bcf anticipated to be imported in 1986. By 1990 a number of Canadian gas import projects currently pending regulatory approval should be concluded, increasing additional short-term potential from this source from 800 Bcf/yr. to 1,300 Bcf/yr.

[2] If the bubble extends to the 1989/90 winter period—as we expect—up to 200 Bcf/yr. from this source is possible.

[3] Volume is well below the physical limitations of the established terminals.

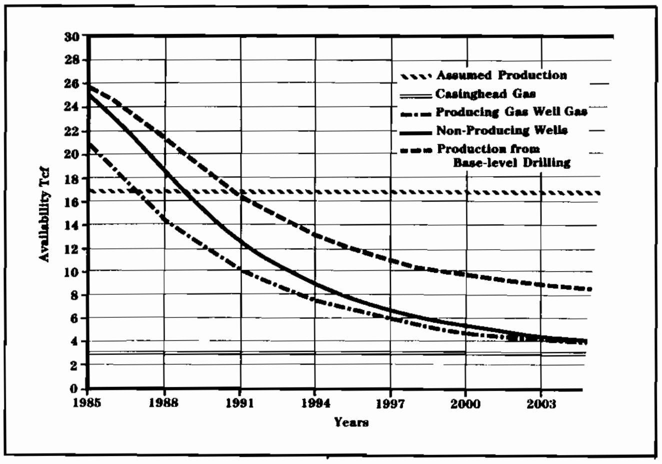


Figure 2 Availability Analysis
17 Tcf Production Lower 48

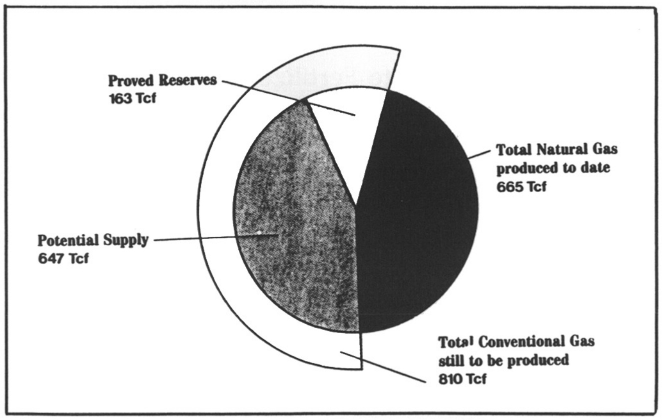


Figure 3 U.S. Natural Gas Conventional Resources for the Lower—48 States

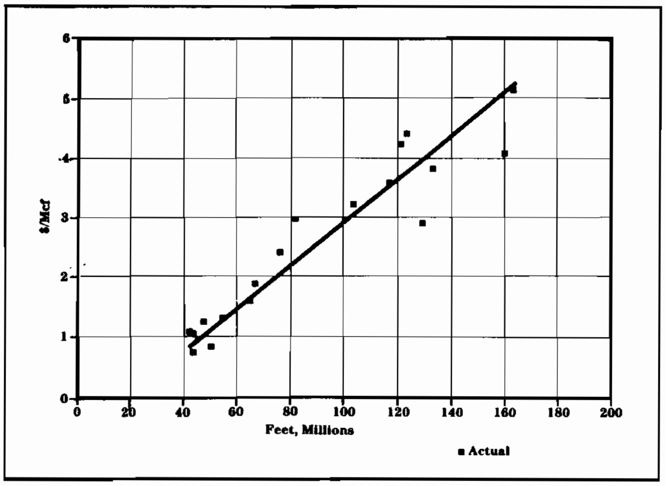


Figure 4 Finding Cost vs Annual Feet Drilled
United States—Lower 48

Variance and Representativeness of the AOAC Fertilizer Bag Sampling Procedure*

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INTRODUCTION

The Uniform State Fertilizer Bill of the Association of American Plant Food Control Officials (AAPFCO) (1) states in Section 8(c), "The methods of sampling and analysis shall be those adopted by the Association of Official Analytical Chemists (AOAC)". In the same document in Section 3(p) the term "investigational allowance" is defined as, "an allowance for variations inherent in the taking, preparation, and analysis of an official sample of fertilizer". An investigational allowance (IA) is used by a control official in judging whether an analytical result from an official fertilizer sample that is below the manufacturer's guarantee should be declared deficient. The current AAPFCO investigational allowances were adopted in 1968 (2) based on published scientific studies by Miles and Quackenbush (3) and Quackenbush, et al. (4). For a detail discussion of the background and rationale of the AAPFCO investigational allowances see Rund (5). These investigational allowances are based on variances associated with the AOAC bag sampling procedure (6), intra-laboratory procedures (sample reduction and analytical), and inter-laboratory analytical procedures.

Since the sampling component of the AAPFCO's IA's was under investigation it would be of benefit to briefly review the background of the IA's and their statistical basis.

In statistical terms we are looking for a pooled variance that includes sampling, intra-laboratory, and inter-laboratory variance. The pooled variance used in constructing the AAPFCO IA's was derived from studies in the late 1950's and early 1960's which were published in the Journal of the AOAC by Miles and Quackenbush.

