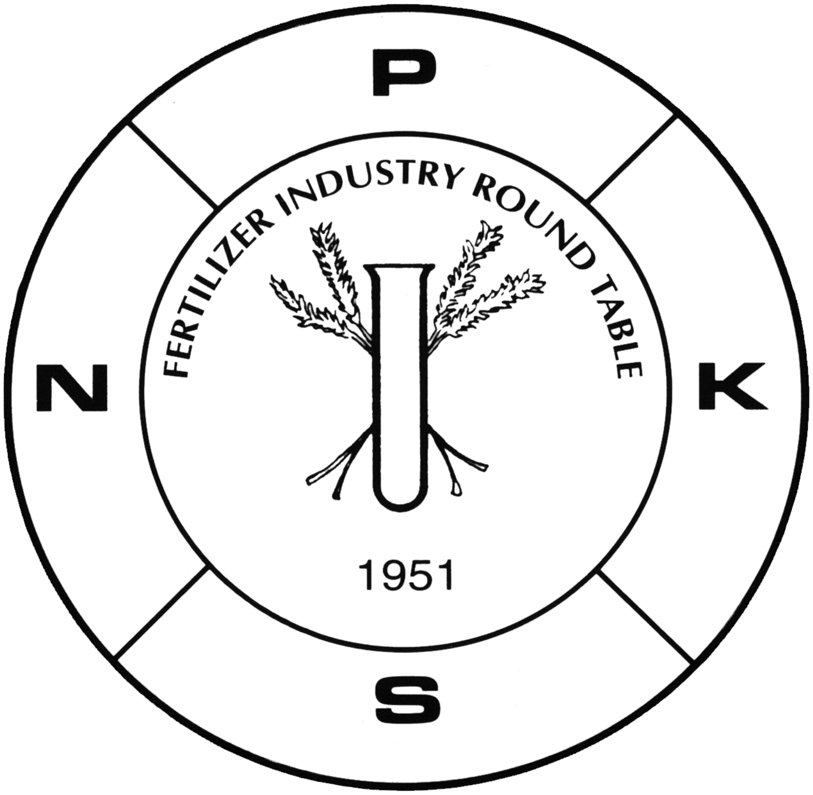
PROCEEDINGS
OF THE 50TH ANNIVERSARY
ANNUAL MEETING
FERTILIZER INDUSTRY
ROUND TABLE
2000



October 4, 5 and 6, 2000
Omni Royal Orleans Hotel
New Orleans, Louisiana

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Wednesday, October 4, 2000

Session I
Moderator:

William L. Hall, Jr.

On Wednesday October 4th, IFA and the Fertilizer Industry Round Table co-sponsored three industry related tours in the New Orleans area. Over 140 people took part in the tours with lunches hosted by the local companies. Our sincere thanks go out to IFA and everyone that took part in organizing buses, leading tours, and hosting the lunches. Significant amounts of coordination and effort went into planning, scheduling, and successfully completing this day. Special thanks go to Diana Scandalin of IFA, Larry Isaac and Bill Hall of IMC, and Hershel Morris, Louisiana's Director of Agricultural Chemistry; all were instrumental in the planning and preparation of the events. The tour leaders at the plant sites included Ed Madere of CF, Thomas Torr of Triad, John Alexander of IMC Fostina, and Cindy Dukes of IMC Uncle Sam.

The day offered three unique tour choices, each is described below.

1. IMC Uncle Sam Phosphoric Acid and
   Triad Urea Nitrogen Plants
   Lunch Sponsor - Triad Nitrogen LLC

2. CF Urea Nitrogen, IMC Faustina DAP
   Plants and Associated River
   Terminals
   Lunch Sponsor - CF, Industries

3. LSU Agricultural Research, Fertilizer/
   Soil Laboratories and Nutrient
   Management
   Lunch Sponsors - Louisiana State
   Chemists Office and IMC

All of the feedback from the tours has been positive and complimentary.

All of the guests were able to experience some real southern hospitality while touring. Hopefully, their experiences in Louisiana were enjoyable and memorable. Again, all that worked so hard to make the day a success deserve a hearty "Thank You"!

Thursday, October 5, 2000

Session II
Moderator:

Ken Nyiri

Opening Remarks

Pat Peterson

Ladies and gentlemen, welcome to the fiftieth anniversary meeting of the fertilizer industry round table. As with all things, there have been many changes in the fertilizer industry over the past fifty years. Some might say that the "golden age" of technology in the fertilizer industry is over. During the fifties and sixties the Round Table Proceedings focused on the technology of ammoniation and granulation, with TVA and many companies involved in research. In the later sixties and early seventies with the advent of bulk blending, more attention was directed to processes and equipment to produce quality NPK blends. In the past ten or fifteen years, the emphasis has shifted to the areas of environment, agronomy, and the production of better quality and compatible sized fertilizer materials. Is technology dead? No! With predictions of the world population doubling in the next fifty or so years, more and more food will have to be produced. This increase will rely on the efficient production and use of fertilizer.

So, fertilizer technology still lives! It has just moved into other areas such as: improvements in existing processes to produce more products more efficiently, process changes due to lower quality raw materials, studies to determine the effects of fertilizer on the environment, building of plants in various and exotic parts of the world, and improving the agronomic performance of fertilizer- just to name a few. I am sure that fifty years from now researchers and scientists will be sitting at the "round table".

Now, it is my great pleasure to introduce our first speaker. This gentleman has attended and supported the fertilizer round table for all of its fifty years of existence. He has been chairman of the round table and has contributed many presentations, such as his dissertation on "Davidson's Trenton Process for Continuous Granulation", circa 1956. He is going to attempt to encapsulate fifty years of history into a thirty-mimute talk. Let us give a warm and well-deserved welcome to Joseph E. Reynolds Jr.

50 Year History of the Fertilizer Industry Round Table

Joseph E. Reynolds, Jr.

In 1951, the demand for farm fertilizers was increasing faster than plants were progressing towards improving quality and achieving more concentrated products. The "dry mix" fertilizer plants were operating with little expertise and were struggling with equipment, raw materials, and concepts that needed revision or replacement. Using management's encouragement of "If you think it will work, try it," process changes were being made in the 200-300 small plants throughout the U.S. Communication between companies at the production level in 1950 was minimum. However, the evolution of:

1) powdered "dry" mixing batching operations to

2) continuous ammoniation systems with only a change in mixer and measuring system to

3) full ammoniation-granulation processing with drier, coolers, and screens was a matter of 3-4 years.

Mixed fertilizer production technology in 1951 was considered more of an art than a science and was not a priority subject for programs of the established scientific organizations. No forum existed where plant managers and supervisors could discuss "practical," "in-plant" problems.

With this background, a small group of men gathered informally with Vince Sauchelli one evening at the 1951 American Chemical Society's meeting in New York. The men cautiously explored operating and technical changes and needs and soon recognized the similarity of problems. One person's questions triggered answers for another person. It soon became apparent that progress could be accomplished faster if more people were pulling together in a cooperative effort. Thus the Round Table was born. The estimated 14 men present agreed to a similar evening gathering at the 1952 ACS Atlantic City Meeting with each person permitted to invite one person.

Although the spontaneous 1951 meeting was not publicized (no notes taken – no records kept), the word was out. An estimated 30 people were present at the 1952 meeting and 60 or more came to the 1953 Chicago meeting. The persons attending came with "loaded" questions looking for some friendly operating person willing to exchange information. Questions and phone calls poured into Vince Sauchelli with suggestions for subjects and speakers. The 1954 session continued to grow and now was a distraction to the ACS. The Round Table had outgrown the half day/or night session and the time was "now" to schedule a two-day Round Table away from the ACS in both location and dates.

The 1955 and 1956 meetings were at the Shoreham Hotel in Washington prior to the October American Association of Plant Food Control Officials' meeting. The attendance was now in the range of 200-300 and the Shoreham could not accommodate us beyond 1956 so the famous "100 question 1957 meeting" was moved across the street to the Park Hotel.

The 1958 meeting was moved again "due to conflicts with other important meetings"—in other words, we had outgrown the Park. With this move, we really got lucky—in 1958 the prestigious Mayflower Hotel took us in, where we stayed for 12 years (See Table 1).

The Round Table concept helped bridge the gap between plant managers from different companies. The Round Table also afforded the engineering and machinery companies a better understanding of the limitations of their plant equipment.

The technical service representatives of all the raw materials suppliers shared their experiences. TVA's National Fertilizer Development Center was rapidly expanding its activities and threw its full support to the Round Table. Many of TVA's developments were first disclosed at the Round Table. The USDA's Beltsville, Maryland fertilizer research laboratories were generous contributors the first 8-10 years. The International Fertilizer Development Center was formed in 1974 and immediately joined the ranks of the Round Table volunteers. The technical and information groups of the International Fertilizer Association, the Fertilizer Society, the Fertilizer Institute, the British Sulphur Corporation, and the Potash and Phosphate Institute also played a vital role in the success of the Round Table.

Corporate management was also in full support and encouraged their plant and maintenance people to attend. The forum of informality, spontaneous questions and discussion broke down any remaining barriers of suspicion and secrecy. The exchange of information is a two way street—you receive when you give.

Farm Chemicals, *Commercial Fertilizers*, *Agricultural Chemicals*, *Crop Life*, and *British Sulphur* publications were at the front with highlighted stories of the unique programs.

The forum for the early meetings was for the speaker to give a 5-10 minute summary, followed by questions and discussion from the floor. Starting in 1957, a tape recording service was employed to capture the unrehearsed discussions for the Proceedings.

Prior to 1956, Vince Sauchelli and "Doc" Marshall organized the program from the many suggestions submitted. Al Spillman and I contributed and edited and in 1958 the four of us were designated as the four man "Executive Committee."

The accompanying 1959 photo (See Photo 1) shows the original Executive Committee of The Round Table. Left to right – Al Spillman, Joe Reynolds, Vince Sauchelli, and Houston "Doc" Marshall.

The Round Table grew from an estimated 14-15 to over 400 by 1960 By the mid-1960's attendance passed 600. As one executive said "If you want to know what is going on in the fertilizer industry, go to the Round Table." Many friendships were formed, doors were opened and contacts continued after the meetings. (See Table 2) identifies the rapid growth in attendance between 1951 – 1959, the peak period of 1960-1969, the downward turn of the 70's and the more stabilized years since 1980. (See Table 3) analyzes the Proceedings of the Round Table as to average in pages, participants and subjects for the period 1955 through 1999. The number of pages increased until 1981-82 when recording was discontinued. The number of recorded participants has decreased (fewer panels). The number of subjects has decreased as number of sessions decreased.

No organizational changes were made from the four man "Executive Committee until 1969; however "Brown's Bar"—a little corner tavern in east Baltimore became the Saturday morning gathering place for men from the estimated 12-15 fertilizer plants and machinery and equipment engineering companies for a cup of coffee and to "talk shop." Everyone was welcome. Many of the topics, suggestions and speakers for the Round Table came from these Saturday morning sessions. Thus the "Kitchen Cabinet" just happened—men who wanted to help.

As the Round Table went beyond 600 attendees in 1967, Vince Sauchelli realized that the four man "Executive Committee" needed an organization with more depth and structure. He also realized that the Round Table was a meeting of fertilizer technology as both an art and science in an informal, spontaneous atmosphere that made us unique. The organizational structure was expanded but the format of the meeting stayed intact.

Our founder, Vince Sauchelli, died in October 1969, and the chairmanship was passed to Al Spillman. The "Kitchen Cabinet" became an official advisory committee in 1969. The 1970 Round Table meeting was moved to Memphis and the current format of rotating officers, a global Board of Directors and active committees was formalized.

Prior to the 1950's most, if not all, of the fertilizer companies were owned by families or small private groups of investors. By the mid-60's most of the fertilizer companies were owned by oil and/or Wall Street chemical companies. Massive investments were made in new technology, expansions, farm service centers with "bulk blends" and/or fluid mixtures. The chemical and oil companies saw the fertilizer industry as a captive route for their products for direct sale to the farmer. Agriculture was "booming" and was very attractive for investors for 10 to 15 years or until the cyclic nature of supply-demand turned around.

The fertilizer industry was rapidly responding to the farm service center concept based on marketing personalized local service, prescription mixing and custom spreading all in bulk. The large phosphate, nitrogen and potash plants responded with expanded production of concentrated products such as granulated DAP, MAP, urea and potash. Suspension and liquid plants were also growing with the availability of improved quality concentrated phosphoric acid and powdered MAP.

In the 1970's, the cyclic fertilizer industry was adversely affected by major consolidations and reorganizations, over saturation in the market place, over supply, and increasing subsidized imports of product into the U. S. The farm economy was also suffering from decreasing world markets and high debt loads.

By the late 1970's and into the 80's the oil and chemical companies who had invested heavily in the fertilizer industry in the 1950's and 60's were rapidly "bailing out."

Decreasing attendance at the Round Table was a direct reflection of the 1980's "turmoil" in the industry. The oil companies with their resources and enthusiasm of the 1950's and 60's were no longer responding with large representations. Remaining companies were sending fewer people due to budget considerations. Research and development and quality control programs disappeared. Technical Service departments were deemphasized. The core group of the Round Table was also reduced due to retirements, plant closings, or mergers.

The increasing reduction and restrictions in TVA's Fertilizer Development programs during the 1980's and ultimate closing by 1990 was a major blow to the U. S. and world fertilizer industry. IFDC is the only known fertilizer development program in the U.S.

The Round Table programs have always been adjusted to changes in the industry with timely subjects. Although the initial programs were 80-85% ammoniation and granulation of mixed fertilizers, subjects were soon expanded to include all facets of "ground to ground" fertilizers (See Table 4). The first bulk blending paper was in 1961, followed by a panel of six bulk blending papers in 1962. Fluids and suspension papers started in 1965-1966 with various panels in the 1970's. The "new" industry audiences started to appear in the 1970's with many attendees without "grass-roots" experiences. The supply-demand outlook papers were adopted in 1971 and have become a major attendance incentive. Magazines and other publications have been most generous in scheduling and reporting, but the publicity and promotion must come from those attending the meetings.

(See Table 5) identifies the programs as highly inclusive of the changing fertilizer industry during the 1970's and 1980's. NPK ammoniation-granulation subjects were declining and shifting to urea, DAP, MAP granulation. Outlook papers were inserted. Blending of NPK's and fluid production received major attention. Environmental concerns, application equipment, safety, quality control, SGN, etc. were discussed.

The Round Table programs continued to adjust to the "down-sized" industry and away from chemicals and physical processing (See Table 6). Attendees ranged from 150 and 240 between 1985 and 1990 and stabilized with an estimated average of 150-160 in the 1990-s. Tours were arranged starting in 1990 and continue as the meeting moves to different cities.

In the 1950's and 1960's the Round Table programs were concerned with mixed fertilizer operations. Dealer/retailers received the finished product. Today's dealer/retailers *are* the *producers* as well as the *retailers*. No intermediate plant is required between the raw material producer and the dealer. Problems, questions, and developments are "out there" as existed in the early 1950's. No known forum exists for these "new" industry people other than the Round Table. The opportunities for a closer relationship between our two groups should be mutually attractive.

It is estimated that today's average retailer has a larger investment in plant, application equipment and operating costs than the average combined mixed fertilizer plant and dealer organization of the 1950's. Our programs are not reaching these people.

Although the Round Table members come and go, a lasting wealth of information has been recorded in the Proceedings. The Proceedings represents a proved legacy and heritage.

The Round Table in 2000 is a survivor, but must continue to recognize a changing industry and *reach out* to all the players.

Although V. Sauchelli and a dozen or so men lit the flame of the Round Table, the "Who's Who" of the industry made the concept a reality. The thousands of participants, the hundreds of Board members, and the sixteen chairmen have all contributed to the stature and recognition of the Round Table. A special thanks to all.

It is difficult to select a "top ten" of dedicated men or group of "blue," but I am taking the liberty of trying. These men have met the behind the scenes needs of the Round Table and industry at various times during the past half century. They made a difference (See Table 7).

FIRT The "Glue"

1. V. Sauchelli (19 years) Organized – Founded on "informality"-program from ground up–not top down. Open discussions. Recognized "need." Members committee as a whole.
2. "Doc" Marshall (20 years) Secretary-Treasurer. Arranged meeting places. Edited Proceedings.
3. Al Spillman Executive Committee – Past Chairman – Edited Proceedings.
4. Travis Hignett and Frank Achorn Head of Chemical Development – TVA. Gave full TVA support – Quoted "If Round Table didn't exist, he would invent it." Past chairman.
5. Paul Prosser Secretary-Treasurer. Gave organizational and Financial stability. Editor Proceedings. Past Chairman. "The Rock"
6. Walt Sackett (30 years) Public Relations - Publicity. Past Chairman. Works closely with Paul.
7. Wayne King (24 years) Nominating Chairman. "Cheerleader" – Directors Breakfast Sponsor
8. Tom Athey (28 years) Obtained sponsors. Arranged meeting locations. Host for summer meetings.
9. The Prosser Co. (29 years) Provided secretarial service. Storage for FIRT records. Host & support.
10. The Kitchen Cabinet (15 years) Support and advice 1954 – 1969.

As we enter the 21st Century, the Round Table must carefully examine the format of the programs and ask our cornerstone questions: "Are these subjects timely?" "Are they interesting?" and "Are they from the ground up and not from the top down?"

Possible subjects and issues for the next 5-10 years could be: (See Tables 8 and 9).

Table 1

FIRT Meeting Locations

Location	Number of Meetings
Washington, DC	22
Atlanta, GA	6
Baltimore, MD	5
Memphis, TN	3
New Orleans, LA	3
New York, NY	2
Orlando, FL	2
Miscellaneous*	7

*One each city: Atlantic City, Chicago, Tampa, Raleigh, Savannah, St. Petersburg, and Annapolis

Photograph 1

This 1959 photo shows the original Executive Committee of The Round Table. Left to right - Al Spillman, Joe Reynolds, Vince Sauchelli, and Houston "Doc" Marshall.

Table 2

FIRT Attendance

Years	**Range**
1951-59	14-425
1960-69	450-625
1970-79	400-300
1980-89	250-150
1990-99	200-130

Table 3

FIRT Number Averages Proceedings

Years	**Pages**	**Participants**	**Subjects**
1955-60	71	34	38
1961-65	89	53	26
1966-70	116	103	24
1971-75	158	48	30
1976-80	172	60	29
1981-82*	255	46	29
1983-90	150	40	25
1991-95	158	29	22
1996-99	150	26	20

* Record Stopped

Table 4

FIRT Subject of Meetings

Year	AMM/GRAN	Rest of Program
1955	83%	Screens, Potash
1957	82%	Raw, Materials, Formulations, Effluents, Instruments
1960	10%	Raw Materials, Production and Usage, Peanut Ralization
1965	15%	26% Nitrophosphates, Phos Acid, European NPK, Sampling P&Q

* Subjects - 100 Questions received and assigned before meeting

Table 5 and 6 Combined

FIRT Subjects of Meetings

Year	AMM/GRAN	Rest of Program
1970	19%	Equal Papers-Pollution, Blends Fluids (1/2 Progams)
1975	11%	Outlook Papers Environmental (19%) Blends, Fluids
1980	29%	Outlook Papers, Blends, Fluids (13%) AAPFCO
1985	30%*	Outlook Papers, Application Equipment, P&Q, Blend & Fluids (20%)
1990	27%**	Outlook Papers, Agronomy, Environment, AAPFCO, Blends
1995	0	Outlook Papers, Perception, Heavy Metals, APP Equipment Environment
1997	0	Outlook Papers, Precision Ag (16%), Risk Assessment, AAPFCO
1999	0	Outlook Papers, SGN, Nutrient Management, Precision Farming, AAPFCO, Slo-Release

* Granulation of Urea, DAP, MAP-No 1960's type plant

** Only 7% related to 1960's type granulation Plant - 20% related to quality and agronomy.

Table 7

FIRT The "Glue"

V. Sauchelli	Founder (1969)*
Doc Marshall	(1972)*
Al Spillman	(1989)*
Travis Hignett, Frank Achorn & TVA	
Paul Prosser	1970-
Walt Sackett	1970-
Wayne King	(1982)*
Tom Athey	(1998)*
The Prosser Co.	1970-99
The Kitchen Cabinet	1954-69

* Year Deceased

Table 8 and 9 Combined

FIRT Subjects and Issues Beyond 2000

1. Developments and Operations
   A) Fluid Plants
   B) Dry Blend Plants
   C) NPK Granulation Plants

2. Developments in Raw Material Plants:
   A) Increase Recovery
   B) Conserve Raw Materials
   C) Conserve Energy

3. Soil and Water Conservation

4. Air and Water Pollution - Fertilizer

5. Education and Promotion of Fertilizer Values

6. Use of Non-Toxic Waste, Products in Agriculture

7. Benefits and Use of Sulphur and Minor and Secondary Elements

8. Safety in Storage and Plants

9. Refinement of Precision Farming

10. Fertilizer is Safe

11. Promote the Round Table

Table 10

FIRT Proceedings*

	Most		Least	
	Year	NO.	Year	No.
Subjects	1957	54	1960	19
Participants	1970*	159	1995	24
			1997	24
Pages	1975*	233	1971*	82

* Recording of discussion and Participants included
Recording discontinued 1982

Table 11 through 13

FIRT 50 Year Summary

Year	**Activities**
1951	First Mtg. - Est 14 present - No records No notes - Invitations 1952-54
1955	First Mtg. away from ACS - No discussions reported - Only papers - In Washington, DC
1957	Most subjects - Famous 100 questions Questions - Longest session 1:30 PM - 7:30 PM, No coffee breaks. Recorder for Questions and discussion, Executive CMT - V. Sauchelli, “Doc” Marshall, Al Spillman, Joe Reynolds
1958	Moved to Mayflower Hotel (Stayed 12 Years) Proceedings cost $3.00, 425 Registered
1967	Executive Cmt. increased to 6, Attendance est. 600+
1969	V. Sauchelli dies 1969
1970	New organization with expanded board and cmts. with responsibilities - including international members. 20 sponsors for cocktail party
1971	Outlook papers started, “Doc” Marshall and Al Spillman retired from offices.
1972	“Doc” Marshall dies 1972

Table 11 through 13 continued

Year	**Activities**
1980	Shortest session - Water came through ceiling, Frank Achorn Presiding
1982	Wayne King dies 1982
1984	Stopped recording
1987	Tours started, cocktail party expanded to buffet, portion of registration added to sponsorship amt.
1988	FIRT Trademark adopted
1989	Al Spillman dies 1989
1991	Started going to different locations each year and tours continued
1998	Tom Athey dies 1998

Keynote Address
The NA Fertilizer Industry: Challenges and Opportunities

John M. Van Brunt, Jr.

Agrium, Inc.

Slide 1

The fertilizer market is a typical commodity business with lots of surprises in the domestic and world markets to keep things interesting. Some of the recent changes in the nitrogen and phosphate market are just a concentration of that fact of life.

Slide 2

Some examples of recent surprises include: Central Florida DAP prices taking a 20% drop (or more than $30/st) in less than five months. This after three years of not changing more than 5%.

Two years ago who would have bet that Russia's largest phosphate producer would be jointly marketing phosphates with PhosChem in Asia and Latin America? Similarly, who would have thought that the Russian potash producer Uralkali would be in a marketing arrangement with Canpotex, the Canadian offshore potash export agency?

Slide 3

Nitrogen price volatility has also been very high over the past five years. For example, US Gulf urea prices reached $184/st in July 1996 and hit a bottom of $84/st in July 1999. By July 2000, they were back up to $156/st. A similar price pattern existed for ammonia and most other nitrogen products. This recent large increase in nitrogen prices would be reason for celebration among this crowd but for the fact that gas prices are more than double what they were last year.

Slide 4

Before I go into the issue of gas prices and the impact on the nitrogen sector, I would like to address a concern that I hear occasionally in talking with analysts and even some colleagues. That is that NA farmers will significantly reduce nitrogen fertilizer purchases rise due to the run-up in gas prices combined with environment of low grain prices! Despite some challenging times in the agriculture sector, farmers cannot afford *not* to buy nitrogen. The average US corn grower is still making a profit from the marketplace as this graphic shows (although it is down from levels received a few years ago). Keep in mind that US farmers still receive the loan rate for every bushel produced, which is $1.90/bu for corn.

Slide 5

This graph shows nitrogen fertilizer use in the US over the past 40 years matched US changes in corn prices. One can see that, in spite of volatile corn prices, the only time that there has been a noticeable decline in nitrogen use was in years of major drought such as in 1983, or where the US government introduced major set-aside programs. We do not see the US government going down this road again in the foreseeable future. As a result, I anticipate optimal nitrogen fertilizer application rates will remain near historical levels.

Slide 6

On the other hand, it is true that NA farmers did cut back on P&K fertilizer use somewhat over the past two years as crop prices fell. However, particularly as a result of excellent crops, they have "mined the soil" of these two nutrients and unless there is a significant reduction in corn and other cereal area (which we do not anticipate) there is little room for additional cuts in use.

Slide 7

It is also true that US grain stocks have risen over the past few years as a result of three years of near record harvests and subsequently US and world prices have declined.

Slide 8

However, it is worth noting that grain production has been stagnant over the past 4 to 5 years and world grain stocks to use ratio is forecast to decline.

Slide 9

In fact the worlds stocks to use ratio is expected to decline to a level, which is below the 10-year average.

Slide 10

Back to the issue of the day, which is North American gas prices, which have increased to dizzying heights. Over the past month alone, gas hit an all-time high of over $5.00/Mmbtu, compared to the average for 1992-98 of $2.40/MMBtu. Lets take a look at the historical gas price levels in North America. Note that there have been a number of price peaks during 1996 to 1998, but they have not tended to last long. This time, things may be different due to growth in demand that has not allowed inventories to increase.

Slide 11

Evidenced by this graphic, for every $1 per MMBtu increase in US gas prices, the average cost of ammonia production rises by $34/ton and urea by $25/ton. The average cost of producing other nitrogen and phosphate fertilizers are also impacted by higher gas prices.

Slide 12

Historically corn prices have tended to be the main driver behind fertilizer prices, as opposed to gas prices.

Slide 13

However, under the current market conditions, the high NA gas prices have been a major factor in higher world fertilizer prices. As shown in this graph and have trended to follow one another.

Slide 14

The key reasons for high NA gas prices include; strong NA economy, a shift to gas fired electric generation, for environmental reasons, strong demand pulling down gas storage, record oil prices, forecast of abnormally cold winter and bullish psychology.

Slide 15

With low inventories and the peak demand period coming, I don't think anyone knows how high gas prices will go over the winter. This graph indicates a consultant's view of gas street levels over the last 3 gas seasons. Certainly shows the low levels resulting from strong demand in 2000/2001.

Slide 16

However I do believe that a decline in NA prices is inevitable. Looking at how fast historical highs have dropped back in the past can back this up. In addition, our gas-forecasting agency projects a gradual decline in prices. As noted earlier, one could certainly argue that we are looking at a new 'base' plateau, perhaps as much as much as $1.00MMBtu above previous levels. It truly remains to be seen.

Slide 17

Certainly, gas exploration and production costs in North America are relatively low, estimated at approximately $2.4MMBtu in the US Gulf and $1.5MMBtu for Western Canada, driving companies to drill at record levels.

Slide 18

One of the reasons prices will decline is that huge new reserves in the North Shores of Alaska and deep water US Gulf will eventually be developed. One can see that, while there is a lag of 1-2 years in production, current record drilling levels on both sides of the border will ultimately lead to a significant increase in available supply.

Slide 19

As mentioned, additional Canadian gas will also be a key component in the increase in NA gas supply. Canadian fertilizer producers have enjoyed a significant cost advantage for many years. As can be seen by this graphic, this advantage has been narrowed from over $1/MMBtu in the past, to as low as $0.3/MMBtu. This has occurred due to new pipelines which have been completed or in the process of starting up with much of the gas contracted on a ship or pay basis. However, the full cost of transporting gas is approximately $1/MMBtu. It is expected that much more of the new gas which will come on stream in the near future will be moved on a spot basis at 70% of total cost, this should widen the spread back out to about $0.7MMBtu.

Slide 20
After all, the following graph shows you, which facilities are in the red at $5/MMBtu, spot gas prices and the September average price of $180/st for ammonia. This model assumes no hedged gas, and historical regional fertilizer price spreads. This graph illustrates that in this situation 60% of North American capacity is losing money on a variable cost basis. Most of the producers who are in the most difficult situation tend to be in the southern US or are older, inefficient facilities. It does beg the question, will we see a substantial increase in temporary or permanent closures in NA? Will a significant proportion of US or North American production capacity be shutdown in the not too distant future?

Slide 21
When considering this issue, it is important to take a moment to step back and view the North American market in the context of the world as a whole. The US and Canada together represent 15% of world nitrogen capacity. (Canada is about 3-4% of this). The thought that this capacity could just disappear over the course of a year or two is out of the question! There is not enough spare capacity in the world today to supply the North American market.

There are a number of ways to look at this. One is to look at North American nitrogen consumption and compare it to world trade.

Slide 22
If all NA consumption were to be provided by offshore markets, it would require that over 80% of current world trade be re-directed to the North American market. Given the limited excess capacity in the world right now, this could not be done without a huge impact on fertilizer markets and prices.

Slide 23
This graph shows current NA nitrogen consumption and offshore imports. Note that if 50% of NA capacity closed tomorrow, offshore nitrogen imports would have to increase by a factor of five, rising from 4 million tons of product to 20 million tons.

Slide 24
Nor is there any chance that additional capacity could be developed quickly enough (less than 3 years), even if long-term market conditions warranted more expansion in world nitrogen capacity. New world nitrogen capacity coming on stream over the next two years is intended to supply future growth in world demand and will add approximately 2 million tons of nitrogen between 2001 and 2003, already well below the anticipated growth in demand. This growth in world capacity will represent just over 10% of the current NA nitrogen demand.

Slide 25
The same is true for the additions to world urea capacity, compared to demand growth. I am not saying that additional industry consolidation is not possible or warranted given the difficult times ahead for many NA producers. However, a wholesale closure of the entire NA industry is not in the cards for the foreseeable future.

Slide 26
It is also important to keep in mind that energy prices and resulting nitrogen production costs are high in many countries with significant nitrogen capacity. Under current conditions, gas prices tend to be regional, 1/3 of world production is at levels 72.00 MMBtu, and therefore it is quite possible to have major changes in North American gas prices without it impacting gas prices in other regions of the world. However, there is some connection between gas and oil prices within North America and many other regions of the world.

Two of the world's largest fertilizer producers and consumers are India and China. Political interference in the form of subsidies and protectionist government policies have often resulted in a highly distorted domestic market within these large markets, which ultimately impact the world fertilizer market. Many of the facilities in these two countries, which would normally lose significant amounts of money under world market conditions, are often supported to continue to operate due to government intervention. Similarly, decisions on production, imports, exports and expansion in capacity within these countries are often not related to market realities, but rather political decisions. This results in significant losses to the local economies as a whole due to misallocation of resources. It also results in a much larger degree of volatility in world fertilizer prices.

Slide 27
For example, in addition to the Chinese ban on urea imports imposed in 1997, we now have a situation where China is exporting urea which has had a significant negative impact on world urea prices. IFA estimates that the average cost of bulk urea at Chinese facilities are about $150/st. The recent export price quotes show that China has exported "bagged" urea from Northern urea facilities, for less than $110/st on a fob basis. They have done so with the help from a government "rebate on taxes" and despite the facts that transportation costs to port are quite high. The Chinese government indicated that the average bulk urea price at Chinese facilities was over $135/mt in August 2000. While I am not an expert on international trading, I doubt this practice would be allowed under WTO rules. This is one example of why Chinese WTO membership is vital to the NA and world fertilizer market.

Slide 28
Also as part of China's accession to the WTO that should take place in 2001, an agreement was reached on a minimum tariff rate quota for urea. This means that if internal Chinese urea prices are above world prices the Chinese must allow this minimum amount in without any significant barriers. This represents 1.3 million tonnes of product in 2001, rising to 3.6 million tonnes by 2006. Totally dependant upon world urea prices! Minimum import quotas were also agreed upon for DAP and MOP.

Slide 29
In India, where their fertilizer subsidy bill is expected to top US$3 billion in 2000 the drive for self-sufficiency in fertilizer production is highly questionable. To put this subsidy bill in perspective, India could have purchased 25 million tones of urea at current world prices with the same amount of money.

Slide 30
India imports the large majority of the required raw materials. In the case of nitrogen this is naphtha, oil and coal. They pay relatively high transport costs to get these raw materials to their domestic port and then on to the fertilizer plant. It makes far more economic sense to import fertilizer products directly from cheaper offshore sources, particularly since the "employment benefits" from existing subsidized production are marginal at best.

Slide 31
The WTO requires a conversion of non-tariff barriers to a tariff basis. This process is now under review for India. Although their own internal special interests are lobbying hard for continued high level of protection and continued domestic expansion, India now has an opportunity to recognize that this system is costing them huge amounts of money and to move toward a more rational economic system. Time will tell!

Nitrogen is the largest expense item for the Indian government at over US$ 2.3 billion. However, phosphate expenses have increased dramatically in the past few years and are expected to account for over $600 million this year.

Slide 32
India doubled its P2O5 capacity between 1999 and 2001 with Oswal and a number of other smaller projects. It is expected that increases in phosphate capacity in India will account for over 40% of the increase in world capacity between 2000 and 2002. This large an increase in capacity has been one of

the major reasons phosphate prices have declined over the past year. Furthermore, it is one of the major reasons that the Indian government subsidies for fertilizers have risen so dramatically.

Slide 33

Government subsidized capacity expansion or significant protection of the domestic industry in any country is important, not only due to the cost for the subsidizing country, but for the allocation of resources and related impacts worldwide. Not only has it the potential to have a major negative economic impact on the subsidizing country, it also plays havoc with the world markets and ultimately our own domestic industry.

Subsidies and non-tariff barriers have largely removed at least half of the world's consumers and producers from the world market. This means that there are only a limited number of markets in the world where adjustments in production and consumption take place. These regions have tended to be in the America's and to a lesser extent Western Europe. The smaller the market, the greater the swings in price levels before supply and demand are brought back into balance.

Slide 34

I heard some comments during the WTO discussions that since North America were not a large exporter of nitrogen products to the world it was not that important to have it included in the agreement. I strongly encourage members of the industry to recognize how very important this agreement is to the world and NA fertilizer industry as a whole.

Slide 35

In summing up, we know there will continue to be growth in world nitrogen demand and capacity will expand to meet that need. There is little doubt that much of the world's new nitrogen capacity will be built where natural gas prices are relatively low, particularly in regions of "trapped gas". Many North American nitrogen producers have started to diversify their gas sources moving to expand their capacity offshore. The following graphic shows the current share of those NA fertilizer companies representing 75% of total NA capacity in domestic and offshore (low-medium price gas) markets. There is little doubt that future growth in capacity will occur outside NA and that over time more reliance on imports will occur and more emphasis on the distribution network for imports will come about. However, there will continue to be a significant base nitrogen capacity maintained within NA.

Slide 36

In closing I would like to say that we are in an industry that helps feed the world. In challenging economic times, one can occasionally lose sight of this important contribution! The challenge to the industry and this group is to continue to make improvements to the production system to help keep the NA fertilizer and agriculture industries competitive within the world. Furthermore, we as a group, must also ensure we continue to strive for a more open trading environment which can help reduce market volatility and provide for more rational economic decisions.

Slide 2

Recent Fertilizer Developments

- DAP prices drop 20% ($30/t) in less than 5 months after 3 years of no change.
- Russia's largest phosphate producer joins marketing arrangement with PhosChem.
- Russian potash producer joins marketing arrangement with Canpotex.

Agrium

Slide 3

Magnitude of N Price Volatility

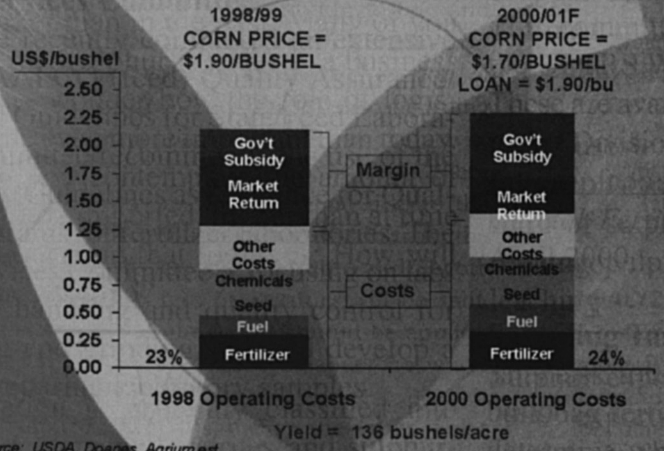
Overview of US Gulf urea prices:

July 1996:	$184/st
July 1998:	$127/st
July 1999:	$84/st
July 2000:	$156/st

Agrium

Slide 4

Margins Still Positive For U.S. Corn Farmers

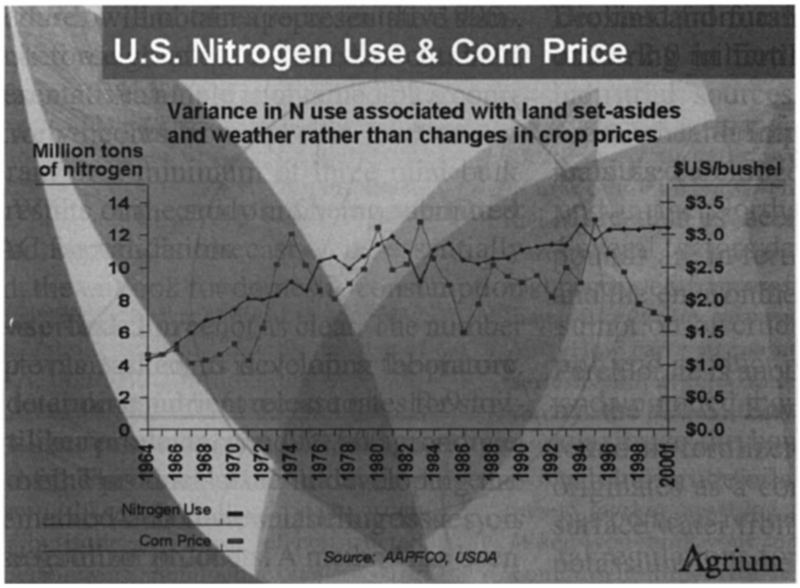


Source: USDA, Doanes, Agrium est

Other variable cost = Overhead, Hired Labour, Repairs

Agrium

Slide 5

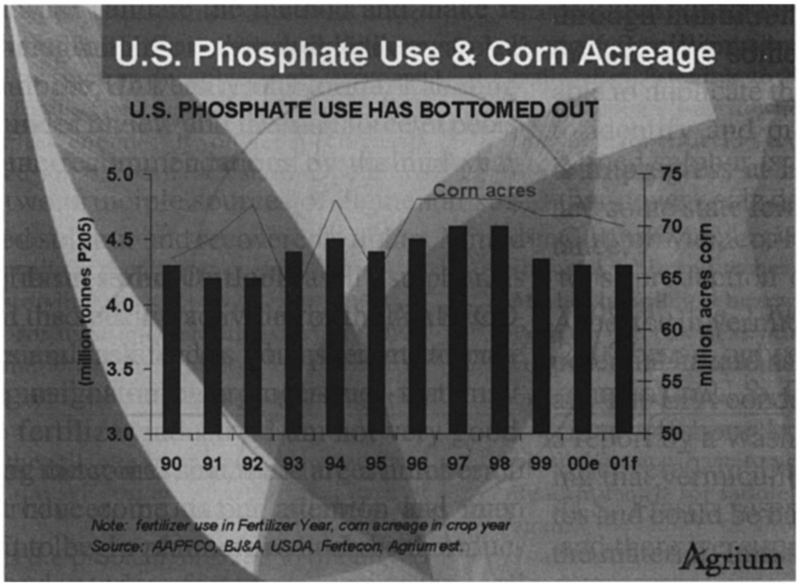


U.S. Nitrogen Use & Corn Price

Variance in N use associated with land set-asides and weather rather than changes in crop prices

Source: AAPFCO, USDA

Slide 6

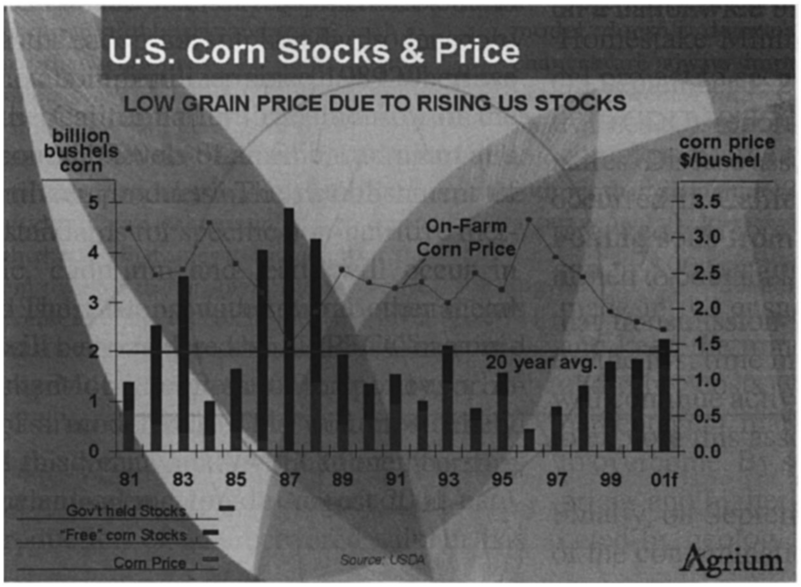


U.S. Phosphate Use & Corn Acreage

U.S. PHOSPHATE USE HAS BOTTOMED OUT

Note: fertilizer use in Fertilizer Year, corn acreage in crop year
Source: AAPFCO, BJ&A, USDA, Fertecon, Agrium est.