The statistical basis for the IA's is the characteristics of the normal distribution. Any normal distribution can be defined by the equation:

$$Z = (Y - \mu)/\sigma$$

where Z = a standard normal variable from a $N(0,1)$ distribution,
Y = an observation from a $N(\mu,\sigma)$ distribution,
μ = population mean of the normal distribution, $N(\mu,\sigma)$, and
σ = population standard deviation (SD) of the normal distribution, $N(\mu,\sigma)$.

The application of these ideas to derive the IA's is described below:

(a) $Z = 2.33$—This value[1] of Z is selected because it includes 99% of the normal distribution, any value greater than 2.33 would happen no more than 1% of the time,
(b) Y = Analytical result from the analysis of an official sample,
(c) μ = Guarantee of the manufacturer, and
(d) σ = IA standard deviation or more specifically the square root of the IA variance which is the sum of the sampling, intra-laboratory, and inter-laboratory variance (pooled variance).

The following assumptions are necessary to make the above application valid:

(a) the sampling, intra-laboratory, and inter-laboratory variances are from independent normal distributions,
(b) the IA-variance is the population variance, and
(c) the sample is from a population that has the manufacturer's guarantee (μ) as its true mean

and the IA standard deviation (σ) as its true standard deviation.

The construction of an IA will now be described for a 20% nitrogen guarantee. The published data (3, 4, and 5) referenced earlier show the following variances:

(1) Sampling 0.0148,
(2) Intra-Lab 0.0457,
(3) Inter-Laboratory 0.0365,
(4) Total (IA-Variance) .... 0.097.

The IA is now calculated as shown below:

$$\text{IA} = \sqrt{\text{IA-Variance}} \times 2.33 = \sqrt{.097} \times 2.33 = 0.73.$$

The interpretation of the IA is that if a nitrogen analytical result (Y) is below the manufacturer's guarantee of 20% (μ) by more than 0.73 (the IA) then we say it is deficient (not from the population whose mean is 20 and whose variance is 0.097). By this procedure the control official makes no more than one error in 100 decisions.

The study that I will now describe involved the re-evaluation of the sampling variance component which is one of the three components of the AAPFCO's IA's. It is, incidentally, the smallest of the three.

Since these investigational allowances were adopted in 1968 based on studies conducted with fertilizers in use in 1955 and 1966, there was interest by both the fertilizer industry and fertilizer regulatory officials in re-evaluating the variance associated with the AOAC bag sampling procedure. In 1983 the AAPFCO appointed a joint task force consisting of representatives from The Fertilizer Institute, AOAC, and AAPFCO to develop an experimental plan and to conduct the study. The final plan was developed and the study conducted in 1983 (8). Progress reports have been published in 1985 (9) and 1986 (10).

The objectives of the study were: (1) to determine the variance associated with the AOAC bag sampling procedure over the range of N, P_2O_5, and K_2O concentrations most commonly found in mixed fertilizer and to recommend changes to the AAPFCO investigational allowances if indicated, and (2) to get an indication if a diagonal core (per AOAC sampling method) from a bag of blended granular materials represents the mixture contained in the bag, within the latitudes imposed by the sampling variance of the AAPFCO investigational allowances.

The following definitions adopted by the task force are critical to accomplishing the objectives of the study:

Manufacturing variation—Compositional differences (variation from guaranteed analysis or "target analysis") in a lot of fertilizer resulting from manufacturing processes, such as, weighing, segregation, quality of base materials, etc. This includes variation from top to bottom or middle to edge of a bulk pile or from bag to bag.

Sampling variation—The variation in composition of successive samples taken repetitively by the same sample tool and method, and, as much as possible, from the same path through the bag or pile.

EXPERIMENTAL

Blend Plant Selection

The fertilizer plant utilized in this study was the W. S. Clark & Sons Company, Tarboro, NC. The plant had a two-ton Burton horizontal mixer with overhead bins for material storage, a bagging hopper with partitions 16 inches by 16 inches, and a St. Reges Forced Flow Valve Pack bagger.

Before the plant was selected the blender was tested to determine the variation among the N, P_2O_5, and K_2O analyses of 10 equally, time-spaced stream cuts taken from a test mix in a preliminary experiment. The blender performed satisfactorily in that none of the analyses for a specific element varied more than 10 percent from the mean.

Fertilizer Materials Selection

The fertilizer materials used in the study were diammonium phosphate (DAP), triple superphosphate (TSP), muriate of potash (MP), urea, and filler made from limestone rock. The particle size distribution was determined on each material using Tyler 6, 8, 10, 14, and 20 mesh sieves; and, the materials selected did not vary more that ±10 percentage points from the average of all materials at any point on the cumulative residue curve.

Experimental Blend Formulations

The five blends used in the study were 5-15-30, 10-20-20, 15-30-15, 20-5-10, and 30-10-5. Each material used in the blends was sampled and analyzed and the results shown in Table 1. Each blend was made with one task force member recording the weights directly from the digital scale readout. Two batches of two tons each of each blend were manufactured. The first batch was used to purge the system and the second was sampled according to the plan described below.

Sampling Design

As each experimental blend was discharged from the blender 10 stream cuts were taken at equally spaced, time-intervals with each cut being placed in a separate, marked container. The procedure and sampling cup used are described by the AOAC bulk fertilizer sampling procedure (7).

Twenty, 50-pound bags from each lot were randomly selected and sampled as directed by the AOAC bag sampling procedure (6) except that each core was identified and kept separate for analyses. Every other bag was sampled twice following, as much as possible, the same path through the bag and again each core was identified and kept separate for analyses.

The bags from each of the lots which were sampled twice were sent to the National Fertilizer Development Center, Tennessee Valley Authority (TVA), Muscle Shoals, AL where they were reduced using a rotary divider. The rotary divider was a Brinkman Retsch Type PT with a Type DR Vibratory Feeder which splits solid material up to 6 mm in size into eight equal portions.

The procedure followed for reduction of the bags through the rotary divider follows:

1. Each bag from each lot was passed through the divider producing 8 equal portions of approximately 6.25 pounds each.
2. Each of the 6.25-pound portions from one bag of each lot was weighed and two of these weighed portions were randomly selected and passed through the rotary divider again producing 16, approximately 0.78-pound samples from one bag of each lot.
3. One of the 6.25-pound portions from each of the other 9 bags of each lot was randomly selected and passed through the divider again which produced 8, 0.75-pound portions.

This procedure resulted in 88, 0.75-pound portions from each lot and 440 total for the experiment. Each of these portions was ground with a Mikro-sampl mill equipped with a 1-mm screen and forwarded to the participating laboratories for N, P_2O_5, and K_2O analyses. The cooperating laboratories were Agrico Chemical Co., University of Kentucky, Arkansas Department of Agriculture, Clemsen University, North Carolina Department of Agriculture, Purdue University, TVA, and Virginia Department of Agriculture.

Samples obtained from each lot were: 4 materials, 10 stream cuts, 30 single cores from bags, and 88 from the rotary divider.

All single cores, stream cuts, and rotary divider portions were ground in their entirety to pass a 40 mesh sieve and thoroughly mixed in preparation for analyses. Replicates on every 10th sample were run several days apart. The grinding of the entire sample effectively eliminated intra-lab sample reduction variance so that the replication gave a measure of the intra-laboratory analytical variation.

RESULTS AND DISCUSSION

This section is preliminary in that all the summary data have not been checked for accuracy and the statistical analyses are not complete.

Sampling Components of Variance

The first objective was to determine the variance components associated with the AOAC bag sampling procedure and to compare them with those currently adopted by AAPFCO (5). Using the Task Force's definition of sampling variation, the study was designed to measure the variation between two core samples taken as much as possible from the same path through the bag.

The analysis of variance for the double probed bags where there were 10 bags double probed with duplicate determinations run on every 10th sample is shown in Table 2.

σ_c^2 is the variance component of cores within a bag which is of interest in accomplishing objective one. It is calculated using the expected mean squares from the analysis of variance:

$$\mathrm{MSC} = \sigma_d^2 + 1.07\sigma_c^2$$

$$\sigma_c^2 = (\mathrm{MSC} - \sigma_d^2)/1.07$$

The AOAC bag sampling procedure specifies that 10 cores will be composited; therefore, the sampling variance would be $\sigma_c^2/10$. The between cores within bag [cores (bag)] variance components (σ_c^2) were calculated for N, P_2O_5, and K_2O at each concentration and are shown in Table 3 along with the currently adopted AAPFCO sampling variances.

Although we have not yet calculated the statistics, the small differences between these variances do not appear significant.

Based on these data we have accomplished our first objective. There appears to be no basis from these data for recommending any change in the AAPFCO's IA's.

Inter-Laboratory Component of Variance

The determination of this component of variance was not one of the original objectives but the design of the experiment allowed its determination.

Each of the ten bags that were double probed from each of the lots was reduced by the procedure described earlier to eight equal portions except for one bag which was reduced to 16 equal portions. Eight different laboratories analyzed all the samples from a specific split from the rotary divider.

The analysis of variance table for the rotary divider data where eight laboratories analyzed splits from 10 bags is shown in Table 4. (Note—This table is quite simplified; the actual calculation is more complicated.) The inter-laboratory component of variance, σ_l^2, may be calculated as follows:

$$\mathrm{MSL} = \sigma^2 + b\sigma_l^2$$

$$\sigma_l^2 = (\mathrm{MSL} - \sigma^2)/b$$

Where b = number of bags = 10

Except for one case the differences among labs and bags for N, P, and K for all lots were significant when tested against experimental error.

Using the mean squares calculated from the analysis of variance, the inter-laboratory component of variance was calculated as described above for each concentration of N, P_2O_5, and K_2O. These components along with those in current use by AAPFCO are shown in Tables 5–7. In 10 of the 15 comparisons the inter-laboratory variance determined in the present study was less than that of AAPFCO and in 5 comparisons they were greater. Overall there was very little difference between the inter-laboratory variance derived from the present study and that of AAPFCO. Three of the differences are significant at the 5% level or higher and these are where the inter-laboratory variances determined in the present study are less than the AAPFCO's.

Comparison of Probe and Rotary Divider Means

The secondary objective of the study was to determine whether a diagonal core from a bag taken according to the AOAC bag sampling procedure represents the mixture in the bag. If we assume that the rotary divider means are unbiased estimates of the true mean of N, P_2O_5, and K_2O in the bag then we must determine if the probe and rotary divider means are significantly different.

t-Tests were run to determine if the grand means for N, P_2O_5, and K_2O from the probe and rotary divider samples were significantly different (Tables 8–10). The variance used for making this comparison was obtained by averaging that obtained from the probe analysis of variance and that obtained from the rotary divider analysis of variance.