Slide 7

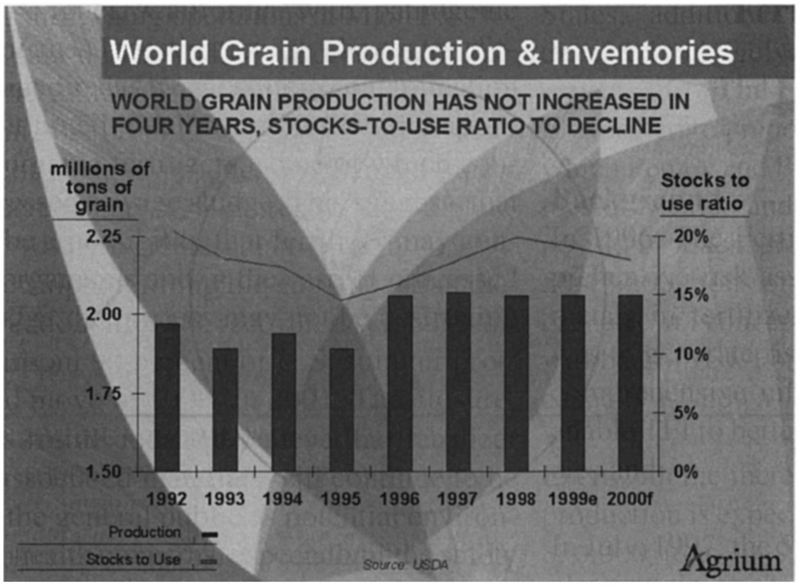


U.S. Corn Stocks & Price

LOW GRAIN PRICE DUE TO RISING US STOCKS

Source: USDA

Slide 8



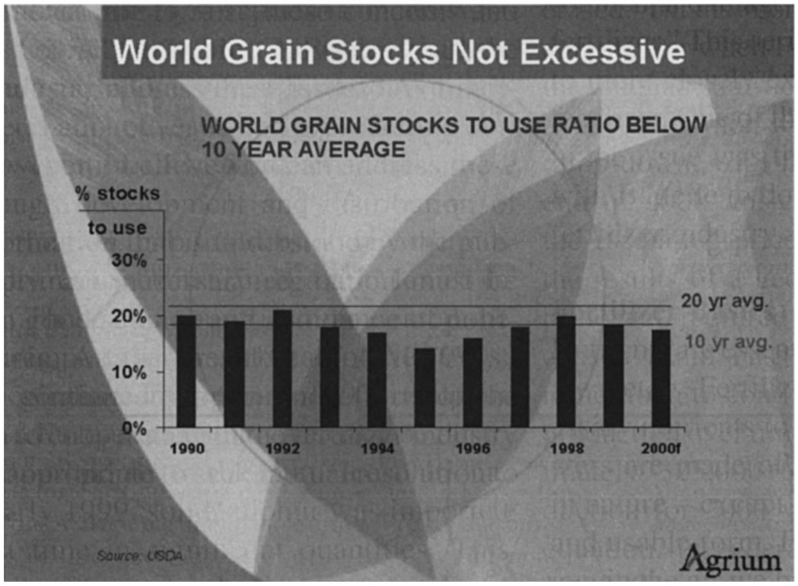
World Grain Production & Inventories

WORLD GRAIN PRODUCTION HAS NOT INCREASED IN FOUR YEARS, STOCKS-TO-USE RATIO TO DECLINE

Source: USDA

Agrium

Slide 9



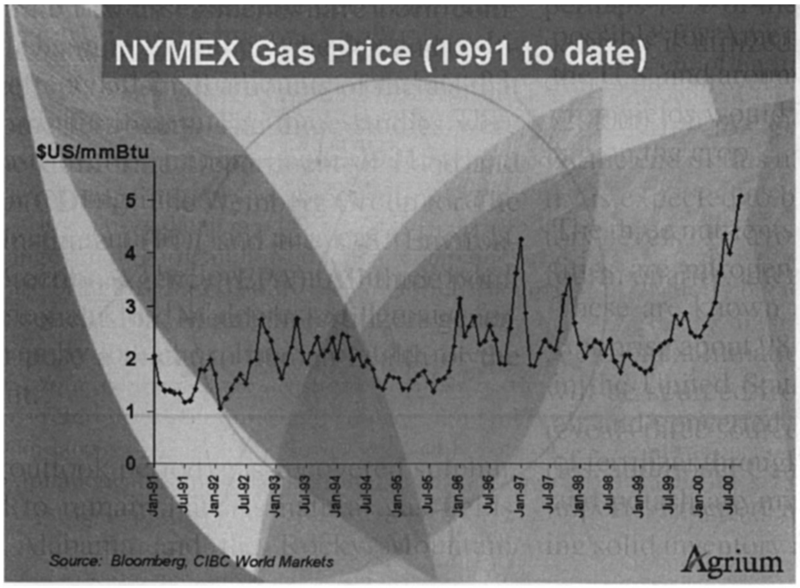
World Grain Stocks Not Excessive

WORLD GRAIN STOCKS TO USE RATIO BELOW 10 YEAR AVERAGE

Source: USDA

Agrium

Slide 10

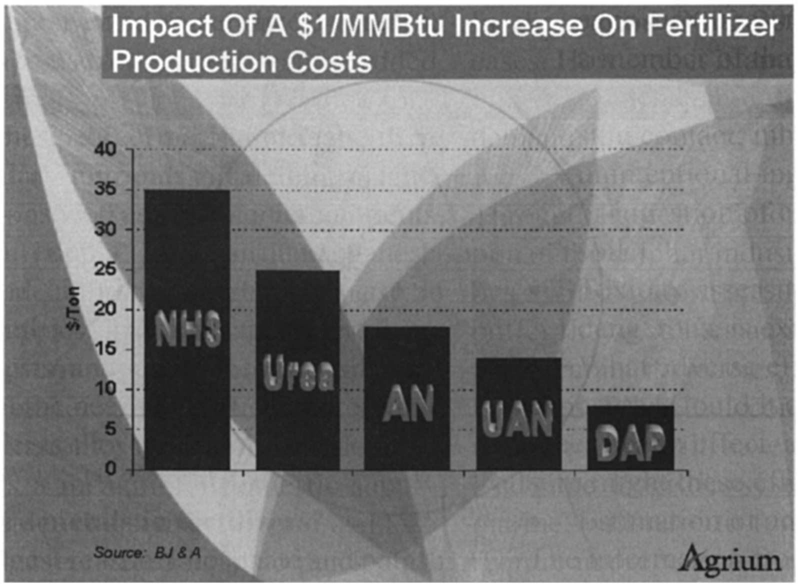


NYMEX Gas Price (1991 to date)

Source: Bloomberg, CIBC World Markets

Agrium

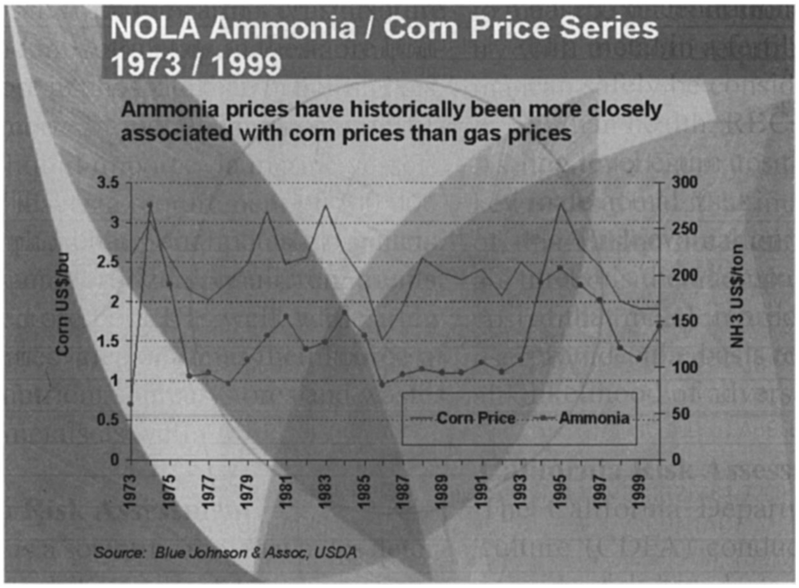
Slide 11


Impact Of A $1/MMBtu Increase On Fertilizer Production Costs

Source: BJ & A

Agrium

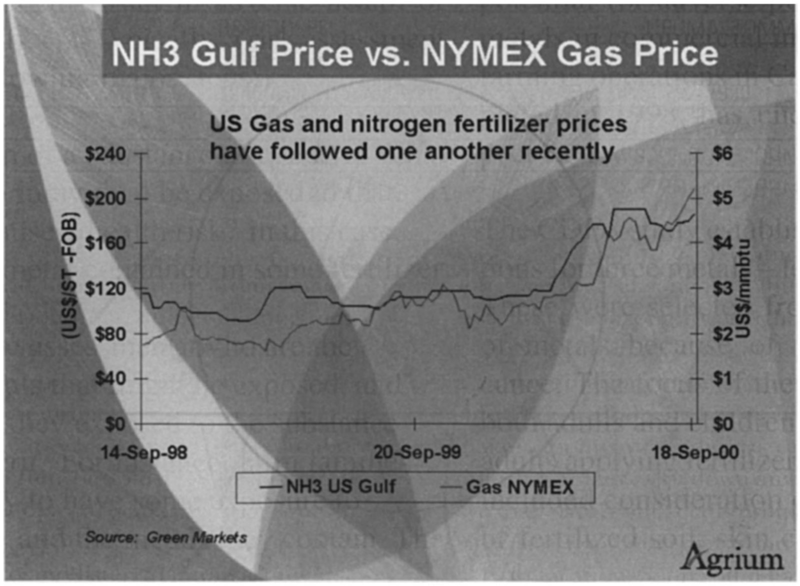
Slide 12


NOLA Ammonia / Corn Price Series 1973 / 1999

Ammonia prices have historically been more closely associated with corn prices than gas prices

Source: Blue Johnson & Assoc, USDA

Slide 13

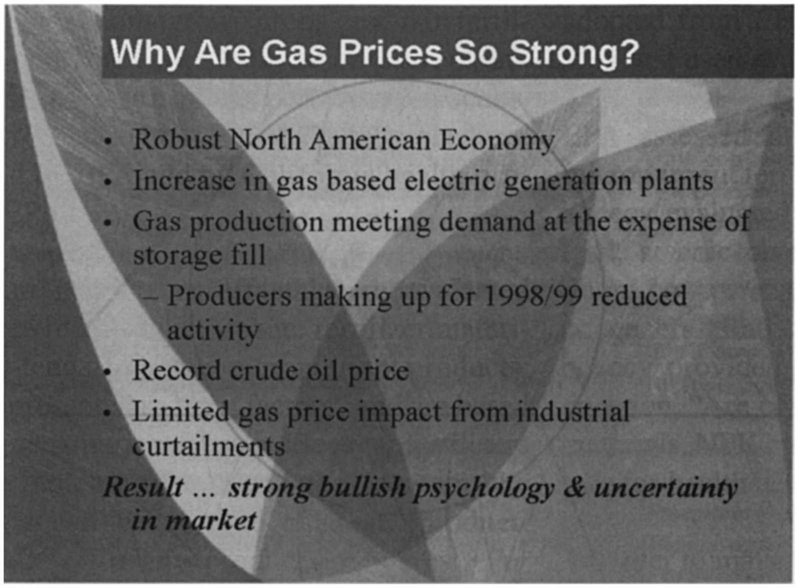

NH3 Gulf Price vs. NYMEX Gas Price

US Gas and nitrogen fertilizer prices have followed one another recently

Source: Green Markets

Agrium

Slide 14

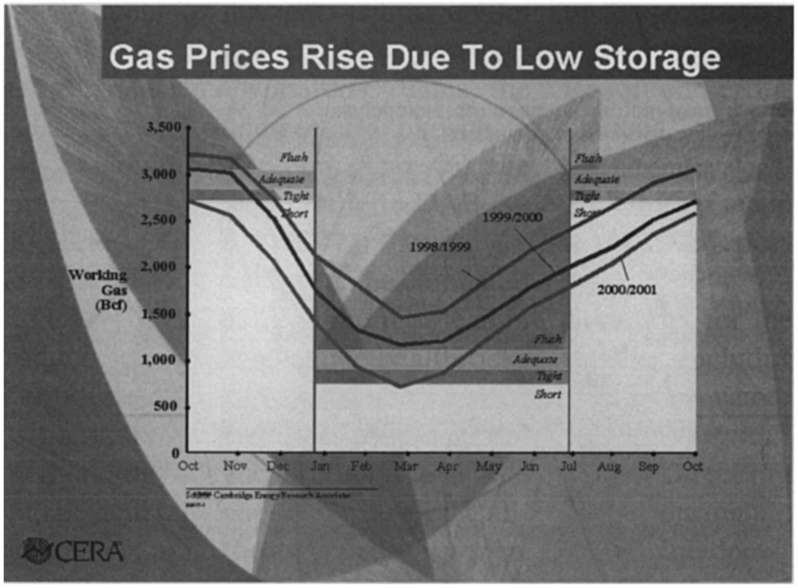


Why Are Gas Prices So Strong?

- Robust North American Economy
- Increase in gas based electric generation plants
- Gas production meeting demand at the expense of storage fill
  - Producers making up for 1998/99 reduced activity
- Record crude oil price
- Limited gas price impact from industrial curtailments

Result … strong bullish psychology & uncertainty in market

Slide 15

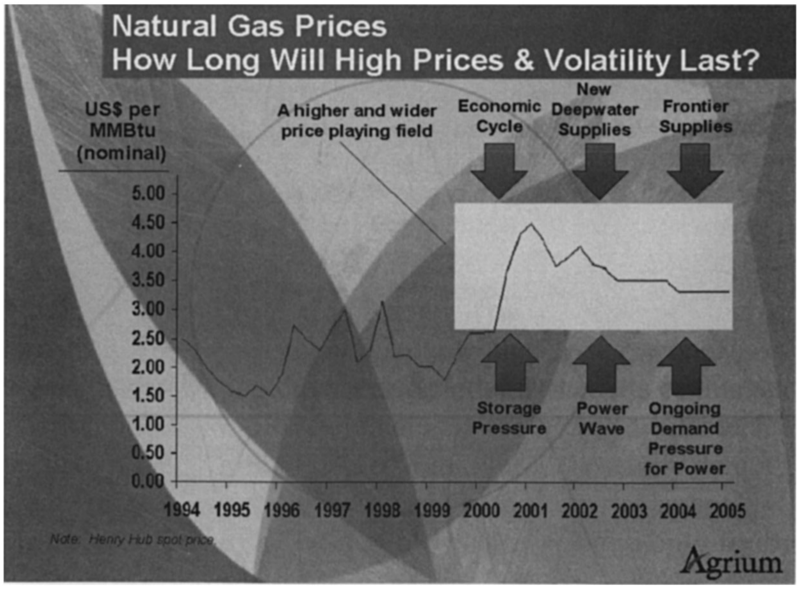


Gas Prices Rise Due To Low Storage

Source: Cambridge Energy Research Associates

CERA

Slide 16

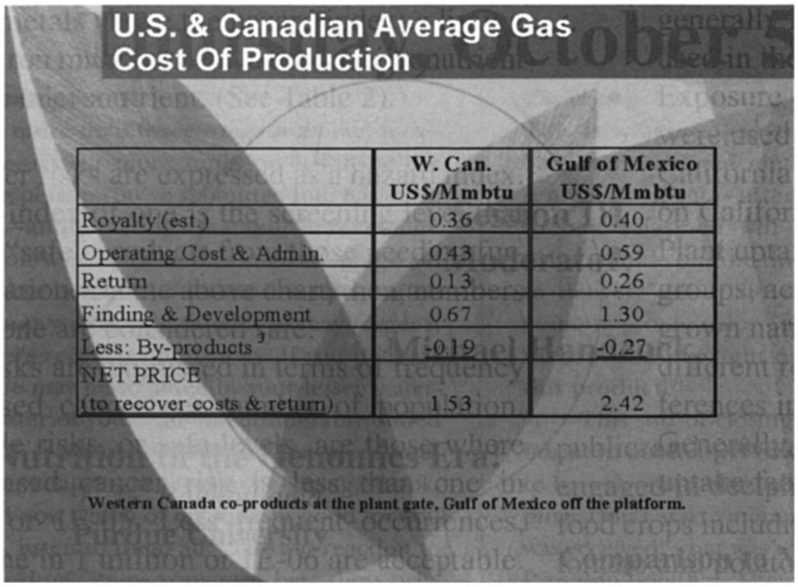


Natural Gas Prices
How Long Will High Prices & Volatility Last?

Note: Henry Hub spot price

Agrium

Slide 17

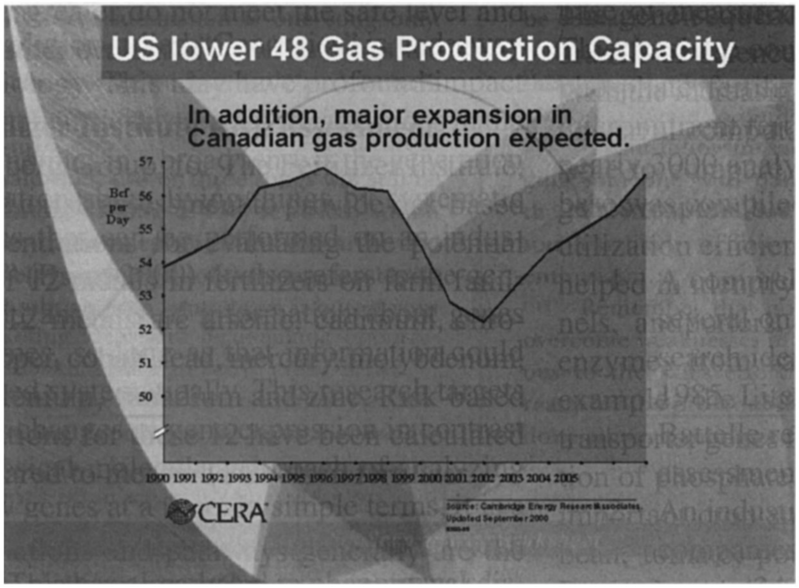


U.S. & Canadian Average Gas Cost Of Production

	W. Can. US$/Mmbtu	Gulf of Mexico US$/Mmbtu
Royalty (est.)	0.36	0.40
Operating Cost & Admin.	0.43	0.59
Return	0.13	0.26
Finding & Development	0.67	1.30
Less: By-products[3]	-0.19	-0.27
NET PRICE (to recover costs & return)	1.53	2.42

[3] Western Canada co-products at the plant gate, Gulf of Mexico off the platform.

Slide 18

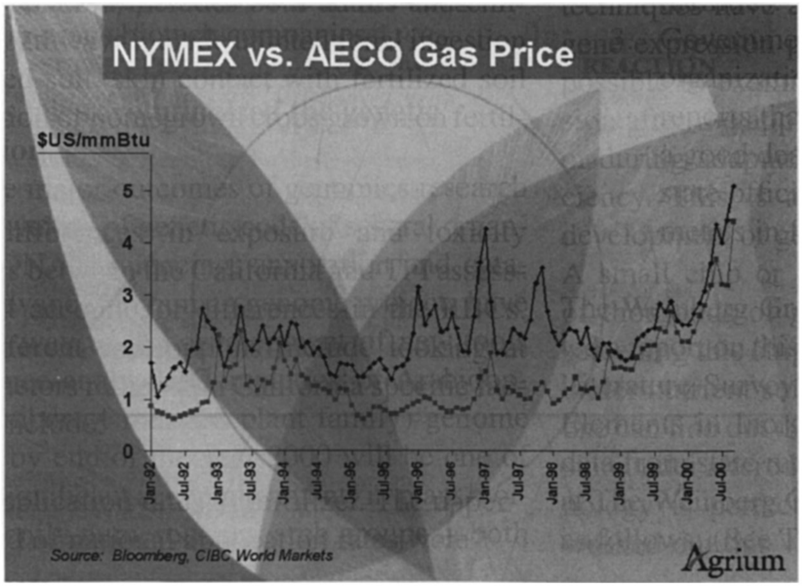


US lower 48 Gas Production Capacity

In addition, major expansion in Canadian gas production expected.

Source: Cambridge Energy Research Associates. Updated September 2000

Slide 19

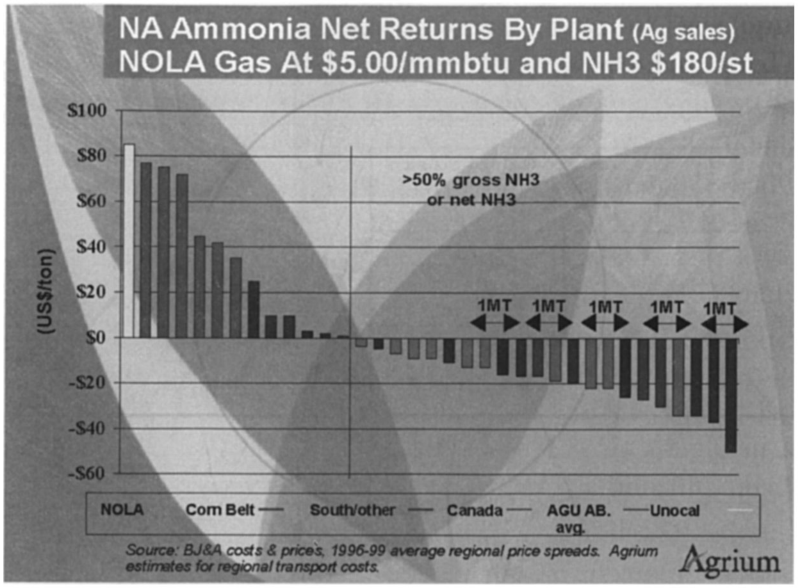


NYMEX vs. AECO Gas Price

Source: Bloomberg, CIBC World Markets

Agrium

Slide 20

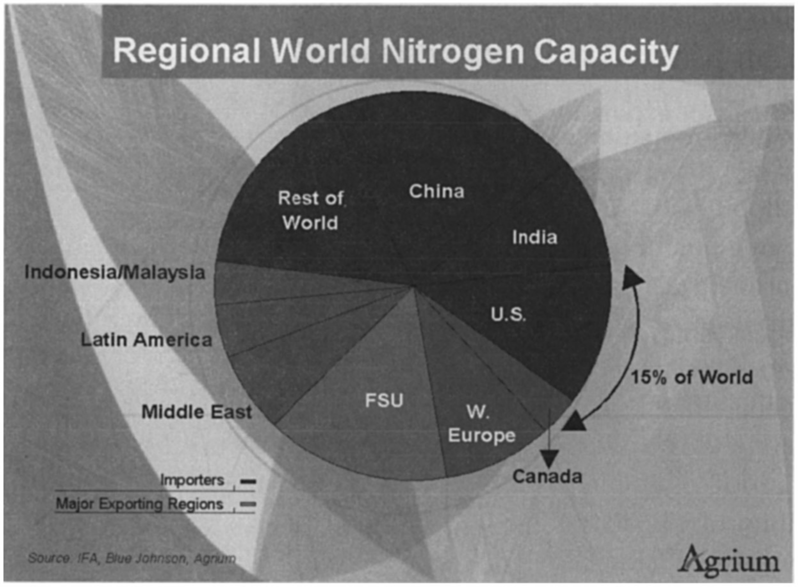


NA Ammonia Net Returns By Plant (Ag sales) NOLA Gas At $5.00/mmbtu and NH3 $180/st

Source: BJ&A costs & prices, 1996-99 average regional price spreads. Agrium estimates for regional transport costs.

Agrium

Slide 21

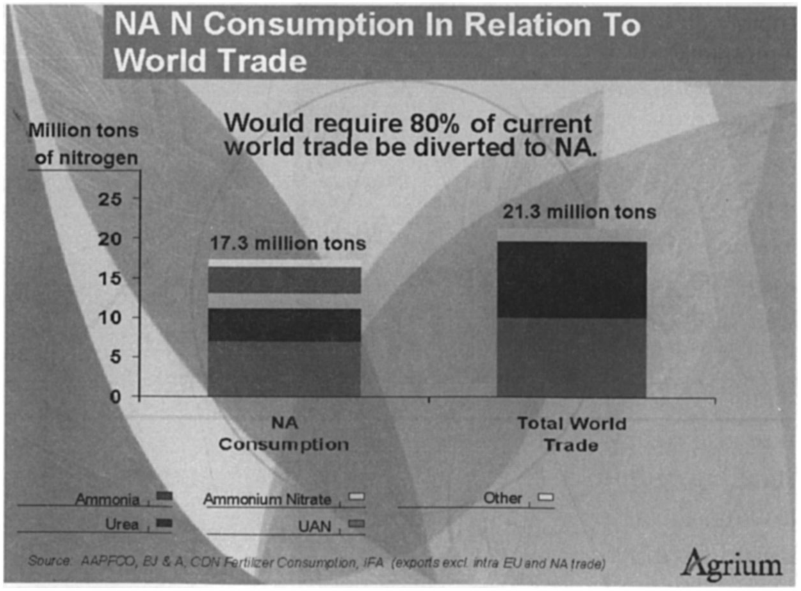


Regional World Nitrogen Capacity

Source: IFA, Blue Johnson, Agrium

Agrium

Slide 22



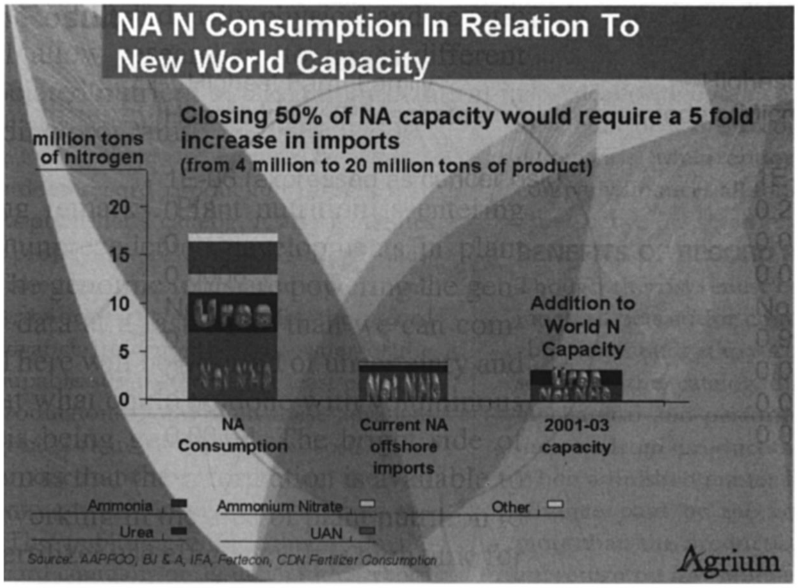
NA N Consumption In Relation To World Trade

Would require 80% of current world trade be diverted to NA.

Source: AAPFCO, BJ & A, CDN Fertilizer Consumption, IFA (exports excl. intra EU and NA trade)

Agrium

Slide 23



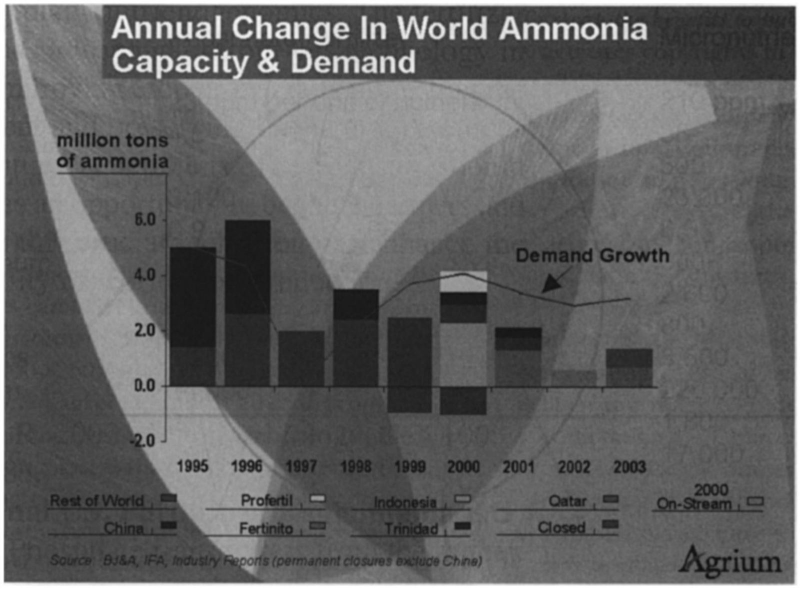
NA N Consumption In Relation To New World Capacity

Closing 50% of NA capacity would require a 5 fold increase in imports
(from 4 million to 20 million tons of product)

Source: AAPFCO, BJ & A, IFA, Fertecon, CDN Fertilizer Consumption

Agrium

Slide 24

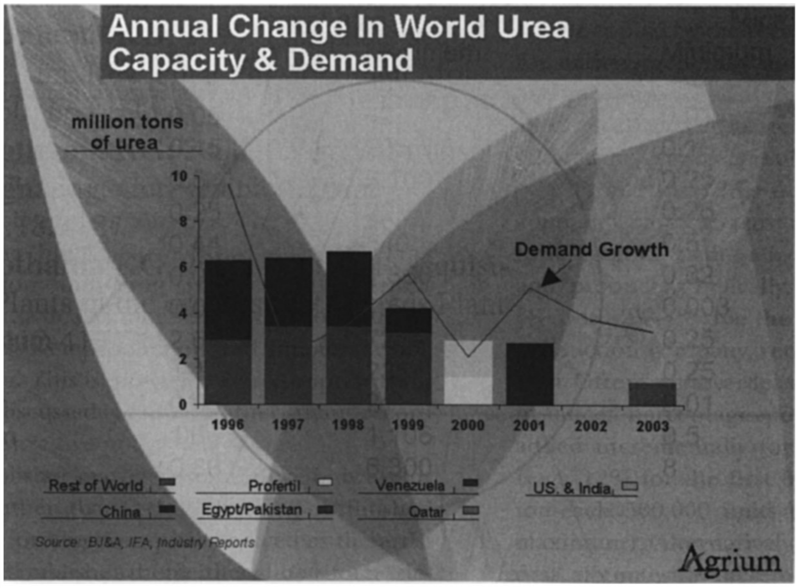


Annual Change In World Ammonia Capacity & Demand

Source: BJ&A, IFA, Industry Reports (permanent closures exclude China)

Agrium

Slide 25

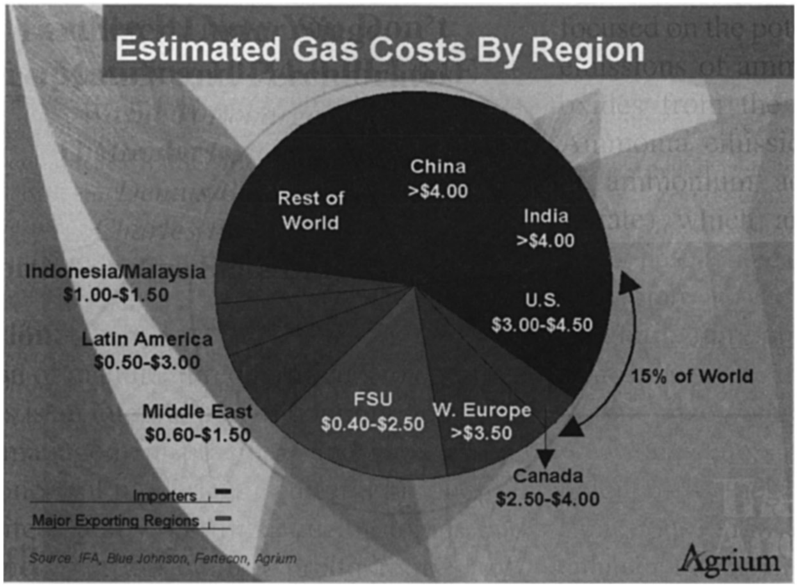


Annual Change In World Urea Capacity & Demand

Source: BJ&A, IFA, Industry Reports

Agrium

Slide 26

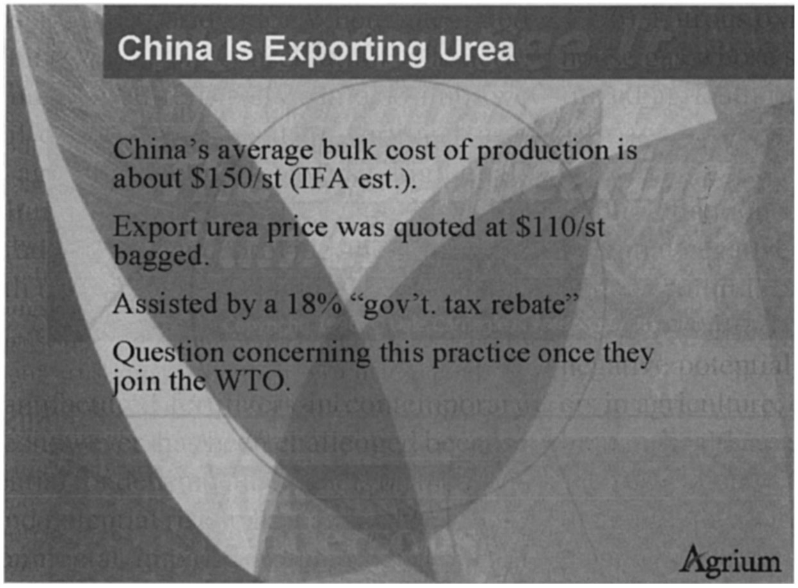


Estimated Gas Costs By Region

Source: IFA, Blue Johnson, Fertecon, Agrium

Agrium

Slide 27



China Is Exporting Urea

China's average bulk cost of production is about $150/st (IFA est.).

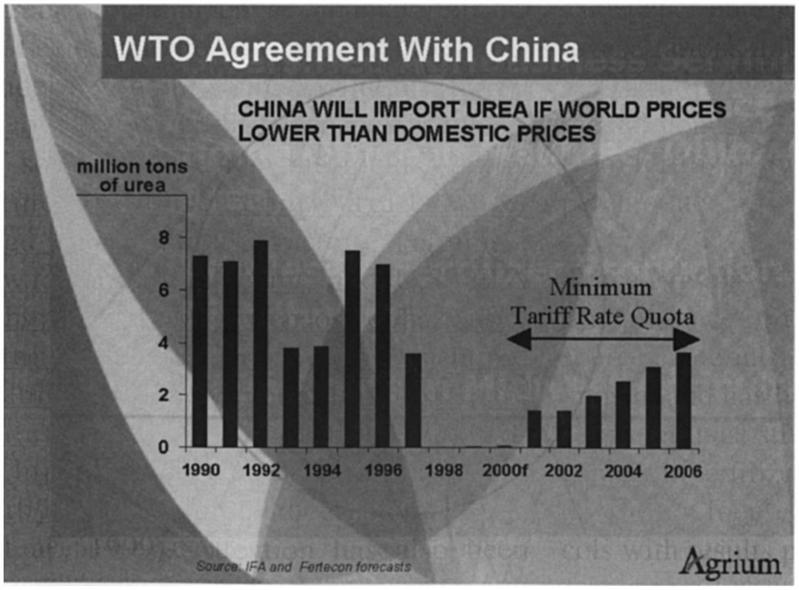
Export urea price was quoted at $110/st bagged.

Assisted by a 18% "gov't. tax rebate"

Question concerning this practice once they join the WTO.

Agrium

Slide 28



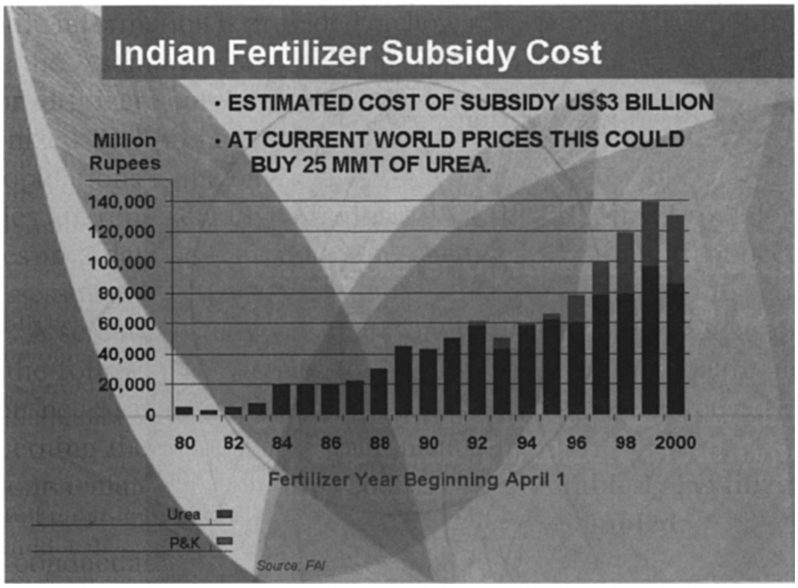
WTO Agreement With China

CHINA WILL IMPORT UREA IF WORLD PRICES LOWER THAN DOMESTIC PRICES

Source: IFA and Fertecon forecasts

Agrium

Slide 29

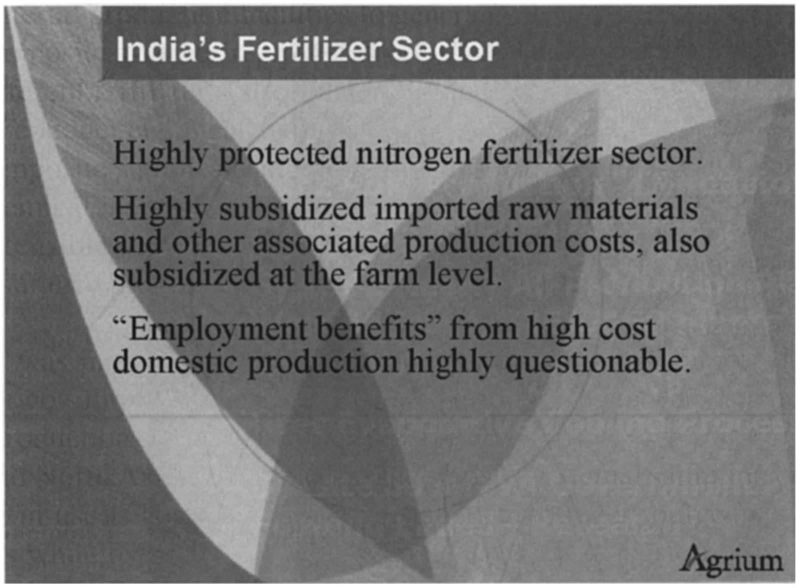


Indian Fertilizer Subsidy Cost

- ESTIMATED COST OF SUBSIDY US$3 BILLION
- AT CURRENT WORLD PRICES THIS COULD BUY 25 MMT OF UREA.

Source: FAI

Slide 30



India's Fertilizer Sector

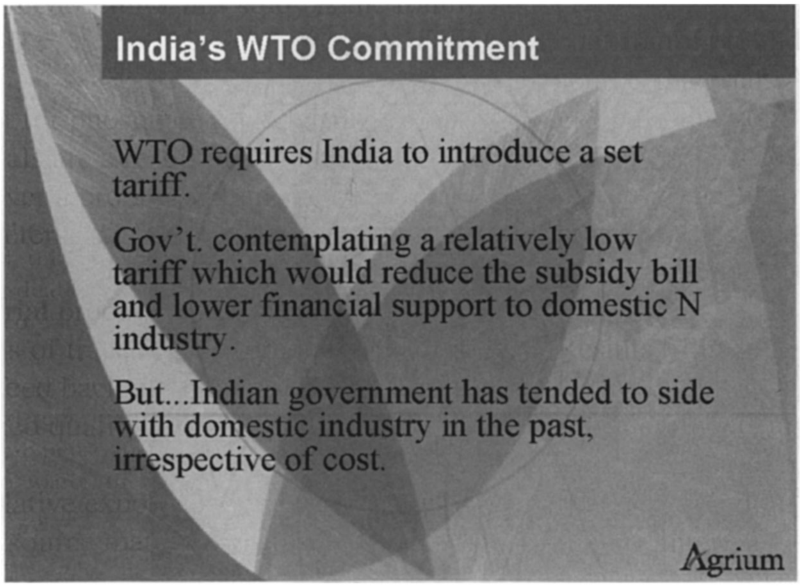
Highly protected nitrogen fertilizer sector.

Highly subsidized imported raw materials and other associated production costs, also subsidized at the farm level.

"Employment benefits" from high cost domestic production highly questionable.

Agrium

Slide 31



India's WTO Commitment

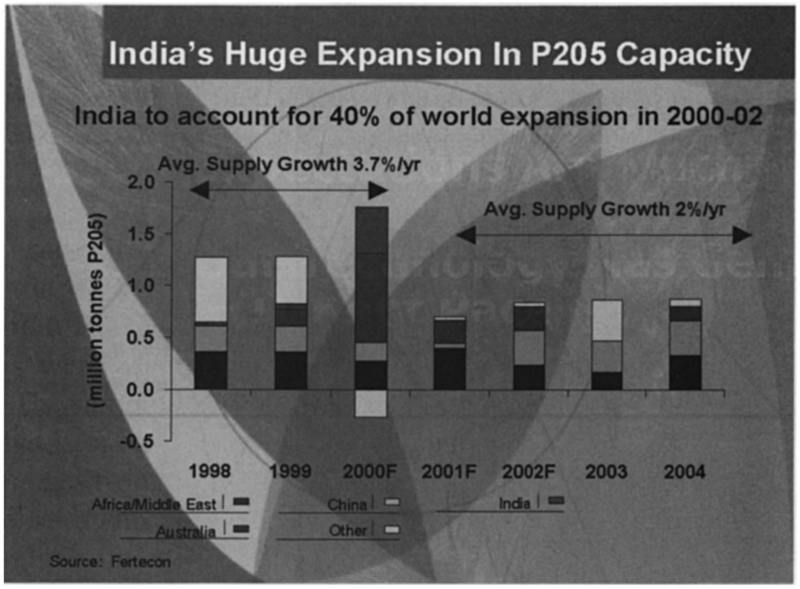
WTO requires India to introduce a set tariff.

Gov't. contemplating a relatively low tariff which would reduce the subsidy bill and lower financial support to domestic N industry.

But...Indian government has tended to side with domestic industry in the past, irrespective of cost.

Agrium

Slide 32

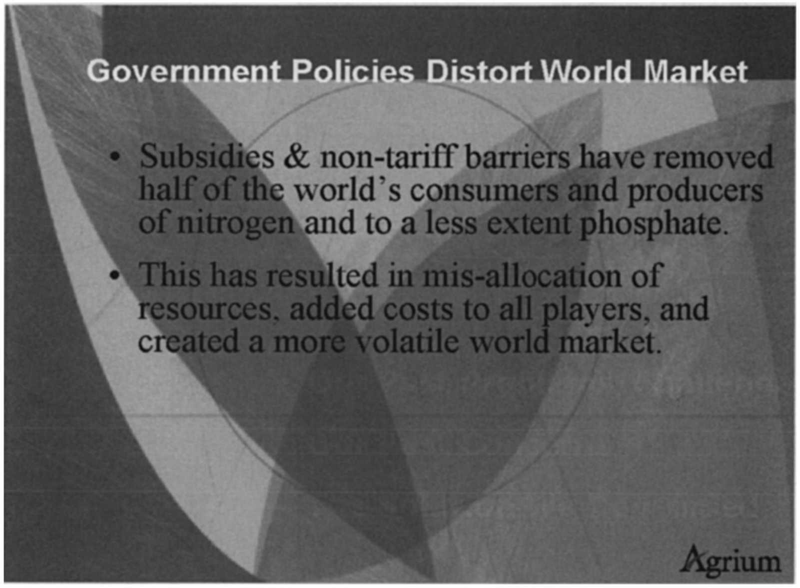


India's Huge Expansion In P205 Capacity

India to account for 40% of world expansion in 2000-02

Source: Fertecon

Slide 33

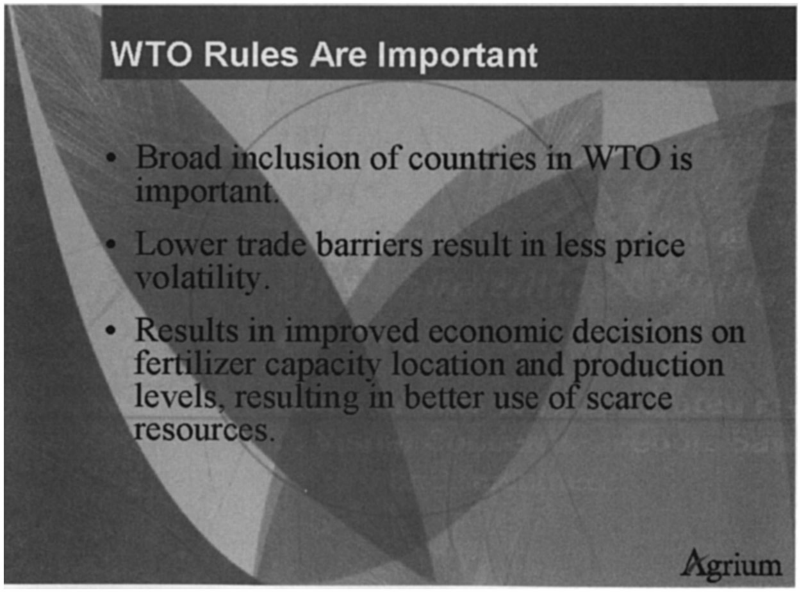


Government Policies Distort World Market

- Subsidies & non-tariff barriers have removed half of the world's consumers and producers of nitrogen and to a less extent phosphate.
- This has resulted in mis-allocation of resources, added costs to all players, and created a more volatile world market.

Agrium

Slide 34



WTO Rules Are Important

- Broad inclusion of countries in WTO is important.
- Lower trade barriers result in less price volatility.
- Results in improved economic decisions on fertilizer capacity location and production levels, resulting in better use of scarce resources.

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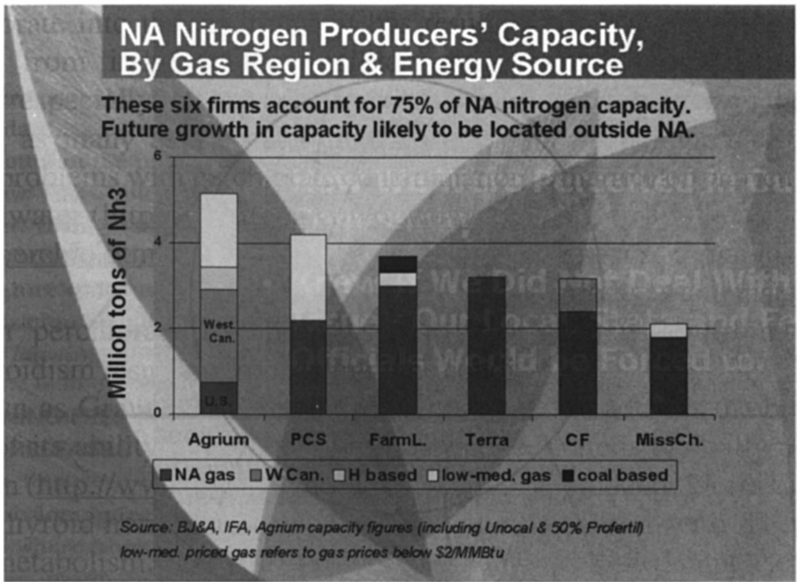
Slide35

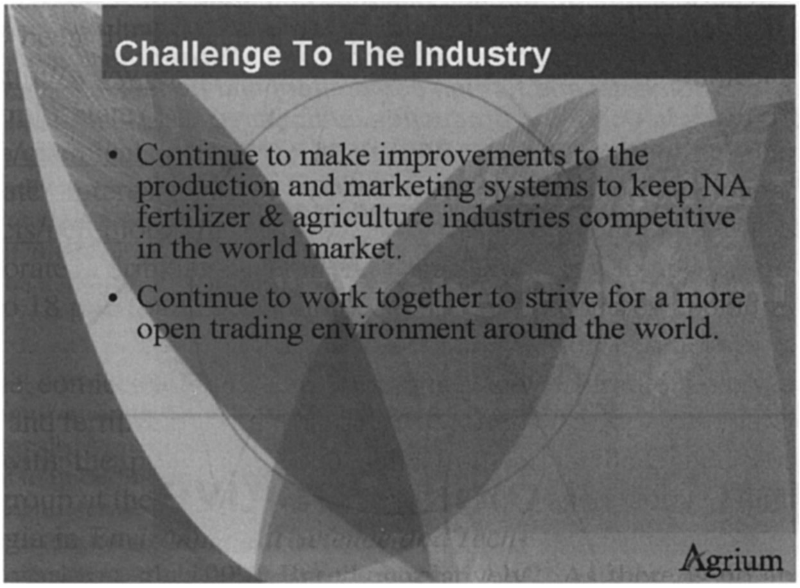


NA Nitrogen Producers' Capacity, By Gas Region & Energy Source

These six firms account for 75% of NA nitrogen capacity. Future growth in capacity likely to be located outside NA.

Source: BJ&A, IFA, Agrium capacity figures (including Unocal & 50% Profertil)
low-med. priced gas refers to gas prices below $2/MMBtu

Slide 36



Challenge To The Industry

- Continue to make improvements to the production and marketing systems to keep NA fertilizer & agriculture industries competitive in the world market.
- Continue to work together to strive for a more open trading environment around the world.

Agrium

Outlook for Nitrogen

Kenneth F. Nyiri
MS Chemical Corporation

Outlook For Nitrogen

Statements set forth in this presentation constitute "forward-looking statements." These forward-looking statements rely on a number of assumptions concerning future events and other uncertainties that are beyond my ability to control. You are cautioned that actual results may differ materially from the forward-looking statements. Important factors which could cause actual results to differ materially from those indicated include, but are not limited to, a variety of items that can materially affect fertilizer demand and prices such as planted acreage, government agricultural policies, projected grain stocks, crop failure, weather, changes in agricultural production methods and status of certain industrial markets and the general economy, seasonal usage of fertilizer, dependence on natural gas, environmental regulations, price competition from both domestic and foreign competitors and possible delays or other problems in obtaining production, anticipated efficiencies and/or lower production costs from, or as a result of, expanded facilities. Also, it should be noted that this presentation is the work of Ken Nyiri and does not necessarily represent the opinion of MCC's management.

Nitrogen Outlook Is Positive

The world nitrogen market has turned upward.

Nitrogen demand is increasing.

Nitrogen trade will also be up.

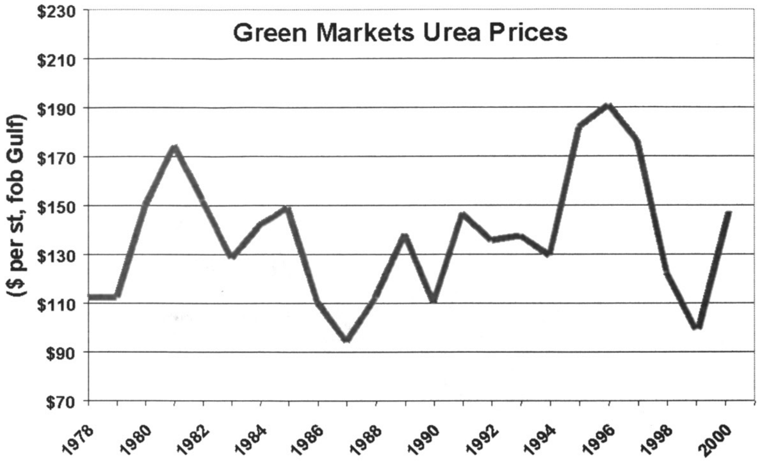
Nitrogen prices are also higher.

Not everyone is enjoying this prosperity.

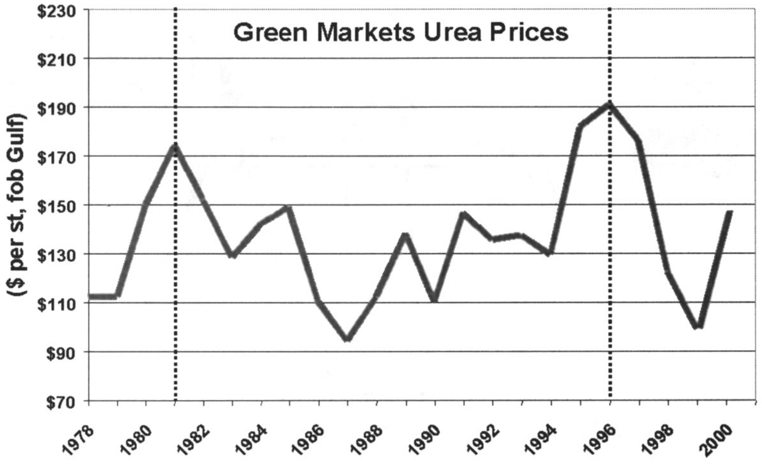
Production costs have exploded.

- Natural gas costs
- Ammonia feedstock

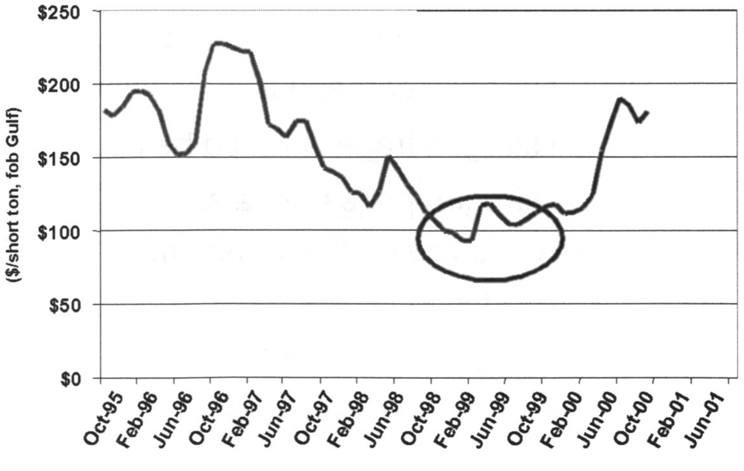
The Nitrogen Market Is Cyclical



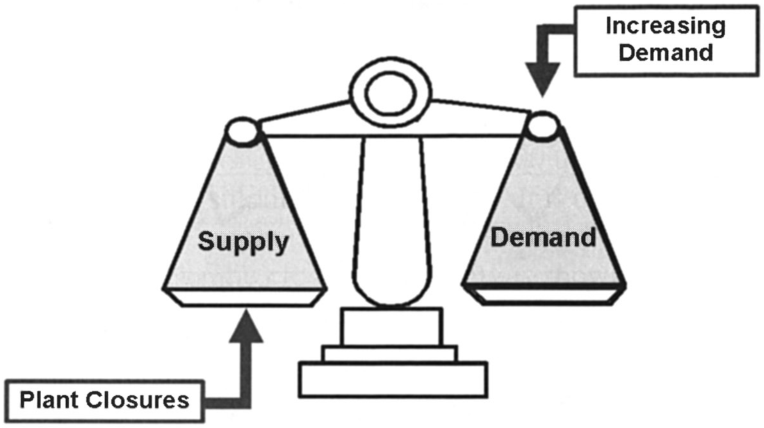
The Last Urea Cycle Lasted 15 years



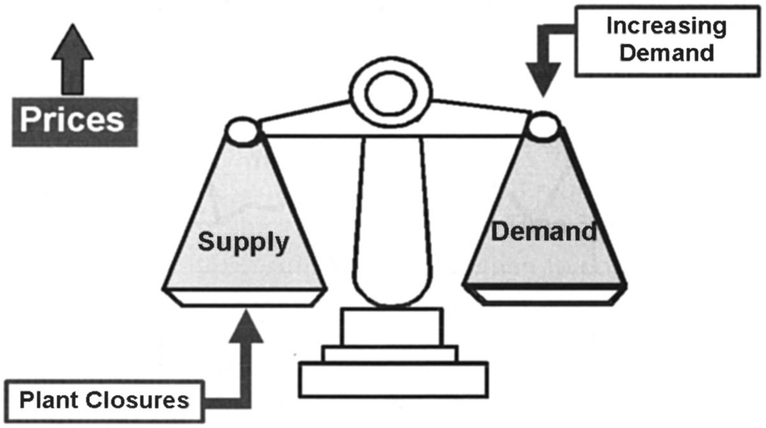
Market Bottomed Out Last Summer



Plant Closures & Increasing Demand Brought Nitrogen S/D Back Into Balance



Nitrogen Prices Responded



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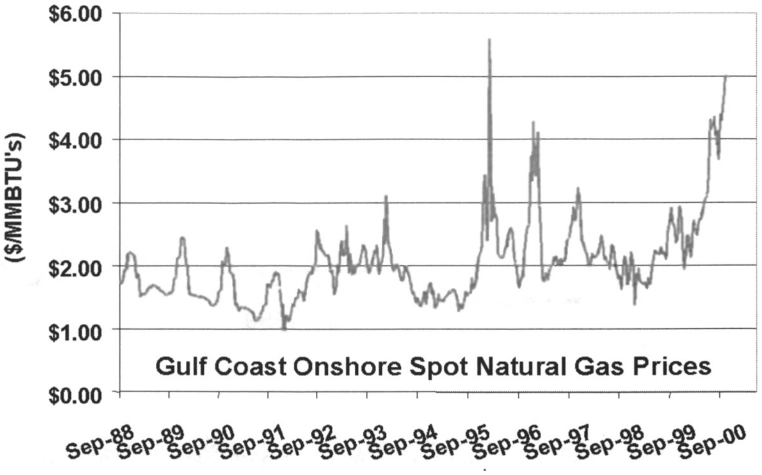
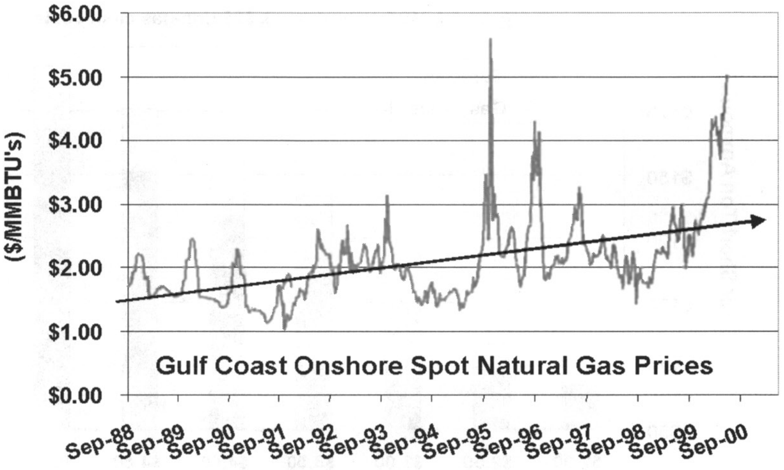
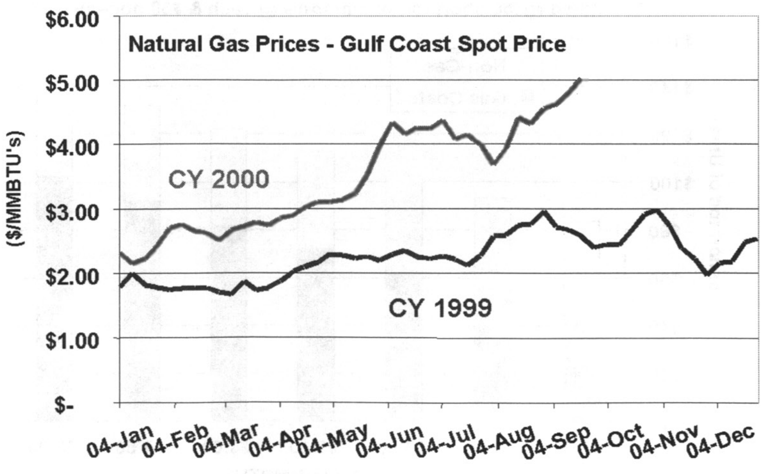
Gas Costs Are Seasonal & Fluctuate Widely



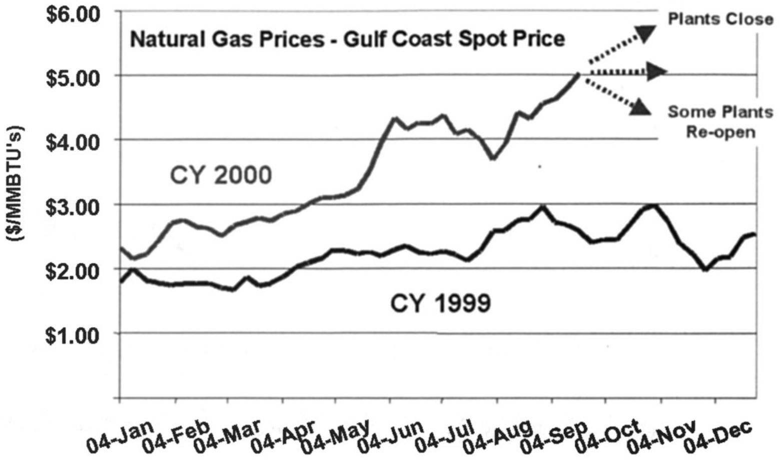
North American Gas Costs Trending Upward



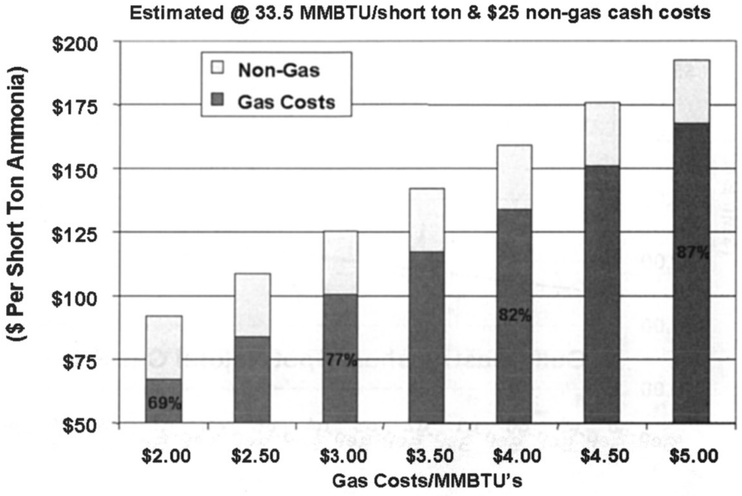
Gas Costs Are High & Remain Strong



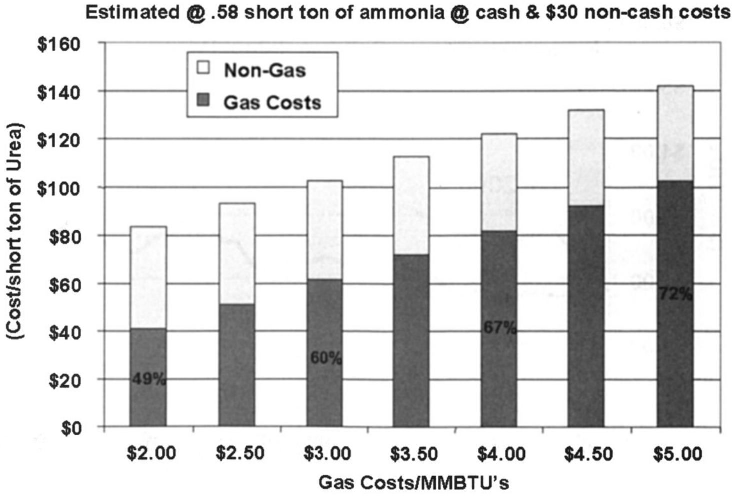
High Gas Costs Could Reduce Production



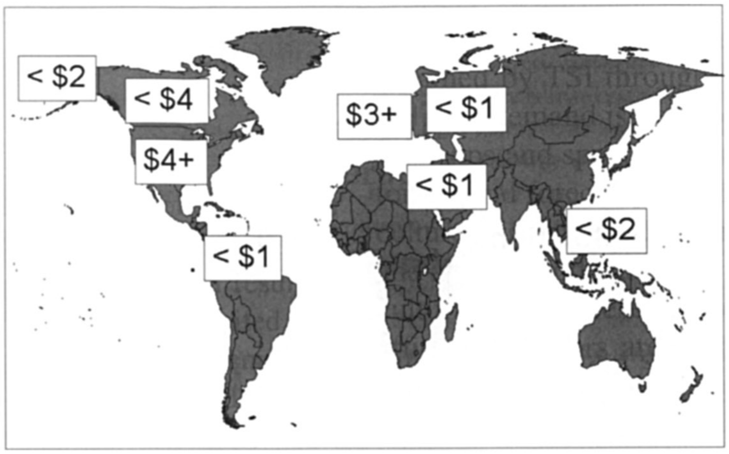
Ammonia Cash Production Costs


Estimated @ 33.5 MMBTU/short ton & $25 non-gas cash costs

Gas Costs Are Also Important For Urea


Estimated @ .58 short ton of ammonia @ cash & $30 non-cash costs

Natural Gas Costs Around the World



United States Is The Second Largest Producer & Consumer & Largest Importer

(Millions Short Tons of Ammonia)

	Production	Consumption	Net Imports
China	38	38	----
➡ U.S.	17	21	4
India	14	15	1
Russia	10	7	(3)
Ukraine	5	3	(2)
Others	59	59	11
World	143	143	16

Note: Includes both fertilizer & industrial production

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Note: Includes both fertilizer & industrial production

Imports Up Across The Board

U.S. Fertilizer Imports
(Millions of short tons of products)

	FY 98/99	FY 99/00	FY 00/01(f)	% Change
Ammonia	4.6	4.7	5.0	7 %
Nitrogen Solutions	0.7	0.9	1.0	11 %
Urea	3.6	3.6	4.0	9 %
Ammonium Nitrate	0.9	1.0	1.0	2 %
Total Nitrogen	6.0	6.2	6.7	7 %

Source: TFI with MCC Market Research adjustments

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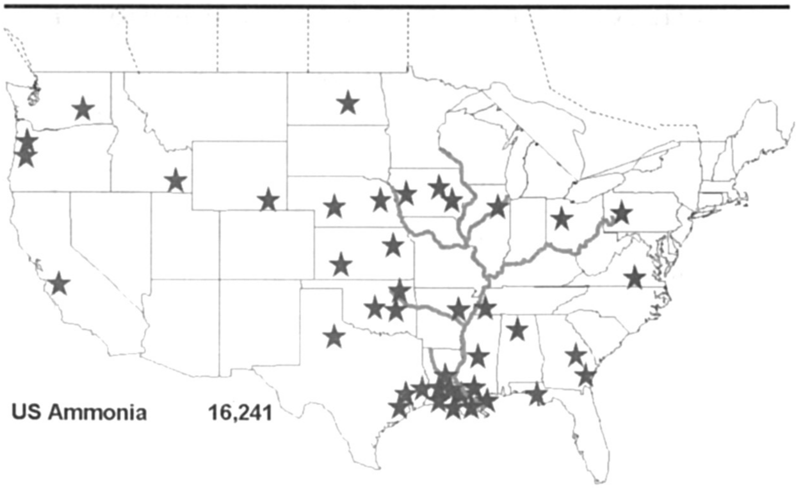
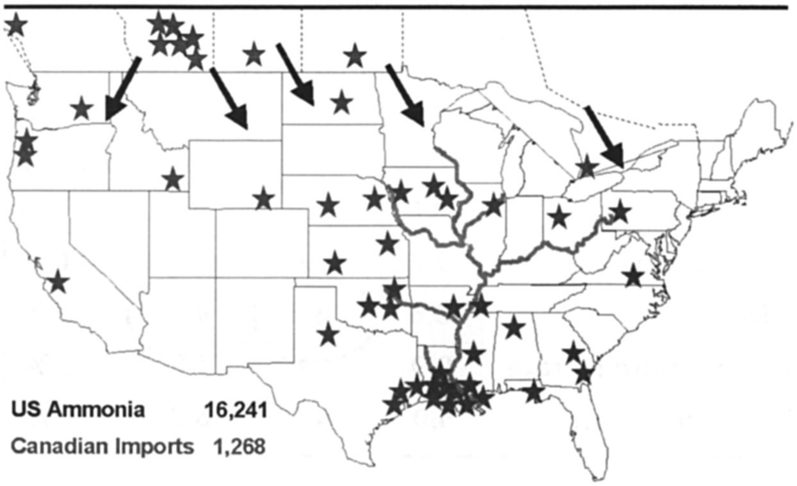
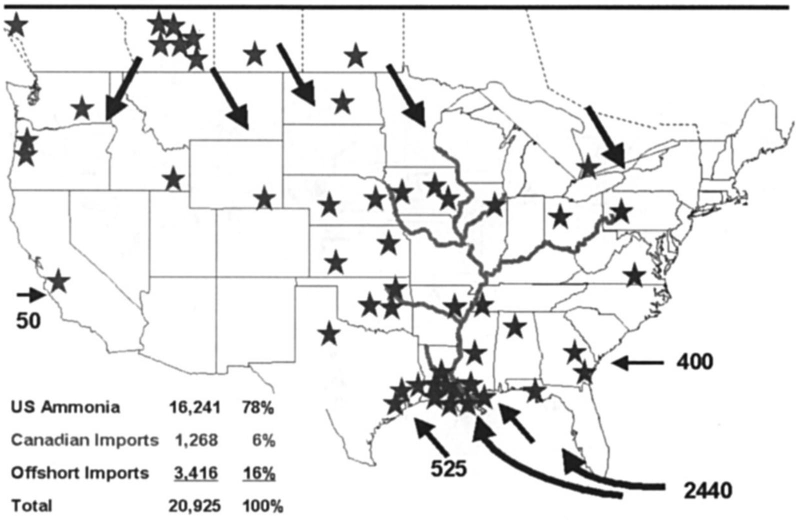
U.S. Ammonia Market - 1999/00



U.S. Ammonia Market - 1999/00



U.S. Ammonia Market - 1999/00



Ammonia Imports Into The Gulf - 1999/00

	Tons	Ocean Freight
Trinidad	2,285	$20 - $25
Ukraine	400	$35 - $45
Russia	200	$35 - $45
Mexico	80	$15 - $25
Total Imports	2,965	

Imports Up Across The Board

U.S. Fertilizer Imports
(Millions of short tons of products)

	FY 98/99	FY 99/00	FY 00/01(f)	% Change
Ammonia	4.6	4.7	5.0	7 %
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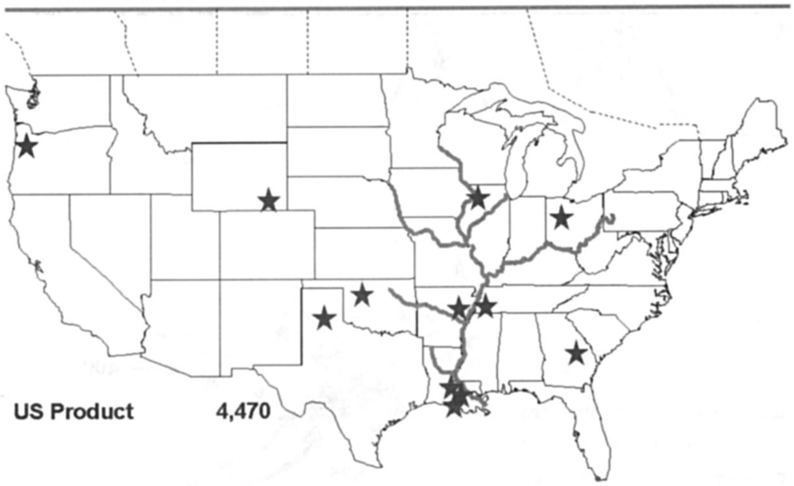
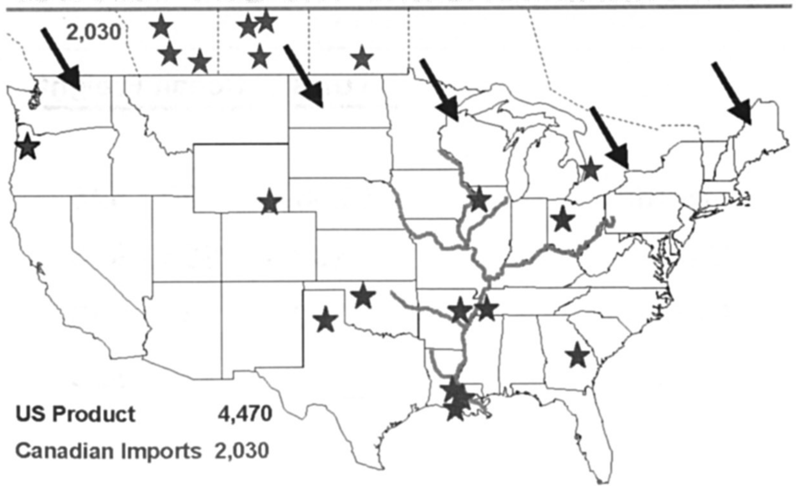
Source: TFI with MCC Market Research adjustments

U.S. Urea Market - 1999/00



U.S. Urea Market - 1999/00



Urea Imports Into New Orleans - 1999/00

	Tons	Ocean Freight
Saudi Arabia	295	$13
Qatar	210	$16
Trinidad	137	$ 9
Bahrain	107	$17
Egypt	95	$15
Kuwait	22	$15
Venezuela	37	$10
Croatia	23	$16
Total Imports	926	$14

Nitrogen Outlook Is Positive

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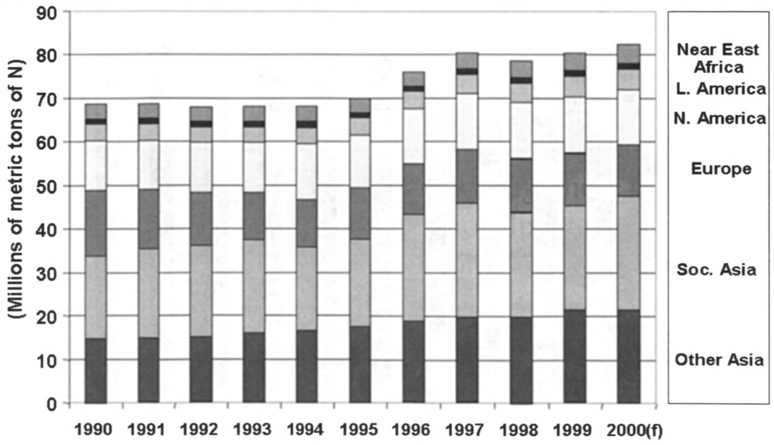
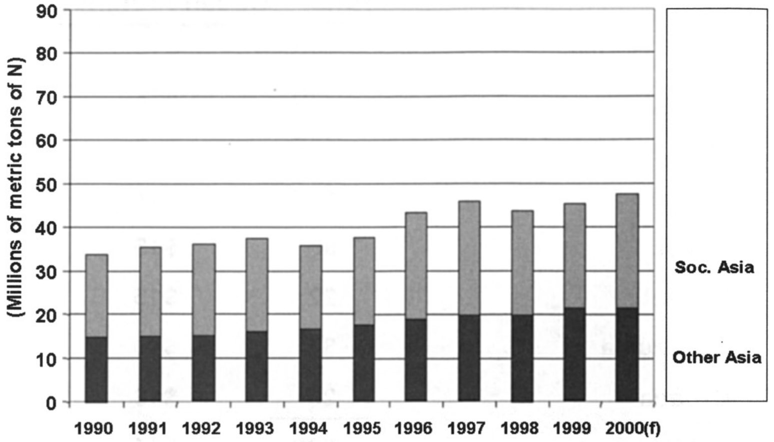
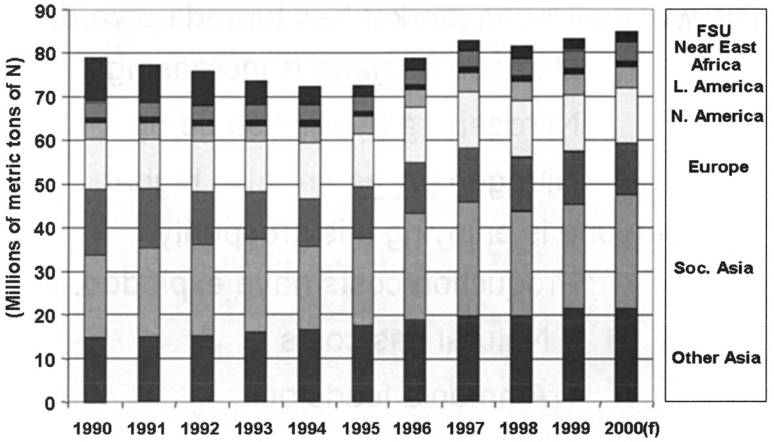
Nitrogen Fertilizer Demand (Ex. FSU) Has Been Growing In The 90's



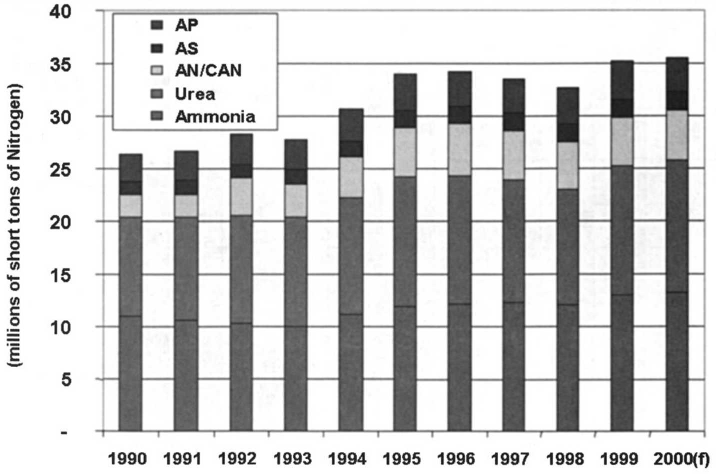
Most Of The Growth In Nitrogen Demand Was In Asia



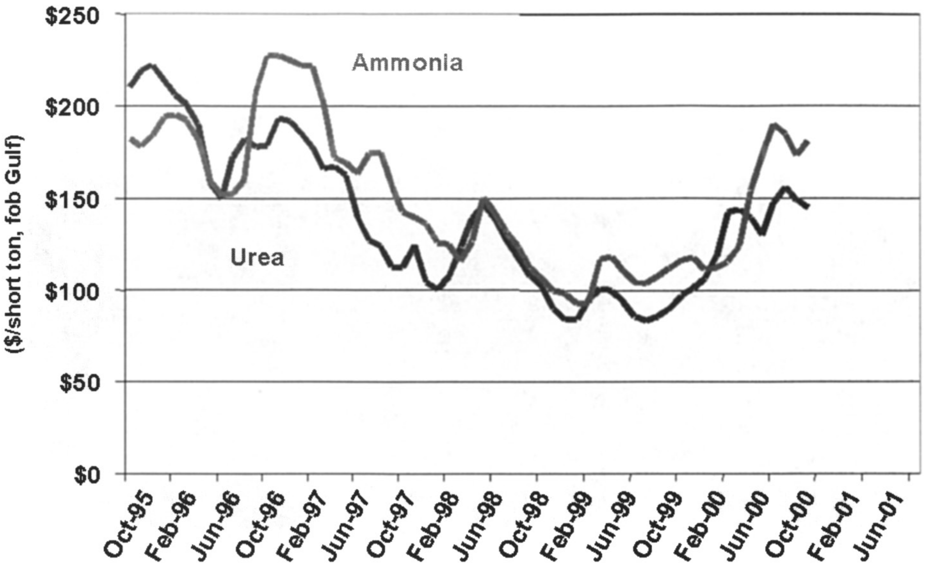
Nitrogen Fertilizer Demand Should Increase Again In 2000



Nitrogen Trade Should Also Be Up



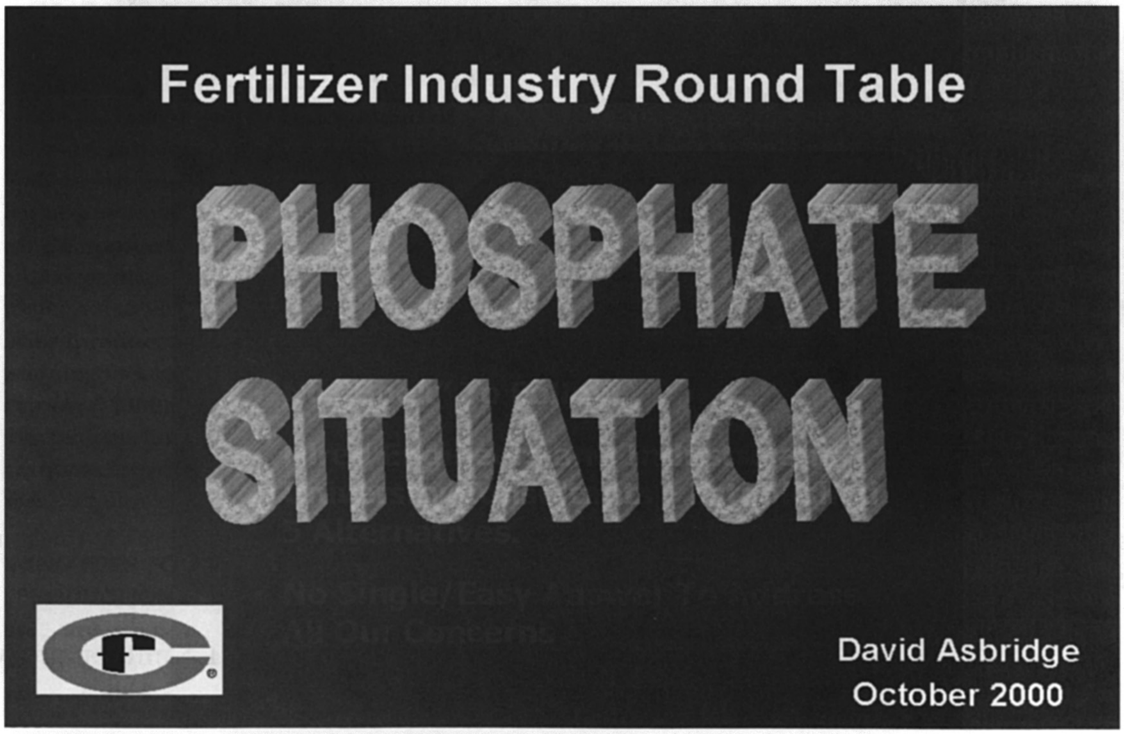
Nitrogen Prices Are Also Higher



Outlook for Phosphate

David Asbridge

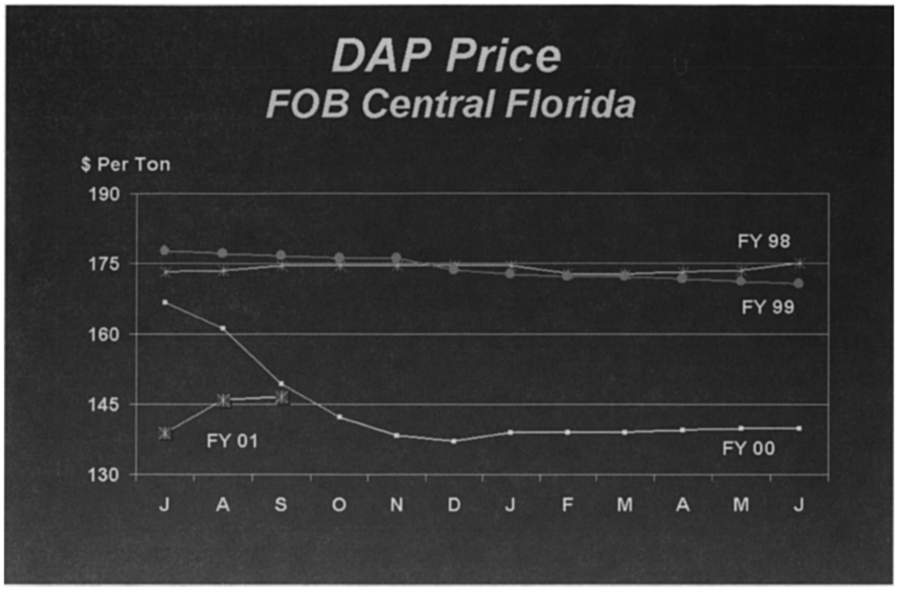
CF Industries, Inc.