Probe error was taken to be the "bag" variance component in the analysis of variance plus the "measurement" and "laboratory" components of variance. There was a question of whether the core to core variance component should have been included also. It is a small component in this study because the same path was used in inserting the probe the second time, therefore, it is biased on the low side. This was omitted from the total but, if included, the error would be slightly larger and tests slightly less sensitive.

The rotary divider error was taken to be the "bag" mean square + the "lab" mean square minus the "bag × lab" mean square. The resulting difference would have variance components due to "bag", "lab", "bag × lab", "duplicates in same bag" and "determination". In general, all variance components obtained from rotary divider data were much smaller than those obtained from probe data. This results in error mean squares estimated from rotary divider data being about 10 times smaller than those estimated from probe data. For this reason a conservative number of degrees of freedom (10) was used for finding the value of tabular t in the t-tests.

From Table 8 it is apparent that nitrogen determined in the probe samples was consistently lower than nitrogen in the rotary divider samples. In four out of five cases, the differences between means for the two groups were significant at the .05 or lower probability levels. There is a tendency for the difference to increase with level of nitrogen although this was not a consistent trend. At the present time we have no explanation for these observed differences. Some postulates are: (1) the core sampler is selective toward finer particles, and (2) the less dense urea particles are disproportionately deflected toward the outsides of a bag filled by a force flow valve pack bagger.

Differences in probe and rotary divider means for phosphorus tended to be of mixed direction with three having negative signs and two having positive signs (Table 9). Four of the five differences were significant, however. There did not appear to be an obvious trend in the level of difference with level of phosphorous in the fertilizer.

In general, the differences between probe and rotary means were small and non-significant in the case of potassium (Table 10). One significant difference was detected and that was only at the 5% level.

SUMMARY

Variances of the AOAC fertilizer bag sampling procedure were determined for concentrations of N, P_2O_5, and K_2O from 5% to 30% in blended mixed fertilizers using materials in common use in 1983. These were found to be not significantly different from the sampling variances determined in earlier studies which are in current use by AAPFCO.

The AOAC bag samples gave consistently lower N results when compared with rotary divider samples where the entire bag was reduced. Differences between the AOAC bag samples and rotary divider samples for P_2O_5 tended to be of mixed directions with the probe samples over-estimating P_2O_5 for concentrations of 5, 10, and 30% and under-estimating P_2O_5 for 15 and 20%. In general, the differences between K_2O in the AOAC bag and rotary divider samples were small and non-significant.

ACKNOWLEDGMENTS

Appreciation is expressed to W. S. Clark & Son Company for supplying the fertilizer materials and equipment to manufacture the blends; to the Fertilizer Institute for financial support, to AAPFCO and AOAC for sponsoring the study; and to the agencies and companies for allowing their personnel to participate.

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TABLE 1
Material Analyses

Material	**N**	**P_2O_5** **%**	**K_2O**
MP	—	—	60.67
TSP	—	45.17	—
UREA	45.68	—	—
DAP	18.02	46.11	—

TABLE 2
Analysis of Variance
Double Probed Bags

Source	**d.f.**	**M.S.**	**Expected M.S.**
Bags	9	MSB	$\sigma_d^2 + 1.11\sigma_c^2 + 1.6\sigma_b^2$
Cores (Bags)	10	MSC	$\sigma_d^2 + 1.07\sigma_c^2$
DUP	2	MSD	σ_d^2

$\sigma_c^2 = (MSC - \sigma_d^2)/1.07$

TABLE 3
Comparison of the AAPFCO Sampling Variance with that from the Present Study

Nutrient* Conc. %	**Sampling Variance**					
	N		P_2O_5		K_2O	
	AAPFCO	Present	AAPFCO	Present	AAPFCO	Present
5	0.002	0.001	0.005	0.003	0.005	0.003
10	0.005	0.001	0.006	0.018	0.013	0.019
15	0.009	0.007	0.006	0.006	0.023	0.011
20	0.015	0.013	0.007	0.005	0.038	0.000
30	0.030	0.024	0.008	0.009	0.076	0.014

TABLE 4
Analysis of Variance
Inter-Laboratory

Source	**d.f.**	**M.S.**	**Expected M.S.***
Lab	7	MSL	$\sigma^2 + 10\sigma_l^2$
Bag	9	MSB	$\sigma^2 + 8\sigma_b^2$
Exp. Error	63	MSE	σ^2

$\sigma_l^2 = (MSL - \sigma^2)/10$

*Simplified—Actual calculation is more complicated.

TABLE 5
Comparison of the AAPFCO N Inter-Laboratory Variance with that of the Present Study

	Inter-Laboratory Variance	
N, %	**AAPFCO**	**Present**
5	0.023	0.007
10	0.028	0.007
15	0.032	0.021
20	0.037	0.045
30	0.045	0.053

TABLE 6
Comparison of the AAPFCO P_2O_5 Inter-Laboratory Variance with that of the Present Study

P_2O_5, %	Inter-Laboratory Variance AAPFCO	Inter-Laboratory Variance Present
5	0.043	0.047
10	0.044	0.014
15	0.045	0.007
20	0.045	0.001
30	0.047	0.127

TABLE 7
Comparison of the AAPFCO K_2O Inter-Laboratory Variance with that of the Present Study

K_2O, %	Inter-Laboratory Variance AAPFCO	Inter-Laboratory Variance Present
5	0.000	0.005
10	0.036	0.017
15	0.074	0.022
20	0.113	0.066
30	0.190	0.013

TABLE 8
Comparison of Probe and Rotary Divider Sample Means: N

Grade	Rotary	Probe N,%	Diff.
05-15-30	5.16	4.85	0.31*
10-20-20	9.93	9.63	0.30**
15-30-15	14.93	14.74	0.19**
20-05-10	19.75	18.62	1.13*
30-10-15	30.12	29.39	0.73

*Sign −0.05
**Sign −0.01

TABLE 9
Comparison of Probe and Rotary Divider Sample Means: P_2O_5

Grade	Rotary	Probe P_2O_5,%	Diff.
20-05-10	5.15	5.23	−0.08**
30-10-15	9.94	10.21	−0.27**
05-15-30	15.27	14.45	0.82*
10-20-20	19.92	19.49	0.43
15-30-15	30.03	30.90	−0.87**

*Sign −0.05
**Sign −0.01

TABLE 10
Comparison of Probe and Rotary Divider Sample Means: K_2O

Grade	Rotary	Probe K_2O,%	Diff.
30-10-05	5.32	5.25	0.07*
20-05-10	10.41	10.25	0.16
15-30-15	15.16	15.62	−0.46
10-20-20	20.34	20.24	0.10
05-15-30	30.26	30.11	0.15

*Sign −0.05

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*For presentation at 36th Annual Meeting of The Fertilizer Industry Round Table, November 19, 1986, Sheraton Inn's Harbor Hotel, Baltimore, Maryland. This report is a preliminary summarization of the data from an extensive sampling study. Since all of the summary data have not been double checked and the statistical analyses are not complete, the final report may vary significantly from this one.

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[1] Tables of Z values may be found in most statistical text books.

Plant Growth Regulators and Maximum Yield Management

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During the twentieth century, new technology combined with focused crop management practices dramatically improved agricultural production. Although the amount of land devoted to actual crop production in the United States in the late 1960's was virtually the same as in 1910, agricultural output in the 60's was two and one-half times greater than that in 1910.

This tremendous increase in productivity was due to many factors operating in unison: increased use of irrigation, improved planting and harvesting equipment, advances in plant breeding techniques, the use of inorganic fertilizers and micro-nurients, selective herbicides, insecticides, fungicides and plant growth regulators. Each of these inputs was geared to reduce the impact of a different yield-limiting factor on the genetic potential of the crop. The use of plant growth regulators during this period was, in the aggregate, a minor portion of total expenditures on crop production, although significant minor crop uses were developed. It was not until the late 70's and early 80's that plant growth regulators were commercialized on large acreage agronomic crops such as cotton, wheat, barley and sugarcane.

In general, plant growth regulators are used to enhance or protect yields, improve harvest efficiency, reduce labor costs or control the quality of the harvested crop. Ethephon, a Union Carbide product, is one of the more widely used plant growth regulators. When applied to a plant, ethephon is absorbed into the plant cells, where it quickly breaks down into phosphate, chlorine and ethylene, all common plant constituents. But the important product of this decomposition is ethylene, a powerful plant hormone which is produced by all plants at various stages of development, and has been observed to produce over twenty different physiological responses. Some of the economically important responses to ethylene are:

SOME PHYSIOLOGICAL EFFECTS OF ETHYLENE

Stimulates or Inhibits Seed Germination
Stimulates or Inhibits Vegetative Growth
Initiates or Inhibits Flowering
Initiates or Inhibits Fruiting
Abscises Leaves, Flowers and Fruit
Modifies Flower Sex
Accelerates Fruit Ripening

You will note that some plant responses to ethylene apear to be contradictory. Ethylene can, for example, *stimulate* or *inhibit* root initiation, it can *stimulate* or *inhibit* plant growth, and so forth. These seemingly contradictory responses are both rate and species related. Higher rates tend to inhibit while lower rates tend to stimulate, and not all species respond in a similar manner.

The yield of rubber has been increased 200–300% by application of ethephon to the tapping cut, which results in an increased period of latex flow. The tapping frequency can be reduced, resulting in substantial savings in labor costs while extending the life of the tree.

Ethephon is used twice on pineapples: early to induce uniform flowering and later to promote uniform ripening to allow a controlled once-over harvest.

Hastening maturity and uniform ripening finds wide application on fruits, nuts and berries. When applied to young, non-bearing apple or pear trees, ethephon will promote flowering one to two years earlier, allowing growers to bring new orchards into profitable production more rapidly. Ethephon causes cherries to ripen uniformly and earlier as well as separate from the stem easier for better mechanical harvesting and longer tree life. Apples sprayed with ethephon turn uniformly red and are at the peak of sweetness because ethephon helps turn starches to sugars. Ethephon protects walnut kernel quality by stimulating more uniform hull split and allows growers to harvest their crops earlier when the kernel is at peak quality.