Fertilizer Industry Round Table

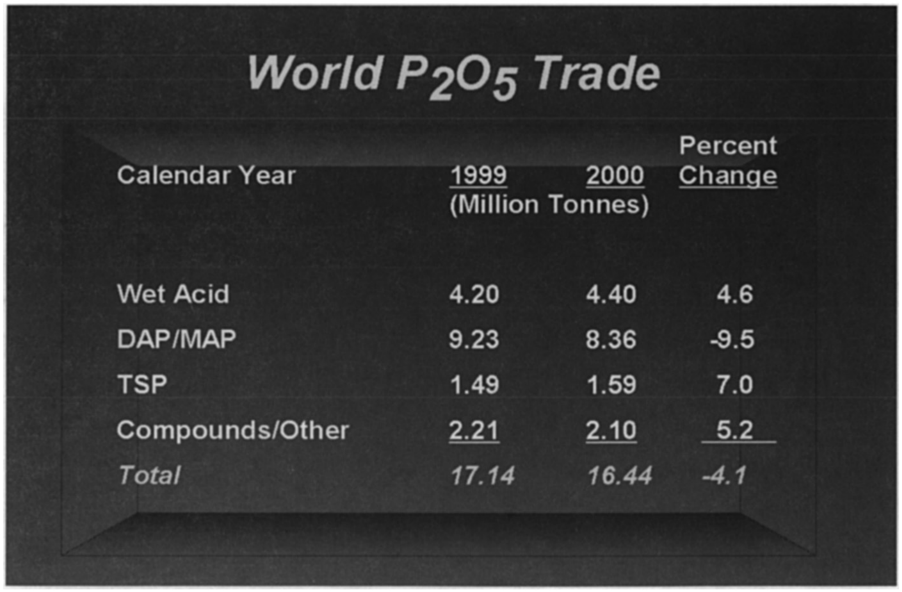
PHOSPHATE SITUATION

David Asbridge
October 2000



The DAP market remained depressed throughout most of FY 2000 as a result of a relatively weak domestic market and a sharp decline in U.S. exports.

For FY 2001, the DAP market showed some signs of strengthening due to IMC's idling the remainder of their phosphate capacity in Louisiana, and the improving outlook for exports. IMC has recently re-opened part of the Louisiana facility.

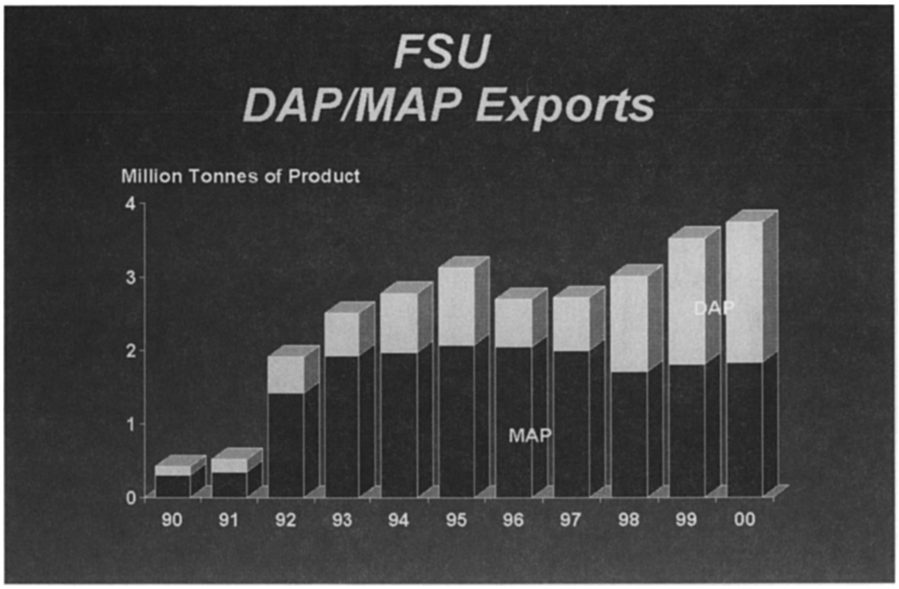


World P_2O_5 Trade

Calendar Year	1999 (Million Tonnes)	2000	Percent Change
Wet Acid	4.20	4.40	4.6
DAP/MAP	9.23	8.36	-9.5
TSP	1.49	1.59	7.0
Compounds/Other	2.21	2.10	5.2
Total	*17.14*	*16.44*	*-4.1*

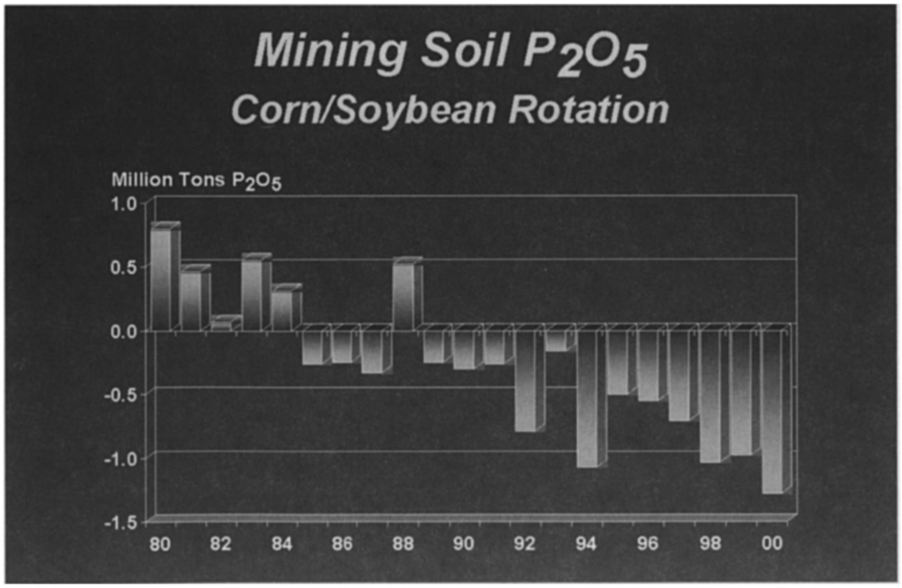
U.S. exports of DAP/MAP are estimated to have dropped by nearly 10% in FY 2000 with the majority of the decline in DAP.

Most of the decline was in exports to China which dropped by an estimated 1.5 million product tons. Exports to India also declined marginally from year-ago levels.



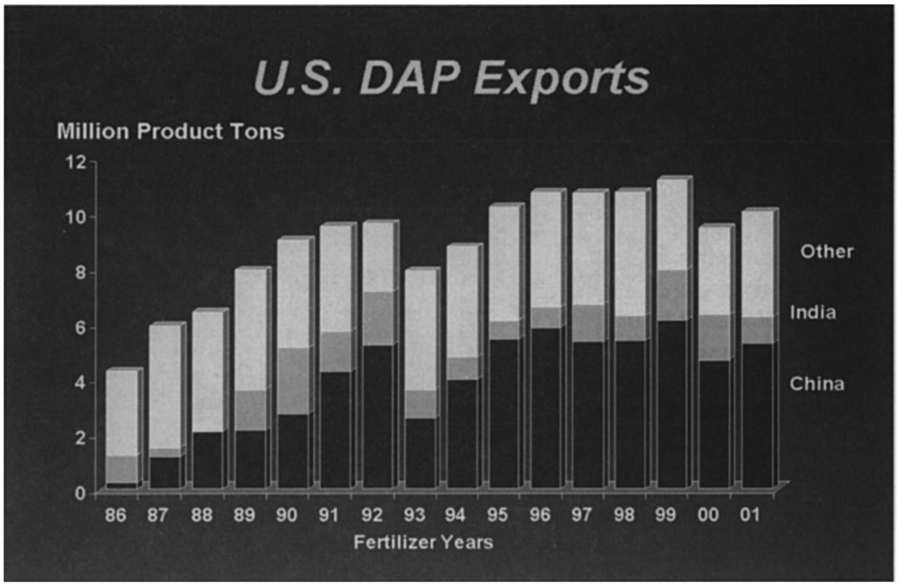
Another key factor for the decline in U.S. exports was the large increase in DAP exports out of the former Soviet Union.

FSU DAP exports have more than doubled over the last few years from 715,000 tons in 1997, to 1.5 million tons in 1999, and to an expected total of 1.9 million tons in 2000. The FSU has been particularly aggressive into Latin America which has traditionally been a U.S. market.



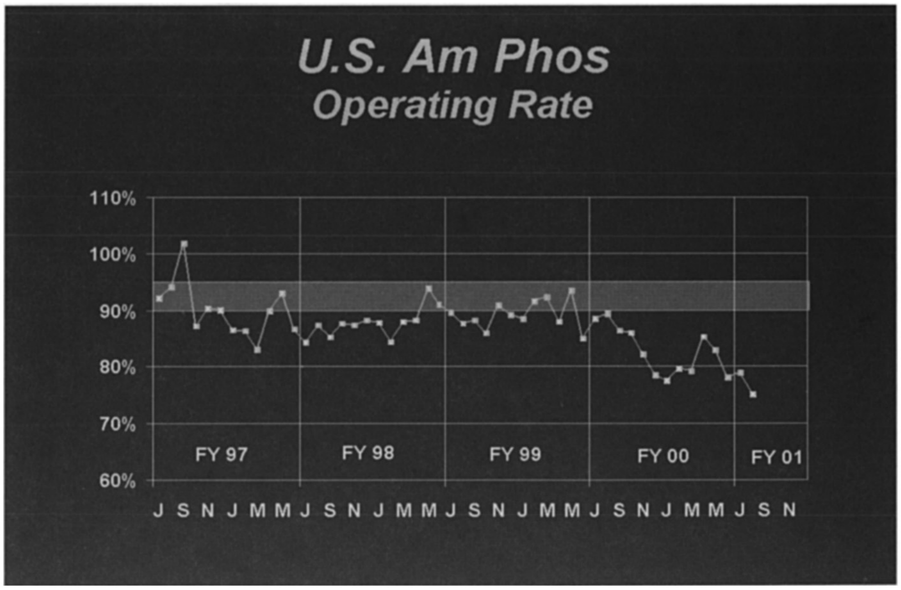
One disturbing feature about the U.S. phosphate market since the mid-1980's is the tendency for farmers to "mine" phosphate from the soil.

Over the last twenty years, U.S. farmers have pulled over 5 million tons of P_2O_5 out of the soil in a typical corn/soybean rotation due to under-fertilization. Short crops, typically due to droughts, show up as increases in nutrients due to the smaller amount of crops that are harvested. This is particularly noticeable in 1980, 1983 and 1988.



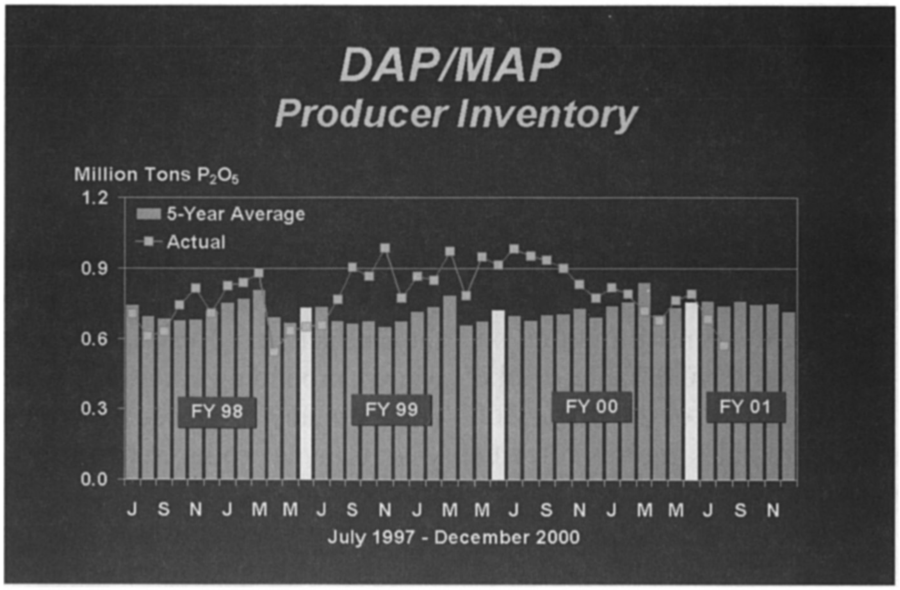
The outlook for exports appears reasonably positive, with a large baseload of tonnage expected to be shipped to China and strong demand in Latin America, Pakistan and other Asian markets.

Although DAP exports are projected to recover from last year's depressed levels, they are not expected to reach the record level of FY 1999.



U.S. DAP production dropped substantially during the second half of FY 2000 with the industry operating rate falling to an average of only 82%. This compares to an average operating rate over the last few years of almost 90%.

The direction of the DAP market will continue to depend on whether producers can continue to match production with demand.



With the drop in production, U.S. producer inventory has declined from the extremely high levels at the beginning of FY 2000.

Assuming U.S. production remains curtailed over the next few months, U.S. producer inventory is expected to stay in a balanced-to-tight position.

DAP/MAP Factors

Positive

- Improved export outlook
- Reduced U.S. production
- Declining inventory

Negative/Uncertainty

- No growth in domestic demand
- Excess capacity

Outlook for Potash

Rick Brasnett

Potash Corporation of Saskatchewan

Thank you and good morning. It is a real pleasure to be here in New Orleans to present our outlook for potash. I intend to provide you with the "big picture" on potash – where the industry is at and where it is going. But first it seems fitting that on the 50th Anniversary of the Round Table, I take you back in time and share a bit of the history of potash. All production and sales figures refer to product tonnes unless otherwise stated.

The term potash is derived from the old method of producing potassium carbonate by leaching wood ashes and evaporating the solutions collected in large iron pots. The white residue left in the pot was called "pot ash" and was used in the manufacture of soaps, glass and medicines. Later, potash became the term widely applied to naturally occurring potassium salts and the commercial product derived from them.

Soluble potash salts were first discovered in deposits in the Stassfurt region of Germany in 1839 and commercial production began 22 years later. France officially began producing potash in 1919 when mines in Alsace came under French sovereignty after WWI. Potash production began in 1930 in Palestine from the mineral salts of the Dead Sea. In the Soviet Union, potash production began in 1931 from deposits in the Ural Mountains. In 1925, potash deposits were discovered at Carlsbad, New Mexico while oil was being drilled for, and production commenced seven years later. The largest high-grade deposits of potash in the world were discovered in the 1940s in Saskatchewan, and production began in 1962.

While reserves are plentiful, they are not widely dispersed. Canada and the FSU have the largest reserve base. Canada's reserves are concentrated in Saskatchewan and cover a large area. It is estimated that Saskatchewan alone can continue to produce at the current level for several thousand years.

Today only 13 countries produce potash, as figure 1 shows - two in North America, four in Europe, two in the FSU, two in the Middle East plus China, Brazil and Chile.

Canada is by far the largest producer and produced over 8 million tonnes of potash in 1999, double the production of Russia, Belarus or Germany. The top six producing countries, which include Israel and Germany, produced 87 percent of the total last year. Canada produced one-third.

More than 150 countries consume potash. The US is by far the largest; it consumed 8.4 million tonnes in 1999, one-fifth of the total. China was a distant second at half that level, followed by Brazil, India, France and Malaysia. The top six accounted for 58 percent of potash used.

In the US, corn is the major consumer of potash and over 40 percent of the total used is applied to corn. In China, where farmers can grow two or three crops a year, rice is the largest consumer. An estimated one-quarter of the potash used in China is applied to rice. In Brazil, roughly 70 percent of potash is used on soybeans, sugar cane and corn. In Malaysia, oil palm is the single largest consumer, taking as much as 75 percent of the potash used.

It should be no surprise that with so few producers and so many consumers, as much as 80 percent of the potash produced crosses borders into other countries.

While the US produces potash, it is not enough to meet its needs and it is the world's largest importer. In 1999, the US imported 7.3 million tonnes, almost 90 percent of its requirements. China and Brazil, also large and important agricultural producers, are in much the same boat. Their potash production is far too small to meet their needs. In fact, like the US, China imported 90 percent of its requirements last year, and Brazil, 85 percent. India does not have any production and imports all of its potash, 3 million tonnes last year. The US accounted for 22 percent of the total imported in 1999. The top six importers, which include France and Malaysia, accounted for 65 percent of total imports.

Who are the largest potash exporters? The largest producers are also the major exporters, with Canada leading the way with 40 percent of total exports in 1999. The top six producers accounted for 95 percent of the total.

With this snapshot of the past and quick review of who's who in the industry, let's now look at recent developments and the outlook for potash.

While demand is growing once again after bottoming out in 1993 following the collapse of Communism in East Europe and the FSU, there is still a lot of surplus potash capacity as can be seen in Figure 2. This remains a problem. But while demand does not always grow steadily, the trend is definitely up. At current growth rates, demand will absorb the existing capacity in 11 years.

Most of the surplus capacity is in the hands of producers in Canada and the FSU, as Figure 3 shows. In 1999, Canadian and FSU producers accounted for 80 percent of surplus capacity. The PCS share of that surplus was 60 percent. Other producers operated at or near capacity in 1999. This year has been much the same although our company is benefiting from continued strong global demand.

The potash industry has gone through some very difficult times. The 1980s were particularly troublesome and volatile markets, imprudent expansions, oversupply and low prices of that decade set the stage for consolidation and rationalization. In Canada, the changes were significant. In 1989-90, there were 87 producers capable of producing nearly 20 million tonnes of potash, as listed in Figure 4. Today there are only three producers and total production capacity is 20.6 million tonnes.

PCS is the largest producer with seven mines – six in Saskatchewan and one in New Brunswick – accounting for 59 percent of total Canadian capacity. IMC produces potash at three locations in Saskatchewan and accounts for 33 percent of Canadian capacity. Agrium has one mine with 8 percent of capacity.

The change in direction for PCS began in 1987 when new management was brought in to shore up the company. Management's strategy from the outset was to try to balance supply with demand. While the company has a lot of excess capacity, and while world demand is increasing, we have continued to try to match production with demand. We monitor demand closely.

Let's turn now to the US where, like Canada, the industry has seen its share of consolidation and rationalization. The five major producers in 1989 have become two; namely, IMC-Kalium and Mississippi Potash, both with facilities in New Mexico. Horizon was shut down in the early '90s and Mississippi Potash closed one of its 32 mines in December 1998 because the ore body was declining. As a result, production in the US has been falling. However, it appears that US production and sales have now bottomed out and will level off in the near future.

That's the story in North America, now let's look at the FSU, another large producer and a major competitor for us.

Two major reserve and production areas – in Belarus south of Minsk at Soligorsk and in Russia on the western slope of the Ural Mountains – comprise the potash industry in the FSU, the second largest world producer when these two countries are grouped together. Belaruskali is government-owned but the Russian producers, Uralkali and Sylvinit, are now privately-held joint stock companies. In 1999, these three producers together produced 12.6 million tonnes.

Production and sales in the FSU began to increase in 1994, as shown in Figure 5, after bottoming out in '93 due to the collapse of Communism. Exports have been rising. Domestic consumption is only a fraction of what it was under the former Communist government. Improvement has been slow and crop production has suffered. In 1999, for example, Russia produced 55 million tonnes of grain, compared to almost twice as much 10 years ago. Some of the decline was due to drought and pests, but much has been caused by the lack of proper fertilizer application. Until demand comes back, producers are expected to continue to look to offshore markets. However, while ports are expanding, we believe there are limits to export growth.

Several of the Russian mines date back to the 1930s and '50s and they need major repairs. The ore grade is low, roughly 14 percent K2O compared to around 26 percent in Canada. Belarus is perhaps in better shape as most of the mines there were constructed in the 1960s and '70s and the ore grade is approximately 18 percent K2O. But perhaps even more significant as time goes on are the productivity levels. In Russia, the work force is close to 21,000 with 12,000 directly involved in mining and milling operations. The situation in Belarus is much the same. This drives the productivity level down and costs way up. The productivity ratio in Canada is 10 times that of the FSU. It takes only one worker in Canada to produce 4,000 tonnes of potash, in the FSU it takes 10. This is not sustainable long-term.

Now let's look at production outside of the two largest producing regions.

As illustrated in Figure 6, production in Western Europe has been declining, while it has been expanding in the Middle East and elsewhere, namely Brazil, Chile and China. But the increase has not been enough to offset the decline in Europe.

The German industry was consolidated after the reunification of Germany. Mines were closed and production was reduced. Some improvement has been made to the two former East German mines still operating. The big change has been in France which is running out of ore reserves; production is to close in 2004, resulting in a loss of 600,000 tonnes KCl. In 1998, Israel's Dead Sea Works purchased Spain's potash industry. While there are plans to improve productivity at the existing mines and mills, there are no signs of it yet. Production was down in the first six months of 2000. The UK has had flooding problems but production has been stabilized. Looking ahead, we do not expect any significant increases in production in Europe.

In the Middle East, Israel and Jordan have both completed expansions and production has been slowly rising, but there are limits to growth. DSW has no room to enlarge its evaporation ponds, which are currently over 90 km square. Jordan is expanding its pond system and milling capacity to bring annual production to 2.4 million MTPA KCl by 2004, an increase of 400,000 tonnes. The build-up of "salt mushrooms" has complicated and reduced production in recent years, but Jordan has for the most part resolved this problem. High temperatures and ideal evaporation conditions helped it reach 1.8 million tonnes last year.

Turning to the remaining three countries, all small producers.

After 15 years and millions of dollars of additional capital, Brazil's sole potash producer has at last reached design capacity, producing 550,000 tonnes last year. While Brazil struggled to bring its mine to capacity, Chile to the west has been gradually increasing its potassium chloride production. In 1999, SQM produced 500,000 tonnes KCl by solar evaporation at its facilities in the Atacama Desert. The KCl is mostly used as feedstock for potassium nitrate production. SQM plans to raise its KCl capacity by a further 200,000 tonnes.

China's potash production is centered around Lake Qarhan, inland in the Province of Qinghai far from the major market area. Two potassium fertilizer factories there produce much of the country's potash. They have the capacity to produce about 400,000 MTPA KCl by solar evaporation. Qinghai Potash Factory is the largest with a capacity of around 300,000 MTPA and is the site of the former Sino-Israeli JV project. Last year China produced an estimated 400,000 tonnes KCl. Several projects have been proposed to expand existing capacity there but to date there has been nothing.

Let's look at the demand side of the equation and growth opportunities before I try to pull it all together.

About 95 percent of the potash consumed in the world goes into fertilizer and potash fertilizer consumption is expected to grow by about 2.5 percent a year, on average, over the period 1999 to 2005. The two largest markets, North America and Europe, are mature as illustrated in Figure 7. Consumption in Europe has been declining due to environmental pressures but should soon begin to stabilize. Application rates were some of the highest in the world. Potash consumption in the US is expected to continue to increase as world demand for food increases.

Most of the growth will be in the developing world, particularly Latin America and Asia (see Figure 8).

The greatest potential lies in Asia and Latin America. At the top of the list are China, India and Brazil. Their NK ratios are still far below optimum levels. China should have a ratio of 4:1but it's closer to 6:1 with compounds included. China's potash consumption is forecast to grow by 4.4 percent per year over the six-year period through 2005 to 4.2 million tonnes K2O. India's ratio has fallen back to 8:1. In time, these markets should approach the US ratio of 2:1. Brazil's ratio is .7:1. It is skewed by the large acreage planted to soybeans and the low N use on corn. Brazil needs to use more of all three nutrients. But one must not forget the other markets in Southeast Asia such as Thailand and Vietnam and those in Latin America, which are rapidly emerging as major consumers and importers of potash and other fertilizers. Vietnam has quadrupled its potash imports in the last four years and Thailand's has tripled in 10 years. And there are others in the wings.

Looking ahead, here is what we see for new capacity and demand growth.

While there has been a lot of talk, no major new capacity additions are expected in the near future – only smaller, incremental additions. In Canada, only 200,000 tonnes are certain. IMC-Kalium is expanding its industrial production but other expansions it announced have been put on hold. Jordan is adding 400,000 tonnes of incremental capacity and Chile 200,000 tonnes. These expansions will be offset in part by the closure of the French industry in 2004 or earlier.

Major potash projects you have heard about, as in China and Thailand, are far from certain. Financing continues to be a problem for these projects take a lot of capital and there is a great deal of risk. The proposed $500-million Sino-Israeli JV project to expand production in Qinghai province by 800,000 MTPA from 300,000 MTPA has been dropped. A new group of Chinese investors is now proposing to add 1 million tonnes of capacity in various stages. In our estimation, it would cost upwards of $1 billion to build a 2-million MTPA "greenfield" potash facility in Thailand. A new mine and mill in that tropical environment is not without significant risks. The proposed ASEAN project has many of the same risks. Potash has been discovered in Argentina but the reserves have not been developed due to their remote location and the lack of existing infrastructure. Down the road, there may well be new "grassroots" production but it is years away.

As can be seen in Figure 9, growth in demand is expected to outstrip new capacity over the next five years. The gap could amount to as much as 4 - 5 million tonnes at its peak. Fortunately for consumers, there is 8-10 million tonnes of surplus capacity in the world.

Who will fill the gap?

The FSU will fill some of the gap, but there are unanswered questions there. Can it continue to produce exclusively for the export market at the expense of the domestic market? What is the future of FSU domestic demand? Who will fill the void left by closure of the French industry? It is certainly possible that when domestic demand comes back in Russia and Central Europe, and as the French industry declines, more FSU production will remain at home and in the nearby markets in Europe.

At Potash Corporation of Saskatchewan, we have 6 million tonnes of excess capacity waiting to be utilized and, with port facilities on Canada's east and west coasts, are well-positioned to handle the new growth opportunities that arise in Asia and Latin America. Yes, it will require some capital to bring our surplus capacity into production but we are committed to doing so. We are excited about what lies ahead.

Thank you for the opportunity to share this view with you. I would be pleased to answer any questions you may have.

This release contains forward-looking statements, which involve risks and uncertainties, including those referred to in the Company's annual report. A number of factors could cause actual results to differ materially from those in the forward-looking statements, including, but not limited to, fluctuation in supply and demand in fertilizer and petrochemical markets; changes in competitive pressures, including pricing pressures; changes in capital markets; changes in currency and exchange rates; unexpected geological or environmental conditions; and government policy changes.

Figure 1

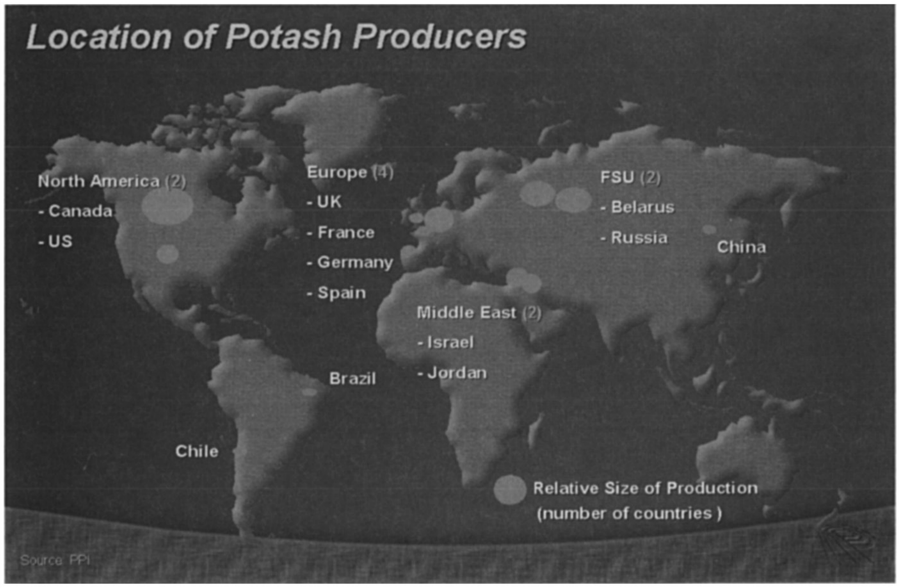
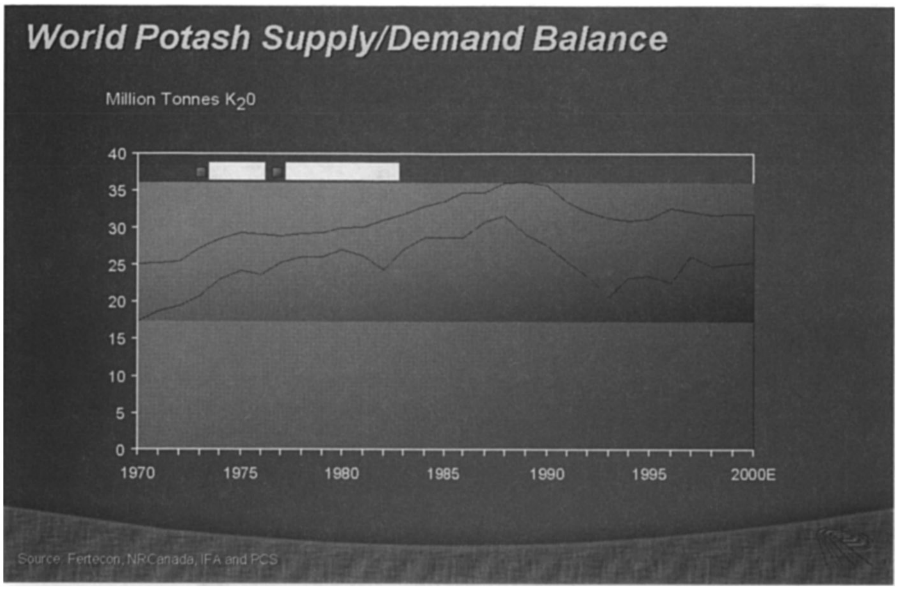


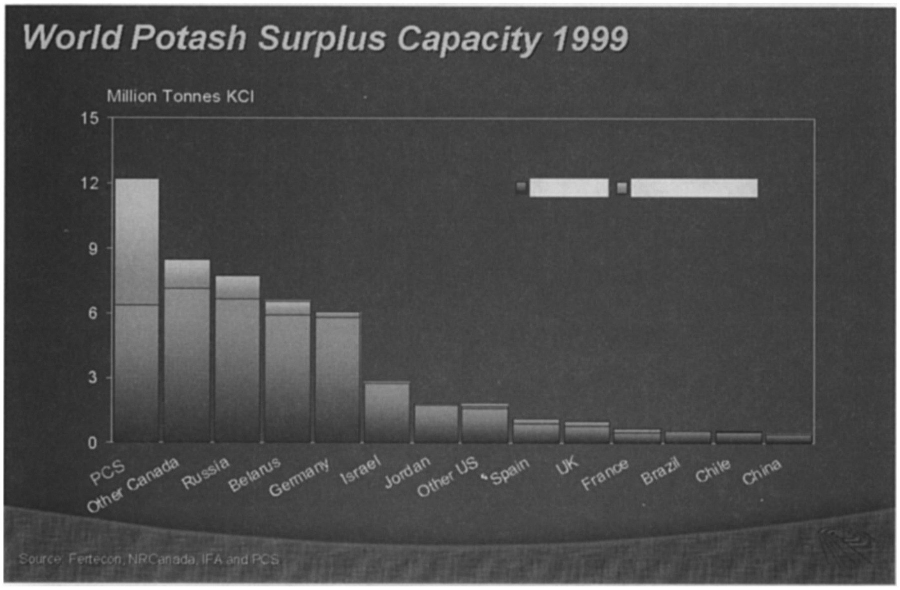
Figure 2



World Potash Supply/Demand Balance

Source: Fertecon, NRCanada, IFA and PCS

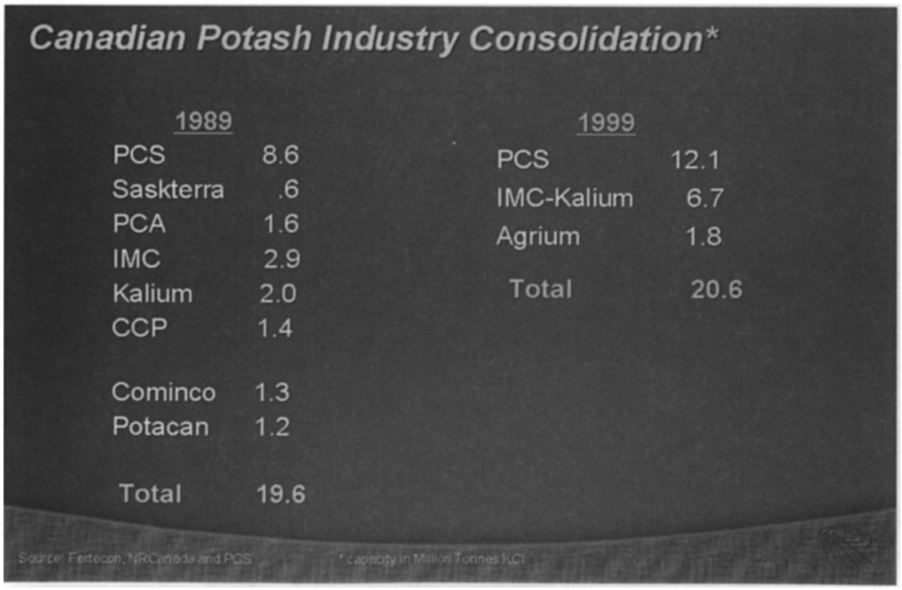
Figure 3



World Potash Surplus Capacity 1999

Source: Fertecon, NRCanada, IFA and PCS

Fugure 4



Canadian Potash Industry Consolidation*

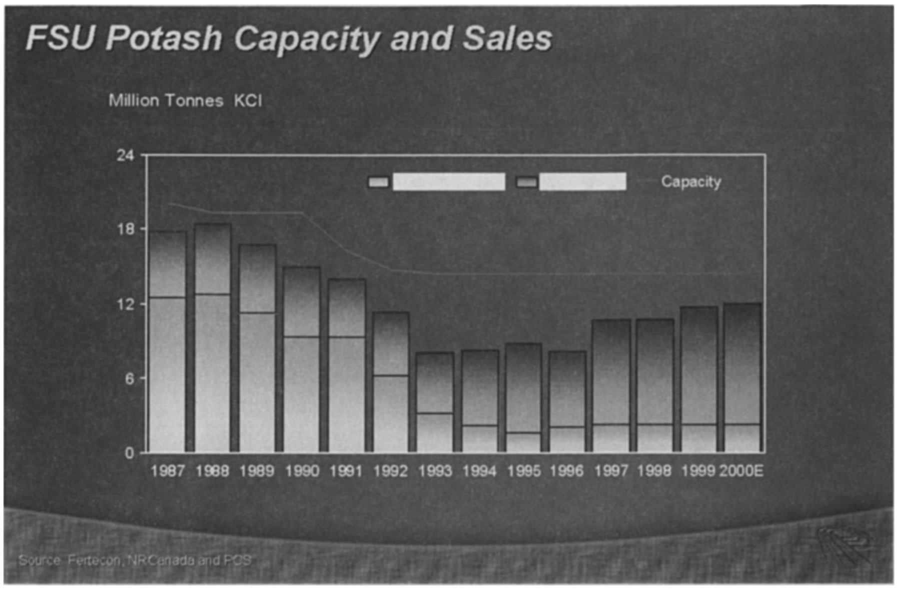
1989	
PCS	8.6
Saskterra	.6
PCA	1.6
IMC	2.9
Kalium	2.0
CCP	1.4
Cominco	1.3
Potacan	1.2
Total	19.6

1999	
PCS	12.1
IMC-Kalium	6.7
Agrium	1.8
Total	20.6

Source: Fertecon, NRCanada and PCS

* capacity in Million Tonnes KCl

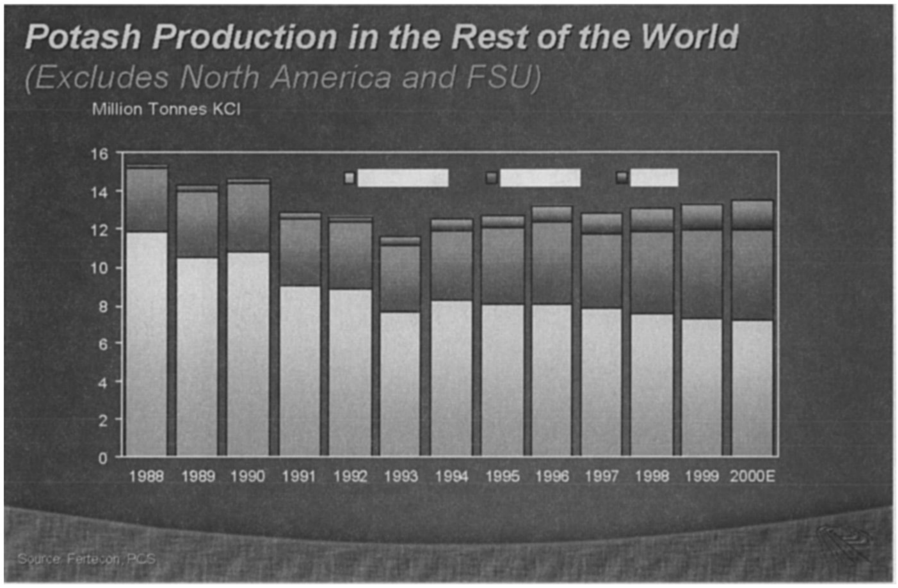
Figure 5



FSU Potash Capacity and Sales

Source: Fertecon, NRCanada and PCS

Figure 6

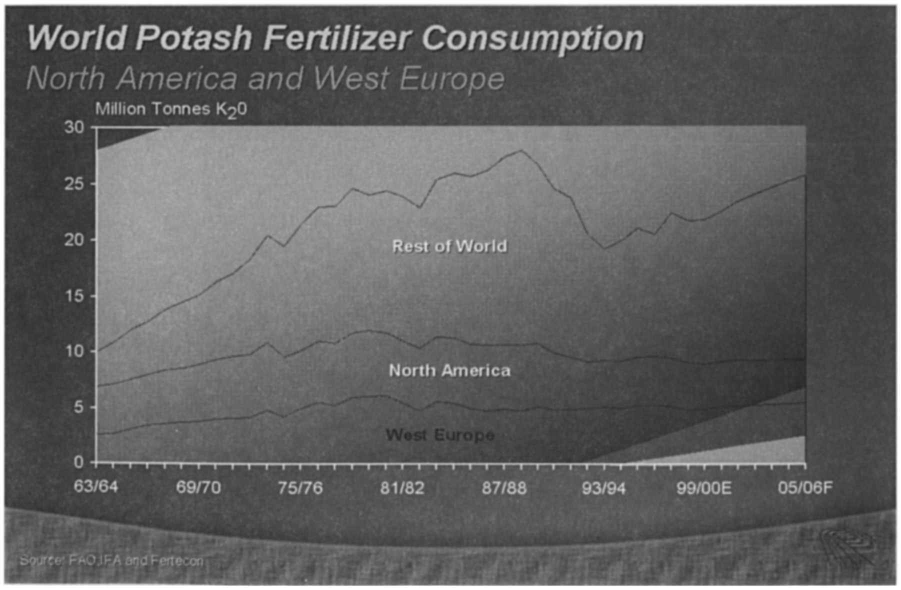


Potash Production in the Rest of the World

(Excludes North America and FSU)

Source: Fertecon, PCS

Figure 7

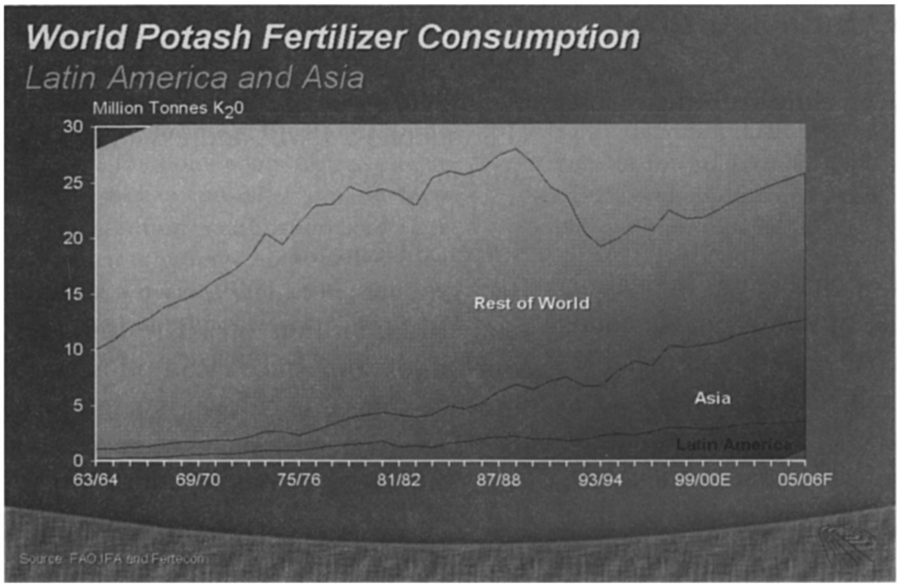


World Potash Fertilizer Consumption

North America and West Europe

Source: FAO,IFA and Fertecon

Figure 8

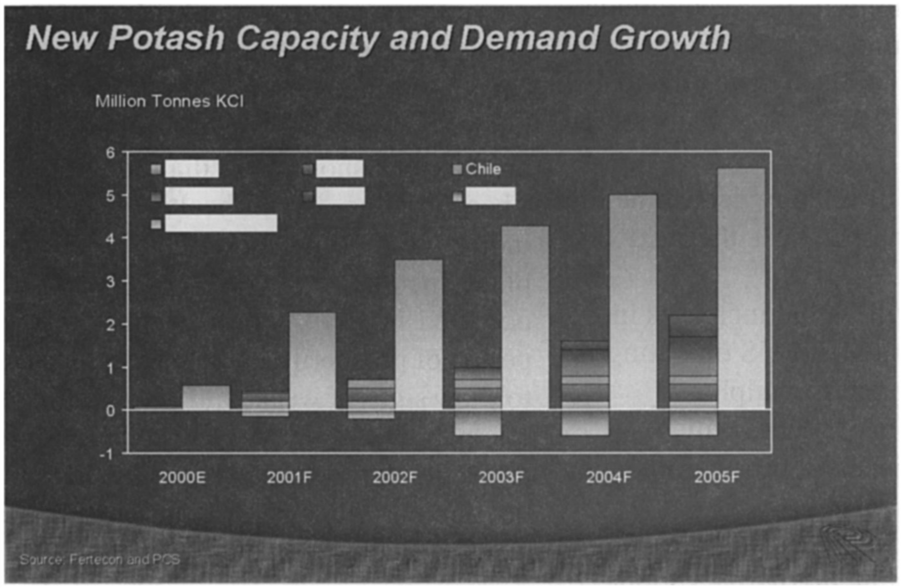


World Potash Fertilizer Consumption

Latin America and Asia

Source: FAO,IFA and Fertecon

Figure 9



New Potash Capacity and Demand Growth

Source: Fertecon and PCS

The U.S. Sulphur Outlook to 2005

Kenneth D. Ellzey
Freeport-McMoRan Sulphur Inc.