A foliar spray of ethephon applied to mature, green fruit accelerates tomato ripening, which increases the early yields of marketable, ripe fruit. Since for process tomatoes, the machine picks all the crop regardless of maturity, green tomatoes must be culled out and discarded. The use of ethephon on mechanically harvested tomatoes typically increases the yield of red, ripe fruit by three to ten tons per acre.

Early ripening of table grapes with ethephon allows growers to harvest and market their grapes in time to take advantage of early season prices. Raisin grape growers use ethephon to accelerate maturity, gaining an extra three to five days, which can mean the difference between profit and disaster if an early season rainfall arrives while grapes are sun-drying in the field.

Coffee berries sprayed with ethephon ripen earlier and more uniformly, making once-over harvesting more profitable, and allowing trees to recover from harvest stress earlier, being therefore more likely to provide a good crop the following year.

Ethephon applied to a mature tobacco plant hastens maturity, reducing drying time in the barn, allowing the grower flexibility in scheduling harvest, and producing a more uniformly colored, quality leaf.

Ethephon was first commercialized on cotton in 1982, and is sold under the trademark PREP™ Increasing the level of ethylene in cotton at a time when the plant is shutting down growth has a profound effect because ethylene helps to stimulate fruit ripening and leaf and flower shedding. Even to an untrained eye, the effect is obvious. Bolls open quicker.

The lint is at its prime quality when the boll opens, and loses weight each day it remains in the field, waiting to be harvested. When applied to mature, unopened cotton bolls, ethephon causes the bolls to open seven to fourteen days earlier, making it a revolutionary cotton production tool. Ethephon also preconditions the crop for defoliation and, at high rates, will also defoliate cotton.

By getting the crop out early, the cotton grower can avoid weather damage from early fall rains or a first freeze, which can cause yield reduction and grade loss. The timing of the cotton harvest can have a substantial impact on economic returns. Research by Dr. David Parvin of Mississippi State, based on long term weather data, shows that if harvesting can begin seven days early, harvesting is complete 27 calendar days sooner, as effective day length grows shorter and available days for harvest grow fewer. Economic yield is increased 7% and revenue 8%, even though no additional cotton bolls were available for harvest. Just as effective harvest time is lost as the season progresses, so also cotton grade deteriorates as the bottom crop is exposed for longer periods to the elements. A crop that is two weeks earlier in maturity will experience a 16% increase in economic yield and increase revenue by 18%.

By opening the top bolls early, a higher percentage of the crop can be harvested on the first pick, and the fiber quality should be higher, demanding a higher price at the gin. Under optimum weather conditions, there's also the possibility of a once-over harvest, eliminating the need for a second pick, which can cost as much as $40 per acre. With the current depressed price of cotton, most growers can't afford to pick twice.

While an application of ethephon will open mature bolls, it will also cause shedding of immature fruit forms that can stain lint. Perhaps one of the most intriguing possibilities for ethephon is as an aid in controlling late-season insects that feed on these young squares and green bolls. By eliminating the food source, the population of over-wintering insects can be dramatically reduced.

Ethephon was originally introduced and continues to be used on sugarcane just prior to harvest to accelerate cane ripening and sugar deposition in the upper portion of the cane. Ethephon has also been found to lengthen the plant's internodes up to 20% in some cane varieties. The resulting increase in sugar storage area means more sucrose and more cane biomass. Ethephon also improves the germination of seedcane and improves tillering. More importantly, applied at the appropriate stage of growth, ethephon also inhibits flowering, an activity which draws on sucrose levels in the cane, reducing the value of the crop. Flowering just prior to harvest can reduce yields as much as 20 percent.

Wheat and barley are the most recent agronomic crops targeted for plant growth regulators in the U.S. Union Carbide's registration of ethephon on these crops in 1985 under the trademark CERONE®, is the key to a total system of managing these crops for maximum profit. As Dr. Gary Paulsen of Kansas State declares about this approach to wheat production: "One thing is certain—it will change the way we grow wheat."

Maximum Yield Management—or Integrated Cereal Management, as the Europeans like to call it—began to take form in Western Europe about ten years ago. A few American growers, particularly in areas of Idaho, Washington, Oregon and the Red River Valley, were already practicing a form of crop management at that time. While most Americans, however, continued to look at wheat as a low input, low yielding crop, our European friends began viewing it as a potentially high-yield crop that deserves the best management the grower can provide. They developed a specific system—a series of operations in the management of the crop—that became known as Integrated Cereal Management.

Union Carbide, through our European operations, not only witnessed the development of this concept in Western Europe, but we actually played a role in bringing the technology together in an integrated package. In this respect, it's interesting to note that much of the intensive wheat management technology—some of the weed control practices and certainly all of the plant growth regulator technology—is American technology . . . technology which originated right here in the U.S.

What has happened to European wheat production with this new technology? To use England as an example, the national average yield in 1974 was 45 bushels per acre. That's a good average yield by U.S. standards, and it reflects the almost ideal conditions that exist in England for growing wheat. But ten years later, in 1983, the English national average yield had doubled to 90 bushels per acre—and in 1984, a good growing year in England, the national average for wheat production was just under 100 bushels per acre. By contrast, the U.S. average wheat yield went from 32 bushels per acre in 1974 to about 38 bushels per acre in 1984, an increase of only 16%.