Introduction:

Over the outlook period, the U.S. sulphur market is faced with a complex set of challenges in dealing with the irrepressible forces of supply and demand. While the trends have been clear, even predictable, these challenges are as substantial as any that it has faced in recent times. A significant amount of domestic production became uneconomic in 2000, and was removed from the supply equation during a period of depressed demand. These volumes can only be replaced by importation of alternative supplies in both liquid and solid form. Accommodating these additional volumes in a period that may not be characterized by depressed demand will test the industry's limits.

The key issues that will ultimately determine the course of the sulphur market over the next few years are:

- Demand: How will global increases in phosphate demand affect US operating rates and the demand for sulphur?
- Alternative Supplies: Where will alternative supplies be sourced from and in what form?
- Costs: What will be the cost to the market of importing alternative supplies?

Logistics, marketing and inventory management will play perhaps an even more critical role in the sulphur market than in the past. Many of you who recognize that sulphur is indeed "a business of logistics" may wonder how the role of logistics could become even more important than today. However, when you contemplate the amount of sulphur that must be imported, higher than at time in the past, the question that looms is: How will these supplies be handled?

General

Sulphur production is generally classified into three categories: elemental, pyrites and sulphur-in-other-forms. Together, the three categories comprise "sulphur-in-all-forms". Elemental sulphur represents over two-thirds of worldwide supplies of sulphur-in-all-forms and about 90 percent in the U.S. supplies. I will address only the elemental sulphur situation.

Sulphur Demand

Background: For 1999, U.S. sulphur demand totaled 12.6 million tons. This includes 11.9 million tons of domestic consumption and .07 million tons of exports. This level is slightly higher than the 1990's average demand of 12.4 million tons per year, and 360,000 tons or about 3 percent below the 1998 level.

Agricultural uses of sulphur dominate domestic consumption. Phosphate fertilizer manufacturing heads the list, accounting for greater than 90 percent of sulphur consumption. Approximately four-tenths of one long ton of sulphur is needed to produce one short ton of diammonium phosphate. Therefore, the overall health of the U.S. sulphur industry has been historically linked to phosphate plant operating rates. This is evidenced by what occurred in 1999, when an unusually protracted period of prosperity in the phosphate sector began to show signs of weakening. U.S. fertilizer producers, particularly large DAP exporters, responded to declining phosphate prices by announcing production curtailments or plant closures. By fourth quarter, IMC Global announced the indefinite and permanent closure of over 20% of its phosphate capacity. Later, Mulberry Corporation closed its Bartow Plant. As a result, sulphur consumption dropped by 9 percent as phosphate operating rates declined from 95 percent in January 1999 to 84 percent in January 2000.

Other uses of sulphur in the U.S. have remained fairly constant, and are generally consumed in the form of sulphuric acid. They include petroleum refining, pulp and paper manufacturing and metals leaching.

Sulphur exports round out the U.S. demand. In 1999, exports totaled 730,000 tons, primarily in solid form from the U.S. West Coast. This level represents the low end of exports for the 1990s, which reached a high of 1.3 million tons in 1991; the last year significant volumes of sulphur were exported from the Gulf Coast.

Outlook: While the outlook for non-fertilizer demand and exports is forecast to be essentially unchanged, the outlook for domestic consumption for fertilizer production is not as clear. The number of phosphate plant closures is clouding the picture. For 2000, total demand is forecast to be 11.9 million tons, a decrease of about 750,000 tons from the 1999 level. This is indeed a dramatic decrease in total demand. A modest but slow recovery is projected beginning in 2001.

Sulphur Supply

Background: The U.S. is the world's largest producer of sulphur, and has remained fairly consistent throughout the 1990s, averaging 10 million tons per year or about 27 percent of world production. The two principle sources of elemental sulphur, mined sulphur and recovered sulphur. Mined sulphur, often referred to as "Frasch" sulphur, is considered discretionary production, while recovered sulphur is produced as a by-product of crude oil refining and natural gas processing.

The U.S. is the world's second largest recovered sulphur producer, producing slightly less than Canada. The levels of recovered sulphur production largely depend on factors governing the total energy demand, and consumption of crude oil and natural gas. Recovered sulphur is produced by more than 50 companies at more than 130 refineries and gas treatment plants, and grew from 6.5 million tons in 1990 to 8.2 million tons in 1999. Production volumes declined slightly from the 1998 level.

Recovered sulphur produced from natural gas largely occurs along the central Gulf Coast and in the Rocky Mountain States. Produced as a by-product, gas-recovered sulphur volumes depend on natural gas demand and production, as well as the average hydrogen sulphide content of the natural gas. Production of gas-recovered sulphur has declined from a 1992 high of 2.5 million tons to about 2.0 million tons in 1999.

Recovered sulphur produced from crude oil is produced in the Gulf Coast States, California, and in the Northeastern and Midwestern States. Several factors determine the volumes of sulphur produced from refineries: energy demand and consumption of crude oil, quality of the crude slate and end product mix. U.S. refineries modernized and upgraded their operations during the 1990s to maximize the benefits of refining imported, high sulphur crude oils. A significant amount of growth has come at refineries due to stricter environmental regulations for low sulphur fuels and increasing sour crude slates. Production of oil-recovered sulphur has grown from 4.2 million tons in 1990 to 6.2 million tons in 1999, almost a 150 percent increase.

Mined sulphur is principally found in the caprock that covers salt domes in the coastal areas of the Gulf of Mexico. From a 1990 high of 3.7 million tons, production declined to 1.8 million tons by 1999. In the 1990s, five U.S. mines closed. As 2000 began, only one sulphur mine remained operating in the U.S., Freeport-McMoRan's Main Pass mine offshore Louisiana. Main Pass mine was discovered in December 1988, at a time when U.S. Frasch reserves were in significant decline and there were serious concerns that supply could not meet demand. A partnership lead by Freeport-McMoRan and including IMC Fertilizer and Homestake Mining undertook the massive capital project to secure the needs of U.S. consumers, investing about $1 billion in a sulphur, oil and gas complex. By the time Main Pass initiated sulphur production in 1992, the Tampa sulphur price had dropped by more than $50 per ton from $140 per ton to $90 per ton. In spite of substantial efforts made in the ensuing eight years to reduce costs, and keep the mine competitive (unit fuel, drillng and other costs were all reduced by double digit percentages), market circumstances were too large to overcome. By second quarter 2000, low sulphur prices and higher natural gas prices were complicated by geologic issues associated with a brine well causing the mining operations at Main Pass to be abruptly shut down. Main Pass ceased sulphur operations on August 31, 2000, the end of an era in Frasch mining history.

Taking a look at how production changed since 1980, the percentage of U.S. recovered sulphur grew from 40% to greater than 80% by 1999, while mined sulphur, filling the gap, moved in the opposite direction. In 2000, recovered sulphur will increase to about 90 percent of U.S. sulphur production, and move to 100% in 2001. The closure of Main Pass mine completes a trend established by the early 1990s.

Mined and recovered production combined, falls short of satisfying requirements for sulphur consumption. Subtracting U.S. exports from the West Coast, the shortfall is magnified. Production less exports, averaged about 9.5 million tons in the 1990's. This is about 2.3 million tons short of the average consumption of 11.5 millions.

As a result, the U.S. imports substantial volumes of sulphur primarily from Canada and Mexico in liquid form. These two countries represented the only sulphur imports for the first half of the 1990s. However beginning in the mid 1990s, sulphur imports from Europe and South America began to be imported, primarily to the East Coast. In late 1998 and early 1999, solid sulphur was imported for the first time in significant quantities. This occurred following a supply disruption at Freeport-McMoRan's Main Pass mine due to difficulties reestablishing production after a hurricane. In 1999, imports totaled 2.8 million tons or about 23 percent of sulphur consumed domestically. This is the highest level of imports since 1991, when the Mexican mining industry was operating, and shipping about 1.3 million tons per year to Florida and North Carolina. The low point was recorded in 1994 during a period of depressed demand for sulphur driven by low phosphate operating rates.

Outlook

During the outlook period, gas-recovered sulphur is expected to remain flat. As natural gas fields decline in Alabama and the Rocky Mountain States, additional production in Wyoming is expected to largely offset this decline. Growth is expected from oil-recovered sulphur. This growth is expected to predominantly come at refineries in which Pemex and PdVSA, the national oil companies of Mexico and Venezuela, have taken equity positions. Each project has the potential to add 50-150,000 tons of additional sulphur production capacity. It is uncertain how much of this capacity will be utilized. For forecasting purposes, 75% of capacity is shown.

Even with the increase in recovered sulphur, U.S. production is expected to decline in 2000 by about 830,000 tons to 9.2 million tons, or about 22 percent of world production, as Frasch supply is erased. This is more dramatic than forecast even at mid-year when Freeport-McMoRan announced the planned shut-down of its Main Pass mine. The expectation then was for a six-month production ramp down, with final production coming at the end of 2000. Instead, depressed sulphur prices, the escalating price of natural gas, together with the results of a geologic and tectonic study of a brine well required in the sulphur mining process, caused Main Pass to cease sulphur production rather than to continue with the plan to phase-out production over time. With this one action, approximately 325,000 tons of planned sulphur production for 2000 was removed from the supply equation. In general terms, Main Pass produced 120,000 tons per month, and closed at a time when perhaps 75% of the Gulf Coast's liquid inventory capacity is utilized, or about 440,000 tons. However, you can well imagine what effect the loss of 120,000 ton per month will have on inventories. By the end of this month, October 2000, the industry is expected to be at minimum working inventory levels. To avoid overstressing inventories in fourth quarter, alternative supplies are required.

A closer examination of where alternative supplies will be sourced from for the fourth quarter 2000 reveals three sources: liquidation of solid inventories, additional Canadian liquid sulphur, and solid imports. Freeport-McMoRan will melt all remaining solid inventory at its Galveston terminal, about

80,000 tons. It is anticipated that about 50-100,000 tons of liquid imports from Canada can be added leaving a requirement for about 50-150,000 tons of solid sulphur imports. Facilities are in place to facilitate this incremental supply to the U.S. through Galveston. Galveston also is helpful in debottlenecking US rail imports through high capacity rail receiving facilitates. While the U.S. fourth quarter supply situation looks very tight, drawing down inventories to minimum working levels, the outlook for 2001 is even more challenging. An evaluation of the supply and demand balance indicates a meaningful domestic supply shortfall is possible. Projecting demand at 11.25 million tons, with a recovered supply of 8.546 million tons, and deducting 700,000 tons for exports, a supply deficit of 3.5 million tons will need to be filled by imports. Assuming Canadian liquid imports via rail of 2.1 million tons, the highest amount ever imported, and Mexican, Germany, and Venezuelan liquid imports via marine vessels of 890,000 tons, leaves a requirement of 500,000 tons of solid imports. Importation, melting and delivery of this quantity of sulphur is something never before done in the U.S. and will strain permitted capacities to their limits if ultimately required.

In the period 2002-2005, the supply situation eases. However, it is anticipated that solid sulphur imports will still be required to meet projected demand.

Throughout the entire forecast period, this description of the sulphur industry as a "business of logistics" will be more apt than ever. Inventories, the buffer that insulates an industry from day-to-day logistical inefficiencies, will no longer be held on U.S. soil. Plans to accommodate shifts in sulphur requirements will have to be made with greater lead-time. Logistics systems, be they rail, truck or marine, will have to function flawlessly and will require unprecedented cooperation between suppliers, transporters, and consumers. The challenge to meet the needs of the sulphur consuming industry will, in short, require a collaborative effort by many.

As illustrated in my introductory comments, the key issues that will ultimately determine the course of this sulphur market over the next few years are ultimate demand, alternative supplies and their cost, and how effectively the logistics systems are used to meet the needs of suppliers and consumers alike.

Thursday, October 5, 2000

Session III
Moderator:

Michael Handcock

Plant Nutrition in the Genomics Era!

K. G. Raghothama
Purdue University

A new revolution called "Genomics" is underway in plant biology. This may have profound impact on how plant nutrients are used to raise crops in the future. Genomics in a broad sense is the generation of information about living things by systematic approaches that can be performed on an industrial scale" (Brent 2000). It also refers to the generation and analysis of information about genes and genomes, so long as that information could be produced systematically. This research targets the global changes in gene expression in contrast to the classical molecular approach of analyzing one or few genes at a time. In simple terms, it is a high input, high intensity and high return research initiative. This has already led to phenomenal discoveries in human health, plant biology, and given birth to numerous biotech companies.

Genomics has revolutionized the genetic information.

One of the major outcomes of genomics research is the unraveling of genetic code of several organisms by DNA sequencing, annotation and cataloging. Advances in human genome projects have paved the way to the development of new tools for sequence analysis. Completion of Arabidopsis (a member of mustard plant family) genome sequence by end of the year 2000 will be one of the most significant accomplishments in plant biology. Currently numerous research groups in both public and private sectors around the world are engaged in deciphering the genetic code of major food crops including rice, corn, sorghum, soybean, tomato and potato.

The gene sequence information has led to a new branch of science called comparative genomics. With the increasing number of gene sequences and powerful computational programs, it is now possible to compare different genomes and identify genes responsible for useful traits such as nutrient utilization efficiency. This technology has already helped in identifying nutrient transporters, channels, antiporters, and organic acid synthesizing enzymes from various plant species. To cite an example, the isolation of first plant phosphate transporter genes from Arabidopsis led to the isolation of phosphate transporters from more than 11 important crop species including corn, rice, soybean, tomato, potato etc (Muchhal et al., 1996, Raghothama 1999). The comparative genomics techniques have also allowed the comparison of gene expression profiles of organisms. Now it is possible to examine the changes in gene expression after the application of N fertilizer to plants or during adaptation of plants to phosphate deficiency. This is accomplished primarily by the development of gene chips and microarray slides. A small chip or a glass slide may contain tens of thousands of gene sequence information. By screening this chip with probes from plants grown under nutrient sufficient and deficient conditions one can find out the global changes in gene expression under altered nutrient regime. Once this technology is perfected and bugs in screening are worked out this will be an amazing research tool to discover genes involved in nutrient usage by plants.

Does genomics has a role in plant nutrition.

The power of the genomics research will help us better understand the complex interactions between organisms and the environment. Nutrient acquisition is a result of one of the most complex interactions between plant, soil and microorganisms. It is becoming clear that nutrient uptake by plants may involve families of genes. Based on the DNA sequencing information nine different high affinity phosphate transporters have been identified in Arabidopsis (Raghothama 2000). The same may be true for other plant nutrient transport processes also. This kind of information would not have been possible without the sequence information and bioinformatics tools. Now the obvious questions are why plants have so many genes producing similar transporters? What is the function of each member of this family of genes? Answers to these questions should come from the emerging field of functional genomics. Functional genomics refers to the systematic generation and analysis of the information about the function of genes. Many research techniques are being used in defining the function of genes. One of the powerful genetic tools is the generation and analysis of mutants. Biologists around the world have generated tens of thousands of mutants in several plant species. These mutants are serving as powerful genetic tools in isolating genes and defining their function in plant nutrient acquisition and utilization. By using the technique of gene knockouts, now it is possible to isolate mutants of individual genes, characterize them and analyze the consequence of the gene knockout. The mutant analysis will also lead to the identification and characterization of key regulatory components involved in nutrient acquisition.

Another branch of genomics research that will have tremendous impact on plant nutrition is the proteomics. Similar to genomics the techniques of proteomics will allow us to gain extensive knowledge about global changes in proteins during nutrient stress or sufficiency. Many researchers around the world are sequencing and analyzing plant proteins. Some groups are working exclusively on plant membrane proteins. Since membranes are the portals of plant nutrient acquisition and transfer, having a road map of membrane proteins will be of tremendous benefit to the field of plant nutrition.

How the genomics information could be used to improve nutrient efficiency?

The real challenge for biologists and plant nutritionists is how to use the vast information generated by genomics tools to improve nutrient efficiency and sustainability of crop production. One tangible approach is the pyramiding of genes in plants to improve nutrient efficiency. During the last several years researchers have identified many genes that are directly involved in nutrient uptake and utilization. The list includes but not limited to transporters, channels and enzymes involved in nutrient acquisition and utilization pathway. These genes could be used directly or modified to improve nutrient efficiency. The utility of this technique can be better explained with the example of phosphate acquisition. In order to obtain sufficient amounts of phosphate, plants have to alter its availability and uptake. First they should be able to convert the organic and bound phosphate in soil to inorganic form. The released phosphate should be absorbed rapidly by plants before it becomes unavailable. The acquired phosphate must be utilized efficiently to increase yield. In order to accomplish these goals a coordinated and regulated expression of genes such as organic acid synthesizing enzymes, phosphatases and phosphate transporters may required. In addition genes responsible for root architecture and root hair formation also need to be altered. A coordinated and regulated expression of these molecular traits in economically important plants will certainly lead to the generation of nutrient efficient plants.

Another area that could benefit from the genomics research is marker assisted breeding program to improve plant nutrition. The plant genome sequence has increased the number of useful markers needed in traditional breeding programs. The development of high density physical and genetic maps will allow researchers to target different traits associated nutrient uptake and utilization in crop breeding programs.

Concluding remarks. Plant nutrition is entering an ear of unprecedented developments in plant biology. The genomic tools are powering the generation of data at a faster rate than we can comprehend. There will be a period of uncertainty and hype about what could be done with voluminous data that is being generated. The bright side of the problem is that the information is available to scientists working in the area of plant nutrition to improve fertilizer use efficiency. It is high time for the fertilizer industry to become active partners in advancing plant nutrient genomics. The fertilizer industry has a lot to gain from this technology in terms of improving crop production, protecting the environment and preserving the natural resources for the future generations. The industry should view this as an opportunity to become partners and owners of this crucial technology to enhance the sustainability of world food production.

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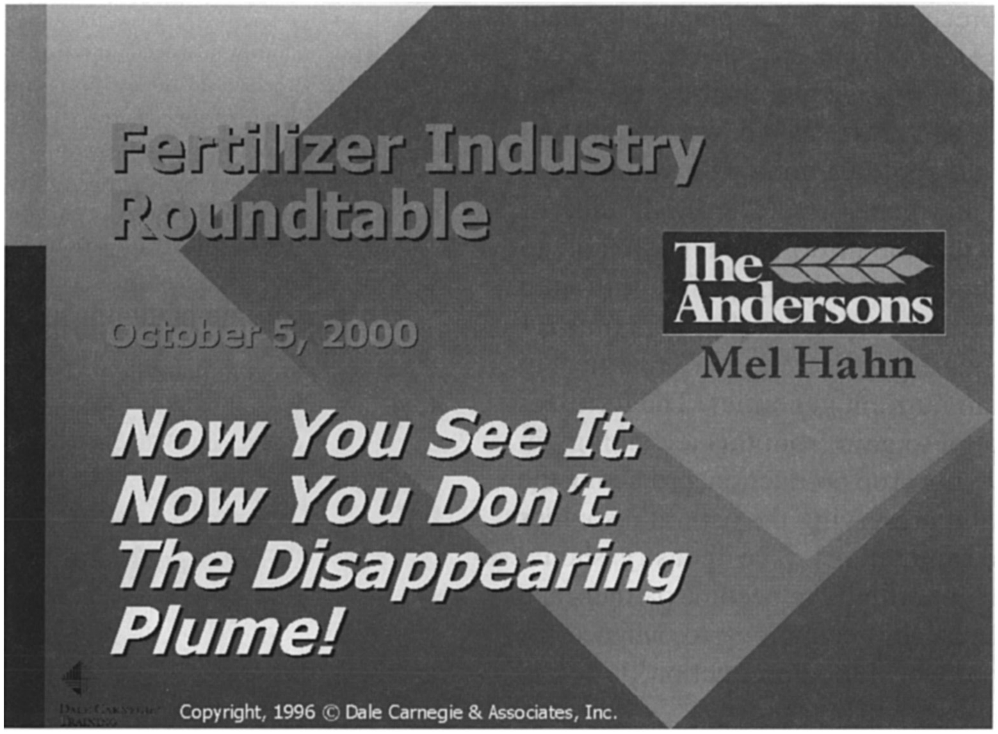
Now You See It, Now You Don't
The Disappearing 10-34-0 PLUME

Ed Norris

The Andersons Inc.



Fertilizer Industry Roundtable

October 5, 2000

The Andersons

Mel Hahn

Now You See It.
Now You Don't.
The Disappearing Plume!

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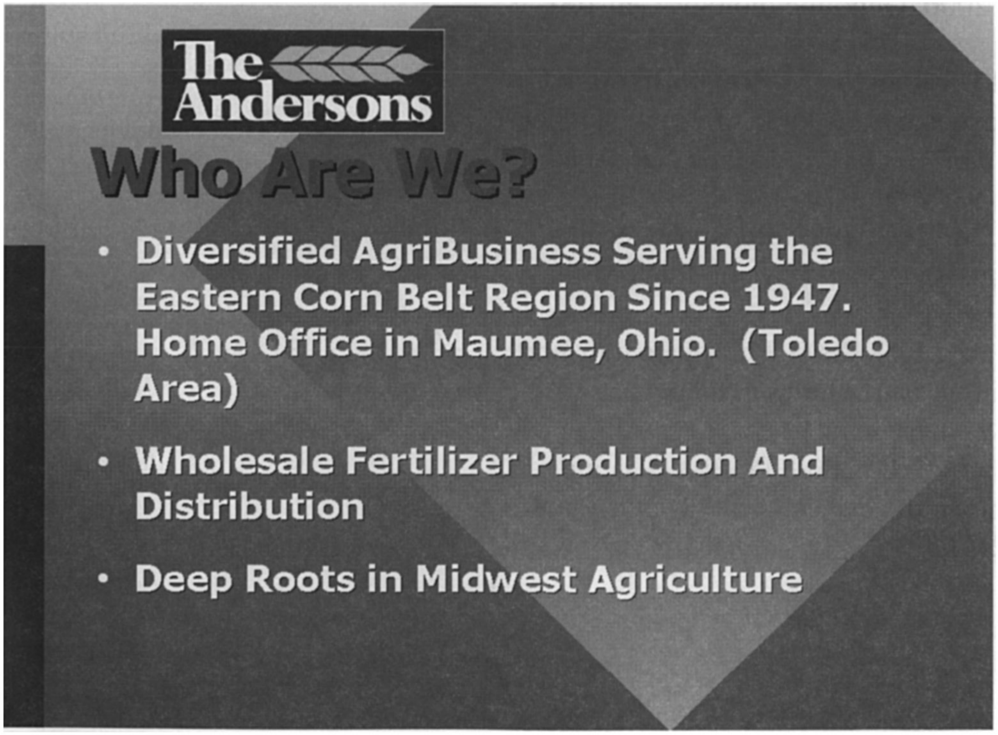
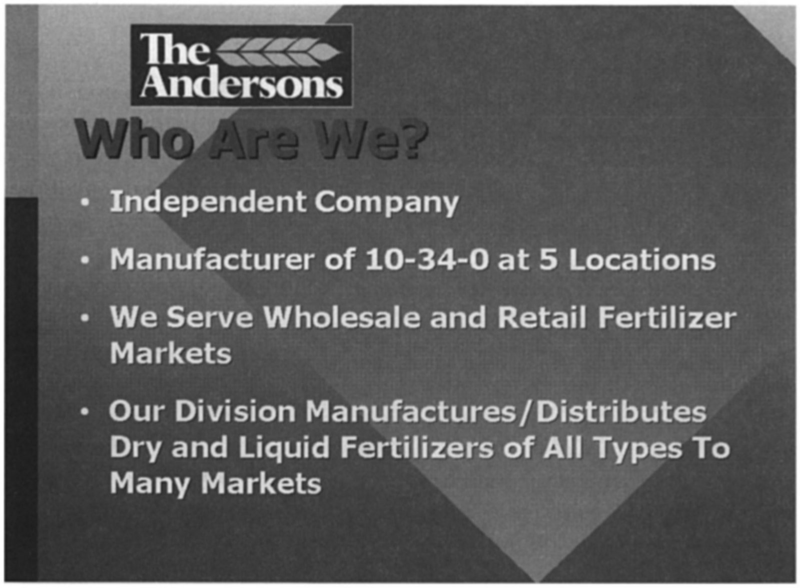


The Andersons

Who Are We?

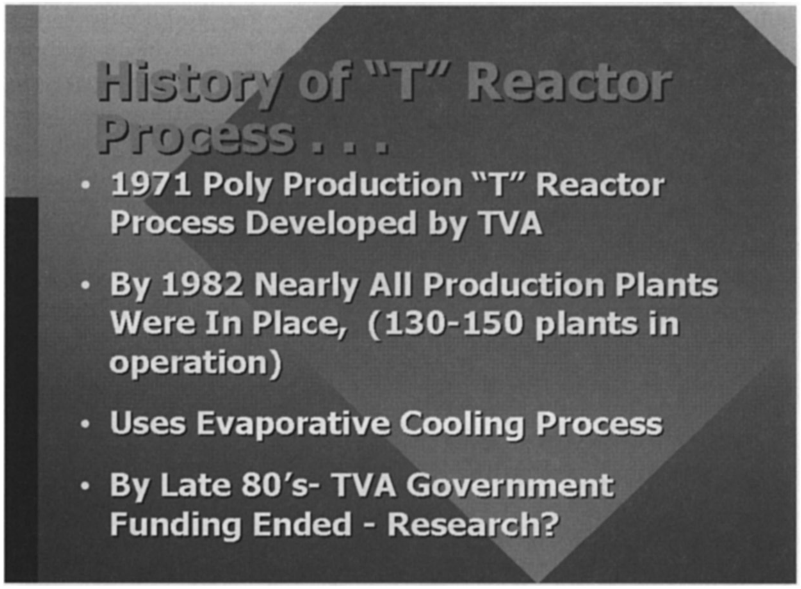
- Diversified AgriBusiness Serving the Eastern Corn Belt Region Since 1947. Home Office in Maumee, Ohio. (Toledo Area)
- Wholesale Fertilizer Production And Distribution
- Deep Roots in Midwest Agriculture



The Andersons

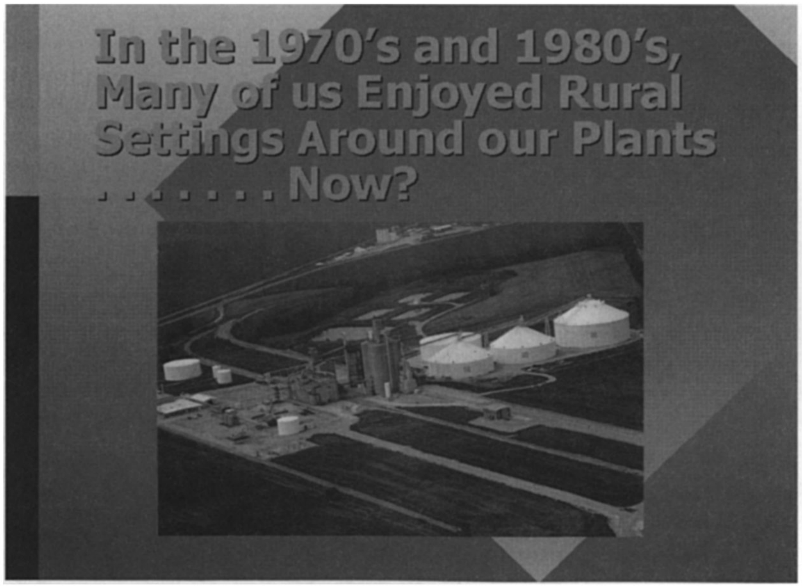
Who Are We?

- Independent Company
- Manufacturer of 10-34-0 at 5 Locations
- We Serve Wholesale and Retail Fertilizer Markets
- Our Division Manufactures/Distributes Dry and Liquid Fertilizers of All Types To Many Markets



History of "T" Reactor Process . . .

- 1971 Poly Production "T" Reactor Process Developed by TVA
- By 1982 Nearly All Production Plants Were In Place, (130-150 plants in operation)
- Uses Evaporative Cooling Process
- By Late 80's- TVA Government Funding Ended - Research?



In the 1970's and 1980's, Many of us Enjoyed Rural Settings Around our Plants . . . . Now?

Today's Standards/ Expectations Are Much Higher

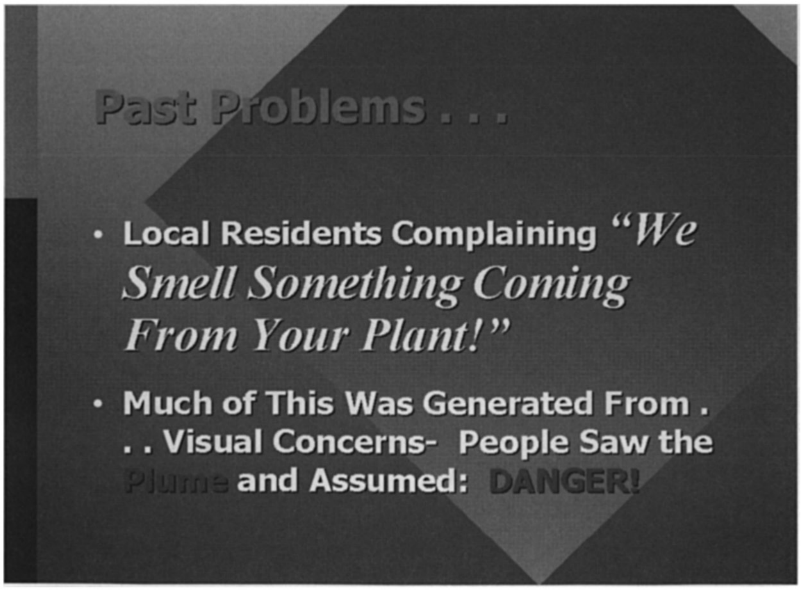
Our Technology Has Generally NOT Kept Pace !!

Until Today!

We Have Now Developed Technology To Match Today's Standards/Expectations.

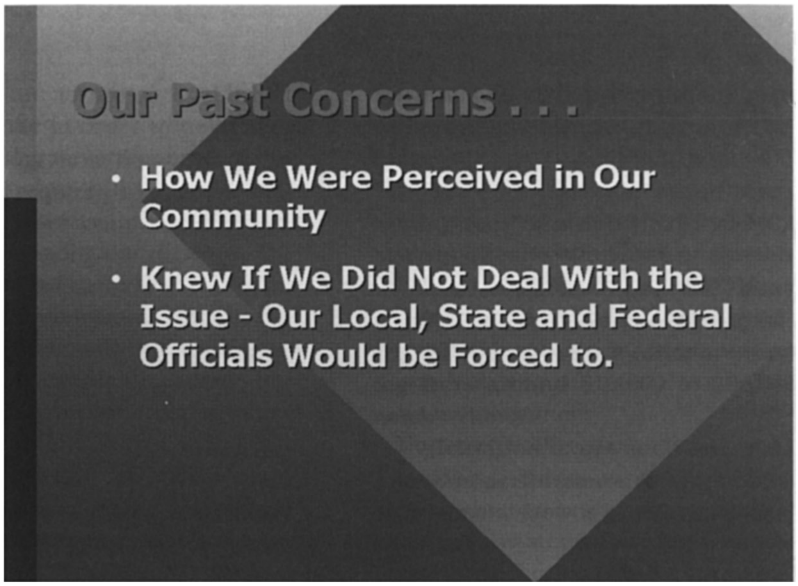
For The First Time, We Want To Share Publicly . . .

- Our Past Problems/Challenges
- Our Past Concerns
- The Solution We Developed



Past Problems . . .

- Local Residents Complaining *"We Smell Something Coming From Your Plant!"*
- Much of This Was Generated From . . . Visual Concerns- People Saw the Plume and Assumed: DANGER!



Our Past Concerns . . .

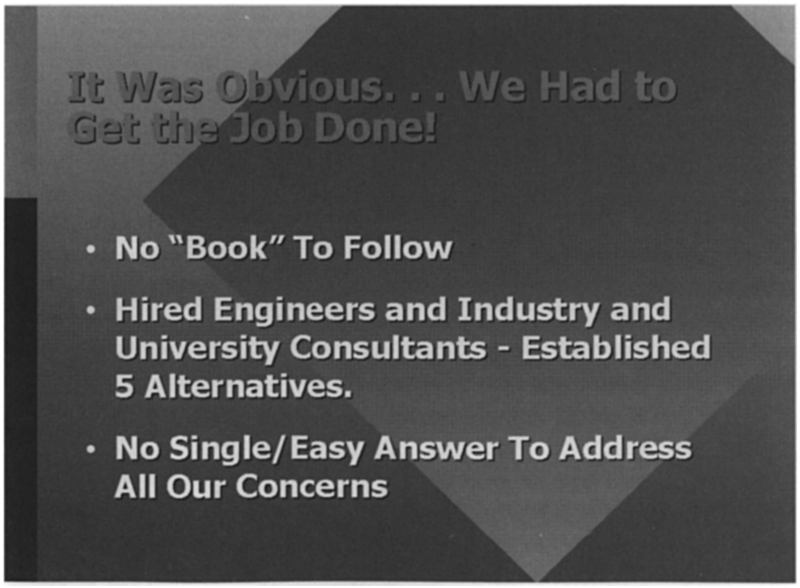
- How We Were Perceived in Our Community
- Knew If We Did Not Deal With the Issue - Our Local, State and Federal Officials Would be Forced to.

People's Expectations Are Higher Today. . Even Higher Tomorrow!!

Our C.E.O. Challenged Us To. .

"Fix the Problem!!"

Who/Where Would The Answer Come From??

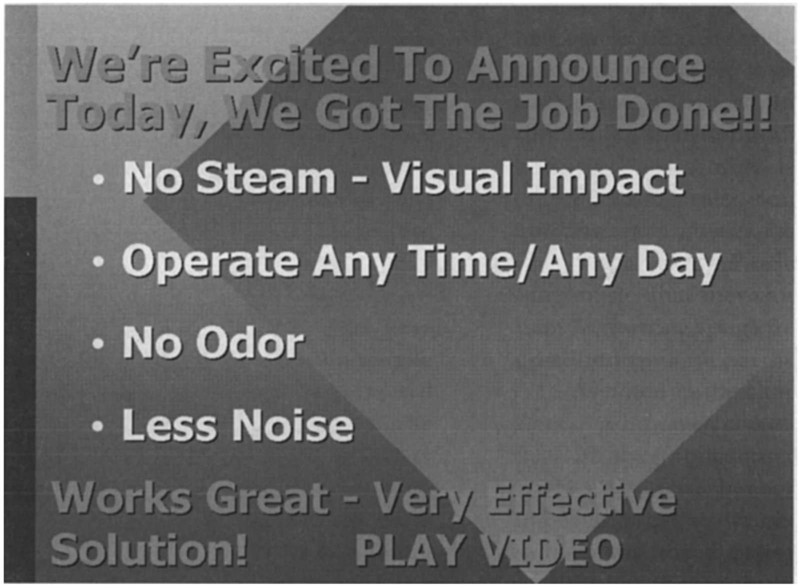


It Was Obvious. . . We Had to Get the Job Done!

- No "Book" To Follow
- Hired Engineers and Industry and University Consultants - Established 5 Alternatives.
- No Single/Easy Answer To Address All Our Concerns

After Much Trepidation We Settled On A Solution That Met Our Goals.

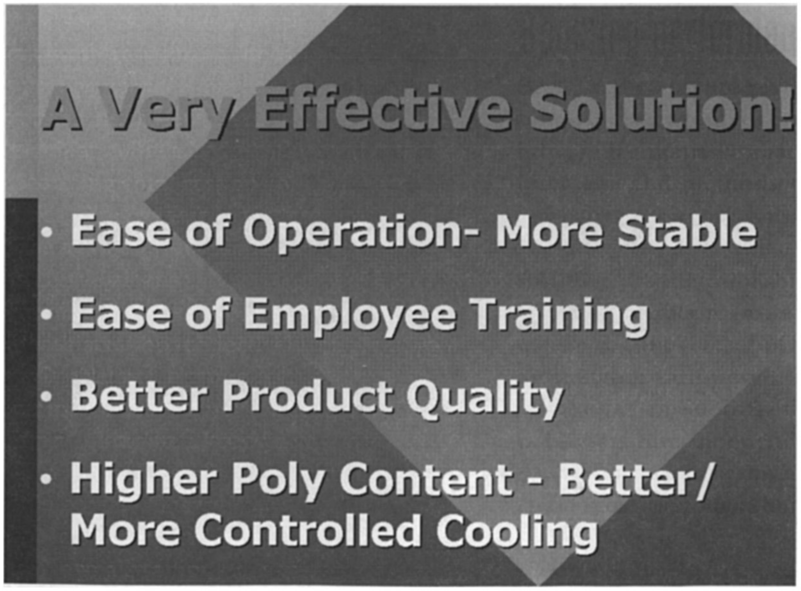
- Purchased Equipment to Begin Testing - Big Time Trial and Error - No Template!
- Spent Many Hours Testing and Modifying Equipment
- Invested >$250,000 In Developing A New/Modified Process!!



We're Excited To Announce Today, We Got The Job Done!!

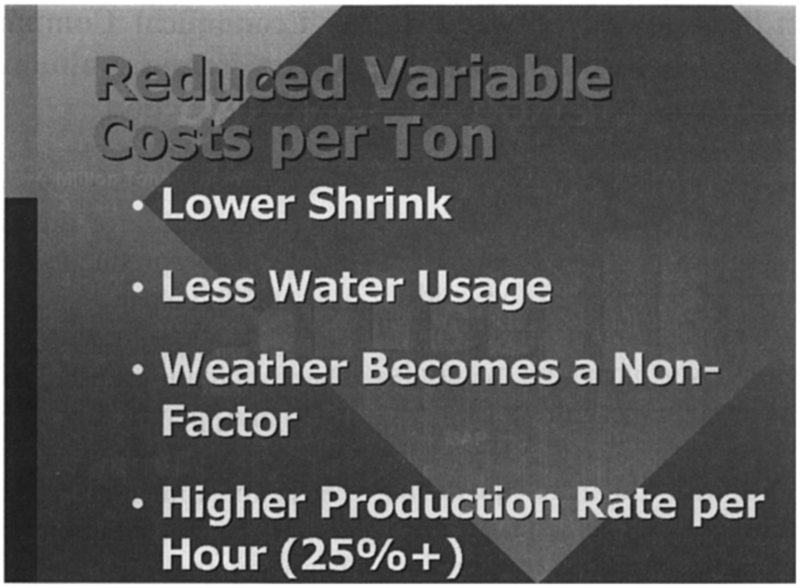
- No Steam - Visual Impact
- Operate Any Time/Any Day
- No Odor
- Less Noise

Works Great - Very Effective Solution! PLAY VIDEO



A Very Effective Solution!

- Ease of Operation- More Stable
- Ease of Employee Training
- Better Product Quality
- Higher Poly Content - Better/ More Controlled Cooling



Reduced Variable Costs per Ton

- Lower Shrink
- Less Water Usage
- Weather Becomes a Non-Factor
- Higher Production Rate per Hour (25%+)

NOW YOU DON'T SEE IT!!!

Questions?

The Andersons

You Can Contact Us:

Ed Norris 800-247-1492

Mel Hahn 800-292-4525

Comparison Between the Three Most Profitable Process Schemes For Urea Mased NPK's

Patrick Bouilloud
Christian D'Emal
Kaltenbach-Thuring S.A.

Urea is a major source of nitrogen in the world. The use of urea in the production of NPKs offers substantial cost savings over other raw materials as ammonium nitrate as source of nitrogen.

KT offers three major routes which are equivalent on a cost basis. The choice will be fixed according to the client raw material capabilities (production of urea, several P_2O_5 sources, ...).

The present paper compares the three best economic routes. It demonstrates that the best way consists in using a straight concentrated urea melt which is partly diluted with the washing water from the scrubber.

A table shows the cost benefits resulting from the use of urea instead of ammonium nitrate in the production of 15-15-15 NPK in a 1000 MTPD plant.

All three processes are described technically and the main economical factors such as material costs, investment and energy consumption are compared to an AN based NPK production plant.

1- Economical Comparison of the Three Routes Versus Ammonium Nitrate Based NPK Production

The following table shows the cost benefits resulting from the use of urea instead of ammonium nitrate in the production of 15-15-15 NPK in a 1000 MTPD plant.

The formulations used for the comparison are listed in Appendix 2.

The ammonium nitrate reference takes into consideration the real situation of an existing NPK plant using ammonium nitrate solution, single super phosphate and ammonium sulphate. This plant is synthesising ammonium salts (phosphate and sulphate) in a pipe reactor.

The prices for raw material are based on the French market (see price list in Appendix 1).

Urea is supposed to be used as solution (95% urea) if the NPK plant is to be built besides a urea plant or as prills if no urea is manufactured on site (the product is supplied from the market). Urea in the solution is supposed to be at the same cost as the urea prills (dry basis).

When urea prills are used they are melted as a pure melt and immediately mixed with scrubbing solution to prevent excess formation of biuret.

TABLE 1. LIST OF THE THREE MAJOR ROUTES

	UREA SOURCE	P_2O_5 SOURCE	SULPHURIC ACID
Route n°1	95% urea solution	Solids (MAP, DAP, SSP, TSP)	as additive
Route n°2	Prills	H_3PO_4 and solids	as raw material
Route n°3	Prills	Solids (MAP, DAP, SSP, TSP)	as additive

Amortization costs are established on a difference basis. It refers to complementary equipment necessary to manufacture the product in comparison with an AN based NPK plant.

ROUTE	Reference	1	2	3
Main economical costs (FF/t NPK)	NPK (AN)	NPK (urea solution)	NPK (prills + pipe reactor)	NPK (Urea melter)
Raw materials cost (France basis - October 99)	827	726	714	726
Amortization difference (FF/t) versus the reference	0,0	3,1	15,3	5,0
Electrical power consumption (kwh/t)	35	45	45	45
Electrical power cost (0,35 FF/kWh)	12	16	16	16
Steam (FF/t) for urea melter	0	0	0	5,4
Fuel oil (kg/t)	13	11	7	11
Fuel oil cost (1 FF/kg FOL)	13	11	7	11
Total (FF/t)	852	755	752	763
Gain over AN based NPK (comparison with the reference) (FF/t)	0	96	100	89

2 - Production of Urea Based NPK using urea solution

ROUTE N°1

2.1 Process Description

Typically, the solids used as raw materials are : MAP, DAP, KCl, K_2SO_4, filler... and the liquid is molten urea solution. The urea solution to be sprayed in the granulator is a 95% urea solution mixed with recycled washing solution. Anhydrous ammonia and fertilizer grade sulphuric acid are used as additive to promote the granulation.

The premixed solid raw materials are introduced into the granulator through the recycled product. Urea solution is sprayed onto the rolling bed. Steam and a small amount of sulfuric acid and ammonia are added to promote the granulation. The granules fall into a dryer, cocurrently with air heated in a burner, then into a second dryer. This second drum increases the crushing strength of the granules. In order to minimize the amount of air required in the process, the air from the second dryer is dry dedusted before being recycled into the first dryer.

The granules pass through the screening section. The oversize granules are crushed and recycled with the fines and the undersize granules to the granulator. A controlled amount of on-size product is also added with the recycled product to keep the recycling flowrate constant. The on-size product is conditioned (cooling, coating) before being sent to storage.

2.2. UTILITIES (assuming a 1000 MTPD plant)

Electricity	:	45 kWh/t
Make up water	:	140 kg/t
Fuel oil	:	11 kg/t
Steam (mean pressure)	:	75 kg/t

2.3. Effluents Treatment

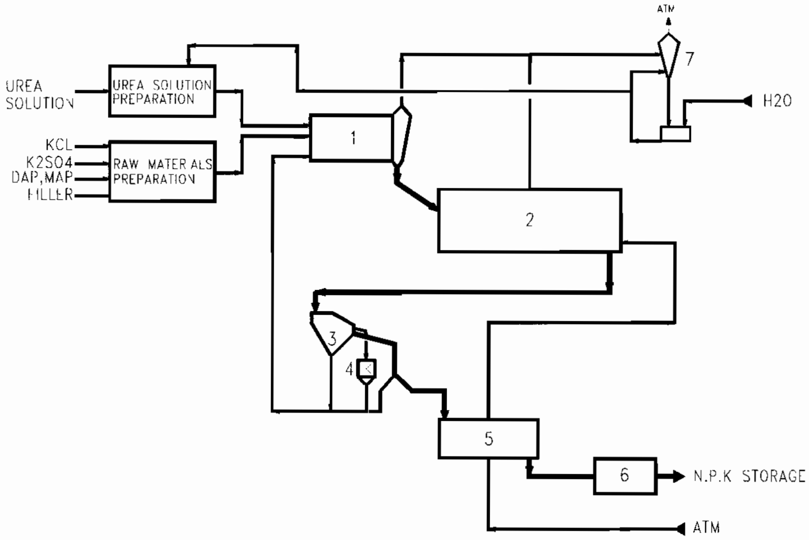
The air from the first dryer is sent to cyclones before being mixed with the granulator air in the scrubber to be efficiently washed before being sent to the atmosphere.

The air sent to the atmosphere typically contains:
- less than 50 mg dust/Nm^3
- less than 50 mg NH_3/Nm^3

The washing solution is totally reused in the process through the urea solution.

2.4. Final Product Characteristics

Typically a 15.15.15 (for example) :
Moisture : 1% max.
Screen analysis : 94% between 2.5 and 4.5 mm
Crushing strength : 4 kg (on 2.5 - 4.5 mm granules)



1 : Granulator
2 : Drying section
3 : Screening section
4 : Crusher
5 : Cooling section
6 : Coating section
7 : Scrubbing section

3 -Production of Urea Based NPK with a Pipe Cross Reactor

ROUTE N°2

3.1. Process DescriptionS

NPK is typically made from :

- Solid raw materials such as KCl, MAP, UREA, ammonium sulfate, SSP, and a filler such as GYPSUM or SAND
- Anhydrous liquid ammonia
- Fertilizer grade phosphoric acid (at a preferred concentration of 54% P_2O_5)
- Sulphuric acid (concentration of 98%)

The process described is based on a three step neutralisation of ammonia :

First step : in a pipe reactor installed in the granulator
Second step : in the rolling bed of granules in the granulator
Third step : in the scrubbing system

Liquid ammonia for the reactor is evaporated and superheated with warm air coming from the stack. This completes the energy integration of the KT process.
All the liquids are fed through the pipe reactor where the acids react with gaseous ammonia to produce a melt of MAP/DAP/AS. The N/P ratio is adjusted to obtain a granulating slurry and to allow a very low recycling ratio (between 2 and 3).

The scrubbing solutions are fed to the pipe reactor to control the temperature of the reaction and to control the moisture of the granules exiting the granulator.

The granules exiting the granulation fall into a chute entering the first rotary dryer where heated air mixed with the warm air recycled from the second dryer ensures the main drying.

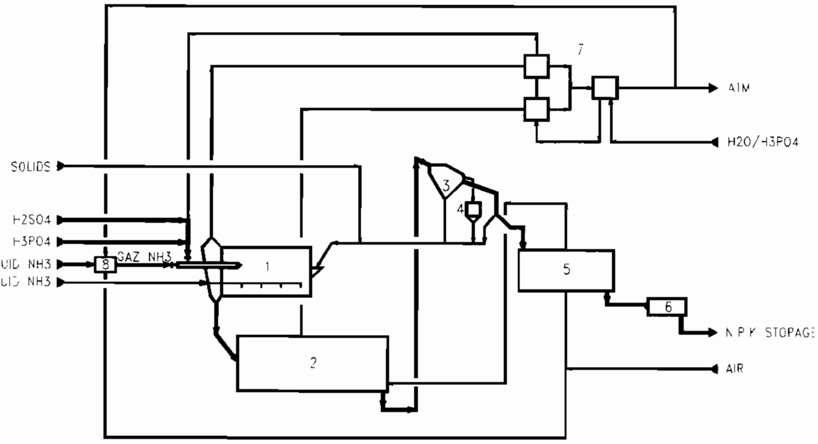
The product goes through a second dryer to continue the drying and mainly to harden the granules before being screened and crushed.

The dust collected directly at the outlet of the cyclones (air from both dryers and cooler) is recycled to the drum granulator.

The dry product is calibrated on a vibrated screen. The oversize fraction is crushed.

The undersize product is recycled to the granulator together with a controlled amount of on-size product to keep the recycling flowrate constant. The on-size product is conditioned (cooling, coating) before being sent to storage.

The warm air from the cooling section is recycled to the second dryer, and after passing through goes to the first dryer, ensuring the total recovery of the heat.



1 : Pipe reactor and granulator
2 : Drying section
3 : Screening section
4 : Crusher
5 : Cooling section
6 : Coating section
7 : Scrubbing section
8 : NH_3 evaporator

3.2. Utilities

Electricity	:	45 kWh/t NPK (for a 1000 MTPD plant)
Process water	:	120 kg/t
Fuel oil	:	7 kg/t
Steam	:	nil

3.3. Effluents Treatment

The air from the first dryer passes through dry cyclones and is washed in a first stage scrubber. The air leaving the granulator is also washed in a separated scrubber before being mixed with the air from the dryer scrubber in a second stage scrubber.

The excess ammonia liberated in the granulator by the pipe reactor and the sparger as well as the fluorine are trapped in the scrubbing system.

The air sent to the atmosphere fulfils the EFMA BAT recommendations and typically contains :

- less than 50 mg dust/Nm^3
- less than 50 mg NH_3/Nm^3
- less than 5 mg F/Nm^3

The total amount of the scrubbing solution is pumped to the pipe reactor.

3.4. Final Product Characteristics

(based on a typical fertilizer grade phosphoric acid)

Typically a 15.15.15 (for example) :

Moisture	:	1% max
Screen analysis	:	94% between 2.5 and 4.5 mm
Crushing strength	:	6 kg (on 2.5 - 4.5 mm granules)

4 - Production of Urea Based NPK Using Urea Prills or Granules and a Melter

ROUTE N°3

4.1. Process Description

Typically, the solids used as raw materials are: urea prills, MAP, DAP, KCl, K_2SO_4, filler...

Liquid ammonia and fertilizer grade sulphuric acid are used as additive to promote the granulation.

Urea prills are melted and mixed with recycled washing solution to prepare the urea solution.

The premixed raw materials are introduced with the recycled product into the granulator. Urea solution is sprayed onto the rolling bed. Steam and a little amount of sulfuric acid and ammonia are added at optimum level to promote the granulation. The granules fall into a dryer, cocurrently with air heated in a burner, then into a second dryer. This second drum improves the crushing strength of the granules. In order to minimize the amount of air required in the process, the air from the second dryer is dry dedusted before being recycled into the first dryer.

The granules pass through the screening section. The oversize granules are crushed and recycled with the undersize granules to the granulator, with a controlled amount of on size product to keep the recycling flowrate constant. The on-size product is conditioned (cooling and coating) before being sent to storage.

4.2. Utilities (assuming a 1000 MTPD plant)

Electricity	:	45 kWh/t
Make up water	:	140 kg/t
Fuel oil	:	11 kg/t
Steam (mean pressure)	:	111 kg/t

4.3. Effluents Treatment

The air from the first dryer is sent to cyclones before being mixed with the granulation air in a scrubber to be efficiently washed before being sent to the atmosphere.

The air sent to the atmosphere fulfils the EPMA BAT recommendations and typically contains :

- less than 50 mg dust/Nm^3
- less than 50 mg NH_3/Nm^3

The washing solution is totally recycled to the process by mixing with the urea solution.

4.4. Final Product Characteristics

Typically a 15.15.15 (for example) :

Moisture	:	1% max.
Screen analysis	:	94% between 2.5 and 4.5 mm
Crushing strength	:	4 kg (on 2.5 - 4.5 mm granules)

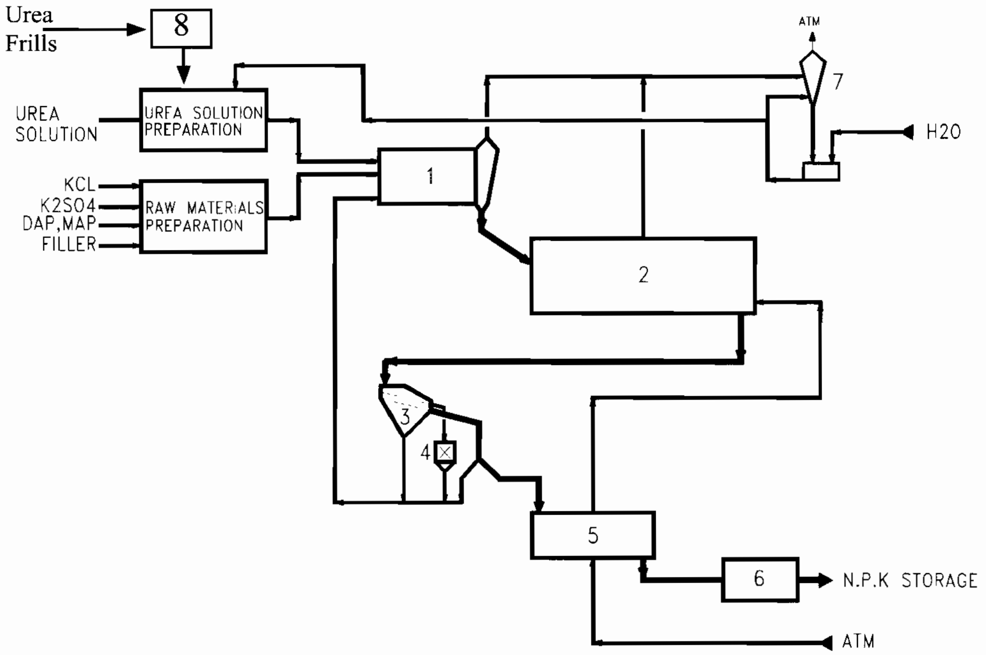
Appendix 1

Raw Material Costs

Raw Material Costs for Calculation

Basis: October-99

	Cost FRANCO: (FF/t DRY BASIS 100%) France basis	
NH_3	1000	FF/t DRY BASIS 100%
H_3PO4(62.4% P_2O_5)	1310,4	FF/t DRY BASIS 100%
UREA prills	600	FF/t DRY BASIS 100%
H_2SO_4 100%	255,1	FF/t DRY BASIS 100%
KCl	750	FF/t DRY BASIS 100%
$CaSO_4$	100	FF/t DRY BASIS 100%
AS	480	FF/t DRY BASIS 100%
Single Super Phosphate (SSP) (18% P_2O_5)	265	FF/t DRY BASIS 100%
Ammonium nitrate solution	900	FF/t DRY BASIS 100%
MAP	1200	FF/t DRY BASIS 100%
DAP	1200	FF/t DRY BASIS 100%



1 : Granulator
2 : Drying section
3 : Screening section
4 : Crusher
5 : Cooling section
6 : Coating section
7 : Scrubbing section
8: Melting section

Appendix 2

Formulations (3 x 15)

1. Routes n° 1 and 3
Urea basis formulation with DAP

	Route 1 Urea solution	Route 3 Urea prills
Formula dry basis (kg/t NPK)	15,15,15	15,15,15
NH_3	0	0
H_3PO_4 (62.4% P_2O_5)	0	0
UREA (solution)	144	0
UREA (prills)	0	144
DAP	267	267
SSP 18	151	151
KCl	250	250
AS	178	178
H_2O + add	10	10
Raw material cost (FF/t NPK)	726	726

2. Route n°2
Urea basis formulation
Pipe reactor and urea prills

Formula dry basis (kg/t NPK)	15,15,15
NH_3	64
H_3PO_4 (62,4% P_2O_5)	204
H_2SO_4	70
UREA (prills)	38
DAP	0
SSP 18	126
KCl	250
AS	225
H_2O+add	10
Raw material cost (FF/t NPK)	714

3. AN basis formulation
Pipe reactor and AN melt

Formula dry basis (kg/t NPK)	15,15,15
NH_3	27
H_3PO_4 (62,4% P_2O_5)	82
H_2SO_4 100%	40
AN solution (100% AN)	282
MAP	120
SSP (18% P_2O_5)	115
KCl	214
AS	0
NPK fines	110
H_2O + add	10
Raw material cost (FF/t NPK)	827

Integrating Cooling and Drying Systems

Lori Coenen
FEECO International, Inc.

Introduction

Many industrial drying systems for production facilities include a separate dryer and cooler. The dryer and cooler are typically rotary drums. The diameter of the cooler is based on a maximum air flow velocity through a cross section, and the length is determined based on a calculated retention time to achieve the proper cooling level. Based on these parameters, the rotary cooler can end up being as large as the rotary dryer. Even a minimal amount of cooling could still require a drum diameter similar to that of the rotary dryer. The rotary cooler will require a drive system, a fan, and most importantly, space. When designing a new system, space must be set aside to allow for this cooling system, and material handling equipment must be added to get material into and out of the drum.

For existing drying systems that do not have an adequate cooler, product temperature can often be uncontrolled. Material out of a counter-current dryer can be so hot as to burn discharge belts, and adversely effect screening and bagging equipment. Product put into storage silos too hot can cause fires and degrading of product.

For existing drying systems that do have a cooler, hot weather can limit the effectiveness of the rotary cooler.

Modern plants, and expansion of materials used, i.e. recycling of organic materials such as animal and municipal sludge, and biosolids, require modification of equipment. Retrofitting a larger cooler for these materials may not be an option in some cases.

In many new plants, space is at a premium. Also, in some existing plants, there is no place to add a rotary cooler. FEECO International Inc. developed this product for drying systems where space constraints limit the use of large rotary cooler, and for existing systems where some additional amount of cooling is required.

Design Development

Theory

Many applications require cooling of a dryer product. The basic premise of the design of our integrated cooling system was to introduce cooling air to a component that is already part of any dryer system. The objective was not to design a fluid bed cooler. It was to develop a product that incorporated all the superior aspects of a fluid bed, without the typical problems of segregation, high pressure drops, high power consumption, and increased fines production. The goal of the design was to minimize the size of a rotary cooler, or in some applications, eliminate the need for this device.

The minimum fluidizing velocity of a particle or the "onset of fluidization" occurs when the drag force of the upward moving gas is equal to the weight of the particles to be fluidized. In actual production, the weight and size of the particles to be cooled is actually a range, not a single value. For most materials, this velocity must be found by experimentation.

The pressure drop in a fluidized bed controls how uniformly the fluidizing air will contact the particles. The pressure drop in a standard fluidized bed can only be maintained if the bed is fluidizing properly. If the pressure fluctuates too much, the result will be a slugging bed. If the pressure drop is too low, the problem may be incomplete contacting of the fluidizing air with all the particles, and result in channeling. Particle size variability effects the quality of the fluidized bed. If material in a fluid bed has both fines and coarse particles, the smaller particles may fluidize while the large remain unsuspended. If the pressure drop is too high, the bed reaches terminal velocity. At terminal velocity, all of the particles are entrained in the air stream. This can cause loss of the fluidization, and the loss of steady state of the fluid bed.

In a standard design fluidized bed, the power requirements are high, since a constant bed depth must maintained to keep the bed at steady state. The power requirements of a fluidized bed can often be so high that they cancel out the advantages of this type of system.

Air slide technology was designed to move material that has a tendency to pack when piled upon itself. An air slide consists of a distributor plate, with an air connection underneath. The low-pressure air fluidizes the material directly above it, causing it to move. The airslide system uses gravity to promote the movement. Generally, these slides are mounted in the cone section of a material tank, on the sloped sides. The material is directed toward the discharge of the tank.

The FEECO International, Inc. Fluidized Cooler Breeching integrates these two systems, and allows for a variety of material sizes to be cooled at the same time without "losing the bed".

The system is a sloped fluidizing grid, mounted directly in the discharge breeching. The integrated system takes up much less space than a rotary drum, and does not require a drive system or expensive material handling equipment.

Experimentation

The development of this equipment has gone through a number of iterations, as testing on various products led to a very flexible design.

Our first design step was to develop a small-scale unit out of wood and Plexiglas. This clear designed allowed us to study the air flow characteristics through the perforated plate. We studied the impact of velocity, pressure drop, and slope on the material. The temperature change at various "retention times" was also documented for several materials. This was done on a batch basis.

Based on this data, and research on various fluid bed and air slide designs, a computer program was developed to simulate the cooler. [Refer to Figure 1] This program allows you to enter the properties of a specific material, and size the grid and airflow required specifically for that material. The program takes into account the evaporative cooling for products.

The next step in the design was a lab scale discharge breeching to test the design criteria on a larger scale. The first unit built had an adjustable slope and an air inlet at the bottom. The hot air from the dryer was not completely separated from the cooler air. Balancing the two airflow became a problem. Distribution across the perforated plate was also a problem, due to lower than anticipated static pressure drops. [Figure 2]

The next generation of the fluid cooler incorporated a distribution scroll at the end of the drum. This forced even distribution of the material from the dryer discharge across the width of the perforated plate. The distribution is important to maintain an equal pressure drop across the whole bed. This generation also included the addition of dams on the bed to retard material flow and increase retention time on the bed. The location of the air inlet was moved to the side, and turning vanes were added to direct the flow across the bottom of the entire grid. [Refer to Figure 3] This resulted in good cooling for many materials tested. The major problem with this design was still the isolation of the hot air from the dryer, and the cooler air. The dryer was under a negative pressure, pulling hot air from the combustion chamber into the dryer then out the stack in the discharge breeching. The cooler was under a positive pressure, and caused a back-pressure in the drum, lessening the effectiveness of the dryer and causing an increase in material carry over to the baghouse.

The latest generation of the design of the Fluidized Cooler Breeching separates the hot and cool systems by the use of an isolation valve and insulated plate between the two systems. The dryer discharge gases and the cooling air are separated, and much less turbulence and carry over of material is seen. [Refer to Figure 4] This has many advantages. The air out of the cooler is preheated, and can be used as make-up air in the dryer combustion chamber. This will lower the energy costs of the system. Because the cooler is an integral part of the dryer discharge, ductwork can be kept to a minimum.

How it Works

According to Davidson [1], gas bubbles are solid-free and circular in shape, and as the bubble rises, the particles move aside. The bubbles through a fluid bed will induce the circulation of solids in a bed. This movement promotes rotation, and increased contact of the hot particles to the cooling air.

The system uses direct convection through aeration to provide cooling of the product. [Figure 4] The temperature gradient between the dryer product temperature and the cooling air is the driving force for cooling.

The system is not a true fluid bed, because the sloped nature leads to the ability to operate with a wide range of material consistencies. That means that both fines and coarse material will pass across the bed and be cooled. The fines tend to move down the bed faster, while the adjustable dams in the bed hold the coarse material on the grid a little longer. The longer retention time for the larger coarse materials increases the cooling. Per Perry's [2], with a good distributor plate, essential equalization of temperatures between the solid and the air occurs within 1 to 3″ of the distributor. In a true fluid bed, the bed height is not less than 1′ and not more than 50′. With this design, the bed depth can be varied, but is usually not over 3″ deep.

The system can also incorporate heat exchanger tubes for conductive heat exchange. The material through the tubes can be cooling air, water or a refrigerant. For high temperature applications, combustion air can be pre-heated in the embedded tubes. The heat transfer rate can be between 5 and 25 times that of the air alone.

Pilot Testing

Heat transfer varies for various materials. The things that will influence the design of the cooler are: Particle size, material density, particle size distribution, material flow characteristics, and desired temperature change. The design and size of the grid and the amount of air required can be predicted based on the computer simulation. The slope of the tray and the depth of the bed are best determined by experimentation. FEECO International, Inc. offers a pilot plant with full process simulation capabilities to test materials.

Advantages of This System

The major advantages of this type of cooling system are:

1. *Improved heat transfer over more static design coolers.* The intimate contact of hot material with cooling air in a "single pass" system maintains a temperature gradient driving force that increases heat transfer from the material to the air.
2. *Takes up much less space than a rotary cooler.* The Fluidized Cooler Breeching is designed to be part of the discharge breeching of a rotary dryer.
3. *Power requirements are minimized due to low pressure drop and lower gas volumes.* Since high pressure air is not required for this design, due to the sloped nature, there is a lower power requirement.
4. *Improved process control through independent supply fan and water flow.* The air for the cooler is provided via an independent fan, with an adjustable damper as the fan discharge to control the pressure drop and air velocity.
5. *Allows for tighter control of product temperature from a rotary dryer.* This is important if you are dumping material onto a belt or discharging directly to a screening and bagging operation.
6. *The design can be adapted to fit onto existing equipment.* The cooler is designed to fit into the dryer discharge breeching. For existing equipment, the discharge breeching can be modified for fit up of this system.
7. *The slope of the bed can be adjusted for different material grades or products.* The characteristics of the product to be cooled will determine the proper slope of the bed.

This can be determined by experimentation using FEECO International, Inc.'s pilot plant. The velocity through the perforated plate can be varied for different material, depending on the weight and density of the product.

8. *The dryer burner load can be lessened by recirculating air.* The air from the cooler is segregated from the dryer air, and can be recirculated back to the dryer combustion chamber as make-up air.

9. *The design of the Fluidized Cooler Breeching is far more flexible than true fluid bed vessels.* The design is much more forgiving and readily adaptable to changes in material density or size distribution.

Summary

The Fluidized Cooler Breeching includes a sloped fluidized bed, which can provide primary or supplemental/secondary cooling of dryer products. As a primary cooler, the system will lower the temperature of the product to a point that is safe to transport and safe to store. It will be designed as part of the dryer discharge breeching. This system is much smaller and more energy efficient than a rotary cooler.

As a supplemental cooler, the unit can be installed in either the dryer or the rotary cooler discharge breeching. It can supplement the cooling when the existing system is overtaxed. The cooler can be adapted existing equipment and plant layout.

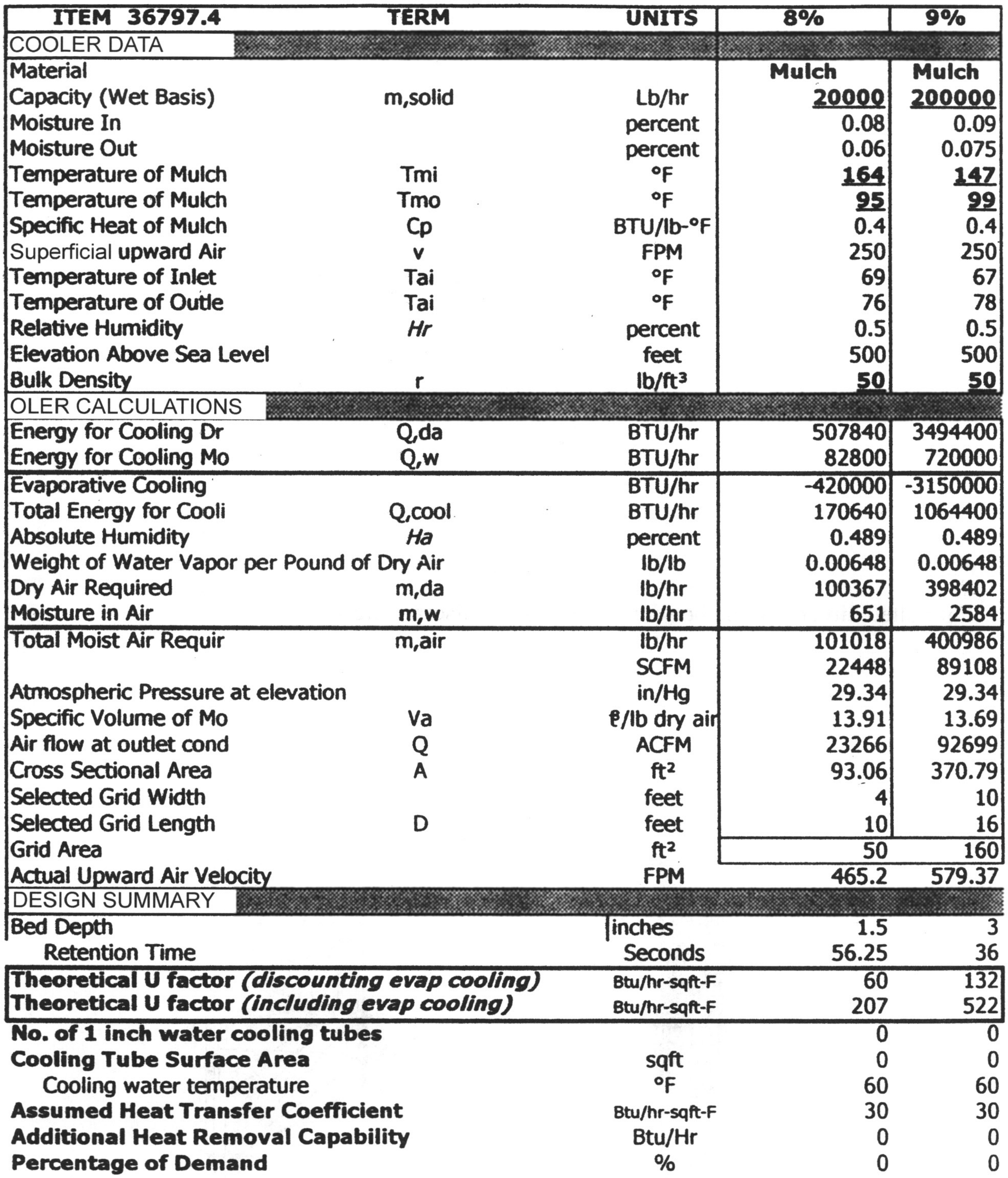
The cooling air can be recycled back to the dryer combustion chamber as make-up air to lower the burner fuel requirements.

References

[1] J.F. Davidson and D. Harrison, Fluidized Particles, Cambridge University Press, New York, 1963

[2] R.H. Perry and D.W. Green, Perry's Chemical Engineers' Handbook, Sixth Edition, McGraw-Hill,Inc, New York, 1984

Cooler Computer Sizing Program



ITEM 36797.4	TERM	UNITS	8%	9%
COOLER DATA				
Material			**Mulch**	**Mulch**
Capacity (Wet Basis)	m,solid	Lb/hr	**20000**	**200000**
Moisture In		percent	0.08	0.09
Moisture Out		percent	0.06	0.075
Temperature of Mulch	Tmi	°F	**164**	**147**
Temperature of Mulch	Tmo	°F	**95**	**99**
Specific Heat of Mulch	Cp	BTU/lb-°F	0.4	0.4
Superficial upward Air	v	FPM	250	250
Temperature of Inlet	Tai	°F	69	67
Temperature of Outle	Tai	°F	76	78
Relative Humidity	*Hr*	percent	0.5	0.5
Elevation Above Sea Level		feet	500	500
Bulk Density	r	lb/ft³	**50**	**50**
OLER CALCULATIONS				
Energy for Cooling Dr	Q,da	BTU/hr	507840	3494400
Energy for Cooling Mo	Q,w	BTU/hr	82800	720000
Evaporative Cooling		BTU/hr	-420000	-3150000
Total Energy for Cooli	Q,cool	BTU/hr	170640	1064400
Absolute Humidity	*Ha*	percent	0.489	0.489
Weight of Water Vapor per Pound of Dry Air		lb/lb	0.00648	0.00648
Dry Air Required	m,da	lb/hr	100367	398402
Moisture in Air	m,w	lb/hr	651	2584
Total Moist Air Requir	m,air	lb/hr	101018	400986
		SCFM	22448	89108
Atmospheric Pressure at elevation		in/Hg	29.34	29.34
Specific Volume of Mo	Va	ft³/lb dry air	13.91	13.69
Air flow at outlet cond	Q	ACFM	23266	92699
Cross Sectional Area	A	ft²	93.06	370.79
Selected Grid Width		feet	4	10
Selected Grid Length	D	feet	10	16
Grid Area		ft²	50	160
Actual Upward Air Velocity		FPM	465.2	579.37
DESIGN SUMMARY				
Bed Depth		inches	1.5	3
Retention Time		Seconds	56.25	36
Theoretical U factor *(discounting evap cooling)*		Btu/hr-sqft-F	60	132
Theoretical U factor *(including evap cooling)*		Btu/hr-sqft-F	207	522
No. of 1 inch water cooling tubes			0	0
Cooling Tube Surface Area		sqft	0	0
Cooling water temperature		°F	60	60
Assumed Heat Transfer Coefficient		Btu/hr-sqft-F	30	30
Additional Heat Removal Capability		Btu/Hr	0	0
Percentage of Demand		%	0	0

Figure 1

Original Cooling Tray Design

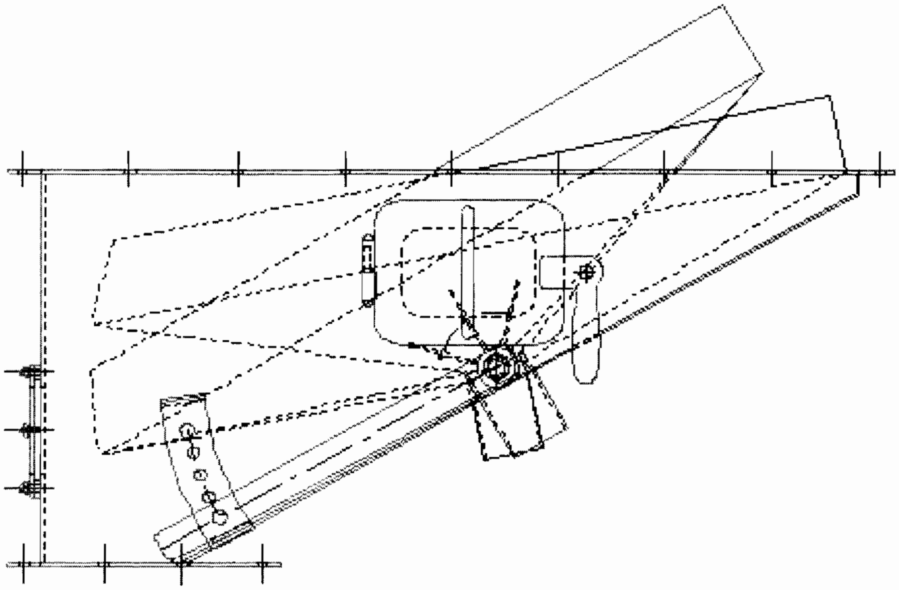


Figure 2

This unit bolted directly to the bottom of an existing discrarg breeching.

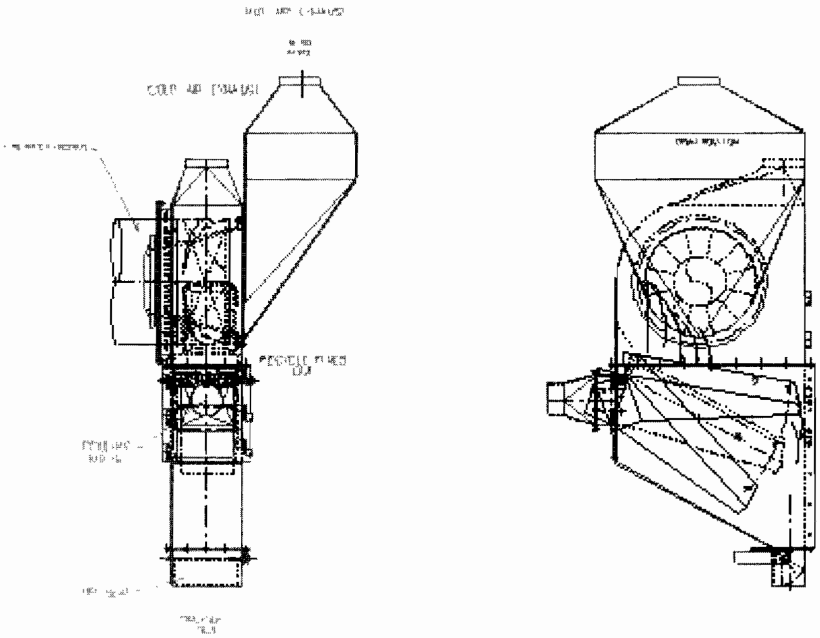


Figure 3

The second generation of cooler hood included a scroll at the end of the drum to better distribute the material across the cooler grid. The grid was designed with 38 degree slope variability.

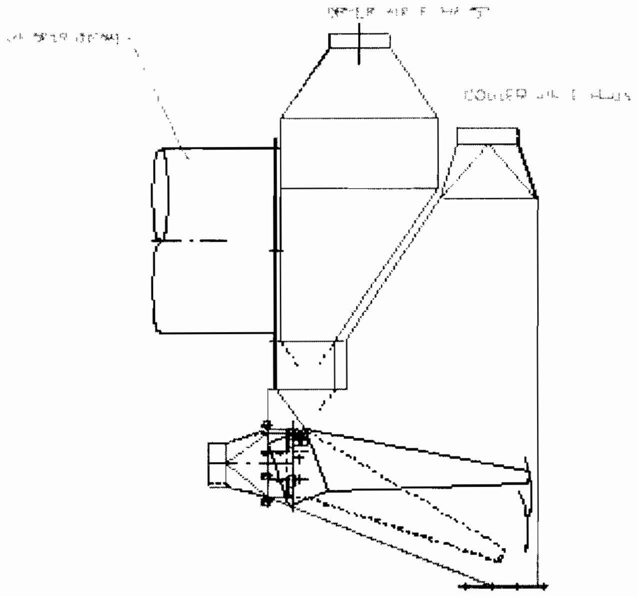


Figure 4

The latest generation of the cooler incorporates positioning the fluidizing grid directly under the normal discharge of material from the drum. An isolation valve was added to minimize intermixing of air between the dryer and cooler. An insulated plate, like rigid polyurethane, was added to minimize heat loss between the two systems of the discharge breeching.

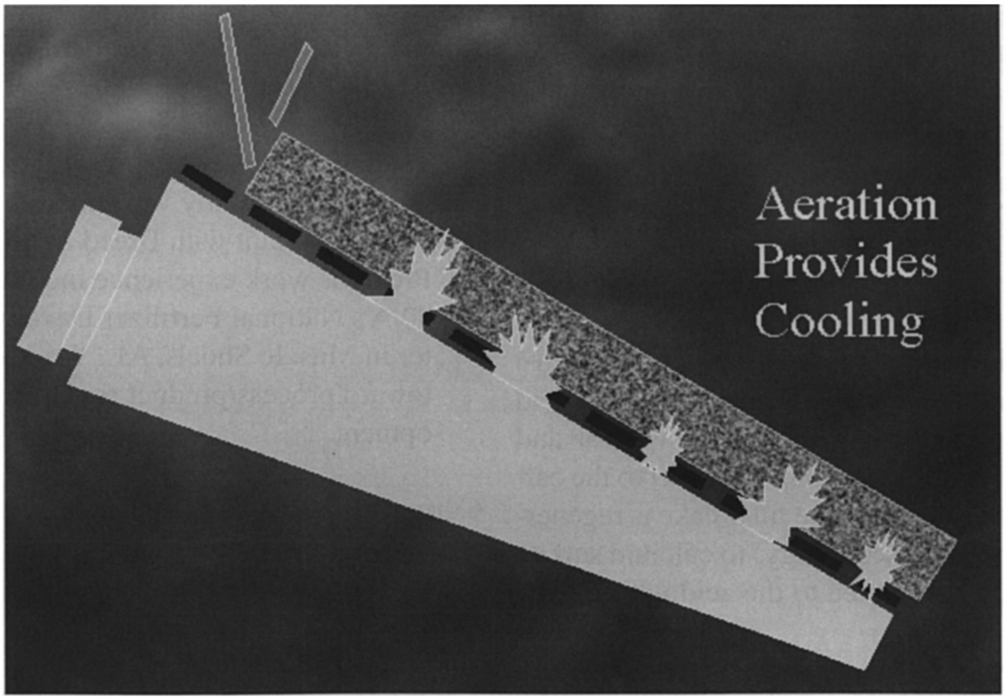


Figure 5

How it works Direct Convection

Direct Production of Clear Phosphoric Acid

Frank S. Sweat
Claude E. Breed
Kenneth E. McGill
H.F. Extraction, LLC

Introduction

The Sweat Process is a newly developed process for the direct production of a clean phosphoric acid. The process was developed by three inventors with over 110 years of fertilizer processing experience between them, Frank Sweat, Claude Breed, and Ken McGill; a brief resume of each is attached (Table 1). HF Extraction, LLC, which is registered in the state of Delaware, holds the patent rights to the process.

The main goals for the company are to offer new cutting edge technology to the domestic and international phosphate industry and to introduce technology/programs to developing countries that will help them become more self sufficient in their fertilizer production/distribution capabilities. Most of the employees of the company are former employees of TVA's National Fertilizer Development Center in Muscle Shoals, Alabama. The research and development efforts are conducted in the same spirit and tradition that made that organization the world leader in fertilizer technology for over 60 years.

The Sweat Process differs from the current phosphoric acid process in that phosphate rock is acidulated with a dilute stream of hydrofluoric acid (HF) instead of the traditional sulfuric acid. The acid produced using this reaction is extremely clean and essentially all of the heavy metals report to the calcium fluoride filter cake. The filter cake is regenerated (using existing technology) to calcium sulfate and HF, which is recycled to the acidulation step.

The process was developed on the bench scale and is being further tested in a larger scale pilot plant. The data from this testing will be used to further evaluate the operating details, economics, and target markets. Future plans include taking it to a plant demonstration. Preliminary economical projections indicate that the operating costs for the process will be about the same or lower that the sulfuric acid based systems. A patent covering the process has been filed with the US Patent Office.

Table 1.
Resumes of Inventors/Partners

The following are brief resumes of the inventors of the Sweat Process and partners in HF Extraction, LLC.

Samuel F. Sweat, Executive Vice President of HF Extraction, LLC

> Total experience in fertilizer industry is 40 years. Currently plant chemist for Mulberry Phosphates, located at Piney Point facility. Past experience include employment with Cornet Industries, Occidental Chemicals, IMC, Florida Institute of Phosphate Research, and Henry Fertilizer.

Current residence is Plant City, Florida.

Claude E. Breed, Vice President of HF Extraction, LLC

> Total work experience in fertilizer industry is 36 years. Currently working as chemical process consultant with Breed & McGill, LLC. Previous work experience includes work at TVA's National Fertilizer Development Center in Muscle Shoals, AL. Work was directed toward process/product research and development.

Current residence is Florence, Alabama.

Kenneth E. McGill, Vice President of HF Extraction, LLC

> Total work experience in fertilizer industry is 36 years. Currently working as chemical process consultant with Breed & McGill, LLC.

Previous work experience includes work at TVA's National Fertilizer Development Center in Muscle Shoals, AL and US Phosphoric, Tampa plant. Work was directed toward process/product research and development.

Current residence is Muscle Shoals, Alabama.

Process Description

The Sweat process was developed to target the problem of increasing levels of impurities in the phosphoric acid and related products. The traditional method for production of phosphoric acid depends upon the total digestion of phosphate rock with sulfuric/phosphoric acid. This results in dissolved impurities in the product acid that cause lower product quality, grade problems with DAP, and major solids management problems during operation and/or shipment.

A simplified flow diagram of the Sweat Process is shown on Figure 1.