Researchers tell us that about half of the over 100% increase in yields that occurred in England over the past decade was due to improved genetic material—better varieties of wheat—and half due to the introduction of intensive crop management practices. In the U.S., on the other hand, there were almost no changes in crop cultural practices during this same period, and the increase that occurred in average yields was due almost entirely to improved wheat varieties.

U.S. research in intensive small grain management with ethephon has produced yields of over 180 bushels per acre in wheat and 200 bushels per acre in barley. These dramatic increases in yield are obtained by managing all production inputs—whether they be seed, fertilizer, weed, insect and disease control or plant growth regulators—to be at the highest level for the most profitable return. The environment, particularly precipitation and temperature, affects the practices for intensive management, but it doesn't change the principles behind the system.

Because Maximum Yield Management is a system and not a single technique, all the operations in the method must be included. You won't get high yields if plant populations are too low to use high rates of fertilizers or if thick, well-fertilized stands are not protected from diseases or lodging. The Maximum Yield Management system, like a chain, is only as productive as its weakest part.

New wheat varieties available to growers today are capable of much higher yields than production averages indicate. Seeding rates are higher for intensive management and row spacing is narrower. The key is an optimum plant population with uniform distribution for efficient use of available resources—especially fertility and moisture.

Fertility is an essential component of maximum yield small grain management. Simply increasing nitrogen at the traditional application times at planting or at spring "green-up" may not be cost-effective. Yields may not be significantly increased by additional nitrogen that is applied too early. Nitrogen is needed to stimulate adequate but not excessive tiller production in early wheat growth. Research shows that the wheat plant needs most of its nitrogen (75 percent or more) after the beginning of stem elongation. Phosphorus promotes root growth and proper seed set. Wheat plants do not tiller adequately when they are deficient in phosphorus and winter kill is often more severe than usual. Potassium needs coincide with nitrogen in terms of maximum uptake periods. Potassium is essential for straw strength and aids disease resistance.

Response to fertilization is governed by moisture availability and plant variety, thus specific recommendations must be localized and a variety which will respond to higher inputs must be selected, for economic success. Generally, nitrogen needs to be provided when required by the plant, which requires two to four applications during the growing season. Although patterns vary according to location, soil type and variety of cereal grown, an example would be nitrogen applied in the fall, followed by two spring applications. The fall application improves over-wintering ability. The first spring application is made at the onset of tillering to increase the number of tillers and the potential number of heads. A second spring application is made as stem elongation begins. This determines the number of tillers that will head and produce fertile ears. If this application is too early, an excessive number of small, low-yielding heads may be produced. And if this application is too late, it may result in nitrogen starvation and poor head fertility. This sequence of nitrogen application also helps plants avoid excessive vegetative growth in the fall, thereby decreasing the probability of disease occurrence, and it allows spring rates to be adjusted to reflect realistic yield goals.

Competition from weeds for moisture, nutrients and light reduces wheat yields even more under intensive management than under conventional management. Foliar diseases can develop quickly and reduce potential yields drastically under intensive management. Insects are usually less of a problem, but they can also severely reduce yields when they occur. Proper timing and choice of herbicide, fungicide and insecticide applications is critical.

Cereal crops frequently suffer severe losses from lodging, especially when the soil is very fertile. The lush, spindly, top-heavy growth of cereals grown in a highly fertile environment makes it susceptible to damage by wind and rain. Early lodging results in poor grain fill and often leads to disease problems. Late lodging hinders harvesting operations and can lower grain quality. Up until recently, the American small grains farmer had only one way of reducing the risk of lodging to his crop—and that was to reduce his fertilization levels. With the introduction of CERONE® plant growth regulator, he has a new tool for reducing lodging while maximizing the potential of his crop.

CERONE® is applied to vigorously growing crops between growth stages 8 and 10 on the Feekes-Large Scale. Growth stages 8 is at the emergence of the last or flag leaf. Growth stage 10 is the late boot stage, but before the awns or spikes have begun to emerge from the top of the boot. On awnless wheat, growth stage 10 is the late boot stage before the sheath begins to split, exposing the head. This application of CERONE® reduces the length of the internodes that still are growing after treatment and stiffens the straw. The greatest shortening effect is seen on the last two or three internodes, especially the peduncle, or top internode.

Head breakage prior to harvest, especially when harvest is delayed by unfavorable weather, can be especially serious with some barley varieties. CERONE® reduces the tendency of barley to "neck" and for the heads to drop off. Elimination of "necking" sometimes increases yield even if lodging is not a problem, particularly with tall-strawed varieties.

Numerous trips across wheat fields are required for applying fertilizers and chemicals at the correct growth stages. In Western Europe, most applications go out with ground equipment, and tramlines are used to avoid the problem of driving over standing wheat. Tramlines are unplanted rows formed by closing one or two drill openings when planting. American growers, although more used to aerial application of chemicals, are showing increased interest in this tramline approach, which is more accurate than aerial application, and often much less expensive.

By reducing the need to include a lodging-resistance variable in their research programs, plant breeders are given greater flexibility to develop high yielding varieties. Some American seed companies have just started looking at new varieties under high input systems.

Growing wheat and barley in the U.S. today is every bit as much of a business as producing chemicals or fertilizers. We all go through good times and bad—and recently times have not been good for the American farmer. Those farmers who will still be producing small grains ten years from now will be those farmers who know how to truly manage their business well. They will, just like in other businesses, be the most cost-effective producers. To do this they must understand—and know when to use—all the technology that can help them produce maximum economic yields. The input costs per acre are higher, thus more money is at risk. But properly practiced and managed, the incremental yields will more than offset the higher input cost per acre to give increased profitability.

We at Union Carbide have been especially pleased to develop this use of CERONE® in a maximum yield management system with the expert and dedicated assistance of associations such as The Potash and Phosphate Institute, the Foundation for Agronomic

Research and the National Association of Wheat Growers. PPI and FAR sponsored their third Maximum Wheat Yield Systems Workshop last March in Denver, and have been instrumental, along with local NAWG organizations, in providing fertility technology for state and local Maximum Economic Yield Workshops. A NAWG foundation project designed to get wheat growers involved in this new management system on a trial basis next season, will be accompanied by a manual provided by PPI/FAR which explains maximum yield management. The NAWG Foundation will also be sponsoring the National Wheat Research Conference, devoted almost exclusively to maximum economic yield technology, in Kansas City next February.

A new experimental compound in development in our R&D facilities has shown extremely interesting promise on soybeans. Initial testing has given a significant increase in the number of pods produced by the plant. Unfortunately, this increase has been accompanied by a slight decrease in yield, as expressed in bushels per acre. Measurements show this yield decrease is the result of a decrease in seed weight. Although the soybean plant has been stimulated to a higher productive level, the plant has been unable to attain this higher level due to a lack of nutrients. We suspect that a foliar application of fertilizer along with this experimental compound would allow the plant to support the increase in pod development and realize the significant increase it has been stimulated to attempt.

From our experience with CERONE®, it would appear that development of this new compound would be most expedient if done in conjunction with the fertilizer industry, as you can provide the expertise in plant nutrient understanding which we sometimes lack.

Thank you for your interest in plant growth regulators and for asking Union Carbide to participate in The Fertilizer Industry Round Table Meeting.

Summary of Business Meeting

1) Secretary-Treasurer Paul J. Prosser, Jr. read the following financial statememnt to the membership.

FINANCIAL STATEMENT

October 24, 1985 to November 12, 1986

Cash Balance—October 24, 1985		$14,907.41
Income October 24, 1985 to November 12, 1986		
Registration Fees 1985 Meeting	$10,550.00	
Sale of Proceedings	3,043.39	
1986 Registration Fees & Cocktail Party Receipts	8,925.00	
Total Receipts October 24, 1985 to November 12, 1986		22,518.39
Total Funds Available October 24, 1985 to November 12, 1986		$37,425.80
Disbursements October 24, 1985 to November 12, 1986		
1985 Meeting Expenses	1,624.85	
1985 Proceedings, Incl. Postage, Stationery, etc.	14,116.92	
Misc. Expenses, Incl. Postage, Stationery and Binding of one Volume of Proceedings	747.75	
Directors Meetings	1,671.27	
1986 Meeting Expenses	2,223.31	
Total Disbursements October 24, 1985 to November 12, 1986		$20,384.10
CASH BALANCE—November 12, 1986		$17,041.70

Respectfully submitted,

PAUL J. PROSSER, JR.
Secretary/Treasurer

Mr. Prosser then reported that the registration for the 1986 meeting was 195 and that sufficient revenues had been received to pay all expenses and provide adequate resources for next year's operation.

2) Mr. Thomas Athey announced the time and place for the next three meetings as follows:

1987—New Orleans, Lousiana, Royal Omni Hotel
1988—Baltimore, Maryland, Hyatt Regency
1989—Atlanta, Georgia (to be announced)

He also asked the membership to acknowledge the support of the contributors to the 1986 Cocktail Party (held at the B&O Railroad Museum), listed as follows:

Atlanta Utility Works
Bird Machine Company, Inc.
Commonwealth Laboratories, Inc.
Davey McKee Corporation
Drewry & Associates
Feeco International, Inc.
J & H Equipment, Inc.
Jacobs Engineering
Petrochemical/Desota, Inc.
The Prosser Company, Inc.
Renneburg, Div. of Heyl & Patterson, Inc.
Resolite, Div. of H.H. Robertson
The A.J. Sackett & Sons Company
Stedman Machine Co., Inc.
Urea Technologies Inc.

3) Mr. Harold Blenkhorn requested that future program suggestions be sent to him.

4) Mr. Walter Sackett presented a plaque to Mr. Adolfo Sisto honoring his longstanding loyalty and service to the Round Table. Mr. John Medbery was also presented a plaque acknowledging his services as Chairman of the Round Table for the past two years.

5) Mr. Joseph Reynolds, in his role as Chairman of the nominating committee, presented the following slate for the Board of Directors:

Director William Sheldrick to position of Vice Chairman of the Board.
Mr. Patrick E. Peterson of C.F. Industries to Board Member.
Vice Chairman Thomas L. Howe to position of Chairman of the Board.

All were elected by majority vote.

Mr. Medbery then adjourned the meeting.