The Sweat Process utilizes hydrofluoric acid (HF) to acidulate the phosphate rock. This step essentially eliminates any dissolved solids in the product acid because there is no dissolution of the phosphate rock and no need for crystallization of gypsum. The HF attacks the phosphate rock and reacts with the phosphate in-situ without the traditional dissolution step. A filter cake of calcium fluoride (CaF_2) is formed. Impurities and heavy metals such as iron, aluminum, magnesium, cadmium, etc. react chemically, remain inside the CaF_2 particles, and do not contaminate the product acid (essentially no impurities are ever put into solution).

Because the impurities are not dissolved into the acid, the quality of the feed rock is not as important as it is in the sulfate process. This will open up marginal deposits and/or skipped over deposits that have not been economical to utilize. Examples of this would be rock from Mexico and domestic sources such as Florida, Arkansas, and Tennessee. In addition, the size of the phosphate rock feed to the process is not critical. The use of a very fine grind is not required. In fact, the ball milling operation would probably not be required.

The reaction between the phosphate rock and the HF is fairly rapid and requires about one hour or less for completion. The need for a large reactor with a long retention time and heavy agitation/recirculation is not required.

The filter cake is separated from the phosphoric acid using traditional methods and equipment such as a table, pan, or belt filter. Filtration rates appear to be similar to the sulfate based systems.
The filter grade acid is free of dissolved solids (no post precipitation) which eliminates major materials handling and maintenance problems that are currently experienced with the sulfate based system.

The evaporation of the filter grade acid to merchant grade is essentially the same as the existing process. Because the product acid is free of dissolved and suspended solids, the boiling point should be lower. It should be possible to evaporate the product acid up to about 60% P2O5 with the same steam requirements.

Because of the expense of using HF acid, the regeneration of the CaF_2 back to HF for reuse is an essential part of the process. The method for regenerating the CaF_2 is an existing process that is commercially used to produce HF from the mineral fluorite (CaF_2). The filter cake or fluorite is mixed with sulfuric acid and the mixture is fed to a heated kiln where the HF is released and solid gypsum is discharged. The dry gypsum contains essentially all of the impurities that were present in the rock feed. This material is stacked similar to the phosphogypsum from the conventional process.

HF fumes from the reactor, filter, evaporator, and regeneration kiln are recovered and are recycled back to the process. Excess HF production is available for sales.

Potential Advantages and Disadvantages of the Sweat Process

There are several apparent advantages for the Sweat Process when it is compared to the existing technology. These include but are not limited to:

- Smaller process equipment/fairly easily retrofitted
- Little or no heat removal required
- Ease of process controls
- More efficient operation of evaporators (longer on stream time, lower boiling point, no solids in loop)
- HF is recycled and surplus is generated for sale
- The HF that is used is fairly low strength and is easy to handle
- Few limitations on the phosphate rock that can be used
- The size of the phosphate rock feed does not have to be fine
- Easier storage and transportation (no solids)
- Cleaner finished products

There are some areas of concern for the Sweat Process that can be listed as potential disadvantages. They include but are not limited to:

- Some process modifications are necessary
- There is some corrosion potential from the HF and the pure phosphoric acid
- There will need to be a change in the operating methods and philosophies
- HF is a hazardous chemical (as is sulfuric acid) and will have to be handled with care
- The regeneration kiln will require the input of energy.
- Currently development is limited to laboratory and large bench scale tests
- The presence of clays in the rock feed presents a problem with the process as it also does in the sulfate based system

Projected Uses for the Clean "Sweat" Acid

The Sweat Process offers exciting potential for the use of the clean acid made from the process. These include:

- On grade DAP
- Low impurity levels in the finished products (example Cd) which increases the overseas potential
- Increased rail and barge shipment of acid
- Increase in the fluid fertilizer market versus dry market
- Competition with superphosphoric acid for the fluids market
- Potential source of acid for technical grade market

Status of the Process and Future Plans

The status and future plans for the Sweat Process can be summarized as follows:

- The process has been tested on a large bench scale with very promising results
- A patent has been filed to cover the process
- Discussions have been and are being held with various companies and agencies concerning the application of the process
- A large-scale pilot plant is under construction and will be operated to develop necessary scale-up data for demonstration or production scale design
- Other patents are being developed to make the process more efficient and more economical

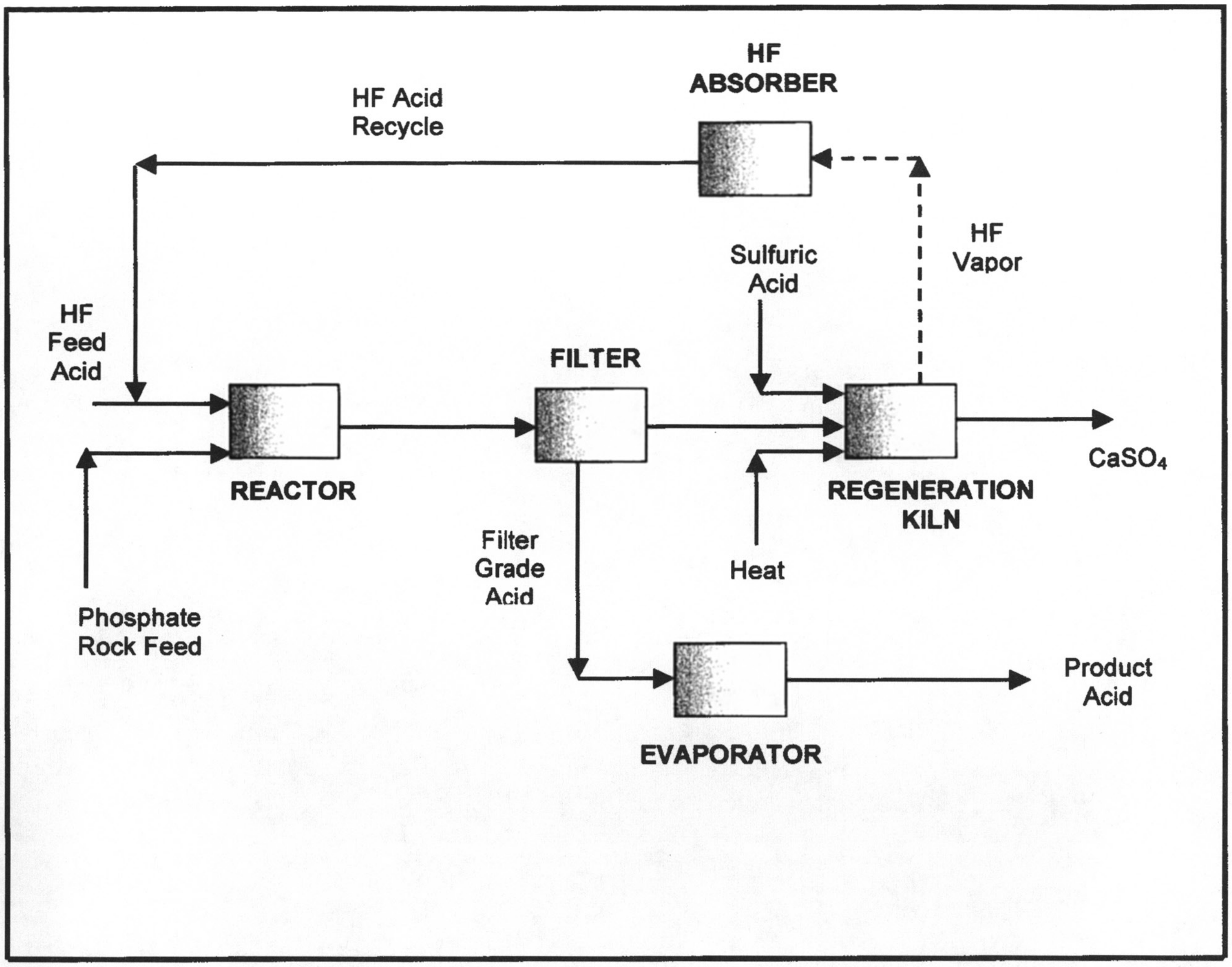


Figure 1

Simplified Flow Diagram for Sweat Process

Friday, October 6, 2000

Session IV
Moderator:

Ed Huber, Jr.

Waste Water Solids and Organically Enhanced Fertilizer

Gary L. Dahms
Jeff Burnham
Cypress Chemical Company

Summary

The innovative full-scale Unity Cross-Reactor Process, originally developed to manufacture chemical fertilizers, converts municipal biosolids into Class A nearly-odorless uniform fertilizer granules that contain commodity level nitrogen, i.e., 12% to 16%, and other nutrients, i.e., phosphorus, potassium and sulfur, that permit selling this valuable product, i.e., The Unity Product, directly into the United States and overseas commercial fertilizer markets.

Background

There are about 35 million metric tons of municipal biosolids (wet weight) as compared to 275 million tons of garbage and 1.3 billion tons of animal manure produced in the U.S. per year (USDA, 1998). The terms wastewater "sludges" and "biosolids" are now used interchangeably to describe the material resulting from the biological, physical and chemical treatment and dewatering of municipal domestic sewage to a liquid, semi-solid or solid state. Biosolids include domestic septage, but do not include industrial sludges, drinking water sludges, sewage sludges containing toxic chemicals, or grits and screenings which are removed from municipal wastewater during treatment. Municipal biosolids which are unsuitable for beneficial use by reason of hazardous components are landfilled or incinerated.

The use of properly treated municipal biosolids is safe. The Water Environment Federation, an association of over 41,000 professionals in water and wastewater management from the U.S. and other countries, has taken a very active role in supporting the use of these products in beneficial recycling programs. The USEPA reviewed data from all over the world in developing the 40CFR Part 503 Rules regarding the use and treatment of municipal biosolids. They point out that no documented negative human health impacts have been identified when biosolids that meet all of the requirements of Part 503 have been land applied under good management practices. There are two product classification standards created by the 503 rule, i.e., the more stringent Class A and lower level Class B. The Unity Process only manufactures a Class A product.

While the beneficial use of biosolids is becoming more of an accepted practice, it is increasingly facing challenges of public and regulatory acceptance from the standpoint of odor and product-value. Odors have become a problem with many biosolids products especially because of ammonia and amine production, e.g., trimethyl amine or dimethyl amine. Most biosolids products can only be marketed as low cost alternatives to conventional fertilizers because of such odor problems combined with inconsistent or low fertilizer values and handling and storage issues. As a result, most biosolids products can only command minimal prices that rarely cover shipping and spreading costs or frequently must be given away or sold with high subsidies.

Cypress Chemical Company

The Unity Process is being run at the Cypress Chemical Plant in Helena, AR. The portion of the Plant occupied by the Unity Process was constructed in 1962, on approximately a 5-acre site. The manufacture of ammonium sulfate ("Nitro-S") and micronutrient granules is carried out in a 4-level metal building, which houses the Unity reactor and granulation machinery. This facility is presently being retrofitted with state of the art dust and air handling equipment, including cyclones, air scrubbers, baghouse and a thermal oxidizer. Acid and anhydrous ammonia tanks and the fertilizer storage facility are each adjacent to rail and truck loading docks. The plant is also connected by overhead piping and conveyor to docks on the Mississippi River, located approximately 1/3 mile East of the processing plant.

Description

The innovative Unity Cross-Reactor Process (1999 U.S. Patent #5,984,992) was designed to create an improved biosolids product that would compete directly with conventional fertilizers because it meets the same strict product quality criteria. The end product has all of the appearance and odor of a conventional ammonium sulfate fertilizer and offers the same high fertilizer values as well. Absent are the typical biosolids odors including ammonia or amines. Most importantly, the product can command commodity market fertilizer prices. For these reasons this technology will have national application, not just its present central U.S. market.

The Unity Process mixes anhydrous ammonia with sulfuric acid and slurried biosolids to create a processing temperature of over 260 degrees F. It produces a small uniform granule that has a neutral to slightly acid pH, is microbiologicalty safe, has an odor equivalent to traditional ammonium sulfatefertilizer, is easy to handle, and that has a nutrient value of over 15% each for nitrogen and sulfur. The standard value for the Unity product is a 16-1-0-19 in N,P,K,S nutrient percentage. Unity also intends to manufacture a 12-12-0-12 granule as well.

The typical Unity product granule has a diameter of about 2 to 2.5 mm. The Unity granules are superior to traditional ammonium sulfate fertilizers because the granules are of increased hardness and have more uniformity of size and shape. Additionally, the products nonflammable characteristic gives it a distinct advantage over traditional biosolid granules or pellets.

Because the reactor temperature in the Unity Process is normally run at 270°F, microbial flora is eliminated and 40CFR Part 503 Class A standards are easily achieved. It is significant to point out that this temperature, when converted to Celsius degrees, is 131°C and is the actual temperature used by U.S. hospitals to sterilize medical waste. The Unity Process exceeds the Class A fecal coliform standard by more than three magnitudes.

The dryness of the product, i.e., above 97%, coupled with its high inorganic ammonium and sulfate constituents make it stable and resistant to any contaminant re-growth and allow the Unity Product to meet Vector Attraction Standards. All regulated metals are in compliance with the USEPA's Rule 40CFR Part 503 governing the treatment and use of municipal wastewater biosolids in the U.S.

One of the major advantages of the Unity Process is that it can be "tailor-made" to customer specifications. The amount of nitrogen can be changed by regulating the amount of municipal biosotids cake, acid and ammonia added at the head of the process. Substituting phosphoric acid for some or all of the sulfuric acid in the process can vary the amount of phosphorus.

Unlike untreated biosolids, or biosolids processed by alkaline stabilization technologies, there are no nitrogenous amines (methylamines), sulfur compounds, (sulfides or mercaptans), or ammonia present in emissions from the Unity Product. Therefore, the nitrogen that enters the product from the biosolids remains crop available in the finished product again enhancing the value of the Unity Product.

The Unity Process is operationally proven because of the large pilot scale project conducted in 1999. At the present time the Unity operation at Helena, AR has a contract to process over 200 wet tons of New York biosolids per day in a joint venture with Hydropress Environmental Services, Inc. and TTJV, Inc.

This innovative Unity Process creates a stable, microbial pathogen-free, nearly odorless product that will meet the most stringent regulations and laws, and that will sell as a valuable nitrogen and sulfur product in commercial agriculture.

AAPFCO Update and Outlook

Steve Wong

California Department of Agriculture

Thank you for inviting me to talk to members of the Fertilizer Industry Round Table. It is nice to be in New Orleans again. I always enjoy visiting this city. As Ed Huber indicated, I am from Napa, California. Napa, today is known for its wine production. When I lived there 40 years ago, poultry, cattle, tree fruits and nuts were the primary agricultural crops produced. Some of the "nuts" may not be the kind that grew on trees. I often wonder if this is how California became known for its rapid, unconventional progress and development into the state it is today.

You asked me to provide an update on the activities of the Association of American Plant Food Control Officials. How many of you know what AAPFCO does? Let me briefly tell you about AAPFCO. AAPFCO is a non-profit organization comprised of officials from state, territory, dominion, province, federal or other government entity on the North American Continent, Hawaii and Puerto Rico charged with the responsibility to enforce laws regulating the production, storage, labeling distribution, sale or use of fertilizers. The purpose of AAPFCO is to provide a forum through which control officials may unite to 1) promote uniform and effective legislation, definitions, rulings and enforcement practices; 2) encourage and sponsor the adoption of effective and adequate analytical methods for fertilizer; 3) develop standards of fertilizer inspection; 4) promote adequate labeling and safe use of fertilizers; 5) provide facilities and opportunities for the free exchange of information, discussion and cooperative study of problems; and 6) cooperate with members of industry to promote the safe use of fertilizer and protect soil and water resources.

How does AAPFCO carry out its purpose? They do so through the work of 13 standing committees, investigators and task forces as needed. Committees are made up of control official and liaisons from industry and academia. I will speak about those committees and task forces that are working on current issues.

Industry-Regulated Council

This committee began during the August 2000 annual meeting to provide speakers on understanding risk assessments. This is an important area as states begin to adopt standards for non-nutritive metals for fertilizers. Many of us including control officials will need to have a through understanding of health and environmental risk assessment in order to adopt and implement such standards for fertilizer. This committee will continue to provide educational information on this subject along with keeping us informed about federal legislative activity impacting fertilizers and their potential effect on the environment. In addition, this committee will provide a speaker at the mid-year meeting of AAPFCO to make a presentation on how AAPFCO works. This is an issue the fertilizer industry requested greater understanding in order to work cooperatively with the association.

Education and Information Committee

This committee will publish a brochure on "How AAPFCO Works" and a "Guide for Industry Liaison Committee Members". It is anticipated that this information may be available by the 2001 annual meeting.

Environmental Affairs Committee

The Environmental Affairs Committee consists of two subcommittees. One to address by-products and recycled materials and the other deals with nutrient management. The By-Products and

Recycled Materials Subcommittee is working to develop a risk based proposal to establish non-nutritive metal standards for fertilizers. AAPFCO has adopted an interim standard employing the Canadian standards for fertilizers and the U.S. Environmental Protection Agency's section 503 bio solid standards. The BPRM is evaluating risk assessments conducted by the state of California and The Fertilizer Institute and expects to propose risk-based standards by the mid-year meeting of the Association.

The Nutrient Management Subcommittee is monitoring the development of the U.S EPA's draft Action Plan for reducing, mitigating, and controlling hypoxia in the Northern Gulf of Mexico. This subcommittee also monitors development of state nutrient management plans required by the federal Clean Water Act.

Good Manufacturing Practices Committee
This committee has drafted a document for a Fluid Fertilizer Blend Manual. This document is under review and may be finalized by the August 2001 annual meeting. The committee has done a study on the use of a 1/2 in. slot bag trier versus a 3/4 in. slot trier. The 3/4 in. slot trier has been recommended by AR Douglas Caine and accepted by the General Referee, Peter Kane from the Association of Analytical Chemist as an official fertilizer sampling trier for bagged fertilizer. The committee is also reviewing proposed definitions for "blender", "blending", "custom blend", and "application".

Laboratory Services Committee
This committee recently completed an extensive review of the AAFCO (feed) Quality Assurance/ Quality Control Guidelines for State Feed Laboratories. The committee recommends the use of the AAFCO Quality Guidelines as reference for Quality Control programs for fertilizer laboratories. The Laboratory Services Committee is focusing on laboratory sample handling and quality control for sample splitting and grinding and will develop a guideline for preparing laboratory samples.

Long Range Planning Committee
Based on the recent release of US EPA's draft report on dioxin, this committee is examining potential concerns about organic contaminants (dioxin) in fertilizer. The committee is suggesting that the AAPFCO and the fertilizer industry investigate the possibility of organic contaminants be present in fertilizers and prepare to address such issues when they arise. Another area this committee began exploring is the possibility of promoting model fertilizer regulations internationally. AAPFCO is currently recognized nationally in the United States and would welcome feed back from other Countries.

Magruder Fertilizer Check Sample Committee
The committee has a web site operational and will post sample results there in the near future. This year' testing will include samples analyzed for all of the heavy metals of interest. The committee has developed a promotional brochure and it is available for distribution.

Uniform Bills Committee
The Uniform Bills Committee completed work on amendment to the Uniform Bill and rules to include provision for directions for use on fertilizer labels. The rules also provide specific direction for use language for specialty fertilizers and for farm use fertilizers. This committee will continue to develop a Lawn Care Service Bill and a Uniform Compost Law.

Uniform Reports Committee
This committee has completed two revisions to the UFTRS Windows Version 4.0, 4.01 and 4.02. These are available through the University of Kentucky Division of Regulatory Services FTP site: ftp://aapfco:uftrs4@128.163.194.57. The *Commercial Fertilizer 1999* report was published in April 2000.

Sampling Task Force
This task force was formed to study sampling of bulk bag fertilizer containers (mini bulk bags) to determine whether the official AOAC bulk sam-

pling procedures will obtain a representative sample. The task force concluded from data obtained that a representative sample is obtained by a composite of twelve cores from specific locations in each quadrant of a minimum of three mini bulk bags. The results of the study are being submitted to the AOAC for validation.

Slow Release Task Force

This group was tasked to develop a laboratory method to determine nutrient release rates for slow release fertilizer products, conduct an agronomic evaluation of the products used in developing the laboratory method and review labeling issues on slow release fertilizer products. A method has been developed and is in the process of AOAC collaborative study to validate the method and make it official. The agronomic research is under way by Dr Sartain at the University of Florida. Labeling issues are under review and the task force expects to have some recommendations by the mid-year meeting.

Emerging Issues and Outlook

Aside from the specific activities of the AAPFCO committees and task forces, you asked me to provide some insight on emerging issues that may impact the fertilizer industry. I am not very good at predicting outcomes, but there are a number of issues that have come to our attention and may require you to begin planning to address them.

I have been involved with development of a basis to support the adoption of standards for non-nutritive metals in fertilizer since 1989 when we informed the California fertilizer industry of the concern about the levels of arsenic, cadmium and lead in fertilizer products. The establishment of risk based standards for specific non-nutritive metals (arsenic, cadmium and lead) will occur in California. These along with several other metal standards will be considered by AAPFCO in a uniform statement of interpretation or policy, or in the form of a model rule. This will most likely be decided this year with AAPFCO membership action at the annual meeting in August 2001.

Dioxins and furans are compounds suspected of occurring in fertilizers whether from natural or industrial sources. These compounds can have serious health impacts on humans and other animals as carcinogens or an endocrine disrupter. More data is needed to determine if such compounds are in fertilizers and their impact on man and the environment.

Perchlorate is another compound initially reported by the U. S. Environmental Protection Agency found in fertilizers. Perchlorate is an anion that originates as a contaminant in ground water and surface water from the dissolution of ammonium, potassium, magnesium or sodium salts. Perchlorate affects the function of the thyroid in humans through inhibition of iodine uptake. Work by the industry and some individual states has not been able to duplicate the reported levels. Addition work to identify and quantify perchlorate in fertilizer is in progress at EPA with the fertilizer industry and some state fertilizer control laboratories assistance.

Asbestos in vermiculite has been raised as another potential hazard associated with fertilizing materials. The EPA conducted an investigation following a report by a Washington state newspaper indicating that vermiculite plant products contain asbestos and could be hazardous to people working with the material. Initial EPA review indicates that risk for home gardeners is negligible, but further study on a nationwide basis is still under review.

On September 1, 2000 the Center for Disease Control (CDC) reported three outbreaks of Legionnaires' Disease associated with potting soils. These occurred in California, Oregon and Washington. Potting soils from two the three cases were confirmed to contain Legionella bacteria. This suggest that transmission form potting soil has occurred for the first time in the United States and the CDC will continue active surveillance and case findings to explore this association.

Finally, on September 15, 2000 we were notified of the contamination of municipal drainage water in Laguna Niguel, California with pathogenic microorganisms. Investigation by the water district found no direct sewage system contamination sources, but noted a number of residential applications of organic fertilizers, some of which contained processed sewage sludge. This suggests that there may be a possibility that fertilizer may contain microorganisms and in the case of processed sewage sludge the process may not be destroying all organisms.

What does this all mean? I believe that fertilizer and other associated materials will continue to be viewed by the general public as potential environmental and health concerns, especially if the safety of food is impacted. The media and special interest groups will continue to raise these concerns and keep them before the public. How can you, the fertilizer industry address these issues? As I indicated earlier, I am not very good at predicting outcomes. However, I believe you can address these issues through development and distribution of factual information that is understood by the public. Secondly, any necessary regulation must be based upon good science and avoidance of political pressures. As the president of AAPFCO, I pledge the continued support and efforts of the association to cooperate with the fertilizer industry whereever appropriate to seek mutual resolution to such issues.

Summary

Three separate risk assessments have been completed that examine the human health and environmental effects of small amounts of metals that occur in some fertilizers. The three studies were done by the California Department of Food and Agriculture (CDFA), The Weinberg Group for The Fertilizer Institute (TFI), and the U.S. Environmental Protection Agency (EPA). All three point to the same conclusion: Metals in fertilizers generally do not pose a threat to human health or the environment.

Fertilizer is Safe!

Ron Phillips

The Fertilizer Institute

Background

In 1996, The Fertilizer Institute initiated a comprehensive risk assessment project on the risk of metals in fertilizer. The purpose of the project was to generate risk information to provide more comprehensive information to customers and to enable TFI to better interact with regulatory agencies and

In July, 1997, the *Seattle Times* ran a series of articles containing charges about the potential of environmental damage caused by "hazardous wastes in fertilizer." This series of articles spurred regulators to more closely examine the impact of metals in fertilizer. One of the regulatory bodies responding to the issue was the U.S. EPA, which contracted with Battelle to do a characterization study of the fertilizer industry.

Fertilizer Basics

Nutrients are essential to all life and some nutrients are metals. Fertilizers (or plant food) provide necessary nutrients to plants in a usable form. Fertilizers are made of the same elements plants find in nature – except they're in a more concentrated and usable form. Fertilizers are made from nitrogen in the air we breathe and also are mined from the land. Fertilizers boost crop yields, making it possible for American farmers to feed people in the U.S. and around the world. Without fertilizers, crop yields would drop 40 to 60 percent, depending on the crop.

The three nutrients plants need in the largest quantities are nitrogen, phosphorous and potassium. These are known as the major nutrients, as they comprise about 98 percent of all the fertilizer sold in the United States. Nitrogen is taken from the air and converted to a more plant-available form of fertilizer through a chemical process. Phosphate and potash are mined from the earth and can be used directly or converted to fertilizer, which is easier for plants to use.

In addition to these three major nutrients, there are three secondary nutrients – calcium, magnesium and sulfur – as well as several micronutrients, including boron, copper, iron, zinc, manganese, molybdenum and chlorine, which plants use in very small quantities. Farmers apply fertilizers based on soil tests and other recommendations designed to meet the needs of particular crops and replace the nutrients they've removed.

So why are there metals in fertilizers?
Nature is the biggest reason. Phosphate and potash fertilizers begin with the mining of phosphate rock and potassium rock from the earth's crust. Nature places small amounts of metals in these ore bodies, generally more in phospate than in potash ores. There is little chance of metals in nitrogen fertilizers.

In addition to phosphate and potash products, some minor element fertilizers, or micronutrients, come from mined ore bodies as well, while a few others may have recycled waste as their source of nutrient. These nutrient sources – ores and wastes – often contain metals as well.

Background on Risk Assessment
Risk assessment is a scientific tool that helps determine the likelihood that contact or exposure to a given substance will result in adverse health or environmental effects. Typically, a risk assessment contains the following major steps:

- Selection of a substance of concern: What could an individual be exposed to that might cause a health risk? In this case, it is the metal contained in some fertilizer products.
- Exposure assessment: Who are the individuals that might be exposed, and how are they exposed to the substance of concern? For instance, farm families are likely to have some exposure to fertilizer and the metals they contain. The exposure assessment measures how much a member of that family will be exposed to metals in fertilizer as a result of skin contact, inhalation of dust or unintentional ingestion of fertilizer soil, or ingestion of crops grown in fertilized soil.
- Toxicity assessment: How toxic, or how dangerous, is exposure to these elements? What adverse effects could result from exposure? Could it cause cancer or some other health effect, and at what level of exposure might these effects show up?
- Estimation of acceptable exposure levels: The information from the previous steps are brought together in calculations of risk-based concentrations (RBCs), or the amount of a metal in a fertilizer product than can safely be considered non-threatening to human health. RBCs are considered screening level estimates that would not underestimate actual risks.
- Risk evaluation: An RBC for a particular metal is then compared to measured levels of that metal in products. This comparison provides the basis to initially determine the likelihood of adverse health effects.

California Risk Assessment
The California Department of Food and Agriculture (CDFA) conducted a risk assessment to provide risk-based standards for evaluating the potential for adverse public health impacts from metals in commercial inorganic fertilizers used in farming operations in California. The report, completed in 1998, has undergone several scientific peer reviews.

The CDFA study established risk based concentrations for three metals – lead, cadmium and arsenic. These were selected from among a larger group of metals because of the toxicological significance. The focus of the study was farm families, both adults and children living on farms including adults applying fertilizer. The exposure assessment included consideration of unintentional ingestion of fertilized soil, skin contact with fertilized soil and ingestion of homegrown crops grown in fertilized soil (including vegetable crops, root crops and grains). The assessment was performed in accordance with basic health risk assessment procedures established by EPA and by California health officials and EPA.

Cancer and non-cancer effects were evaluated for the three metals in phosphate fertilizer materials, NPK blends and zinc micronutrient products. RBCs are presented as "unit factors" and are based on one percent nutrient content. Because fertilizers vary in the amount of nutrients they contain, the unit factors can be used to calculate product-specific RBCs for any product of interest. For example, the CDFA RBC for cadmium is 16 ppm for each one percent of nutrient. Diammonium phosphate is a fertilizer product that contains 46 percent of the nutrient phosphorous. Thus, the cadmium standard for diammonium phosphate (DAP, 10-46-0) would be 736 ppm (16 x 46), the 46 representing 46 percent phosphate in DAP.

The product-specific RBC values can be compared to measured levels of arsenic, cadmium or lead in specific products in order to evaluate health risks of specific products to farm families. The CDFA report does not make such comparisons but provides the methodology for such a comparison. The results would be generally applicable beyond California but keeping in mind the assessment was performed using crops, soil conditions and fertilizer usage representative of California.

California RBCs:

Phosphate Fertilizer	Micronutrient Fertilizer
Cadmium 16 ppm per unit of nutrient	134 ppm
Arsenic 19 ppm	155 ppm
Lead 97 ppm	738 ppm

EPA Risk Assessment

The U.S. Environmental Protection Agency conducted a fertilizer risk assessment to guide the Agency's decisions regarding the need for federal regulatory action on non-nutritive elements in fertilizer. The agency used probabilistic methodology to estimate increased risks of both cancer and non-cancer health effects. The methodology was adopted from EPA's risk assessment for cement kiln dust used as an agricultural liming agent.

EPA assessed macronutrient (NPK) fertilizers, micronutrient fertilizers and soil amendments. The agency evaluated risk from 9 metals: cadmium, lead, arsenic chromium, mercury, nickel, vanadium, copper and zinc, in addition to 17 dioxin congeners. Rather than calculating RBCs, the agency provided a "yes" or "no: answer to the question, "Are commercially available phosphate materials, NPK blends and micronutrient products safe for health and the environment?

In order to make its evaluations of risk, EPA first commissioned Battelle to prepare a report on fertilizer production, use and the incidence of metals in fertilizers. The report, entitled "Background Report on Fertilizer Use, Contaminants and Regulations," is available on the web at www.epa.gov/ncephihom/catalog/EPA747R98003.html. Following is a summary of metals levels in fertilizers as contained in the EPA report. (See Table 1).

Receptors for the EPA risk assessment are farm families, including adults and children. Five exposure routes were evaluated:

- Direct ingestion of fertilizer products during application (adult only)
- Incidental ingestion of fertilized soil
- Inhalation of particles and vapors during fertilizer application
- Ingestion of plant and animal products produced on fertilized soil
- Ingestion of home-caught fish from streams adjacent to fertilized fields

EPA concluded that "of the large number of fertilizer products evaluated, only a few had contaminant levels high enough to potentially cause cancer risk or noncancer hazard of concern. Therefore, the results of this analysis indicate that, based on the data available, hazardous constituents in fertilizers generally do not pose harm to human health or the environment." The summary explains the agency found only four individual product samples with levels of metals above the hazard index: a liming agent, an iron micronutrient, a boron micronutrient and a zinc micronutrient. (See Table 2).

Non-cancer risks are expressed as a hazard index. A hazard index of one is the screening level that separates "safe" products from those needing further evaluation. On the above chart, then, numbers less than one are considered safe.
Cancer risks are expressed in terms of frequency of increased cancer per number of population. Acceptable risks, or safe levels, are those where the increased cancer risk is less than one in 100,000, or 1E-05. Less frequent occurrences, such as one in 1 million or 1E-06 are acceptable. More frequent occurrences, such as one in 100,000 (1E-05) or greater do not meet the safe level and require further evaluation.

The Fertilizer Institute Risk Assessment

The Weinberg Group, for The Fertilizer Institute, completed a risk assessment to provide risk-based safe concentrations for evaluating the potential impacts of 12 metals in fertilizers on farm families. The 12 metals are arsenic, cadmium, chromium, copper, cobalt, lead, mercury, molybdenum, nickel, selenium, vanadium and zinc. Risk-based concentrations for these 12 have been calculated and compared to measured levels in fertilizer.

The populations and pathways generally are the same as those for the California study. The farm family population includes both adults and children, and pathways include unintentional ingestion of fertilized soil, skin contact with fertilized soil and ingestion of homegrown crops grown on fertilized soil.

Several differences in exposure and toxicity parameters between the California and TFI assessments that account for differences in the RBCs. These different assumptions include looking at national factors rather than California specific factors, and include:

- Application rates of fertilizer. The upper end of national application rates were generally higher than the application rates used in the California assessment.
- Exposure duration. National defaults were used in the TFI assessment, whereas California modified these factors based on California-specific information.
- Plant uptake. Slightly different crop groups, accounting for different crops grown nationally and in California, and different references used account for differences in crop uptake assumptions. Generally, the TFI study assumed higher uptake factors. (See Table 3).

Comparison to Measured Levels

TFI has compiled and continues to add to a database of measured levels of metals in fertilizers. This database contains more than 900 samples of phosphate fertilizers and about 140 samples of micronutrient fertilizers. These samples produced nearly 3000 analyses of metal content. The database was compiled from three sources:

1. A comprehensive literature search using several online scientific databases. The search identified articles published since 1985. Literature from both the EPA Battelle report and the CDFA risk assessment was used to add to the data.
2. An industry survey of TFI member companies. A survey was designed and sent to 24 companies with about 200 facilities.
3. Government and non-government organizations were contacted for relevant reports that are unpublished. In particular, a good deal of data was obtained from state officials who periodically test for metals in fertilizer.

The Weinberg Group in December 1998 submitted a report on this database entitled, "Industry and Literature Survey of Nutritive and Non-nutritive Elements in Inorganic Fertilizer Materials." The data from state monitoring programs are archived at The Weinberg Group. A summary of the data is as follows: (See Table 4).

In addition, TFI has contracted with North Carolina State University (NCSU) to conduct a statistically valid sampling program of all major, basic fertilizer products in the United States. Those samples will be tested for levels of metals, adding additional information and confidence to information compiled about the incidence of metals in fertilizers. The NCSU database will be used to give a complete and universal assessment of the incident of metals in fertilizer.

The RBCs developed in this risk assessment, when compared to measured levels in fertilizer, show wide margins of safety.

Summary

Risk assessments have been completed which focus on a number of metals commercial inorganic fertilizer and potential health effects on two key populations: farm families and fertilizer applicators, and effects on the environment. Actual measured data of metals in fertilizer show these products are safe for farm families, applicators and the environment with wide margins of safety for all NPK and nearly all micronutrient products.

Policymakers considering the need to set standards for non-nutritive elements in fertilizer should carefully consider the results of these risk assessments.

Recent Developments

Newly published information regarding soil partitioning values (K_d) suggests lower range kd values were used in the California and Weinberg risk assessments. California has recalculated its RBCs using higher K_d values.

However, an analysis of the data shows a correlation between K_d values and plant uptake factors (PUFs). As K_d values risk, PUFs should be lowered, as higher Kds indicate lower metal amounts are available in soil solution. TFI believes this relationship must be considered as new RBCs are developed.

The debate over proper K_ds and PUFs is bounded by these observed facts:

1. We don't observe problems with metals in groundwater, as would be expected with low values
2. The Food and Drug Administration's annual marketplace survey shows the levels of metals in food are declining.
3. Long-term experiments around the world show there is no long-term build-up of metals in soil, as would be expected with high K_d values.

	Phosphates		Micronutrients	
Metal	Minimum	Maximum	Minimum	Maximum
Arsenic	0.05	155	0.5 ppm	4,950
Cadmium	0.03	250	0.75	2,165
Chromium	4.3	896	1.3	580
Copper	0.2	1,170	1.5	39,900
Lead	0.1	5,425	5	52,000
Mercury	0.003	0.2	0.01	3.36
Nickel	0.5	195	2.5	8,950
Vanadium	25	721	0.5	41
Zinc	1	2,193	6	94,300

Table 1

EPA Risk Results:

Metal	Highest Farm Family Hazard Index (Phosphates)	Highest Hazard Index (Micronutrients)
Arsenic	1E-06 (expressed as cancer risk)	1E-05
Cadmium	0.18	0.21
Chromium	0.015	0.0011
Copper	0.0006	0.00001
Lead	No risk	No risk
Mercury	0.3	0.9
Nickel	0.0011	0.015
Vanadium	0.007	0.0001
Zinc	0.001	0.03

Table 2

TFI Risk Assessment RBCs

	Phosphate Fertilizer	Micronutrient Fertilizer
Cadmium	23 ppm per unit of nutrient	210 ppm
Arsenic	4.5	38
Lead	73	500
Cobalt	3,100	23,000
Mercury	0.9	6.5
Molybdenum	42	300
Nickel	350	2,600
Selenium	120	800
Zinc	1,200	8,600
Chromium	34,000	220,000
Copper	280	1,800
Vanadium	2,200	17,000

Table 3

	Phosphates		Micronutrients	
	Minimum	Maximum	Minimum	Maximum
Arsenic	0.05	42	0.01	6,190
Cadmium	0.15	205	0.1	3,900
Chromium	0.5	5,100	0.25	8,100
Cobalt	0.25	22	0.25	786
Copper	0.44	540	0.5	1,680
Lead	0.05	1,860	0.32	27,700
Mercury	0.001	1.5	0.003	12
Molybdenum	2.5	72	0.25	850
Nickel	1.1	235	0.25	560
Selenium	0.05	21	0.01	25
Vanadium	11	1,106	0.5	46.5
Zinc	0.83	6,300	8	348,000

Table 4

Fertilizer Under Siege
Trace Matals and Perchlorates

Wayne P. Robarge
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Introduction

Application of manufactured fertilizers to optimize crop yields is an integral part of contemporary soil and crop management practices and is an essential component of modern agricultural production in the United States. Fertilizer technologies and use have increased agricultural productivity, profitability, food security, and diversity in food and fiber crops grown worldwide. When integrated with recommended soil conservation practices, use of manufactured fertilizers can also improve overall soil quality. As a result of fertilizer use, American agriculture exports diverse, high quality agricultural products which act to offset the national trade deficit and provide the American people with the lowest per capita food costs in the world.

Use of manufactured fertilizers in contemporary agriculture, however, has been challenged because of the potential for detrimental impacts on the environment and potential risk to human health. Potential environmental impacts arise primarily from the application of nitrogen and phosphorus bearing fertilizers. Potential environmental impacts that have been attributed to agricultural fertilizers include: non-point source pollution (http://www.epa.gov/OWOW/NPS/), trace metal contamination of soils (see "Fear in the Fields", http://seattletimes.nwsource.com/extra/browse/html97/regu 070497.html; "Factory Farming", http://www.factoryfarming.com/; and U.S. EPA WEB site http://www.epa.gov/epaoswer/hazwaste/recycle/fertiliz/risk/index.htm), hypoxia (seehttp://www.sws.uiuc.edu/docs/hypoxia/hypoxia.asp; http://water.usgs.gov/pubs/circ1133/exec-summary.html;http://wwwrcolka.cr.usgs.gov/midconherb/hypoxia.html) and perchlorates (see Susarla et al., 1999). Attention has also been focused on the potential for enhanced atmospheric emissions of ammonia, nitric oxides and nitrous oxides from the use of agricultural fertilizers. Ammonia emissions can lead to the formation of ammonium aerosols (primarily ammonium sulfate) which are considered to constitute a large percentage of atmospheric particulates < 2.5 microns in size (see http://www.epa.gov/ttn/amtic/amticpm.html). Regulations regarding atmospheric concentrations of particulate matter in this size range have been proposed (http://www.deq.state.va.us/air/pm25.html) due to their potential for negative impacts on human health. Emissions of nitric oxides from fertilized soils can enhance the production of ozone in rural regions, which are typically nitric oxide limited (Aneja, 1996). Nitrous oxide is an important global greenhouse gas whose source has been attributed to fertilized agricultural fields (Coolman and Robarge, 1995).

Public attention continues to be focused on the potential negative aspects of fertilizer use in modern agricultural (see "Nitrogen Glut", September 28, 2000, http://www.sunspot.net). Clearly, any negative potential impact from the use of fertilizers in agriculture, either on the environment and/or human health, needs to be evaluated. However, such an evaluation must be conducted according to the guidelines of rigorous scientific investigation that provides results suitable for proper assessment of the risk in the context of today's modern society. This paper outlines the current status of two such investigations initiated by The Fertilizer Institute (TFI) (http://www.tfi.org) that address environmental concerns regarding fertilizers formulated from fertilizer source materials: trace metals and perchlorate.

Trace Metals

The presence of trace metals in various fertilizer source materials, fertilizer blends, and fillers is known, and has been addressed by past research. However, past studies addressing the trace metal content in fertilizers and fertilizer source materials have often focused primarily on analytical protocols with results provided for individual samples.

Usually, little information is provided on how representative these samples are of the population of fertilizer or fertilizer source material. It is generally recognized that probability sampling of the relevant populations is the only way to guarantee that samples are representative (Taylor, 1987). If the samples in a database are not representative, then risk assessment based on these samples can be inaccurate. A scientific study was therefore initiated with the following objectives to provide the information necessary for a suitable risk assessment concerning the presence of trace metals in fertilizer source materials (Phillips, 2000):

1. To conduct a statistically valid sampling of all TFI member fertilizer source material production facilities to generate composite samples representative of different fertilizer source materials, and
2. To conduct chemical analysis of the composite samples using modern chemical instrumentation and a defensible quality control /quality assurance program.

The study was initiated in 1999 with the goal of obtaining two samplings during a 365 day period from the production of a variety of fertilizer source materials in North America (Table 1). The statistical design in use is based on inductive statistical procedures whereby random samples can be used to characterize a population. Inherent in the statistical design chosen for this study is the following assumptions:

- Except for phosphate rock, fertilizer source materials are a result of an industrial process to deliver a product within specified quality parameters.
- Industrial processes will average out concentrations of trace metals (product streams typically feed back upon themselves to arrive at specified quality criteria).
- Cumulative exposure to trace metals in fertilizer source materials involves dispersal of large quantities of material spread over large areas (e.g. agricultural cropland in North America).
- In this study, it is the mean value of trace metals in a fertilizer source material that is important because fertilizer source material is mainly dispersed in bulk, not as individual units. Focus on mean values allows compositing that reduces analytical burden and analytical cost.

Table 1. Fertilizer Source Materials to Be Sampled.

Fertilizer Source Material	Abbreviation
Di-ammonium phosphate	DAP
Mono-ammonium phosphate	MAP
Ammonium sulfate	AS
Potassium chloride (red)	KCl
Phosphate rock	P Rock
Triple super phosphate	TSP
Single super phosphate	SSP
Urea (granular and prill)	Urea
Ammonium nitrate	AN
Potassium/magnesium sulfate	KMAG
Urea/ammonium nitrate solution	UAN
Anhydrous ammonia	NH3

Actual sampling of production sites for a given fertilizer source material is carried out over a selected time period (typically 30 consecutive days). During this time period, every production plant generating a particular fertilizer source material is contributing to the 30-day population of fertilizer source material. The daily contribution from a given production facility to the 30-day population is termed a site-day lot. The 30-day population is therefore the sum of all site-day lots. This 30-day population is a bulk and was therefore sampled in accord with bulk sampling practice.

Results from a preliminary sampling investigation led to the use of an increment made up of four sub-increments taken at four evenly spaced times over the 24 hour period at a site-day lot. The start time was randomly chosen from the 24 fifteen-minute intervals from 0:00 AM to 5:45 AM and then every 6 hours afterwards. In the case of DAP each sub-increment was to contain from 500g to 2kg depending on flow rate. For all cases, the flow rates and the sizes of the sub-increments were recorded.

Selection of the site-day lots to be sampled began by listing the 1996-1997 production amounts for each site from TFI reports. Then numbers of sampling units were assigned proportional to those amounts. The sampling unit (SU) is an amount of material that is of an equal size throughout a site-day but changes from day to day depending on the actual flow rate. This amount was set to be always larger than the sum of the four sub-increments so that an increment can be viewed as a subsample of a sampling unit. In the case of DAP, for example, the total number of sampling units was set at 2295150 and there were 19 sites. The first site had 247,211 SU's, the second got 65,771 and so on to the nineteenth, which got 82,501. Notice that 30 divides evenly into 2295150. A one-start systematic sample was drawn of 30 SU's from the 2295150 and this showed which sites were selected. The systematic feature also guaranteed geographic spread among the sites. Finally the 30 sites were randomly re-ordered to show which site to have the four sub-increments extracted the first day, which for the second day and so on.

Use of this above approach greatly simplifies the protocol required to carry out the sampling at each facility while preserving randomness in the overall design. Samples from each production facility during a designated 24-hour period are collected by the respective quality control staff using normal quality control procedures. The collected samples are placed is sample bags that are provided, and then returned (without further handling) to North Carolina State University. No special instructions are required should a facility experience a breakdown during the designated 24 hour sampling period, or is not in production during the selected sampling period. If a given facility is not in production, it is not contributing to the total population of a given fertilizer source material being produced during the selected sampling period. The material in sample bags for each source material was next split down into replicate laboratory samples at North Carolina State University by using a rotary riffler. The riffler has 16 splits and each bag of, for example, DAP was put through two passes. Thus it was split into 256 portions. Random ones of these 256 were designated by computer program to go into the replicate laboratory sample so that about 16 g comes from each sub-increment. A total of eight replicate laboratory samples are generated (odd sampling days and even sampling days, 4 sampling times in a 24 hour period). The resulting laboratory samples are then ground in a stainless steel mill (<0.5 mm screen), placed in wide-mouth HDPE bottles and mixed end-over-end for 24 hours before sub-sampling using a scoop and the sampled portion analyzed. A summary of the fertilizer source materials sampled and replicate laboratory samples generated as of August 15, 2000 is given in Table 2.

Chemical analysis of the composite samples will be carried out for a variety of elements (Table 3) using written protocols and modern analytical instrumentation (primarily ion-coupled optical emission spectroscopy and ion-coupled mass spectrometry). Instrumental neutron activation analysis (INAA) (Nuclear Services, Department of Nuclear Engineering, North Carolina State University, Raleigh, NC) will be used in support of quality assurance/quality control for the project. INAA analyses for composite DAP/MAP samples generated from samples collected during February-March 1999 (Table 2) are shown in Table 4. The variability from time to time in Table 4 reflects only sub-increment extraction and sample preparation and analysis. Site-to-site differences are evaluated by comparing samples collected on even and odd days.

Perchlorate

Perchlorate is an inorganic anion used as a component of solid rocket propellant and in other industrial applications. Perchlorate salts are soluble in water and the perchlorate anion is considered exceedingly mobile in aqueous systems such as surface waters and groundwater. Introduction of perchlorate into the environment has resulted primarily from industrial and military-related activities, especially in Nevada, California and Utah, but as many as 14 states may now have potential problems with perchlorate contamination of groundwater (http://www.epa.gov/ogwdw/ccl/perchlor/perchlo.html).

Potassium perchlorate has been used to treat hyperthyroidism resulting from an immune condition known as Grave's disease (http://ngdf.org) because of its ability to reduce thyroid hormone production (http://www.epa.gov/ncea/perch.htm). Because thyroid hormone deficiencies can affect normal metabolism, growth and development, especially in children, the potential for human exposure to perchlorate in areas with contaminated groundwater or irrigation water used to grow crops has been the subject of relatively intense federal (http://www.epa.gov/ogwdw/ccl/perchlor/perchlo.html), state (http://www.dhs.cahwnet.gov/ps/ddwem/chemicals/perchl/perchlindex.htm), and private interest (http://www.awwarf.com/newprojects/perchlor.html). Current action levels for perchlorate in drinking water in California have been set to 18 ppb (parts per billion).

A possible connection between perchlorate and fertilizers and fertilizer source materials was raised in 1999 with the publication of results from a research group at the U.S. EPA laboratory in Athens, Georgia in *Environmental Science and Technology* (Susarla, et. al., 1999). Based on relatively few analyses of fertilizers and fertilizer source materials, the conclusion was reached that fertilizers and fertilizer compounds contain perchlorate at levels up to 0.8% by weight, and that fertilizers in general should be considered a major source of perchlorate contamination to agricultural cropland. Publication of this report initiated a period of intense activity among federal, state and private agencies (lead in part by the efforts of The Fertilizer Institute, http://www.tfi.org/perch.htm) which resulted in the publication of an ERRATA statement by the authors of the original article (Susarla et al., 2000). The ERRATA statement retracted a number of analyses initially reported showing perchlorate in certain fertilizer source materials, and also retracted statements regarding the potential for fertilizers and fertilizer source materials in general being a major source of perchlorate contamination on agricultural croplands. The ERRATA statement, however, still maintained that perchlorate was found in certain lawn and garden fertilizer products and that the potential for perchlorate contamination from use of these products existed.

To address the broader issue of whether perchlorate is typically a trace contaminant in fertilizers products, North Carolina State University, in cooperation with The Fertilizer Institute, initiated a series of sample collections and analyses to survey for the presence of perchlorate in fertilizers and fertilizer source materials. This work built upon the unique set of composite samples of fertilizer source materials already acquired as part of the trace metal project described earlier in this paper (Table 2). In addition to the composite samples representing many of the fertilizer source material production facilities in North America, various samples of fillers, ore samples and quality control samples were provided from fertilizer industry sources, including products derived from Chilean nitrate deposits which are known to contain perchlorate. Lastly, a number of lawn and garden fertilizers were purchased from four different regions in the United States and tested for the presence of perchlorate (Table 5).

As there is no approved analytical procedure for extraction and analysis of fertilizers and fertilizer source materials for perchlorate, a suitable analytical protocol was developed in cooperation with Dr. Tim Collette, U.S. EPA-Athens, GA, Dr. Ed. Urbansky, U.S. EPA-Cincinnati, OH, and Mr. Bill Hall and Ms. Linda Weber, IMC-Global, Mulberry, FL. The protocol consisted of extraction with distilled-deionized water (1:10 solid to solution ratio) for a period of 8 to 12 hours, followed by clarification of the extract using a combination of centrifugation and filtration through membrane filters. Potential retention of perchlorate by the membrane filters was considered and found not to be a problem. Determination of perchlorate in the clarified distilled-deionized water extracts was carried out via ion chromatography using a Dionex AS-16 analytical column. Instrument configuration used in the analyses and a chromatogram for a sample containing perchlorate is given in Table 6 and Fig. 1, respectively. All extractions and analyses were carried out in duplicate with two spike additions used per sample to confirm the ability to detect perchlorate at the calculated method detection limit (typically < 1 mg perchlorate kg^{-1} solid $= < 1$ ppm). The actual method detection limit was found to lie between 5 and 10 mg perchlorate kg^{-1} solid (5 to 10 ppm).

To date, 48 composite samples of fertilizer source materials, 25 lawn and garden fertilizers, and over 30 individual samples of fillers, ore samples, quality control samples have tested for the presence of perchlorate. Excluding the samples derived from Chilean nitrate deposits (and known to contain perchlorate in varying amounts, Fig. 1), perchlorate has been detected at trace levels in only two samples: a lawn and garden fertilizer purchased in Denver, CO; and in a Sylvinite (KCl) ore sample. The lawn and garden sample (KGRO Tomato 5-10-8) was found to contain 15 mg perchlorate kg^{-1} (Fig. 2). The amount of perchlorate in the Sylvinite ore sample was < 10 mg perchlorate kg^{-1}, and was only detected after extracting a 100 gram aliquot (Fig. 3). None of the composite fertilizer source material samples were found to contain perchlorate. nor was perchlorate detected in filler material commonly used in fertilizer preparations.

Failure to detect the presence of perchlorate in fertilizer source materials and in the vast majority of samples tested in this study is consistent with the results of other researchers who have conducted similar such surveys since the initial report published in 1999 (Urbansky et al., 2000; Mr. Bill Hall, IMC-Global, personal communication). It is now the general consensus among the researchers who have been involved with this issue for the past several years that fertilizer source materials do not contain perchlorate. The occurrence of perchlorate in the lawn and garden fertilizers collected in 1998 by researchers at the U.S. EPA-Athens laboratory is still unexplained.

Conclusion

Webster's College Dictionary (1992) provides several definitions for the word siege. The first definition deals with the act or process of surrounding and attacking a fortified place to compel the surrender of the defenders. The word siege, however, also can be used to refer to a prolonged period of trouble. Use of commercial fertilizers is vital to the continued success of modern agriculture to provide the diversity and quality of agricultural products typically found in our society. However, there is no doubt that continued use of commercial fertilizers will come under ever increasing scrutiny for potential harmful effects on the environment and/or human health. Clearly, potential threats to the environment and/or human health from the continued use of commercial fertilizers must be investigated, but such investigations must be conducted using rigorous scientific methods, and be designed to yield appropriate information that can be used to properly assess the risks to modern society. Inherent in such rigorous scientific studies must be an evaluation of the representativeness of the samples that are collected to be analyzed, and the suitability of the analytical techniques selected for conducting the analyses.

Acknowledgements

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Table 2. Summary of Fertilizer Source Materials Sampled as of August 15, 2000.

			Days Sampled	
Product	**Dates**	**Planned**	**Actual**	**%**
DAP/MAP	Feb. - Mar. 99	30	23	70
AS	April - May 99	30	27	87
KCl	May - June 99	30	27	79
UREA	Aug. - Sept. 99	30	19	62
KMAG	Mar. - April 00	3	3	83
P Rock	Mar. - April 00	30	25	73
DAP/MAP	Mar. - April 00	30	24	76
TSP	Mar. - April 00	15	13	75
AS	Mar. - April 00	30	26	80
AN	April - May 00	30	20	49
UREA	May - June 00	30	21	63
SSP	May - June 00	14	8	55

Table 3. Elemental Analyses Planned for Composite Samples.

Micronutrients

Boron
Cobalt
Copper
Iron
Manganese
Molybdenum
Zinc

Trace Metals

Antimony
Arsenic
Beryllium
Bismith
Cadmium
Chromium
Lead
Mercury
Nickel
Selenium
Silver
Thallium
Vanadium

Radionuclides

Radium
Uranium
Thorium

Other

Aluminum
Barium
Strontium
Titanium

Table 4. INAA Analysis of DAP/MAP Composite Samples Generated from Samples Collected on Even Days During Period February-March 1999. Time 1, 2, 3, 4 Refers to Sampling During a 24 Hour Period at Each Facility. (Units = mg/kg)

Element	Time 1	Time 2	Time 3	Time 4	Mean
Aluminum	8153	8370	8490	7995	8250
Antimony	2.4	2.2	2.3	2.4	2.3
Arsenic	11.5	12.1	11.3	11.4	11.6
Bromine	4.3	4.8	3.6	4.8	4.4
Cerium	65.2	60.5	63.5	63.3	63.1
Cesium	1.1	1.1	1.1	1.0	1.1
Chromium	156	163	154	149	155
Cobalt	6.4	8.7	7.3	7.7	7.5
Iron	11360	11780	11890	11520	11640
Lanthanum	25.8	25.0	23.0	23.3	24.3
Manganese	264.4	256	270	260	263
Samarium	4.7	4.9	4.7	4.7	4.8
Scandium	8.3	8.5	8.1	8.1	8.2
Thorium	7.8	8.1	7.9	7.6	7.8
Uranium	144	148	149	145	147
Vanadium	172	175	175	172	173
Zinc	166	155	152	136	153

Table 5. Lawn and Garden Products Collected for Perclorate Analysis (Cities: Raleigh, NC; Valrico, FL; Tazoo City, MS; Denver, CO; August 1999).

Product	Formulation	Location
Osmocote	18-6-12	Raleigh
Sta-Green	18-6-12	Raleigh
African Violet food	12-36-14	Raleigh
SchultzAll Purpose	20-30-20	Raleigh
Scott's Veg. food	20-27-5	Raleigh
Jobes Spikes	13-4-5	Raleigh,Yazoo City
PetersAll Purpose	20-20-20	All 4 locations
KGRO All Purpose	15-30-15	Raleigh, Denver
KGRO Tomato	18-18-21	Raleigh
Miracle Gro	15-30-15	Raleigh
KGRO Lawn food	36-6-6	Raleigh,Yazoo City
Scott's Evergreen	31-3-10	Valrico
Scott's Citrus food	18-5-18	Valrico
Scott's Rose food	18-11-16	Valrico
Vigoro Azalea et al	17-7-7	Valrico
Vigoro Citrus	12-5-18	Valrico
Colorburst	11-40-6	Valrico
Vigoro Palm	6-5-12	Valrico
Vigoro Nursery	12-6-6	Valrico
Vigoro Rose	15-5-13	Valrico
Scott's Azalea et al	16-2-3	Valrico
Jobe's plant food	10-10-4	Denver
Miracid	30-10-10	Denver
KGRO Tomato	5-10-8	Denver

Table 6. Instrument Configuration for Ion Chromatograph.

Instrument System:	Dionex Model 500 with AutoSampler
Pump	Dionex GP-40
Detector	Dionex ED-40 Electrochemical Detector
Suppressor	Dionex ASRS-II self-regenerant suppressor
Columns	Dionex ATC-1 Anion trap column Dionex AG-16 Guard column Dionex AS-16 Separator column
Software	Dionex PeakNet Ver. 5.0
Computer	Pentium-PC with 16-bit LAN card
Autosampler	Dionex AS-40 autosampler (0.5 or 5 mL sample vial)
Sample Loops	10, 100 or 1000 uL (uL = microliter)
Eluent	60 mM NaOH in ROP water at 1.5 mL per min Follow Dionex procedure to avoid carbonate in NaOH
Standards	Range: 0 to 5000 ppb (micrograms per Liter)
Standard Source	99.999% ammonium perchlorate

Figure 1. Chromatogram showing the presence of perchlorate in Bull Dog Soda.

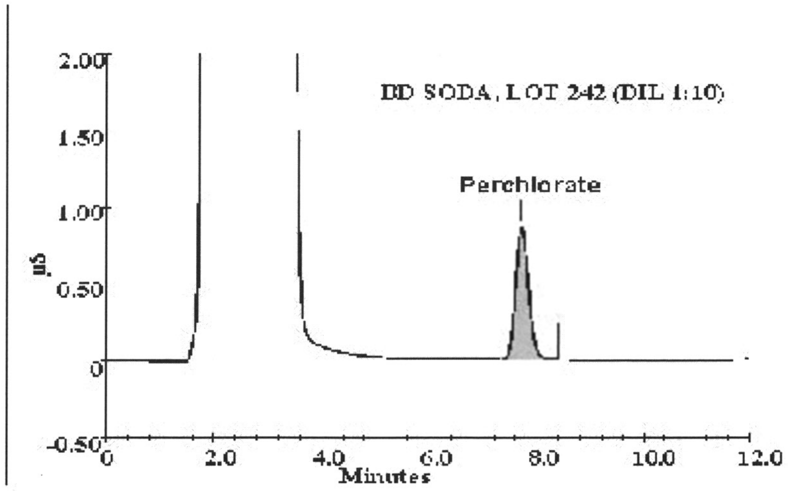


Figure 2. Chromatogram showing the presence of perchlorate in a lawn and garden product.

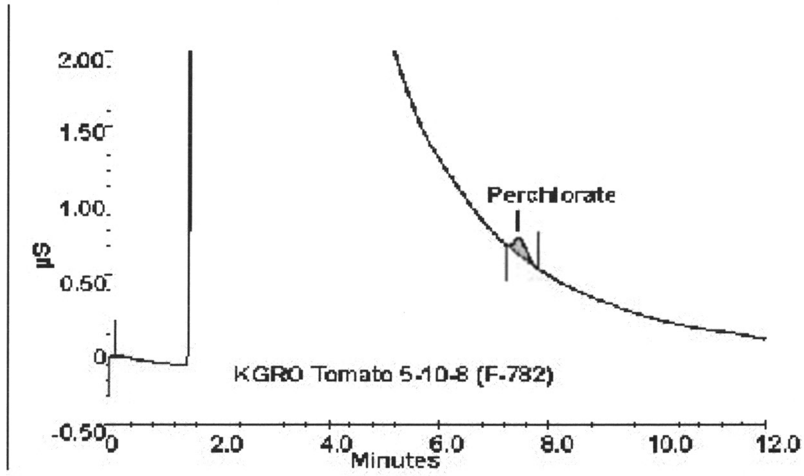
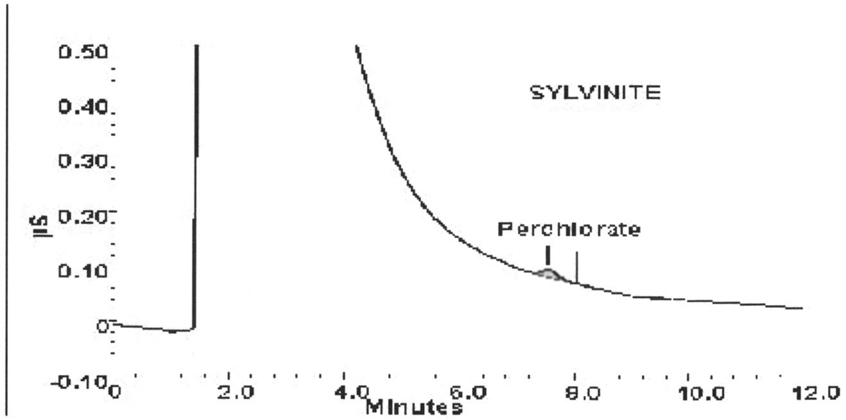


Figure 3. Chromatogram showing the presence of perchlorate in Sylvinite ore.



Not All Sulphur Fertilizers Are The Same

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Introduction

The consumption and need for sulphur fertilizer continues to expand worldwide. Intensification of agricultural production is the natural result of increasing world food demand facing limited new land availability. Fertilization with nitrogen, phosphate, and potash fertilizers has increased accordingly, even though phosphate and potash use has lagged that of nitrogen in many regions. This has created major nutrient imbalances, including sulphur. Empirical studies demonstrate that adequate sulphur supplies are required to ensure efficient nitrogen and phosphate utilization. The increased trend to use high-analysis fertilizers devoid of sulphur, combined with some regional decline in levels of soil organic matter, a significant potential source of sulphur, which can result from intensification, have reduced soil sulphur content to levels where sulphur is increasingly becoming a limiting factor to higher yields and production. Tightening environmental regulations principally in the developed world, but also increasingly in developing countries, have decreased atmospheric sulphur deposition. Single superphosphate (SSP) and ammonium sulphate account for about three-fourths of global sulphur fertilizer use of about 10 million tons sulphur. These products continue to be important sources; however, research and development efforts have produced new materials which are gaining market share, and a growing array of sulphur fertilizers are available to accommodate different soil, crop and application conditions and situations.

Plant Nutrient Sulphur Model

The Sulphur Institute (TSI) developed a model to track and forecast plant nutrient sulphur trends. The model, based on historical data, forecasts soil sulphur supply and demand on a country and regional basis and includes all major crops. Sulphur supply is represented by total fertilizer application and their relative efficiency in soils based on climatic and soil considerations. Sulphur fertilizer application information is based on International Fertilizer Industry Association (IFA) data and that obtained by TSI through various public sources. Sulphur demand is derived from production data for crops and specific animal products using historical and forecast data from the Food and Agriculture Organization. The sulphur content of crops and animal products are derived from leading agricultural sulphur research organizations. Fertilizer efficiency factors are used to account for losses by leaching and mineralization for tropical and temperate regions of the world. The difference between sulphur requirements, fertilizer application, and fertilizer efficiency variables, determines sulphur deficiencies (surpluses) for each country or region. Field trials conducted by TSI and others have confirmed the indications of the model.

In 1998, 10.1 million tons of sulphur were applied to soils worldwide through fertilizers. The current potential plant nutrient sulphur market is estimated to accommodate an additional 8 million tons. With increased food production raising sulphur requirements, and assuming slower expansion rates for sulphur application in accordance with recent history, the unfulfilled requirement for sulphur fertilizers is projected to grow to 10.7 million tons by 2009 (Figure 1).

A regional breakdown of world sulphur deficits is shown in Figure 2. Asia is the region manifesting greatest shortfalls. Intensified agricultural production, pressured by the backdrop of food self-sufficiency goals and limited land resources in the globe's two most populous nations, China and India, has created a sulphur nutrient imbalance. Asia's annual sulphur fertilizer deficit, currently estimated at about 4 million tons, will increase to over 6 million tons by 2009, with approximately two-thirds represented by China and India. China s current deficit of about 1.3 million tons is expected to grow to 2.1 million tons. India s deficit is projected to increase from 1.3 million tons to 2 million tons in 2009.

A host of field trial data provides evidence that sulphur deficiencies are undermining agricultural productivity in China and India. Experimental results, in part carried out by TSI, indicate that at least 30% of soils in the major agricultural regions of China and India are sulphur deficient. In China's Anhui, Fujian, Guangdong, Guanxi, Hainan, Heilongjiang, Henan, Hunan, Jiangxi, Shaanxi and Yunnan Provinces, this is especially true. In 1998, the Chinese government recognized sulphur as a plant nutrient and placed sulphur-containing fertilizers on the development priority list. In India, soil sulphur deficits were detected at different locations in many states, including Andhra Pradesh, Bihar, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, and Uttar Pradesh.

The Western European sulphur market is one of the more advanced in the world. The significant drop in sulphur dioxide emissions since the 1970s, coupled with intensive agronomic practices including the use of high-analysis, sulphur-free fertilizers spurred the region to action to correct the deteriorating sulphur nutrition status. Sulphur deficiency was qualified as a major nutritional problem in arable crops. Comprehensive agricultural research and extension systems facilitate farmers' response to the deficit. It is projected that the market will expand slightly from the current level of over 400,000 tons to 500,000 tons in 2009 within Western Europe, as the increased need for sulphur, particularly in the North, is partially offset by efficiency gains in fertilizer application. Sulphur deficiencies are expected to continue expanding as sulphur dioxide depositions are expected to be reduced further by 2005. Additional commercial opportunities are expected to arise in Eastern Europe, as several countries project sulphur dioxide reductions in part resulting from their proposed entry to the European Union. The current Eastern European sulphur deficit of 300,000 tons is expected to rise by at least 100,000 tons by the end of the decade.

In North America, the reduction in atmospheric deposition of sulphur dioxide combined with crop intensification continue to shape sulphur deficiencies. The Environmental Protection Agency estimates that sulphur dioxide emissions were reduced by 4 million tons between 1995 and 1999, following the 8 million ton reduction from 1970 to 1993, with further declines projected. Sulphur deficiencies occur more frequently in temperate regions, where the sulphur contributions from precipitation and irrigation water are low and soils predominate from moderately- to highly-weathered parent materials. Both conditions exist in major portions of the U.S. western states and in Canada's western provinces. The sandy soils of the Southeast, Mid-Atlantic and the Corn Belt also present sulphur deficiencies. Continued reductions in sulphur dioxide emissions and increased yields are expected to expand areas of sulphur deficiency, most notably in soils with lower organic matter of the Midwest. Furthermore, some research institutions are evaluating the need to increase current sulphur fertilizer recommendations in line with existing trends. The North American deficit for sulphur fertilizers is expected to increase from the current 1.2 million tons to 1.5 million tons by 2009.

Latin America is developing as a market for plant nutrient sulphur. Agricultural production increased significantly over the last decade, which in conjunction with the rising use of high-analysis fertilizers leads to increasing instances of sulphur deficits, particularly in Argentina. The largest fertilizer consumer, Brazil, is an important and growing user of ammonium sulphate and SSP. The current increased market opportunity in Latin America is estimated at 600,000 tons sulphur, and is projected to rise to at least 900,000 tons sulphur by the end of the decade.

Sulphur Fertilizers

There are two types of sulphur fertilizers: those that are in the sulphate form and those that need to go through a chemical reaction to get into that form for plant uptake. The bulk of sulphur fertilization comes from multi-nutrient fertilizers that are already in the sulphate form. Ammonium sulphate, single superphosphate (SSP), and potassium sulphate (K2SO4) are the leading products by volume. Although these products were originally applied for their nitrogen, phosphorus, and potassium content, respectively, they are increasingly recognized for their sulphur content in its own right. Sulphur is not called the fourth nutrient in vain. All major multi-nutrient sulphur fertilizers provide sulphur in the form of the sulphate (SO4 2-) anion, readily available for uptake by plants. Adding to the array and sophistication of available sulphur products, elemental sulphur in various formulations and liquid fertilizers are capturing increasing shares of sulphur fertilization, currently still mainly in the developed world.

The trend to increase the nitrogen, phosphorus, and potassium analyses of fertilizers over the last four decades gradually squeezed out most of the sulphur content in the major nitrogen, phosphorus and potassium fertilizers, urea, DAP and MOP, respectively.

Multi-Nutrient Sulphur Fertilizers

Ammonium sulphate is mostly produced as a co-product of other industries. An estimated 70% of global output originates from the production of caprolactam, an intermediate for the manufacture of synthetic fibers and plastics. A small amount is recovered from coke oven gas, with most of the remainder produced synthetically from sulphuric acid and ammonia. In 1999, approximately 17 million tons of ammonium sulphate fertilizer were produced, equivalent to 4 million tons sulphur. Over 3 million tons of sulphur equivalent are used directly, with the remainder used for blending with other fertilizers. Improvements in the ammonium sulphate formulation process allow for increasing shares of premium granular material, easy to handle and suitable for bulk blending. This has greatly increased application options and spreading performance. In the Western European fertilizer market, compounds predominate as opposed to bulk blends. In this market, ammonium sulphate is commonly used either in the manufacturing process, or sometimes as a physical blend, to obtain the desired sulphur analysis.

Single superphosphate was the main phosphate fertilizer produced during the first half of the 20th Century. A trend to higher-analysis ammoniated phosphates started in the 1950s. In contrast with ammonium sulphate, most SSP is consumed in the country of origin. Most SSP is produced and consumed in China, India, Brazil, FSU, Australia and New Zealand, with the benefits of the sulphur component often being recognized, particularly in the latter two countries. Total sulphur content in SSP used in 1998 was 4.5 million tons. Production of SSP is relatively stable with a tendency to decline; the majority of phosphate capacity expansion plans include tradable compound fertilizers and ammoniated phosphates; this contributes further to sulphur deficiencies down the road and the need to replace the foregoing sulphur source.

Potassium sulphate is the main sulphur-containing potash fertilizer. For purposes of this discussion potassium-magnesium sulphate is also included. The current global market for these materials is approximately 1.6 million tons of product, equivalent to close to 300,000 tons sulphur per year. About half of global production is mined directly. Potassium sulphate can also be produced based on the reaction between potassium chloride and sulphuric acid, known as the Mannheim Process. Potassium sulphate is normally used for situations and crops susceptible to high chloride and salt concentrations; it is facing increased competition from potassium nitrate as a chloride-free potash fertilizer, thus signaling another potential source of sulphur deficit. Potassium-magnesium-sulphate is used in situations similar to potassium sulphate, but when magnesium is also desired.

Gypsum (calcium sulphate) is not as widely used as a fertilizer compared to ammonium sulphate. Most gypsum that is available is in forms that are not as easy to handle, blend, and spread.

Ammonium sulphate, SSP, and potassium sulphate materials remain important sulphur sources; however, their stable or even declining production base against the backdrop of growing sulphur deficiencies and the increasing sophistication and understanding of fertilizer actions has attracted new sulphur sources that are increasing market share. Sulphur fertilizer producers are introducing new products to meet diversified and specific application requirements. These can be categorized broadly into elemental-sulphur-based fertilizers and liquid sulphur formulations.

Elemental Sulphur-Based Fertilizers

The use of elemental sulphur as fertilizer is increasing mostly in the developed world and is projected to continue. Two features of elemental sulphur highlight its use as a controlled-release fertilizer for permanent pastures and crops. First, it is the most concentrated sulphur form, which lowers transport and application costs. Secondly, it offers reserve availability. Elemental sulphur is converted to sulphate over time. Thus, availability is a function of this process, which depends on the specific source and environmental factors. Elemental sulphur fertilizers are now manufactured in Oceania, North America, Western Europe and West Asia.

The effectiveness of elemental sulphur as a fertilizer is governed by its oxidation rate, which is a biological process carried out principally by bacteria of the genus Thiobacillus. The bacteria feed on elemental sulphur and oxidize it to the sulphate form, making sulphur available to plant roots. Physical factors, including soil temperature and moisture, play an important role in determining rates of sulphur oxidation. A third critical physical factor influencing oxidation is particle size of the applied elemental sulphur. Finer particle size increases the oxidation rate, as the greater specific sulphur surface area provides for greater access and action by microbes. The application of coarse elemental sulphur historically produced low yield response in sulphur-deficient annual crops, attributable to low oxidation rates associated with large particle size. The elemental sulphur fertilizer industry has come a long way since those early days.

New Zealand and Australia, along with the United States and Canada, were at the forefront in elemental sulphur fertilizer research and technology, with sulphur deficiencies recognized and addressed since the 1950s. Most research was oriented to areas of deficiency, suitable diagnostic tests, plant sulphur requirements, sulphur cycle modeling, oxidation modeling of elemental sulphur, and development of effective sulphur fertilizers. This research developed soil sulphur testing procedures well-correlated with plant uptake.

The development of suitable elemental sulphur fertilizers includes intensive trial work conducted most frequently in Australia and New Zealand. Much of the work focused on methodologies to incorporate elemental sulphur with fertilizers, either during processing or into the finished product. More recent sulphur fertilizer research in New Zealand was directed toward the development of technology to produce fine-particle elemental sulphur suitable for incorporation into high-analysis phosphate fertilizers or as a degradable granulated product appropriate for dry blending. An emulsifying process was also developed.

Sulphur bentonite products are manufactured by a number of processes, with molten sulphur blended with swelling bentonite clays and solidified into useable forms, usually granules or pastilles. This material has gained popularity in North America and Western Europe. Commercial sulphur bentonite mixtures were originally marketed on a limited basis in the United States in the late 1960s, with some early products not successful mainly due to large particle size. Generally, research results indicate that particle sizes of 150µm to 200 µm or smaller are required if elemental sulphur is to be fully effective during the growing season in which it is applied. Recent innovations in production technology and anti-dusting agents resulted in the marketing of more effective products. The modern concept behind sulphur bentonite fertilizers is that after application the bentonite or other binding agent absorbs moisture from the soil, causing it to expand and subsequently dissolving the pastille into minuscule elemental sulphur particles that oxidize rapidly. A product with a range of particle sizes is preferable in many circumstances, allowing for short-term and long-term release. In

North America, a water-degradable product containing 90% sulphur granulated with bentonite clay is being produced. Produced in pastille and granular forms, these products can be used in bulk blends, direct soil applications, and suspensions. Sulphur bentonite is also produced via a drop-forming technology to produce a pastille. Another sulphur fertilizer produced is a granular elemental sulphur fertilizer material using a water-dispersible binding agent. The particle size of the elemental sulphur is comparably uniform and designed to oxidize in a given cropping cycle.

Alternative formulations of elemental sulphur, particularly tried in Oceania, included mixtures with phosphate rock, SSP, either molten or in dry form, in some cases inoculated with sulphur-oxidizing bacteria, and with partially-acidulated phosphate rock. A process for adhesion of elemental sulphur to finished products, such as triple superphosphate (TSP), DAP, and urea, was developed and offers other new opportunities. This approach is an alternative to the methodology to form elemental sulphur into granules or prills using bentonite or other binders. A new process was developed, which solved some problems regarding sulphur fertilizer application in flooded and non-flooded crops and pastures, including improved sulphur dispersion from the granule and better spatial distribution characteristics. A product, with micronized sulphur bonded onto granules of high-analysis TSP is also available. The process establishes an elemental sulphur coating on the surface of the TSP's granules. The sulphur is non-leachable, but in a form that is readily oxidized by soil microorganisms. The special coating process involves the creation of an adhesive film on the surface of the granules by spraying minute quantities of water into a tumbling bed. The sulphur-based dry coating material is applied after the adhesive film is established. This product offers a valid combination for situations requiring high-analysis fertilizers and the need to apply sulphur. An expanded product line is available using other granular fertilizers, including DAP, MAP, and urea.

Sulphur Fertilizers in the Liquid Form

Sulphate fertilizers are used for liquid formulations on a limited basis. For example, ammonium sulphate can be dissolved but the concentration of sulphur achieved in the final product must remain relatively low, particularly with liquids containing potassium sulphate, in order to avoid salt formation. The more widely used alternative is ammonium thiosulphate solution (ATS). It is compatible with most materials used for liquid fertilizers and thus higher concentrations of sulphur can exist in the resultant mixes. Fertilizer-grade ATS in its commercial form is in a 60% aqueous solution with a 12-0-0-26S analysis. It is compatible in any proportion with neutral to slightly acidic phosphate-containing solutions or suspensions, as well as with aqueous ammonia (NH3) and nitrogen solutions. It is not compatible with anhydrous ammonia or strong acids. A wide variety of N-S, N-P-S, and N-P-K-S formulations are possible utilizing this material. Ammonium thiosulphate can be applied directly by drip, sprinkler or flood irrigation. Thiosulphate sulphur is unique in that it exists in two oxidation states, making it more suited to the sulphur uptake patterns of most plants; it decomposes in the soil to form approximately equal amounts of sulphate and elemental sulphur. The sulphate is available immediately whereas the elemental sulphur is converted to sulphate by bacterial oxidation.

Ammonium thiosulphate has gained prominence in North America and is growing in use and importance in Europe, because of its versatility and high sulphur concentration in fluid formulations. Other products related to ATS are now available and include: ammonium polysulphide solution (20-0-0-40S), potassium thiosulphate (0-0-25-17S, particularly suited as a starter fertilizer) and calcium thiosulphate solution, for crops and situations requiring these other nutrients besides sulphur. Thiosulphates (S2O3 2-) are noncorrosive and nonhazardous to handle. They are clear, liquid fertilizers that are suitable for direct applications or blending, offering versatility to farmers and fertilizer retailers. Several manufacturers produce thiosulphates in North America. This material has also gained interest in the United Kingdom, Germany, Italy and France.

Conclusion

This paper has presented an overview of the fertilizers available to correct sulphur deficiencies that are on the rise globally. There is a wide variety of materials currently available to use. These products are diverse and include: dry and liquid materials, materials that offer immediate nutrient availability, those that offer immediate and reserve availability, and several available for use when other nutrient deficiencies exist. The decision on which product to use will depend on availability, management and economics, but all have a place in modern agriculture. Management decisions with these fertilizers will affect performance and need to be considered. However, the data that has been generated provide a convincing case that sulphur fertilizer use on deficient soils is of significant benefit to the farmer.

Figure 1. World Plant Nutrient Sulphur Balance.

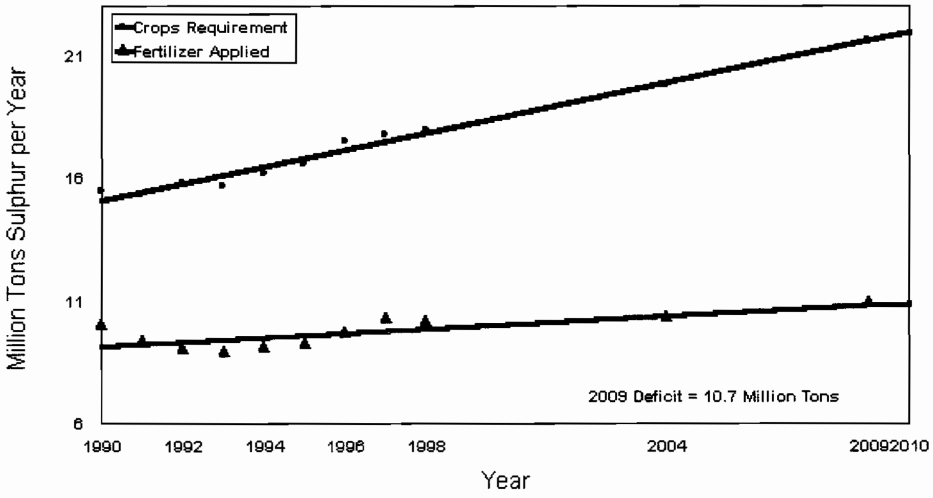
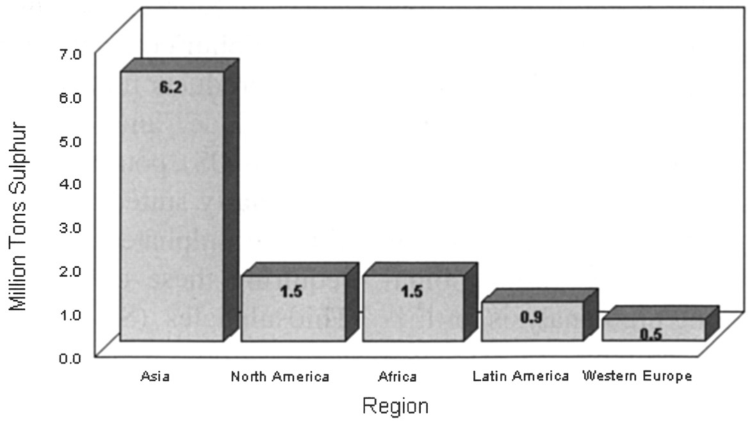


Figure 2. Regional Projected Plant Nutrient Deficit in 2009.



Appendix I: Compilation of Various Sulphur Containing Fertilizers Available Worldwide.

(Taken from The Sulphur Institute Fertilizer Producers Directories)

PRODUCT NUTRIENT ANALYSIS TABLE

SULPHUR FERTILIZERS	CONTENT (%)			
	S	N	P2O5	K2O
Ammonium Phosphate Sulphate	6-17	Variable	Variable	0
Ammonium Polysulphide	45	20-21	0	0
Ammonium Sulphate	24	21	0	0
Ammonium Sulphate Liquid	9	8	0	0
Ammonium Thiosulphate	43	19.5	0	0
Ammonium Thiosulphate Solution	26	12	0	0
Calcium Sulphate (Gypsum)	17	0	0	0
Micronized Sulphur*	50-99	0	0	0
Mixed-Grade NPs with Sulphur	2-21	Variable	Variable	0
Mixed-Grade NPKs with Sulphur	1-18	Variable	Variable	Variable
Nitrogen-Sulphur Solutions	2-5	7-35	0	0
Potassium Magnesium Sulphate	8-22	0	0	22
Potassium Sulphate	17-18	0	0	48-51
Potassium Thiosulphate	17	0	0	25
Soil Sulphur	50-100	0	0	0
SSP	11-14	0	20	0
Sulphur Bentonite	90	0	0	0
Sulphur-Coated DAP	12	16	40	0
Sulphur-Coated SSP	22	0	20	0
Sulphur-Coated TSP	10-20	0	38-43	0
Sulphur with Micronutrients	2-80	0	0	0
Urea with Sulphur	5-6	40	0	0

*Includes wettable/dusting powders (dry powder) and flowable sulphur (liquid suspension)

THE FERTILIZER INDUSTRY ROUND TABLE

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FINANCIAL STATEMENT
OCTOBER 27, 1999 TO OCTOBER 4, 2000

Cash Balance October 27, 1999		$ 59,947.33
Income October 27, 1999 to October 4, 2000		
Registration Fees - 1999 Meeting & Cocktail Party & Coffee Break Receipts	$ 9,516.44	
Sale of Proceedings	740.90	
Registration Fees - 2000 Meeting & Cocktail Party & Coffee Break Receipts	23,750.00	
Total Receipts October 27, 1999 to October 4, 2000		34,007.34
Total Funds Available October 27, 1999 to October 4, 2000		$ 93,954.67
Disbursements October 27, 1999 to October 4, 2000		
1999 Meeting Expenses (Incl. Cocktail Party)	$ 17,000.49	
Misc. Expenses Incl. Postage, Stationery, etc.	1,120.05	
1999 Proceedings	7,470.00	
2000 Meeting Preliminary Expense	5,690.73	
Directors' Meetings	2,938.71	
Secretarial Contract Expense	10,000.00	
Total Disbursements October 27, 1999 to October 4, 2000		44,219.98
Cash Balance October 4, 2000		$ 49,734.69

Respectfully submitted,

Paul J. Prosser, Jr.
Secretary\Treasurer

PJPjr:ts

Meeting Attendance: 120